Available online at www.sciencedirect.com

ScienceDirect

ELSEVIER

Procedia - Social and Behavioral Sciences 96 (2013) 728 – 740

Procedia
Social and Behavioral Sciences

13th COTA International Conference of Transportation Professionals (CICTP 2013)

Design and Implementation of Freeway infrastructure safety and emergency management system

Minli Ge [a,] * Lu Sun[a, b] Yiyong Pan [a] Yifeng Li[a]

[a]School of Transportation Engineering, Southeast University,Nanjing, 210096, China

[b]Department of Civil Engineering, the Catholic University of America,Washington, DC 20064, USA

Abstract

As an important content of freeway safety management, the freeway infrastructure safety and emergency management system can bring great social effect. In this article, a comprehensive freeway infrastructure safety and emergency management system was built by following steps: firstly, research significance, research status and the paper framework were illustrated. Secondly, in allusion to five kinds of transportation infrastructure: pavement, bridge, tunnel, side slope and ancillary facility, the existing infrastructure testing indexes were summarized, and the relations between traffic safety and these testing indexes were quantified. Thirdly, according to the different characteristic of five kinds of infrastructures, comprehensive safety evaluation models were proposed in order to evaluate the safety of freeway infrastructure. Fourthly, the system of emergency management and emergency plans were expounded. Finally, the system software was developed on the base of research about system framework, database system and Web GIS technology. This system has strong practicability, which can compensate for the deficiencies of the infrastructure detection in the past and provide a new informationalized management platform for freeway management.

Selection and peer-review under responsibility of Chinese Overseas Transportation Association (COTA).

Keywords: freeway; infrastructure; comprehensive safety evaluation; emergency management; system

1. Introduction

Along with a rapid development of transportation in China, freeway infrastructure is improving continuously and its performance is gradually becoming an important part of traffic safety. Especially, a traffic emergency, as a kind of inevitable traffic phenomenon, will usually cause great disruption and loss of lives and properties.

* Corresponding author. Tel.: 025-83792619.
E-mail address: geminli0901@gmail.com

Selection and peer-review under responsibility of Chinese Overseas Transportation Association (COTA).
doi:10.1016/j.sbspro.2013.08.084

Hence, the impact on the freeway operation safety based on infrastructure performance and emergency management is becoming more serious than ever before.

Since the 1960s, the whole world has been in a peak time of emergencies, thus a series of emergency management measures have been proposed, emergency management mechanism has been steadily established and modern information technologies have been applied in disaster prevention and mitigation.

Some developed countries have complete emergency management mechanism and traffic emergency management systems. In the US, Federal Emergency Management Agency (FEMA) developed Freeway Incident Management System (Deng Zeying2000). And US Department of Homeland Security developed National emergency management system (NIMS) (Barnes C F, et al., 2007; Kenneth A. Duda et al.,,2005; William L, et a1,2007). German traffic safety department has Traffic Incident Assistance System (TIAS) (Feng Qi, 2006). Japanese Vehicle Information and Communication System (VICS) has accumulated rich experience in practice of emergency management(Aloysisus J. Rego, 2001).

While, domestic research on emergency management systems has just started (Xianyuan DONG, et a1, 2012). A traffic emergency management system based on risk coupling and presents the architecture model, frame design, and operating environment design was constructed (Jiang, 2011). The linkage mechanisms of provincial highway traffic emergency rescue were discussed and a standard provincial highway emergency rescue command system was established (Chai, Pu, and Wan, 2008). The principal tasks needed to build an emergency rescue system were enumerated (Ma, 2004). Compared with developed countries, China has not established an emergency management system for effectively handling unexpected traffic incidents.

From the result of literature research, in recent times, there are some research and application in the field of infrastructure operation safety and emergency management system, but there are some problems to be solved:

(1)Most of the infrastructure management systems at home and abroad are aimed at managing a single infrastructure (such as pavement). While, freeway is a complex which consists of pavement, bridge, tunnel, slope and ancillary facilities. Therefore, all the components of freeway must be considered overall during freeway operation safety evaluation and emergency treatments making.

(2)Detection indexes involved in most of the infrastructure management systems serve for maintenance and prediction. Few indexes were put forward from the perspective of operation safety.

(3)Most of the operation safety and emergency systems are managed by client software, thus, management will not be able to continue if breaking away from terminal equipment installed client software. Management system with the client which was developed based on web-technology will greatly improve the work efficiency.

(4)Most of the operation safety and emergency systems only deal with relational databases, in which data are simple and lack of intuitiveness. Using GIS technology to highlight rescue resource and associated apparatus in the scope of emergency, will greatly improve the work efficiency.

By considering the research actualities and shortcomings of freeway infrastructure safety and emergency management in China, this paper presents a freeway infrastructure safety and emergency management system. The main content of this paper is organized as follows. Section 2 summarizes infrastructure evaluation indexes and analysis the relationship between them and safety. The freeway infrastructure safety comprehensive evaluation methods are explained in section 3. Section 4 the system of emergency management and emergency plans were expounded. Section 5 the system software is developed on the base of research about system framework, database system and Web GIS technology. And then the final section gives the conclusion and discusses the future work.

2. Infrastructure detection indexes and the relations between traffic safety

Freeway is a complex which consists of pavement, bridge, tunnel, slope and ancillary facilities. Firstly, in allusion to these five components, in compliance with state regulations and existing research, detection indexes are summarized. Secondly, the correlations between these indexes and traffic safety are analyzed by using the expert scoring method. Finally, according to their correlations with safety, detection indexes are divided into three levels, namely recommended index, selective index and negligible index, among which the recommended index will be used for comprehensive evaluation in the next section. Technology roadmap of this section is shown in fig. 1.

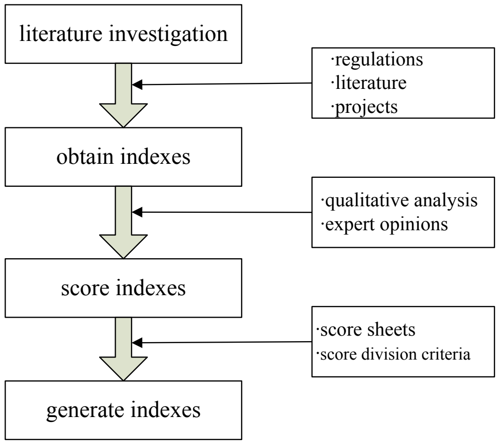


Fig. 1. Technology roadmap of this section

Through summarizing the expert scores of the five kinds of infrastructure detection indexes from the aspect of traffic safety, the degree of correlation between each detection index and traffic safety is analyzed. On this basis, each index is decided whether chosen to be recommended or not. In this paper, expert scores of infrastructure detection indexes are divided into three sections, each section represents different qualitative evaluation between index and traffic safety, and corresponding definition of each section is given, shown in Table 1.

Table 1. Division criteria of detection index score

Export score	Index qualitative evaluation	Definition of index
7~9	strongly related to traffic safety	Recommended index
4~6	Partly related to traffic safety	Selective index
1~3	Lightly related to traffic safety	Negligible index

According to the export score of index and the division criterion, the definition of five kinds of infrastructure indexes is summarized in table 2.

3. Freeway infrastructure safety comprehensive evaluation

In this section, freeway infrastructure safety comprehensive evaluation is achieved by the following steps: (1) on the basic of evaluation indexes analyzed in the last section, and fully considering the characteristics of the five components of freeway infrastructure and their relationship with safety, evaluation indexes are selected to calculate comprehensive index; (2) selected evaluation indexes are dimensionless processed; (3) a comprehensive evaluation index of each infrastructure is proposed according to corresponding comprehensive evaluation formula; (4) evaluation criteria of each comprehensive index are divided to achieve infrastructure safety level.

3.1 Pavement safety

As early as 1962, AASHO carried out research according to pavement safety, put forward the concept of pavement performance, which is the main indicators of pavement performance evaluation. While, previous pavement evaluation was proposed mainly according to the structure performance, which can ensure no structural damage caused traffic disruption (Sun Lijun, 2009). With the continuous development of the transportation, the demand gradually improved on pavement function and quality of service, and the concerns transferred from the unitary structure performance to safety performance (Temple, W.H., et al., 1988).

Table 2. Summarize of infrastructure detection index

	Recommended index	Selective index	Negligible index
Pavement	pavement roughness	bearing capacity of pavement	
	skid resistance		
	rutting		
	pavement damage		
Bridge	bridge deck pavement	bridge deformation	appearance
	drainage facility	wind load	riverbed
	ancillary facilities	earthquake	
	expansion joint	structure	
	sidewalk	wing wall	
		conical slope, slope protection	
		bridge stress	
		bridge vibration	
		temperature	
		foundation	
		abutment	
		bearing	
Tunnel	pavement	leakage	
	power supply facilities	tunnel portal	
	lighting facility	lining	
	drainage facility	external load	
	monitoring devices	material deterioration	
	tunnel portal	maintenance path	
	interior decoration	suspended ceiling	
	ventilation facility		
	Fire-fighting and rescue facility		
Slope	Surface deformation	ground water	
	precipitation	deep displacement	
	earthquake	inner stress	
	crack	supporting structure stress	
Ancillary facilitiy	protection facility		
	isolation facility		
	anti-dazzle facility		
	sign and marking		
	Visual induced facily		

3. Freeway infrastructure safety comprehensive evaluation

In this section, freeway infrastructure safety comprehensive evaluation is achieved by the following steps: (1) on the basic of evaluation indexes analyzed in the last section, and fully considering the characteristics of the five components of freeway infrastructure and their relationship with safety, evaluation indexes are selected to calculate comprehensive index; (2) selected evaluation indexes are dimensionless processed; (3) a comprehensive evaluation index of each infrastructure is proposed according to corresponding comprehensive evaluation formula; (4) evaluation criteria of each comprehensive index are divided to achieve infrastructure safety level.

3.1 Pavement safety

As early as 1962, AASHO carried out research according to pavement safety, put forward the concept of pavement performance, which is the main indicators of pavement performance evaluation. While, previous pavement evaluation was proposed mainly according to the structure performance, which can ensure no structural damage caused traffic disruption (Sun Lijun, 2009). With the continuous development of the transportation, the demand gradually improved on pavement function and quality of service, and the concerns transferred from the unitary structure performance to safety performance (Temple, W.H., et al., 1988).

Pavement safety evaluation includes four indexes: pavement damage, roughness, rutting and skid resistance, as shown in Table 3. These four indexes are non-dimensionally processed at first, and then the comprehensive index PTSI is obtained by the following formula (1).

Table 3. Pavement safety comprehensive evaluation index

Comprehensive evaluation index	Individual performance index	Evaluation index	Dimensionless index
PTSI	pavement damage	PCI	P_1
	pavement roughness	RQI	P_2
	rutting	RDI	P_3
	skid resistance	SRI	P_4

$$PTSI = w_1P_1 + w_2P_2 + w_3P_3 + w_4P_4 \quad (1)$$

Where: P_1 is the dimensionless value of pavement damage, P_2 is the dimensionless value of pavement roughness, P_3 is the dimensionless value of rutting, P_4 is the dimensionless value of skid resistance; w_1、w_2、w_3、w_4 are the weights of P_1, P_2, P_3, P_4, which are calculated according to AHP and fuzzy entropy method (Sun Lu, 2011; Zhou Zhengbing, 2011), shown in Table 4.

Table 4. Index weight of PTSI

	weight coefficient	w_1	w_2	w_3	w_4
Asphalt pavement	weighted value	0.35	0.40	0.15	0.1
Concrete pavement	weighted value	0.5	0.40	-	0.1

Pavement safety comprehensive evaluation index PTSI, calculated according formula (1), can be used to evaluate the security of a pavement. And its evaluation criteria are shown in Tab. 5.

Tab. 5 Pavement safety comprehensive evaluation criteria

Evaluation criteria	Excellent	Good	Fair	Inferior	Poor
Pavement safety comprehensive index PTSI	≥85	70~85	55~70	40~55	<40

3.2 Bridge safety

Back in the 1970s, several states in the United States successively put forward a variety of bridge evaluation index system based on NBIS (National Bridge Inventory System). Bridge safety evaluation mainly targets bridge decking, which includes five indexes: bridge deck pavement, drainage, ancillary facilities, expansion joint and sidewalk. Comprehensive evaluation of bridge decking safety is shown in Table 6.

Table 6. Bridge decking safety comprehensive evaluation method

	Index	Weight	Formula and criteria
R_1	bridge deck pavement	30	（1）comprehensive evaluation formula：$D_f = 100 - \sum_{i=1}^{n} R_i W_i / 5$ Where：R_i——evaluation scale of the ith civil structure (range 1 to 5, 5 is the worst) (JTG H11-2004)；
R_2	expansion joint	10	
R_3	sidewalk	10	

R_4	ancillary facilities	20	W_i ——index weight， $\sum W_i$ =100； D_f ——Bridge safety comprehensive evaluation value (range 0 to 100, higher scores represent better safety condition). （2）bridge safety comprehensive evaluation criteria $D_f \geq 88$ good $88 > D_f \geq 60$ fine $60 > D_f \geq 40$ inferior $40 > D_f$ poor
R_5	drainage facility	30	

3.3 Tunnel safety

Scholars at home and abroad have done research on highway tunnel safety evaluation for many years. While, due to the indeterminacy there is no unified tunnel safety evaluation method (Yang Yuan, 2007). Tunnel safety evaluation includes four parts: electrical equipments, tunnel pavement, drainage facility , tunnel portal and interior decoration. In this system, a single tunnel is divided into small sections of 30m for each section. And tunnel safety comprehensive evaluation of each section is calculated respectively by the following method:

Table 7. Tunnel safety comprehensive evaluation method

	Index	Weight	Formula and criteria
E_1	power supply facility	20	（1）Comprehensive evaluation formula： $$T_n = 100 - \sum_{i=1}^{n} S_i W_i / 5 - \sum_{i=1}^{n} E_i W_i / 5$$ Where： S_i ——evaluation scale of the ith civil structure (range 1 to 5, 5 is the worst)(JTGHl2-2003)； E_i ——evaluation scale of the ith electrical equipments (range 1 to 5, 5 is the worst)(JTGHl2-2003)； W_i ——index weight， $\sum W_i$ =100； T_n ——tunnel safety comprehensive evaluation value (range, 0 to 100; higher scores represent better safety condition). （2）Tunnel safety comprehensive evaluation criteria $T_n \geq 90$ good $88 > T_n \geq 60$ fine $60 > T_n \geq 40$ inferior $40 > T_n$ poor
E_2	lighting facility	15	
E_3	monitoring devices	10	
E_4	ventilation facility	5	
E_5	Fire-fighting and rescue facility	5	
S_1	tunnel pavement	20	
S_2	drainage facility	15	
S_3	tunnel portal	5	
S_4	interior decoration	5	

3.4 Slope safety

Slope safety is a dynamic phenomenon from slope deformation to damage and to deterioration (Zhao Zhifeng, 2007). The threshold method and tendency judgment method are two ways often used to evaluate the rationality of a particular engineering project. The tendency judgment method has a tremendous advantage on the issue of the evaluation of slope security situation.

Slope monitoring includes deformation, stress and environment three aspects, among which the safety performance of slope surface deformation, crack, deep displacement and stress can be evaluated by tendency judgment method; the safety performance of supporting structure, stress, groundwater, precipitation and earthquake can be evaluated by threshold method.

Slope safety comprehensive evaluation includes three indexes: slope deformation, slope stress and slope environment. And non-dimensionally should be processed at first. Slope safety comprehensive evaluation index, namely HTSI, can be calculated according to the following formula:

$$HTSI = w_1 P_1 + w_2 P_2 + w_3 P_3 \tag{2}$$

Where: w_1, w_2, w_3 are the weight of P_1, P_2, P_3, which are calculated according to AHP and fuzzy entropy method (Sun Lu, 2011; Zhou Zhengbing, 2011), shown in Table 8.

Table 8. Index weight of HTSI

eight coefficient	w_1	w_2	w_3
weighted value	0.5	0.2	0.3

Slope safety comprehensive evaluation index HTSI, calculated according formula (2), can be used to evaluate the overall security of a slope. And its evaluation criteria are shown in Table 9.

Table 9. Slope safety comprehensive evaluation criteria

Evaluation criteria	Excellent	Good	Fair	Inferior	Poor
HTSI	1	1~2	2~3	3~4	4~5

3.5 Ancillary facilities safety

Ancillary facilities safety evaluation using artificial survey marking method evaluate ancillary facilities by five indexes: safeguard, separation fence, sign, marking and greening. Then calculate comprehensive evaluation index ACI (Ancillary facility Condition Index). It can be calculated according to the following formula:

$$ACI = \sum_{i=1}^{5} w_i (100 - GD_{iACI}) \tag{3}$$

Where：ACI-Ancillary facility Condition Index，The range of values is 0 to 100; GD_{iACI} - deducted score of the ith facility damage type，maximum value is 100; w_i - the weight of the ith facility damage type; *i*-sequence number of facility damage type.

4. Traffic flow state recognition and emergency management theory

Based on summarizing the development of traffic flow state recognition theory and emergency decision theory at home and abroad, this section will analysis models for traffic information module and emergency management module.

4.1 Traffic state identification

- A. Demand characteristics analysis

Freeway traffic state identification is the foundation and basis of user decision making. The user generally includes three types: traveler, manager and decision maker. As they have different traffic information needs, their purposes are different. While the freeway traffic operation safety and emergency management system is mainly for manager and decision maker, so this article carries on analysis of user demand of these two types of user.

The requirements of traffic state information can be summarized as follows: ①the information can reflect section traffic flow states from the macro level on real-time; ②managers can quickly and effectively formulate the specific solutions when the event occurs; ③ the information can provide data support for traffic state analysis, and storage the real-time information as a static information.

- B. Traffic flow operation state classification

In many cases, using qualitative fuzzy language is easier to be understood than using specific figures when describing traffic flow operation state. For example, “crowded” is more evocative than “traffic density is 50car/km/lane” (Guiyan Jiang et al., 2003).

So it is in need to classify traffic flow operation state, and each category corresponds to one category of “degree of crowdedness”.

In China, freeway service level can be classified into four grades (Zhang Qiseng et al., 2002; JTG B01-2003), each service level, respectively, corresponds to a different operating state of the freeway traffic flow.

- C. Traffic flow operation state assessment

Table 10. Traffic flow operation state assessment indexes

Freeway traffic flow operation state assessment	Section utilization	Road section capacity
		Road section traffic
		Section saturation
	Section service level	Average speed
		Average travel time
		Section occupancy
		Road traffic density
		Average travel delay each section
		Section accidents
		Section average fuel consumption
	Traffic environment pollution	Traffic pollutant emissions
		Traffic noise

According to the demand characteristics analysis of traffic flow state information and evaluation indexes in Table 10, we can get the traffic flow running state evaluation analysis table as follows.

Table 11. Traffic flow running state evaluation analysis table

Sequence number	Index name	macro	micro	real time	static	manage	decision-making
1	road section capacity	√	×	×	√	√	√
2	Road section traffic	√	√	√	√	√	√

3	Section saturation	√	√	√	√	√	√
4	Average speed	√	√	√	√	√	√
5	Average travel time	√	√	√	√	√	√
6	Section occupancy	√	√	√	√	√	√
7	Road traffic density	√	√	√	√	√	√
8	Average travel delay each section	√	√	√	√	√	√
9	Section accidents	√	√	×	√	√	√
10	Section average fuel consumption	√	×	×	√	×	×
11	Traffic pollutant emissions	√	×	×	√	×	×
12	Traffic noise	√	√	√	×	×	×

4.2 Emergency management theory

- A. Freeway emergency management process

Ministry of Transport of the People's Republic of China enacted a new Highway Traffic Emergency Plan on April 2009 (Transportation ministry unit of the People's Republic of China, 2009), which was built based on summarizing the disaster relief experiences of severe snow storm in southern region and massive earthquake in Wenchuan of Sichuan province in 2008. The emergency plan clearly defined the freeway incident classification (natural disasters, highway traffic accidents, public health events and social security incident) and grading (level Ⅰ- extraordinarily serious, level Ⅱ-serious, level Ⅲ- major, level Ⅳ-ordinary), and also provided the following information: alert information to be captured during emergency operation, alert level, emergency response, command and coordination work system, information exchange and release system, resource allocation system and emergency response terminates program , and so on.

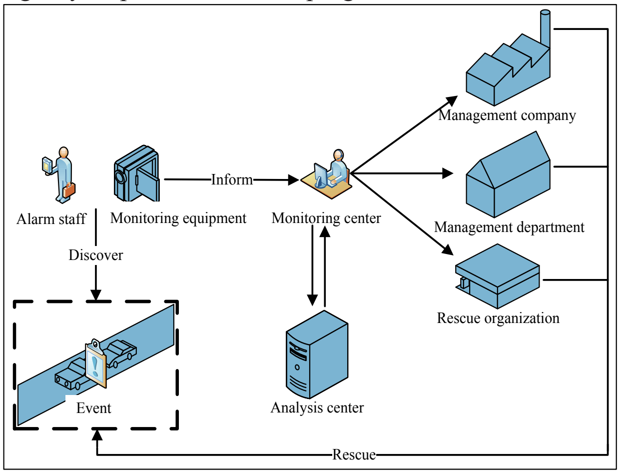


Fig. 2. Freeway emergency management processes

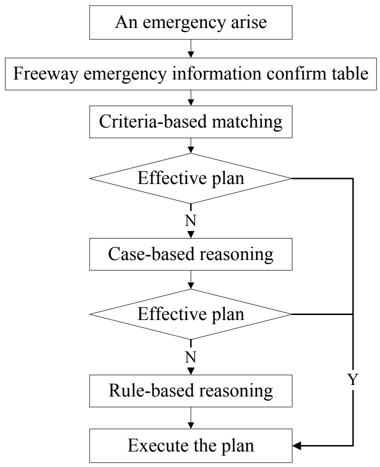


Fig. 3. The generation process of the emergency plan

- B. Generation process of the emergency plan

Freeway incident management requires sufficient real-time data and management experience. With the development of technology, all kinds of information collection technology, information transmission method and the emergence of real-time database make it more convenient to access to real-time data and information. And managers can make the best decision in the right moment.

When facing emergency, the emergency plan is the most important emergency basis for decision making, whose purpose is to reduce the incidents of injuries and losses to a minimum degree. Emergency plans divide into the overall plan and the special plan: the overall plan refers to the organization, procedures, principles of emergencies, and effective control measures, countermeasures, such as the general requirements; the special plan refers to organizing and commanding the management rescue units to take emergency corresponding effective measures and countermeasures in accordance with the emergency of different categories. Generally, there are three algorithms used to quickly generate emergency plans: criteria-based matching, case-based reasoning and rule-based reasoning. The generation process of the emergency plan is shown in figure 3.

When freeway incident occurs, there is need to define event, that is to fill in the emergency information confirm table, and then confirm the category of event.

The implementation of freeway traffic operation safety and emergency management system in this paper uses criteria-based matching algorithm to generate emergency plans, as shown in figure 4.

Following confirmation of events category, evens will be entered into emergency information database and will be divided into four different levels, which are gradually serious from high to low, that is Ⅳ is the slightest event and Ⅰ is the most serious event. Then select some indicators from the emergency information table for information processing, and extract category information after refining, which can be condition of starting emergency plans. That way, it can automatically retrieve and match emergency and plans through the start condition when generating plans.

At this point, all the theoretical part of the freeway traffic operation safety and emergency management system has been built.

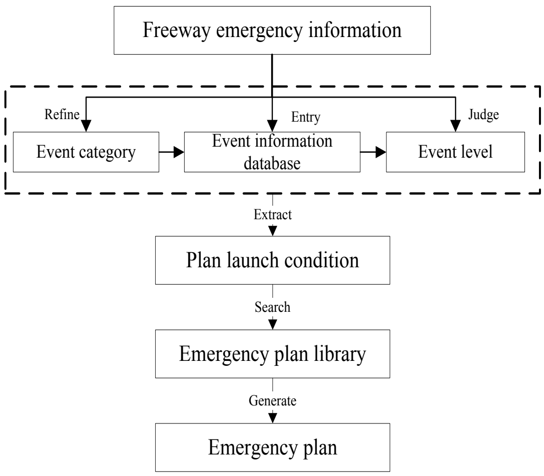


Fig. 4. The generation process of criteria-based matching algorithm

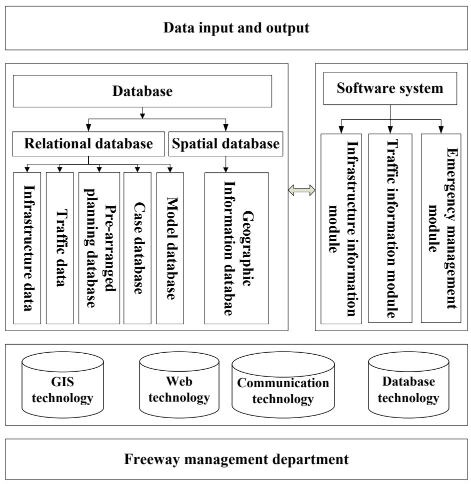


Fig. 5. System framework

5. System Design & Implementation

5.1 System framework

The freeway infrastructure safety and emergency management system is a comprehensive software system, which relates to multi-sector, multifunction, multi-technology. The framework is shown in figure 5.

System database is divided into relational database and spatial database. The relational database refers to the two-dimensional table that is establishing the one-to-one relationship between freeway unit, event and its attributes (such as stakes, names etc.); the objective of the spatial database is to achieving infrastructure indicators graphical display by establishing the one-to-one relationship between freeway unit and its geographic information (such as position, etc).

A variety of software technology is need in the process of implementing the system: (1) GIS technology is used to generate map using infrastructure and traffic flow information and provide a range of the corresponding function; (2) Web technology is used to present the function of system in the form of web pages, if the system software is deployed in a server, other users can use the system software by accessing server; (3) Database technology is the foundation of the whole system.

5.2 System function design

System functions include infrastructure information, traffic flow information and emergency management three modules. Each module corresponds to a variety of specific functions. (shown in figure 6)

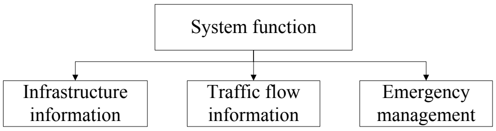


Fig. 6. System function

5.3 System implementation

System environment is shown in Table 12.

Table 12. System environment

Development tool	Microsoft Visual Studio 2008
Data base	Oracle 10g
WebGIS software	ArcGIS Server 9.3.1
Spatial Database Engine	ArcSDE 9.3
Development language	ASP.NET(C#)、JavaScript

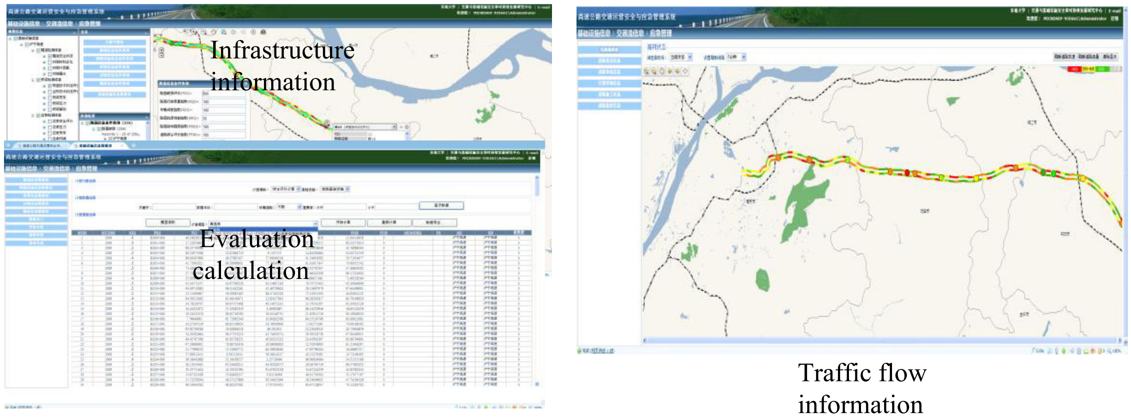
System Interfaces are shown as follows:

- (1) Login page

Monitoring center

Login page

- (2) Infrastructure and traffic flow information interface



- (3) Emergency management interface

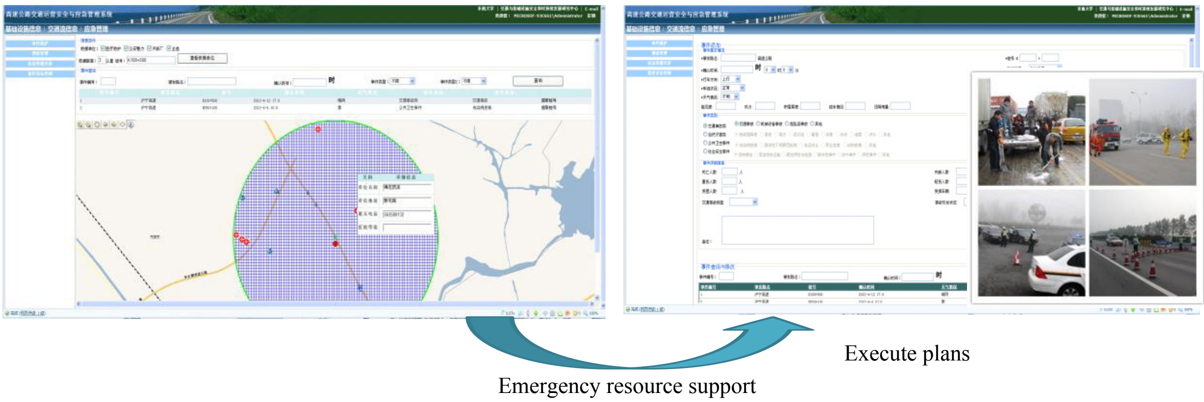


Fig. 7. System Interfaces

6. Conclusions and future work

In this paper, a freeway infrastructure safety and emergency management system was developed based on comprehensive infrastructure safety evaluation, aimed at remedying the shortage of infrastructure safety monitoring and offering informationalized emergency management system for freeway manager.

In the future, we'll pursue development by improving infrastructure safety comprehensive evaluation models based on traffic safety, taking established cases into account when doing decision making and upgrading software system.

7. Acknowledgements

This study was sponsored in part by the National Science Foundation under Grants CMMI-0408390 and CAREER award CMMI-0644552, by the American Chemical Society Petroleum Research Foundation under Grant PRF-44468-G9, by National Natural Science Foundation of China under grants51050110143, 51250110075 and U1134206, and by Jiangsu Natural Science Foundation under Grant SBK200910046, to which the authors are very grateful.

References

Aloysisus J. Rego(2001). National disaster management information systems & networks: An Asian overview. http://www.adpc.net/v2007/ikm/ONLINE%20DOCUMENTS/downloads/PaperAtGdin01.pdf.

Barnes C F, Fritz H,YooJ(2007).Hurricane Disaster Assessments with Image Driven, Data Mining in High Resolution Satellite Imagery. IEEE Transactions on Geo science and Remote Sensing, 2007, 45(6): 1631-1640.

Chai, G., Pu, J., & Wan, S. (2008). "Discussion on the linkage mechanism of provincial expressway emergency rescue." *China Safety Science Journal*, 18, 5, 68-73.

Deng Zeying(2000). The new trend of American highway traffic safety. *Journal of Foreign Highway*, 2000 (1):9-13.

Feng Qi(2006). Enlightenment from Management System of Emergency Response in Germany. *City and Disaster Reduction*. 2006(2):17-19.

[93]Guiyan Jiang, Jiangfeng Wang, Xiaodong Zhang (2003). The Study on the Application of Fuzzy Clustering Analysis in the Dynamic Identification of Road Traffic State. Shanghai, The IEEE the International Conference on Intelligent Transportation Systems-Shanghai, 2003:408-409.

Jiang, N. (2011). "The research on traffic safety emergency management system based on risk coupling.Wuhan University of Technology, Wuhan, 48-70.

Kenneth A. Duda and Michael Abrams(2005). ASTER and USGS EROS Disaster Response: Emergency Imaging after Hurricane Katrina. IEEE Transactions on Geoscience and Remote Sensing, 2005, 1 (12):1346-1350.

Ma, S. (2004). "Research on emergency rescue system for Road traffic accident." *Journal of Chinese People's Public Security University*, 3, 87-91.

Sun Lijun(2009). Roads and airport facilities management[M]. Beijing: China Communications Press, 2009.

Sun Lu, Zhou Zhengbin, Jin Jiaoping, et al(2011). Assessment of weather condition for traffic safety of mountain highway based on fuzzy entropy and analytic hierarchy process. *Journal of highway and transportation research and development*, 2011,28(12):138-144.

Temple, W.H., and S.L. Cumbaa, "Serviceability Index Base for Acceptance of Jointed Concrete Pavements", Pavement Evaluation and Rehabilitation, *Transportation Research Record* 1196, Transportation research board national research council, Washington, D.C, 1988:251-256.

Transportation ministry unit of the People's Republic of China. Highway bridges and culverts maintenance standard (JTG H11-2004).2004.

Transportation ministry unit of the People's Republic of China. Highway tunnel maintenance standard (JTGHl2-2003).2003.

Transportation ministry unit of the People's Republic of China (2003). Highway technical standard (JTG B01-2003) 2003.

Transportation ministry unit of the People's Republic of China(2009). Highway traffic emergency plan[S]. 2009.

United States Department of Homeland Security (2004). "Emergency Response Guidebook."

William L, Breckinridge VII，Najafi F T, et a1(2007). A summary review on the importance of transportation planningreparation and execution during a mass evacuation. TRB.The 86th Transportation Research Board Annul Meeting. Washington DC: TRB, 2007:974-980.

Xianyuan Dong, Yue Wang, Haozhe Cong (2012). Research on Active Emergency Management Systems Based on Predictions of Traffic Incident Radiation Scope in Regional Road Networks. Beijing,CICTP 2012：2482-2493.

Yang Yuan (2007). Development of highway tunnel health digital system. Shanghai: Tongji University, 2007.

Zhang Qiseng, Zhang Yaping(2002). Road capacity analysis.Beijing: China Communications Press,2002.

Zhao Zhifeng (2007). Theory and method research of safety assessment of high rock slope based on displacement monitoring information. Nanjing: Hohai University, 2007.

Zhou Zhengbing, Sun Lu, Li Yifeng, et al. (2011). Importance assessment model for highway tunnel based on analytic hierarchical process and fuzzy entropy [J]. *Journal of Transportation Engineering and Information*, 2012,10(4):36-43,81.