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Network based temporary facility location for the Emergency Medical Services considering the disaster induced demand and the transportation infrastructure in disaster response

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ABSTRACT

Pre-hospital Emergency Medical Service (EMS) provides the immediate and appropriate aid to patients in emergencies. As part of the traditional triad of first responders, EMS plays an important role in disaster response. In this work, the transportation infrastructure, which the EMS is dependent on, is considered. The objective of this research is to improve the effectiveness of EMS after the disaster by applying integer programming and the network-based partitioning to determine temporary locations for on-post EMS facilities. Integer Programming problems are formed for the optimization problem in different scales, and the Lagrangian Relaxation is adapted to extend the problem further into larger scale. Network based partitioning of demands are also proposed and tested. Numerical results are provided, and a case study is presented. In the case study, the facility location problem takes into consideration of both disaster triggered and usual EMS demand that forms a worst-case scenario. The analytical results are expected to facilitate decision making, and to serve as benchmarks for the planning of post-disaster EMS.

1. Introduction

The performance of pre-hospital Emergency Medical Service (EMS) relies on the existing transportation infrastructure and the medical resources, which are limited and critical. The response time for ambulances is in general considered as a critical factor to the survival of EMS patients. For patients with urgent needs, the response time is decisive of mortality.

When disaster strikes, civil infrastructures have great chances of being affected, and traveling on the transportation infrastructure could become difficult (Holguín-Veras et al., 2008). The lack of access, standardization, coordination, and communication of basic information, such as emergency medical resources, compromise situational awareness and decision making (Chen et al., 2011; Dynes, 1983; Fritz and Mathewson, 1957; Holguín-Veras et al., 2008; NRC, 1999; Quarantelli, 1983). As a consequence, the performance of the pre-hospital EMS is bound to be affected. Additionally, the EMS demand will increase after a disaster. To improve the performance of disaster response, the allocation of resources should be carried out efficiently (Peña-Mora et al., 2010).

In the immediate aftermath of a disaster, a robust system for EMS is to be established so that victims in the affected area will have shortest response and transport times to receive medical care. At the scene of disaster, the Emergency Medical Technician (EMT) will perform a medical triage to set up priority of victims, and the EMT will also perform a first stage

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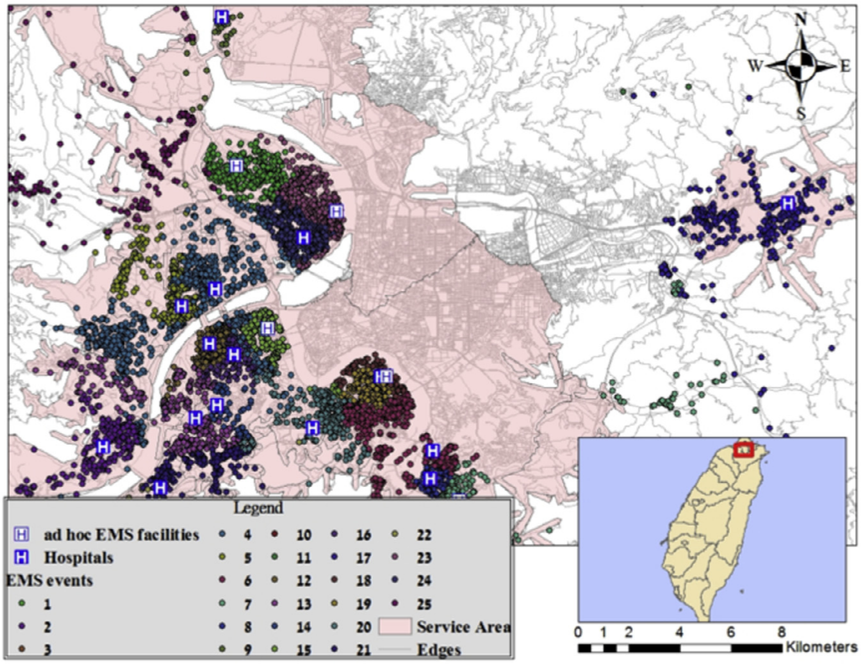

Fig. 1. Facility location problem for post-disaster EMS services.

screening to decide whether a patient will require medical treatment offered only at specialized medical centers. Others will be transported and treated at temporary medical facilities or hospitals still in function. For those patients later discovered to require specialized medical treatment, they will be sent to a specialized medical center afterwards.

The objective of this research is to improve the effectiveness of EMS after the disaster through location planning of temporary EMS facilities. These temporary EMS facilities are assumed to be equipped with advanced emergency medicine equipment such as the Mobile Emergency Room (M-ER) and will serve as the location to receive and manage medical resources. Because disaster management problems could have very different outcomes of damage and casualties, we propose an approach to take the actual conditions into account after a disaster. As a result, this approach has to have high time-efficiency to facilitate decision making, while satisfying certain degree of operational efficiency.

In this work, we consider demand locations, the transportation network and its post disaster conditions, location of existing hospitals, and available number of temporary facility locations. Demand locations are composed of victim locations triggered from the disaster and demand locations in the disaster recovery phase. Victim locations are known from civilian reporting systems or estimation from the local emergency management (EM) officials. If we do not consider EMS service in the disaster recovery phase, only victim locations are considered. In the case when EMS service in the disaster recovery phase is considered for the disaster affected area, predicted demand is also added into the total demand. The transportation network is given from existing data, and the post-disaster condition is expected to be updated into the network. The post-disaster condition of the transportation network is expected to be known from existing technology or human reporting. The number of functioning hospitals is to be known from the local EM, and temporary facilities are to be determined by available medical resources such as the number of M-ER. Fig. 1 illustrates an expected result with circle markers representing EMS victims, the blue H symbol representing existing hospitals, and white H symbol the resulting temporary EMS facilities. In this work, we assume the demand to be each of the victims without the aggregation of them into groups. We believe this best describes the actual condition, and this is a more generalized case. In other words, this approach could be specialized with any approach for the aggregation of demands.

The contents of the paper are organized in the following order. Section 2 provides the literature review of related works, which include EMS, civil infrastructure systems, disasters, and facility locations. The methodology is presented in Section 3, and the numerical examples and case study are presented and discussed in Sections 4 and 5. Finally, Section 6 concludes this paper with contributions and future directions.

2. Literature review

EMS is a specialized and unique type of intelligent transportation system. It plays an important role in saving human lives in both normal and disastrous situations (Kuwata and Takada, 2004; Levick, 2008; Pradhan et al., 2007). Pre-hospital EMS is the first safety measure for people who have encountered emergency injuries, and provides on-site medical treatment and