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An emergency vehicles allocation model for major industrial disasters

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Abstract

One of the main issues in the event of a major industrial disaster (fire, explosion or toxic gas dispersion) is to efficacy manage emergencies by considering both medical and logistics issues. From a logistics point of view the purpose of this work is to correctly address critical patients from the emergency site to the most suitable hospitals. A Mixed Integer Programming (MIP) Model is proposed, able to determine the optimal number and allocation of emergency vehicles involved in relief operations, in order to maximize the number of successfully treated injured patients. Moreover, a vehicles reallocation strategy has been developed which takes into account the evolution of the patients health conditions. Alternative scenarios have been tested considering a dynamic version of the Emergency Vehicles Allocation Problem, in which patient health conditions evolves during the rescue process. A company located in Italy has been considered as case-study in order to evaluate the performance of the proposed methodology.

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1. Introduction

The presented research is part of a broader project (DIEM-SSP - Disasters and Emergencies Management for Safety and Security in industrial Plants) aimed at managing major industrial emergencies by considering both medical and transport/logistics issues. The study of the scientific literature confirms that the severity of a disaster can be highly

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influenced by the efficacy of the logistics operations during the disaster response phase (Yi and Özdamar, 2007; Berkoune et al., 2012; Holguin-Veras et al., 2012). Since in these circumstances time is crucial, one of the major issues in emergency conditions is to ensure a quick response of the rescue operations by an efficient vehicle fleet management (Pedraza-Martinez and Van Wassenhove, 2012). From a practical point of view, it is essential that Emergency Vehicles (EVs) be located so as to ensure an adequate coverage of the interested area and that logistics operations provide an effective response to the emergency. Normally, an EV call starts with a triage, where a qualified medical staff determines the severity of each injured patient and the urgency of the call. As a subsequent step, each vehicle has to be assigned to a patient and has to be sent to the call site where the patient is located. At this purpose, a large amount of information needs to be transferred from the Emergency Site (ES) to the various EV base locations. Moreover, it should also be considered that during the emergency response phase the operations have to be executed under challenging conditions like uncertainty of information, limited availability of resources, hospital congestion and so on (Najafi et al., 2014; Yi et al., 2010). For the above reasons, logistics relief operations are not trivial issues which can be successfully managed without the help of specific support tools. The majority of existing studies have dealt with three main problems:

- Emergency vehicles **location** problem. It implies finding vehicle bases within an area such that a certain response time is guaranteed to reach the potential ESs within this area (Brotocorne et al., 2003; Schmid and Doerner, 2010);
- Emergency vehicles **dispatching/allocation** problem. It consists of assigning EVs to answer the emergency calls in order to maximize the coverage throughout a planning horizon (Hanghani et al., 2003; Goldberg, 2004; Andersson and Varbrand, 2007). This problem is commonly solved in combination with the location problem (Toro-Diaz et al., 2013; Ibri et al., 2012; Schmid, 2012; Andersson and Varbrand, 2007) or with the routing problem (Jotshi et al., 2009)
- Emergency vehicles **routing** problem. It consists of finding a shortest (fastest) path from one location to another taking into account traffic conditions and the infrastructure damage caused by a disaster (Goldberg and Listowsky, 1994; Talarico et al., 2015).

This specific study focuses on the EV allocation problem, assuming that initial vehicles location is a priori known. The main goal of this research is to correctly address critical patients from the ES to the most suitable hospitals by deciding which vehicle has to be assigned to transport each injured patient in the most efficient way.

This work proposes a Mixed Integer Programming Model for the EV allocation able to define the optimal number and allocation of ambulances and helicopters which must be involved in relief operations, in order to maximize the number of successfully treated injured patients. Moreover, a dynamic vehicles reallocation approach has been considered, taking into account that patients health conditions can become worse during the rescue process and can be reevaluated.

A fire/explosion within a company located in Italy, has been considered in order to evaluate the performance of the proposed methodology. Furthermore, three alternative scenarios have been developed in order to show the results of the first EV allocation plan and of the EV reallocation strategy as a result of the evolution of the patient health conditions during the rescue process. The first scenario deals with the first triage. In the second and third scenarios it is assumed that one yellow-code patient become a red-code patient and one green-code patient become a yellow-code patient at the 8th minutes and 15th minutes after the first patient health evaluation respectively.

The model takes into consideration a variety of crucial information and data about both disaster severity (injured patients, injury type, injury severity, etc.) and medical resources availability (number of ambulance, helicopters, hospital specializations, etc.).

The remainder of the paper is structured as follows: Section 2 describes the methodological approach and proposes a Mixed Integer Programming Models for EV allocation, Section 3 describes the data collected to perform the analysis, Section 4 introduces the case-study and discusses the main results obtained for the various scenarios, Section 5 highlights conclusions and discusses future developments.

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