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Theory Establishment and Data Preparedness for Modeling Emergency Medical Service in case of a Mass Casualty Incidents in Road Tunnels

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Abstract

The road system in Taiwan has expanded with remarkable speed resulting in great concern regarding the response to a mass casualty incident (MCI) by the Emergency Medical Services (EMSs). Accidents in road tunnels have the potential to cause major casualties due to their particular configurations and confined conditions. To meet this sudden demands involving huge uncertainties and complexities, EMSs provided by fire services need to be better prepared and more efficient. The recent research into EMS response to MCI aims at identifying effectiveness of life preservation and strategies of emergency mobility through outcome indicators to evaluate performance for different aspects of disaster management. However, the conducting of experimental studies is either impossible or ethically inappropriate. This study tries to use realistic injury statistics for EMS simulations based on medical records of a previous case study and an EMS database currently used in Taiwan. These statistics are temporarily used in a proposed trial MCI/EMS model where injury entities evolve in the medical response model, i.e. the model focuses only on the prehospital phase which includes triage, treatments at the scene and transportation processes - to understand the utilization of resources including Emergency Medical Technicians and ambulances. The outcome indicators also highlight the length of waiting including both before treatment at the Medical Post and before departure at the Delivery Post for each serious injury, and the total operation time to review the emergency response plan for an incident in Hsuehshan tunnel. This study also illustrates how such a model could be used to assess the impact on resource availability, implemented prioritization rule and various other strategies relating to emergency management.

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Keywords: mass casualty incident, emergency medical service, road tunnel

1. Introduction

As of 2008, more than half the world's population live in cities (www.who.int/gho/en/). The Population Reference Bureau predicts that 70 percent of the world population will be urban dwelling by 2050, and that most urban growth will occur in less developed countries. This process of urbanization is already well developed in Taiwan, hence, the road

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network has expanded at a remarkable rate leading to a substantial increase in passenger volumes over recent years. Notable examples in relation to this study are the 12.9 km Hsuehshan tunnel and the soon to open tunnels along Suhwa Expressway in the northeastern part of the island.

The busy weekend and holiday period traffic is a particular area for concern with mass causality incidents more likely in future. The emergency response to cases of sudden mass casualty incidents (SMCIs) in these types of road tunnel is one of the major concerns for traffic authorities, healthcare providers and the fire services.These incidents cause unique difficulties for on-site emergency medical services (EMS) due to their particular geometry, configurations and confined conditions. It is therefore of great importance that adequate EMS strategies for various scenarios are developed to cope with any possible SMCIs in those road tunnels.

Before 2000, research into the subject of emergency responses has been primarily qualitative and descriptive. The use of defined, validated evaluation methods and/or evidence-based approaches to identify the performance of an emergency response, including EMS for MCI, has been rare. Operational research into emergency medical management is limited by the fact that the conduct of prospective and randomized controlled studies in the real world is impossible or ethically inappropriate. Computer simulation, fortunately, has been used to overcome these methodological problems. For example, Brailsford and Hilton have compared system dynamics and discrete event simulation (DES) to see which method should be applied in specific circumstances [1]. Su has used an object-oriented simulation software to improve the emergency medical service of Taiwan [2]. Tomasini and Van Wassenhove have evaluated the evolution of supply chain management in disaster relief and the role of new players such as the private sector [3]. G¨unal and Pidd have presented a literature review on DES for performance modeling in health care [4], while Mes and Bruens have developed a DES model for an integrated emergency post [5]. They present a generalized and flexible simulation model, which can be adapted to several emergency departments. Van Wassenhove and Pedraza Martinez have adapted supply chain best practices to humanitarian logistics [6]. Aboueljinane et al. have also proposed a DES model implemented using ARENA software to analyze possible changes in the EMS processes (called SAMU 94) that could lead to enhanced operational efficiency for coverage performance [7].

In the above-mentioned papers, a stochastic DES has been widely applied to construct a model by using specific tools such as ARENA, a commercially available SIMAN programming language-based simulation software, and this tool is also used in this study. Learning references for ARENA include Kelton et al. [8] and Guo[9]. The trial simulation model is expected to consist of 3 interacting submodels including the injury creation, the medical response and the pathway model, which originally has been based on Debacker et al's work [10]. However, the proposed simulation model in this study is still limited to a single medical process on the disaster scene to lay the foundation of a complex system that the injury entities will combine the injury pathway submodel in parallel for the further works. This paper, therefore, focuses on the improvement of the medical response submodel first to continue author's previous works [11]. A pilot scenario depicting a major traffic accident in a road tunnel has been studied and is expected to validate and verify the simulation model in the further study. The outcome indicators of pilot study include the length of waiting (LW), total operation time (OT) for serious injuries, and the utilization of response resources (UR). In section 2 we introduce the EMS process in long road tunnels in case of MCIs regulated in Emergency Operation Plans (EOPs). In section 3 we propose a more realistic medical response model with eight response strategies for various scenarios. In Section 4 we explain how the proposed model translate into a computer simulation mode, describe the pilot model, and then discuss the results. Finally, we conclude and discuss future work in section 5.

2. The Emergency Scenario in Road Tunnels

To further emulate EMS practice in the real world, the tunnel layout described below was chosen as the main reference in setting the simulation scene for the study. In Hsuehshang tunnel both the 12.9 km east-bound and the west-bound tubes of the main tunnel are of a unidirectional-twin-lane design. There is also a pilot tunnel along the entire length of the tunnel. This pilot tunnel is situated just below the center of the two main tubes. Its diameter is 4.88 m. The pilot tunnel was excavated before work on the main tunnel started and, therefore, served as a prospecting tunnel for geology along the length of the tunnel, and for pre-draining of the tunnel. The pilot tunnel can also serve as supplementary transportation route. Following completion of the Hsuehshan main tunnel the pilot tunnel's road was surfaced to 3.0 m wide with net clearance of 2.9m, and a one-way traffic system. Stairs have been installed to facilitate connection to the pedestrian cross connections and the vehicular cross connections. The main role of the pilot tunnel is in providing access for operational and maintenance traffic, ventilation rooms, and additional emergency access for personnel and ambulances, independent of the main tunnel. For traffic, cross connections are assigned at distances of 1.4 km along the tunnel. The total number of traffic cross connections is eight. These also serve the purpose of allowing vehicles to evacuate casualties in case of an emergency. Where each vehicle cross connection connects with the two main tunnels, there is an emergency parking bay. Fig. 1 presents