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Decision support system for emergency management: Road tunnels

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ABSTRACT

Recent disasters have shown that road tunnels are especially complex environments for decision making. A fast and effective response to emergencies in road tunnels is a key factor for life safety. This paper presents a decision support system (DSS) for emergency management in road tunnels. Based on a specific methodology, the system provides the operator with decision recommendations to deal with the emergency in real time. Furthermore, the system uses predictive tools to estimate the severity of the accident or incident, as well as rescue and evacuation times. This information is very useful during the first stages of an emergency when information is scarce, incomplete and inaccurate, yet the tunnel operator is required to make the right decisions under a high level of stress. The DSS reduces the decision circle and allows the operator to make critical decisions based on dynamic alternatives. The system has been tested in various hypothetical emergency cases based on the Tunnel of Lantueno in the A-67 Highway, Spain. The application cases show that the DSS provides reasonable and consistent results.

1. Introduction

Accidents in road tunnels can and do occur. A fast and effective response by the tunnel operator can mean the difference between life and death, especially when a fire occurs. Recent history has shown that tunnels constitute dangerous environments in case of emergency. In the last few decades (1987–2008), just seven tunnel accidents have caused over 400 deaths (Carvel and Marlin, 2004). Disasters such as the Mont Blanc Tunnel fire (Italy–France, 1999) and the St Gotthard Tunnel fire (Swiss Alps, 2001) have caused many deaths and serious injuries. The most recent is the bus crash in the Sierre Tunnel in Switzerland with 28 deaths, 22 of them children. These tragedies have shown the need for an effective emergency response and the tragic consequences of incorrect or delayed decision making (Burns, 2004). Tunnel safety is dependent on three main factors: (1) tunnel design, (2) tunnel management, and (3) emergency response. However, current road tunnel safety is limited by the traditional approach, which is focused on tunnel design and facilities, risk analysis and contingency plans.

Prevention is a key factor in tunnel safety, but does not solve the problem once the emergency occurs. Instituting a proper emergency management plan is a critical way to minimise the risk of injury and death by maximising the speed and effectiveness of a response.

The tunnel operator is the first person to deal with the emergency and inform the tunnel users, supervisor and emergency services regarding the situation (Tesson, 2009). In many cases, the decisions of the tunnel operator are based on fixed protocols that may not cover all possible situations during the continuous development of an emergency. Furthermore, some critical decisions, such as evacuation, may depend not on the tunnel operator but upon other authorities. For this reason, the initial information should be as clear and complete as possible. Nowadays, technology can be a key tool to improve the effectiveness of emergency management and human safety in road tunnels. The advantage of using decision support systems (DSSs) for emergency management in complex situations is well known (Yoon et al., 2008; Yu, 2011). In this domain, the GIDAI Group (University of Cantabria, Spain) has finished a research project – funded by the Spanish Ministry of Transport – whose aim was to produce a DSS for emergencies in road tunnels. The DSS analyses the current situation and guides the course of decisions to deal with the emergency (Capote et al., 2011, 2012a, 2012b, 2012c). Furthermore, the system provides real-time estimation of the severity of the accident, required safe egress time (RSET) and rescue times.

This paper is divided in two parts. The first part describes the three models integrated in the DSS: (1) Incidents model, (2) Evacuation model, and (3) Decision model. The second part shows the application cases for different hypothetical emergencies in a double-bored, unidirectional, 670 m road tunnel located along the A-67 Highway in Spain.

2. Decision support system overview

When an accident occurs, the tunnel operator detects the emergency mainly through the Automatic Incident Detection (AID)

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system and/or CCTV, or by other tunnel facilities such as an SOS or fire detection system. After that the tunnel operator inputs some preliminary information about the accident to the DSS such as fire or spillage detection, injured people, vehicles involved and trapped. It should be noted that in following versions of the System, the possible integration of the DSS into the current tunnel facilities will enable to increase the automation level (i.e. the traffic counters might offer the information about the number of vehicles trapped). Firstly, the system provides the course of decisions to deal with the emergency according to the own tunnel's contingency plan. Furthermore, the DSS offers additional information about the situation: (1) estimation of the severity of the accident by providing the number of people involved and the number of injured and seriously injured people and (2) evacuation times for the people involved and trapped in the tunnel, when included in the course of decisions. This is very useful information during the communication process between the operator and the emergency services.

As Fig. 1 shows, the DSS is an integration of three models: (1) Incidents model, (2) Evacuation model, and (3) Decision model. These three models are connected; outputs from the Incidents models are inputs for the Evacuation and Decision models. These outputs are divided into two parts: (1) estimations about the tunnel's users, and (2) location of the accident.

The Decision model processes the information and displays the actions, such as close the tunnel, inform and/or deploy the mobile patrol and/or the emergency services, and inform the tunnel users. If evacuation is required, then the Evacuation model simulates the self-rescue and rescue processes, providing information about their possible outcomes in real time. In addition, the system permits feedback. This means that the operator may obtain new results as the accident characteristics change. The DSS permits the analysis of possible situations and scenarios in a few seconds. It can run on any PC. Fig. 1 shows the DSS schema.

The DSS employs a determinate set of input data according to a specific tunnel which is included into a *.ds1 file (tunnel data). That kind of file is generated by the auxiliary software *paramSI.exe*. This program has the capability to implement or modify any *.*ds1* file. There are two types of data in the *.*ds1* file:

1. *Tunnel characteristics*: Number of lanes, number of surveillance cameras, tunnel length and width, distances to the first camera and between cameras, height, focal and visual angles of the cameras, number of cross passages, distance to the first cross passage and distance between cross passages.
2. *Probability data*: Probability of injured persons, probability of seriously injured persons, probability of deceased persons and probability of injured persons in a non-serious accident. The current file employs default values obtained from the statistical processing of available databases about world tunnel disasters (Eurotap, 2008). However, the authors consider that it would be possible to improve the accuracy of this probability data by including a wider database of accidents or by considering the accidents in the application tunnel or geographical area. Furthermore, this file includes data about the occupancy of the vehicles (light vehicles, heavy vehicles and buses). The probability data are input in the auxiliary software *paramSI.exe*. and it can be modify at any time by the user.

3. Incidents model

The Incidents model is based on Boolean algebra, probability theory and a black box model (Wiener, 1961) due to the lack of a priori information. The inputs of the system (Fig. 2 and Table 1) are defined by the main types of information obtained from the tunnel facilities (AID, CCTV, SOS, fire detection system, etc.).

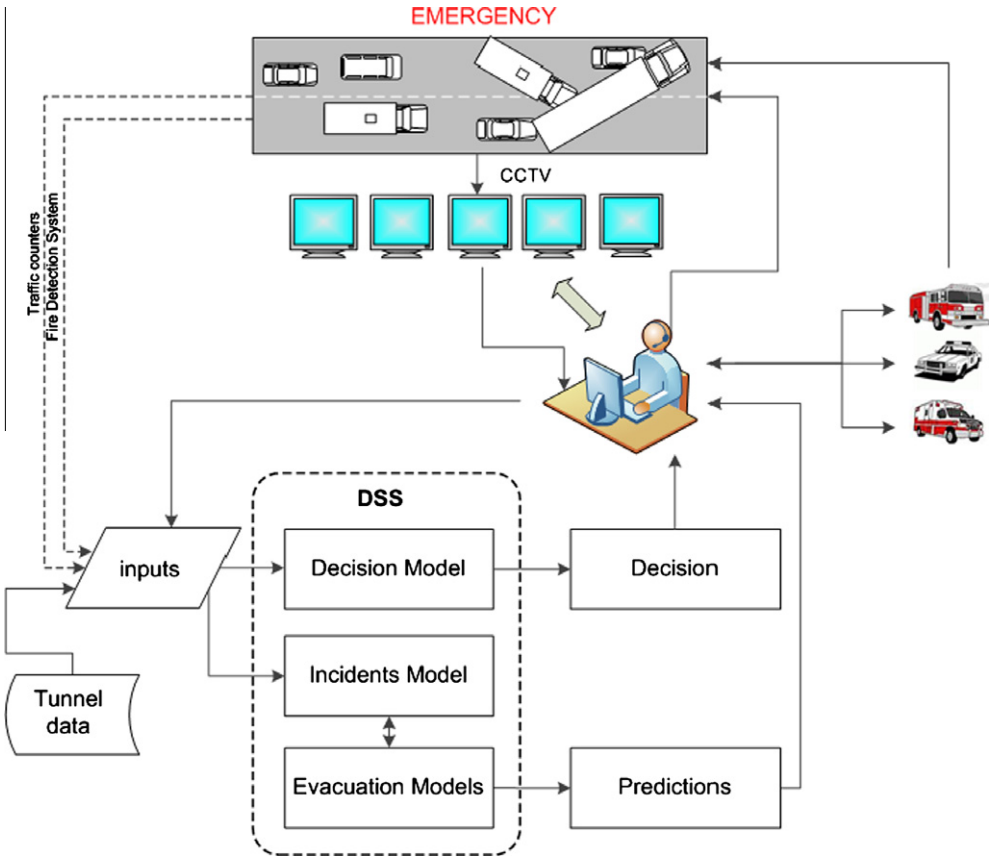

Fig. 1. Decision support system schema.