THE DEVELOPMENT AND APPLICATION OF AN INCIDENT MANAGEMENT SYSTEM FOR THE NORTHERN SECTION OF NINGLIAN EXPRESSWAY

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ABSTRACT

The Nanjing-Lianyungang Expressway, which is referred to in this paper as the NingLian Expressway, was opened to traffic in 1999 and operated normally without an incident management system until March 2006. To improve the safety and emergency service of the northern section of the Expressway, an incident management system was developed and applied. Three major parts of the system, namely the demand analysis, system design, and system application, are described in this paper. For the demand analysis, the management method for the northern section of the NingLian Expressway, which can be regarded as representative of the management of most of the expressways in Jiangsu Province and even the whole country, was first investigated. Next, the detailed state of affairs and the relationships between the interrelated agencies involved in incident management were analysed and the resource distribution of each agency was determined. Finally, a demand analysis of an incident management system, that is most suitable for Chinese expressways, was completed. The principal functions of the system design are as follows: confirmation of the incident classification, real-time incident information display based on an integrated GIS map and automatic generation of an incident plan by the rules-based expert system, control of the incident management process, real-time incident information dissemination via mobile phone short message service and Internet sites and automatic generation of management report forms. The system has been formally in use since April 2006 at the management centre of the northern section of NingLian Expressway. According to the statistical analysis, by September 2006, the decision-making correctness rate of the expert system was above 85% and the mean rescue time was reduced by 30%.

KEYWORDS: Incident management, NingLian Expressway, expert system, decision-making

1. INTRODUCTION

By the end of December 2005, the total length of expressways in China exceeded 41 000 km (Ministry of Communications, 2005), which ranks it second in the world. In order to meet the national economic development requirements, it is pointed out in the “National Expressway Network Plan” drawn up by the Ministry of Communications that the expressway network will cover 82 000 km and serve a population of more than one billion, which almost rivals the 88 000 km of expressways in the USA. This will greatly improve China’s transportation status and promote rapid development of the economy. However, the rapid increase in the expressway traffic volume in recent years has led to various types of traffic accidents.

Research in many countries has shown that the key to freeway operation management is to be able to deal with congestion so as to ensure high traffic volume, speed and safety on the freeway. An incident management system is an important sub-system of the freeway management system that has been in operation in Chicago, USA, since the 1960s.

Recently, the use of ITS overseas has been improved by incident management technology such as traffic flow surveillance, communication and dissemination of information to the user. Therefore incident management systems have been moving towards automation. Incident management systems in many developed countries with their own distinctive features have been implemented after several modifications (Ozbay and Kachroo, 1999). The highly effective incident management systems of some countries have already produced remarkable benefits.

China has just recently started on research and implementation of incident management systems, and only the rapid incident response systems set up by provincial capital freeways have been reported so far. Although China is still far behind developed countries, we have come to realize that freeway management, especially incident management, is essential to guarantee safe, fast, efficient, comfortable and convenient freeway operation. Several metropolises such as Beijing and Shanghai are beginning to install modern freeway traffic flow detecting and monitoring equipment, which will lay a good foundation for an incident management system and also offer the opportunity for urgently needed research in this field.

2. AN EMERGENCY RESCUE MANAGEMENT SYSTEM FOR THE NORTHERN SECTION OF NINGLIAN EXPRESSWAY

2.1 Introduction of an emergency rescue system for the northern section of NingLian Expressway

The northern section of NingLian Expressway totals 138 km, passing through Huaian, Lianshui, Gaogou, Guannan, Guanyun and ending at Lianyungang. This section is managed by the management department of the northern section of NingLian Expressway. The expressway administration is the responsibility of the second team of the Huai'an expressway administration department and the first team of the Lianyungang expressway administration department. The clearance team is based at the management department of the northern section of NingLian Expressway and at the Lianshui tollgate, which also has some clearance equipment, and is responsible for clearances. The framework for the NingLian Management Department is shown in Figure 1.

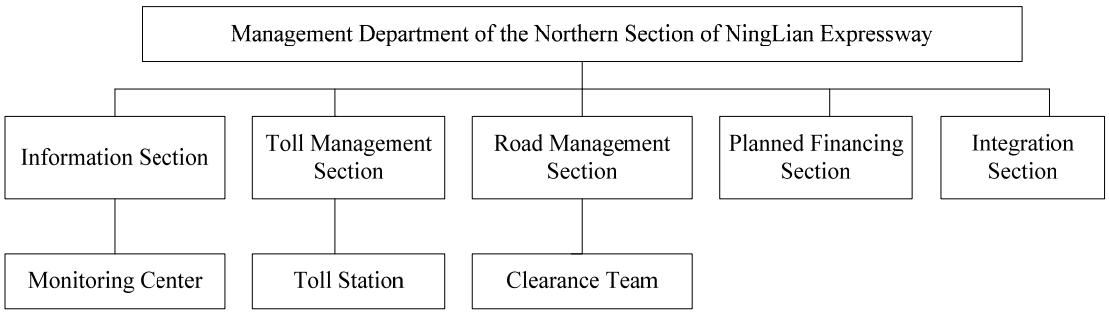


Figure 1. Organisation of the NingLian Management Department

Rescue work during incidents on the northern section of NingLian Expressway is managed mainly by the expressway patrol, the road administration team and the management department. The responsibilities of the three departments are as follows: the expressway patrol deals with traffic incident clearance and traffic control, the road administration team is

responsible for the management of expressway property and administration, and the maintenance company is in charge of expressway maintenance. The three departments are part of different administrative systems, and the relationship between them is only one of cooperation without any formal management or leadership mechanism. Incidents are dealt with through coordination of the expressway patrol, the road administration and the control centre. According to the level and circumstances of the incident, and whether hospitals and fire-fighters or any other departments are needed, the control centre takes charge of coordinating the activities of the responding departments. The conditions may differ according to different situations. In some places, the hospital and the expressway patrol set the traffic lights from the incident zone to green, which improves the speed of response, and also makes a positive contribution to reducing fatality rates and improving rescue efficiency (Jiang Hua-ping et al., 2004). The organisation of the emergency rescue system of the northern section of NingLian Expressway is shown in Figure 2.

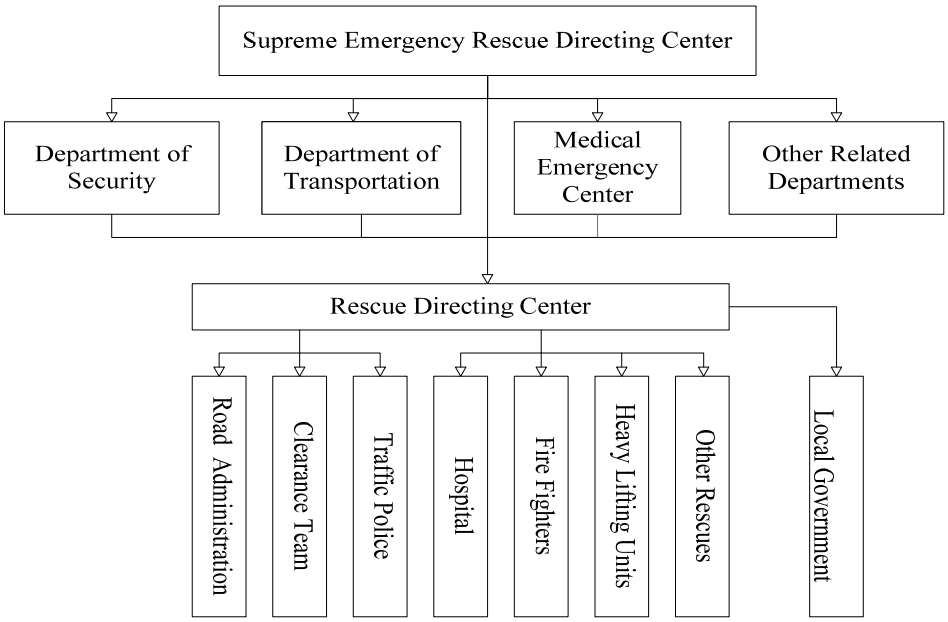


Figure 2. Organisation of the emergency rescue system of the northern section of NingLian Expressway

Communication of information between the management department and the expressway patrol is of the utmost importance in incident rescue. However, in the current system, it is difficult to communicate information among different departments, the reason being conflict of interest among the different departments. The division of responsibility of duty and law enforcement in China makes it almost impossible for different departments to communicate with each other. The information exchange when dealing with incident clearance on the northern section of NingLian expressway is shown in Figure 3, in which the control centre mainly plays a role of information communication.

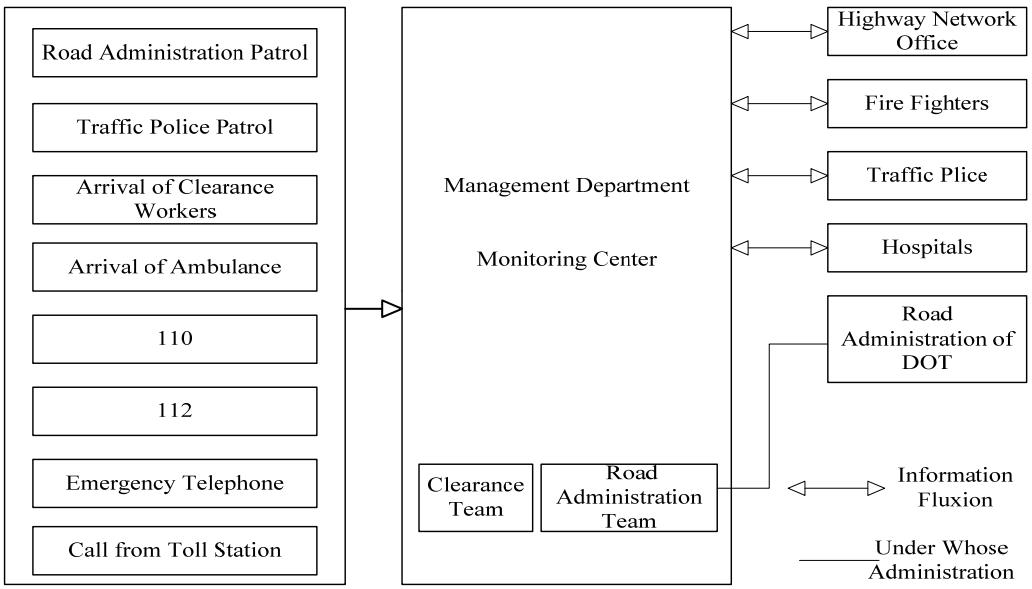


Figure 3. Information exchange during incident clearance on the northern section of NingLian Expressway

2.2 The problem of incident rescue on the northern section of NingLian Expressway

The overall condition of the northern section of NingLian Expressway is basically good. However, the distribution of traffic incidents is not uniform, which is mainly the result of climate, geography, road condition and other factors. Incidents that occur during inclement weather are relatively more frequent, especially in areas that experience fog, which is a serious threat to traffic safety. Incidents that occur on rainy days form a large proportion of the total number of incidents, and the number of secondary incidents is greater (Hernández et al., 2001). Therefore the expressway management departments have made plans for responding to emergency incident clearance and have determined the responsibilities of the responding incident management departments.

However, the following problems still exist during actual operations:

- Weak function of the monitoring centre: The monitoring centre only collects preliminary incident information and transmits it to the different departments, but it cannot do a comprehensive analysis of the preliminary incident information nor take measures to direct the incident clearance.
- Coordination among different departments: There is a clear division of authority among the expressway patrol, road administration and expressway management departments in the current management systems. Due to the lack of system security, some problems still exist during the coordination of the above departments.
- Poor circulation of information: The different departments mostly rely on telephones, which reduces the rescue efficiency and delays the rescue time.
- Rapid confirmation of incident location: Due to the less frequent use of emergency telephones during emergency incidents, the expressway patrol and road administration can only search for incidents according to the general location, which leads to very low rescue efficiency.
- Emergency lanes and rescue equipment: Major or serious traffic accidents always block the expressway, and the rescuers cannot do their work quickly. Moreover, rescue equipment is not used rationally.

2.3 The application framework of the incident management system and system design for the northern section of NingLian Expressway

2.3.1 Database design

The characteristics of incident management have been fully considered in the database design, in which data are classified according to several categories, namely traffic operation data, traffic incident data, road condition data, emergency resource data, field equipment and management department resource data, emergency strategy data, emergency plan data and rules list data. The classification and structure are shown in Figure 4. According to incident type and location, this system divides incidents into five categories, namely traffic control, warning incidents, toll-station incidents, road incidents and service area incidents. A brief introduction to the five categories of incidents is given below.

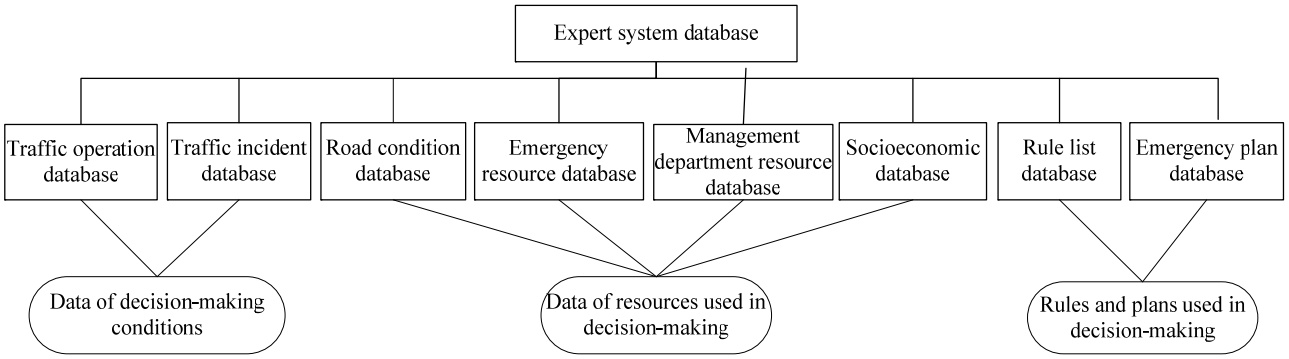


Figure 4. Database framework of expert system in incident management

The E-R diagram (Entity-Relationship diagram) of incident management data in the system database is shown in Figure 5. It reflects the directions and interrelationships between data, amongst which user data are relatively independent, and are mainly used when users log in. Incident condition data and plan data correspond via rules, and are connected by incident serial numbers. The plan data then links to the rescue resource data, data reported to leaders, field equipment data, geographical information data and so on.

2.3.2 Implementation of response rule base

Once the incident is verified, the response procedures commence. In the process of formulating a response plan, all the incidents types were first broadly classified as vehicle and non-vehicle incidents, which has several sub-classes. This allows identification of all services required at the incident site based on the incident's characteristics. The services are then related to the agencies. A list of tasks performed by each agency and inter-agency responsibilities are then identified. The response procedures are used as the basis for development of the response rule base. The rule base constitutes the core of the system response module. These rules were collected during the assessment of user requirements, through personal interviews with the various users and through literature studies. The knowledge base consists of forty-three different sets of rules. Table 1 shows an example of the rule base sets.

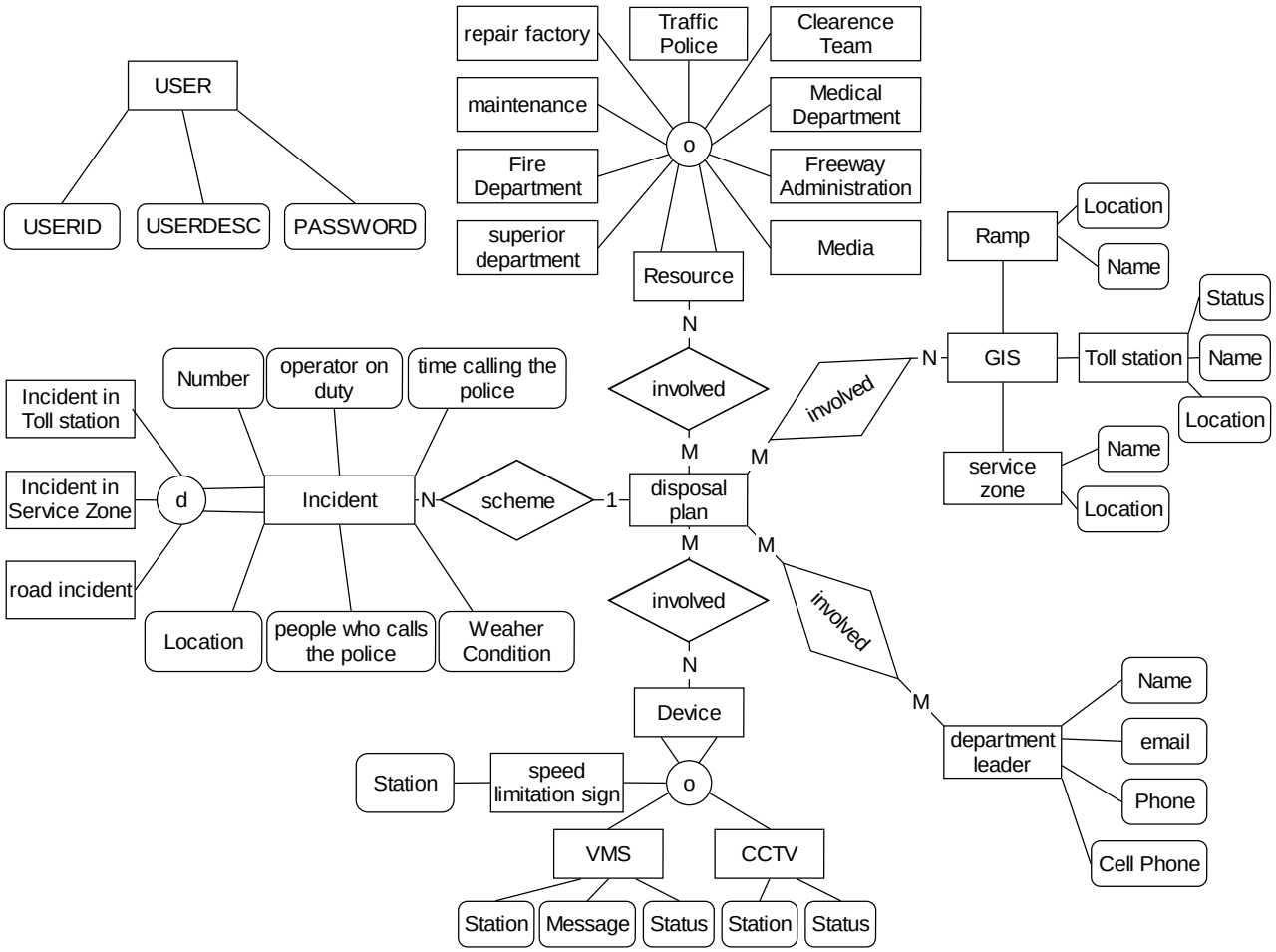


Figure 5. E-R diagram of expert system data in incident management

Table 1. Rules for changeable message signs and speed limit signs

If		Then	Then
Incident Severity Index		Disseminated on VMS 35 km upstream of incident location	Speed limit on changeable speed limit sign within 25 km upstream of incident location
Severity Index = 1		Incident ahead, reduce speed	80 km
Severity Index = 2		Incident ahead, reduce speed	60 km
Severity Index = 3	No division	Incident ahead, reduce speed	40 km
	division	Incident ahead, detour advised	30 km
Severity Index = 4	No division	Incident ahead, reduce speed	20 km
	division	Incident ahead, detour advised	20 km

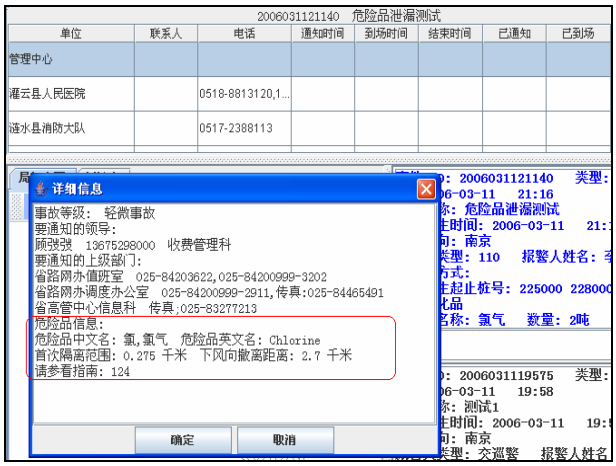
2.3.3 Human-machine interface (HMI)

The development of the HMI was based on the user requirements and the subsequent transformation into functional specifications. The HMI is GIS based, which operates on a PC platform and supports the following functions: (a) it serves as a front end for entering real-time information into the system, (b) provides features for extracting and displaying all information stored in the data base, (c) displays the location of the incidents and their related information using different colours, (d) displays the protective action zone and initial isolation zone for hazardous materials/dangerous goods incidents,(e) forms the dispatch plan, (f) displays a list of the on-scene actions, (g) interacts with users for getting feedback

with regard to the incident management process, (h) disseminates real-time incident information from the Internet and broadcast and mobile devices. Figure 6 presents some interfaces of the system.

Incident Inputting Interface

Plan Table



Process Management

Internet Information Dissemination

Figure 6. System interface

2.3.4 Case study

The system was formally put into use at the management centre of the northern section of NingLian Expressway in April 2006. According to the statistical analysis, by September 2006 the decision-making correctness rate of the expert system was above 85% and the mean rescue time was reduced by 30%. The data are shown in Table 2.

Table 2. Before and after comparison according to incident type

SN	Incident type	Before system application		After system application	
		Number of incidents	Overall time (min)	Number of incidents	Overall time (min)
1	Disabled vehicle	20	69	19	48
2	Property damage	8	122	10	122
3	Personal injury	4	184	3	125
4	Vehicle fire	0	0	0	0
5	Fatal incident	5	198	1	142
6	HAZMAT incident	1	473	1	243
7	Fog-related	0	0	0	0
8	Cargo spill (poultry)	2	197	0	0
9	Incidents at toll stations (conflicts between drivers and toll collectors, etc.)	20	31	22	15
10	Incidents in service area	0	0	0	0

3. CONCLUSIONS

This system provides modern technological methods for the statistical analysis of traffic incidents, rational dispatch of clearance resources as well as coordinated actions of related agencies. Integration of a GIS map with the expressway operation system and emergency system allows the location and status of traffic incidents on the expressway to be graphically and immediately displayed. This provides an effective support for workers responsible for incident clearance. Artificial intelligence and a rule-based clearance plan, as well as B/S design mode, are built into the system, which assists in the dissemination of short message, radio and real-time Internet information on expressway incident management. By applying the evacuation and HAZMAT models in the system, timely and effective clearance of HAZMAT incidents could be provided.

Further research is needed on the following aspects:

- With the rapid development of expressways in China as well as the improvement of field devices, there will be an urgent and increasing demand for automatic detection, which requires accurate algorithms.
- Detecting traffic incidents timeously through sensors (Abdel-Rahim and Khanal, 2004).
- Further study of incident management systems of traffic corridors.
- Comprehensive consideration of network traffic control and diversion as well as an improvement in the standards of incident management data.

4. ACKNOWLEDGMENTS

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