AN ACCIDENT PREVENTION AND EMERGENCY RESCUE SYSTEM FOR EXPRESSWAY TUNNELS

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ABSTRACT

Using the idea of safety management for the technical transmission of modern traffic and network information as the basis, this paper sets up a traffic accident prevention and emergency rescue system for expressway tunnels, which is an important means of improving the safe operation and management of expressway tunnels. According to the characteristics of traffic accidents in expressway tunnels, the traffic accident prevention and emergency rescue system administration, consisting of a supervision layer, an infrastructure layer, a shared layer and a value-added service layer, is an integrated, comprehensive, systematic platform which incorporates data communication, database and GIS into an organic whole and has a certain intelligence function. This paper then studies the framework of an accident prevention and emergency rescue system for expressway tunnels and describes the primary function modules and workflow. Finally, the paper examines the Shaoguan tunnel of the Jing-zhu expressway in China and puts forward some constructive suggestions for setting up an accident prevention and emergency rescue system.

Key words: traffic engineering; expressway tunnel; accident; emergency rescue system

1. INTRODUCTION

With the rapid economic development of our country, more and more tunnels have been constructed on expressways to shorten mileage, eliminate the grade, improve the alignment, reduce the effects of frost, snow and natural disasters, protect the environment and realise sustainable development. Because the tunnel is the throat section of the expressway, serious traffic accidents often occur in conditions of heavy traffic and bad weather. Furthermore, in the operational control of domestic expressway tunnels, the faultiness of traffic accident prevention and emergency rescue systems, and the lack of professional rescue teams make traffic accidents very serious.

The measures to ensure tunnel safety can be divided into two approaches: the one is to reduce the possibility of traffic accidents, and the other is to mitigate the seriousness of accidents. Therefore this paper, starting with traffic control, aims to reduce the response

time of emergency rescue measures, improve rescue efficiency and reliability, speedily resume operation of the expressway tunnel, and decrease direct and indirect economic costs and personal injuries. It offers a basic framework for traffic accident prevention and an emergency rescue system, which have direct practical significance for accident prevention in complex traffic conditions. It aims to construct a modern control system and improve the existing control level in expressway tunnels, and at the same time lays the foundation for an intelligent expressway tunnel management technology for our country.

2. FRAMEWORK FOR AN ACCIDENT PREVENTION AND AN EMERGENCY RESCUE SYSTEM FOR EXPRESSWAY TUNNELS

Traffic accident rescue should follow an orderly course, which includes identifying and confirming, fast reaction, information, on-the-spot management, traffic control and clearing up. The factors that affect the safety of expressway tunnels are various and their mutual relationship is complex. Not only should a proper traffic information database be set up, but also the principles of modern traffic safety management should be used, as should advanced information technology, control technology, network information technology, etc. to monitor the dynamic changes on a highway section in real time, to allow the prediction of possible occurrences and measures to prevent accidents. Or once the accident has occurred, measures should be taken to reduce losses as much as possible and rapidly resume orderly traffic flow. Therefore in this paper it is considered that accident prevention and the emergency rescue system of an expressway is composed of four parts as follows:

1. Safe administration and supervision layer: This is the core of the system; the main content includes monitoring, analysis and forecast of the safe state of the expressway tunnel, traffic control, traffic safety management and the dissemination of traffic information.

2. Infrastructure layer: This is composed of the information transmission network and the traffic geo-information platform. It is the foundation of and condition for the system operation.

3. Information shared layer: This is used for interfacing the traffic information with other related information.

4. Incremental service layer: This provides information services to all levels of society.

The basic framework of accident prevention and an emergency rescue system for expressway tunnels is shown in Figure 1.

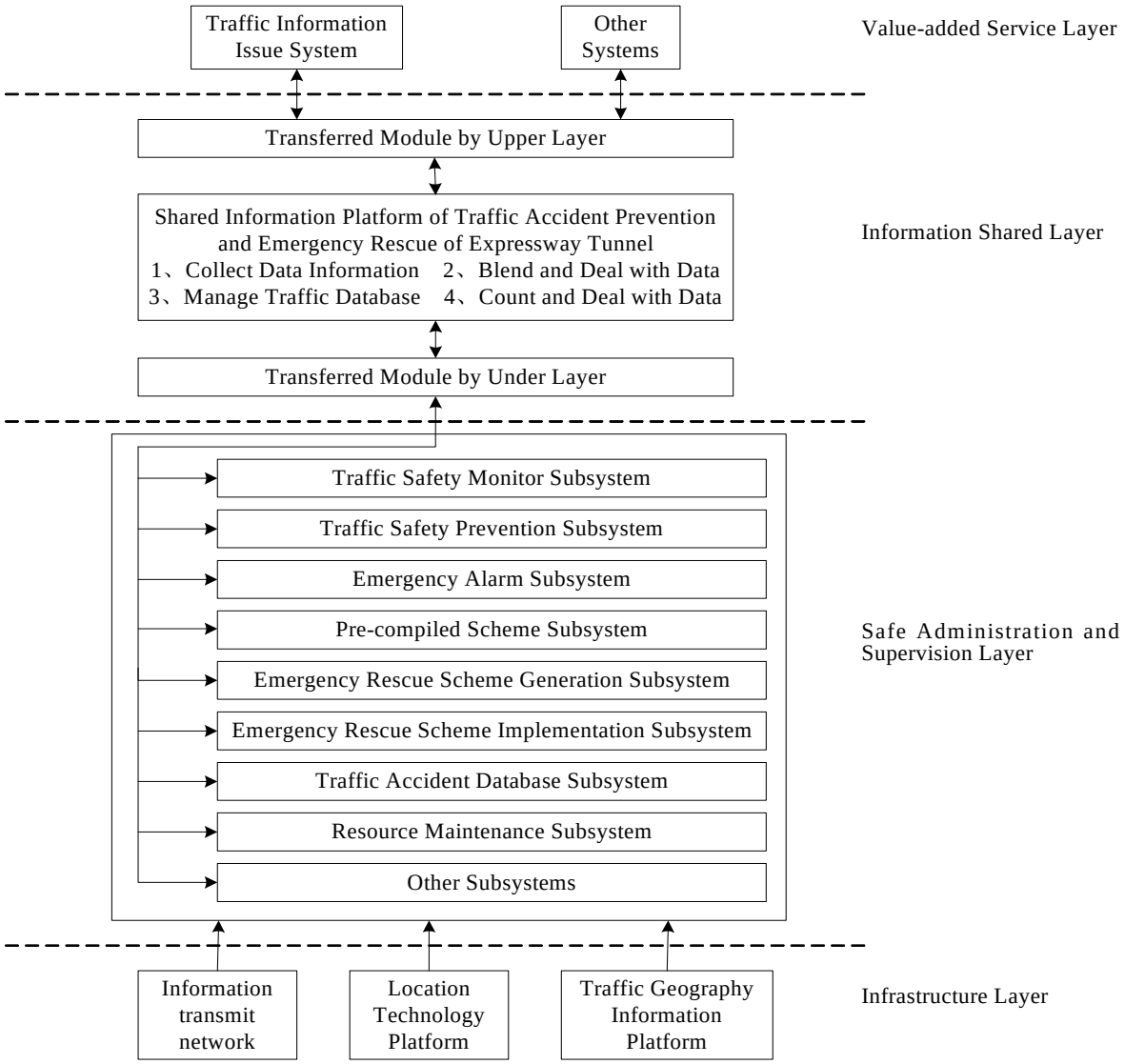

Figure 1. Framework of a traffic accident prevention and an emergency rescue system for expressway tunnels.

3. MAIN FUNCTION OF AN ACCIDENT PREVENTION AND EMERGENCY RESCUE SYSTEM OF EXPRESSWAY TUNNELS

For safety management of expressway tunnels, the basic function of accident prevention and an emergency rescue system is constructed as follows:

3.1. Traffic safety monitoring subsystem

Closed circuit television, vehicle detectors installed in tunnel sections, and patrol cars monitor in real time the state of vehicles in tunnel sections to obtain information on the state of traffic safety. The information is transmitted to the monitoring and information processing centre through the information transmission network to support the safety analysis and forecast.

3.2. Traffic safety prevention subsystem

A sharp drop in road capacity resulting from a random cause and the sudden change of traffic flow are known as abnormal traffic phenomena. By analysing the traffic volume, speed and occupancy using the method of abnormal automatic traffic detection, we

distinguish whether the road is jammed or not and the causes, and whether abnormal traffic has occurred or not and the site and the severity.

3.3. Emergency alarm subsystem

This subsystem can receive various kinds of alarm, and confirm and display the site on the electronic map automatically according to the alarm message. For each alarm message, the alarm is recorded automatically. The alarms may be saved in the database, with the time, contents, phone number, person, accident site, response time from the centre, etc. This subsystem can provide information to distinguish repeat alarms, continue real-time tracking and provide multi-input methods for quick response to alarms.

3.4. Pre-establishment scheme subsystem

This subsystem can provide inputs for staff to devise an emergency dispatch scheme in advance and to contact the respective leaders according to the traffic. This system can automatically devise several schemes for accident emergency aid, provide emergency aid approaches for various kinds of accidents and form the foundation for the creation of an emergency aid scheme.

3.5. Emergency rescue scheme creation subsystem

This subsystem is the main body of the whole system. On the basis of the pre-scheme, it can confirm the emergency aid scheme through the collection of accident information, and analyse and synthesise the feedback information from the rescue group. It then it confirms the respective rescue departments based on priority according to equipment of all kinds in the resource maintenance subsystem database. At the same time, it provides rescue routes for various departments. For typical accidents in particular sections, the system can call out the accident management pre-scheme from the subsystem and provide a detailed message and geo-information. But in practice, for the rescue scheme to generate automatically, it must carry on with the rational optimisation according to the different parameters. It can provide the relevant scheme and the support for the leaders' decision-making.

3.6. Emergency rescue scheme implementation subsystem

This subsystem is the core of the whole rescue system. During the rescue, full-time, real-time monitoring and controlling should be done to track the situation at the accident site until the rescue has been completed. In the process of the rescue, the rescue and monitoring centre must provide the administrative procedures and the condition of the relevant roads for salvagers, and adjust the information contents according to the feedback information, display the rescue regulations on the electronic map or the relevant computers and highlight the status of the accident management (including the names of rescue staff, the safety equipment at the site, the scheme in the target area).

3.7. Traffic accidents database subsystem

This subsystem can store information on traffic accidents and the rescue process, and automatically generate a rescue report. The report includes the management report at accident site, the final treatment report, the on-the-spot investigation report recording the details of the accident (accident site, vehicle number, name of person responsible, casualties, contaminated area, damage of highway equipment, etc.), the provisional rescue

measures (direct residents to vacate, help the injured, prevent secondary pollution, salvage property, protect highway equipment, etc.), the nature of the accident and the coverage and record of enquiries at the site, etc. In such a way it can regulate the status of the traffic accident database and interconnect with the database.

3.8. Resource maintenance subsystem

This subsystem realises the operational function of the traffic accident database for managers. The long-term accident records will form a valuable data resource for handling all kinds of documents, which can supply resources for the management decision-maker and investigator to analyse traffic accident characteristics in expressway tunnels, and provide a basis for improving the level of control in expressway tunnels. In the emergency aid system, we can build three separate databases for human resources, material resources and social resources. The resource maintenance subsystem will be responsible for enquiries and statistics and improving and maintaining the databases. These data will provide a convenient data service for the rescue system.

4. WORK FLOW OF ACCIDENT PREVENTION AND EMERGENCY RESCUE SYSTEMS FOR EXPRESSWAY TUNNELS

The flow chart of accident prevention and emergency rescue systems for expressway tunnels is shown in Figure 2. The accident prevention and emergency rescue system for expressway tunnels is based on the monitoring and control system of the expressway tunnel of the emergency rescue command centre.

During or after an accident, the traffic flow will be abnormal which will be automatically detected. When the staff in the control centre detect accidents by traffic state analysis, they will control the traffic to that section. At the same time, the road administration and point constables go to the site immediately to carry out field control and confirm whether an accident has occurred. If so, the emergency aid measures are implemented immediately.

After an accident has occurred, the management staff in the monitoring centre find the accident in the area covered by CCTV. The accident victims or witnesses can raise the alarm on the emergency telephone in the tunnel section of expressway or by cellphone. The traffic police or the patrol car of the road administration department gives an alarm call on the car telephone. After receiving an accident alarm, the emergency rescue command centre immediately records the accident information, including time, place, accident type, accident description and so on, makes a preliminary analysis and confirmation, and the emergency rescue pre-project will be generated automatically. At the same time, the accident information and related traffic control or guide information will be issued through the information system. After the road administration department and traffic police have confirmed the accident type at the site, the accident type will be confirmed further, and the emergency rescue command system will give an emergency rescue project on the pre-project. Then the rescue orders will be issued through the communication system and the emergency rescue project will be carried out. According to the different rescue requirements and functions of departments, the accident and rescue requirement information will be distributed to all the relevant departments which are involved in the rescue. A major accident should be reported to the main department, which will give the

command control orders. After receiving the accident report, all relevant departments do their work in association with the emergency rescue command centre. The situation at the accident site is transmitted to the command centre so that the emergency rescue command system can modify the rescue project in time. After the accident action is finished, the command centre issues an order that the action has ended, and the traffic system returns to normal. At the same time, the command centre will record a detailed accident rescue treatment report and analyse the treatment result.

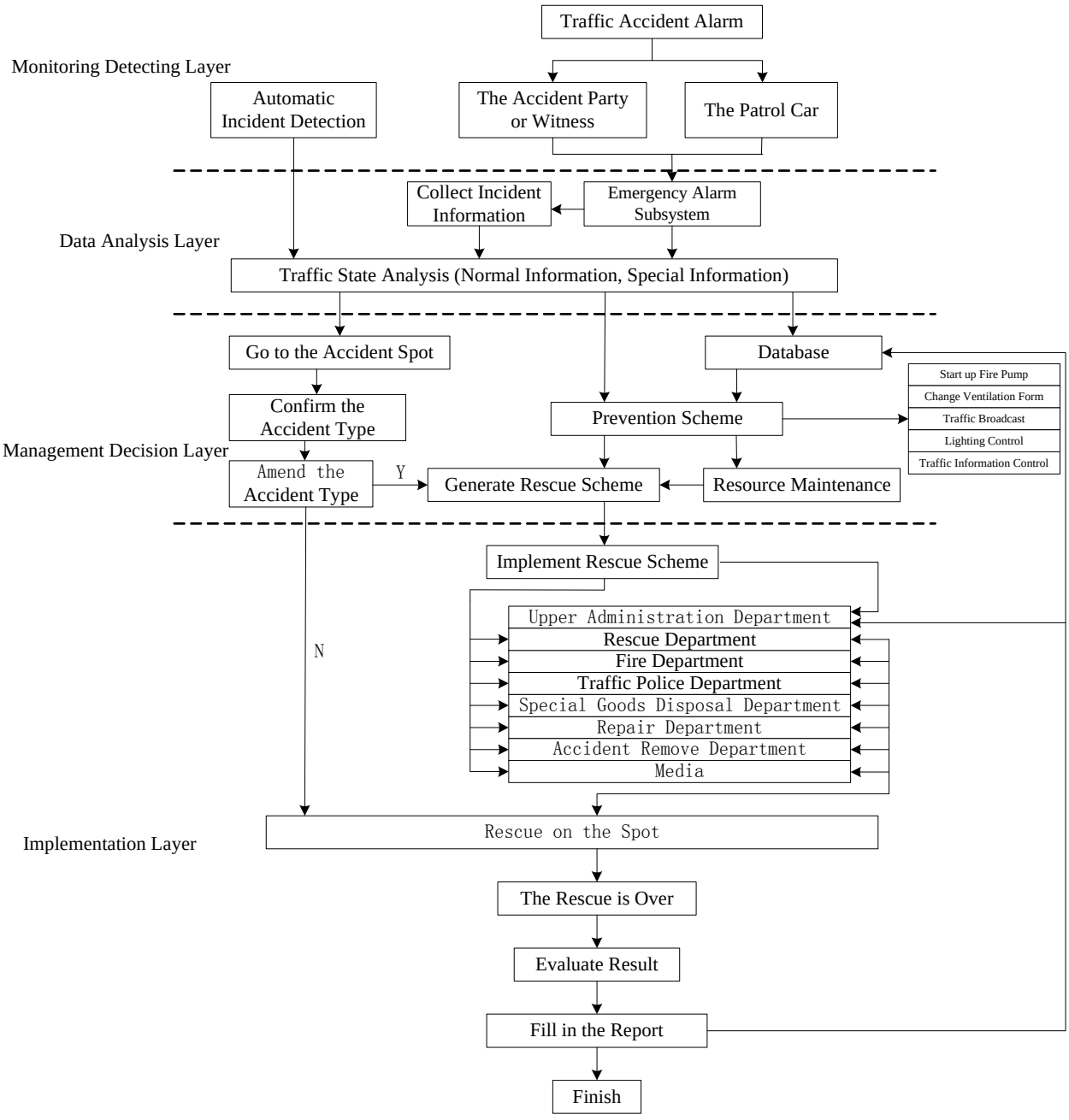

Figure 2. Flowchart of Traffic Accident Prevention and Emergency Rescue System of Expressway Tunnels.

5. APPLICATION

As a part of the Beijing-Zhuhai National Trunk Line, the Gantang-Wengcheng section in Guangdong Province is the national and Guangdong provincial key project, which was built in 1998 and opened to traffic in January 2001. This section is 54.21 km long, and has three long tunnels (Kaoyishan Tunnel, Dabaoshan Tunnel and Baolinshan Tunnel) and one short tunnel (Wulongling Tunnel).The total length of the tunnels in this section is about 24 km which is 45% percent of the length of the Shaoguan section. The geography of this section is high mountain and foothill landform and the design speed of the tunnel on this road section is 100 kph. Electrical storms often occur in this section, which belongs to the thunderstorm and foggy zone. Because there are high side slopes and a great deal of heavy-duty vehicles, this section belongs to the accident and hidden hazard area.

The tunnels are basically complete at present. The electromechanical system cost approximately ¥20 000 000 and the monitoring and control system cost about ¥ 12 000 000 (not including electric power). In the tunnels, the electromechanical system is equipped with a ventilation control system (composed of a CO monitoring instrument, visibility meter, wind gauge, jet fan, ventilation power box, etc.), a lighting control facility (composed of a light intensity monitor, local control instrument, etc.), automatic fire alarm system (composed of temperature-sensitive copper tube, detector and local control), a closed-circuit television system, a traffic monitoring system, emergency telephone system, fire-fighting equipment, etc. In the Shaxi Tunnel, a monitoring centre was established to manage the operation and facilities of tunnel.

At present, if an accident occurs in the tunnel section, the staff in monitoring centre can find the accident in the area covered by the closed-circuit television system. The victim, witnesses, or the patrol cars of the traffic police and road administration inform the monitoring centre of an accident. Then the monitoring centre informs the road administration, traffic police and other related departments where the site is to confirm the accident type and prepare the rescue project according to the actual situation. At the same time, the monitoring centre will control the traffic control in the affected area. Finally, the centre will record and file the type, cause and other information in the traffic accident database.

The existing facilities in tunnels of the Shaoguan section of the Jingzhu Expressway does not completely meet the requirements of accident prevention and emergency rescue, nor reducing the response time of emergency rescue, increasing the rescue reliability, resuming traffic movement in the tunnels, decreasing the direct and indirect economic losses and casualties. So on the basis of existing facilities in the expressway tunnels, it is necessary to construct a set of accident prevention and emergency rescue systems to accommodate the traffic characteristics of the Shaoguan section and meet the traffic requirements to improve the efficiency of accident prevention and rescue through intelligent information systems.

6. CONCLUSIONS

The traffic accident prevention and emergency rescue system is an important part of ITS, and we should give our attention to the following aspects:

1. As the traffic accident prevention and emergency rescue system is an important constituent of ITS, it requires the application of advanced technology and administration methods. Traffic security administration should be linked to other aspects of traffic administration to fully utilise the system's efficiency and increase the expressway traffic security level.

2. A traffic accident prevention and emergency rescue system of an expressway tunnel requires advanced information, control and network information technology and the integration of related systems so as to share the traffic information widely and bring all of them into play. A common information system that meets all requirements should be established.

3. The control and administration of dynamic traffic information is the core of traffic accident prevention and an emergency rescue system of expressway tunnels, and the authorities should further develop the collection, transmission and analysis aspects to ensure the system’s proper operation.

4. The establishment of an accident prevention and emergency rescue system for expressway tunnels not only depends on the installation and use of equipment, but also on the broad support of society, especially adherence to traffic rescue regulations and the enhancement of civil consciousness.

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