



Emergency transportation network design problem: Identification and evaluation of disaster response routes

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ABSTRACT

Since disasters have considerable effects on transportation networks, the functionality of an emergency transportation network can play an important role in mitigation phase, especially in developing countries that sometimes suffer the sad experience of almost complete destruction of several cities. Transportation related disaster response activities typically include search and rescue, emergency medical care and fire-fighting trips. In this paper, the emergency transportation network design problem is proposed to determine the optimal network to perform emergency response trips with high priority in the aftermath of earthquakes. The problem has three objective functions designated to identify the optimal routes for emergency vehicles considering the length, the travel time and the number of paths as performance metrics of network vulnerability. A combined approach for considering the three objectives including weighted sum and lexicographic methods is used. The proposed model is solved using a branch-and-cut solution method. The suggested method is tested on the well-known Sioux-Falls network as well as on the real-world network of Tehran metropolis, Iran. Computational experiments are conducted to examine the effects of varying the maximum network length, and the relative weights of other objectives.

1. Introduction

Natural disasters such as earthquake, flood, and hurricane inflict significant human and financial losses every year. The number of natural disasters and people affected by these natural disasters has increased in recent years [1]. Comparing yearly earthquake death rates among Iran, Japan and the USA during three different periods revealed that while Japan and the USA have reduced their yearly rates, Iran's status has been worsening [2]. Unlike developed countries where the main concern is to return the city to the pre-disaster conditions quickly, developing countries attempt to rescue more people in the response phase [3]. Many Iranian cities have suffered from earthquakes. Statistical analyses show that Iran has experienced almost 130 earthquakes with magnitudes of 7.5 Richter or greater during the last century [4]. Tabas city, destroyed by an earthquake in 1978, Manjil and Rudbar cities, destroyed in 1990, and Bam, which was mostly reduced to rubble in 2003 [5]. Iran, like other developing countries, suffers earthquake casualties and economic damages. In the devastating Bam earthquake in 2003, conditions were not returned to normal and desired status in a reasonable period, e.g. within 72 h. Following the earthquake, the airport was closed because of severe nonstructural damage suffered by

the terminal and control tower [6]. In the Bam disaster, almost all of the major hospital facilities were destroyed, and a number of their doctors and nurses were seriously injured or killed. This resulted in the need to transport a great number of people to hospitals in unaffected backup areas [7]. The 26 December 2003 earthquake in Bam did not damage the roadway or the bridges in any significant manner. However, in reality, the capacity was severely lowered within the 25 km vicinity of Bam. Due to the heavy influx of rescue cars and private vehicles belonging to those searching for relatives, a lengthy traffic jam occurred along the Bam-Kerman road immediately after the earthquake. After about 8 h, the police managed to control the traffic. In Bam, civil and military aviation organizations played an important role in the rescue effort [6]. In addition, in Manjil (1990) and Bam (2003) earthquakes, nearly all narrow roads in the cities were partially or completely blocked, causing considerable delay in rescue and relief operations. Basically, most of the old urban areas in Iran suffer from narrow roads and streets [8]. Generally, natural disasters result in many devastating damages in developing countries compared to developed ones, and, therefore, make the rescue and relief operations more significant. The increase in natural disasters in the last few decades and the strong dependency of developing countries on their transportation systems has

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