Automation in Construction 20 (2011) 637–648

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

A collaborative GIS framework to support equipment distribution for civil engineering disaster response operations

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ARTICLE INFO

Article history:
Accepted 11 December 2010
Available online 14 January 2011

Keywords:
GIS
Disaster response
Resource management
VRP
Split delivery

ABSTRACT

After an eXtreme Event (XE) hits an urban area, well-organized response operations are required to mitigate the chaotic situation. Efficient allocation of resources such as construction equipment is critical to the performance of disaster response operations. This paper presents a Geographic Information System (GIS) based framework that facilitates equipment allocation in response to disasters. The framework is composed of three subsystems to facilitate information gathering and decision making for equipment distribution. First, an application that runs on mobile devices for on-field resource request is developed. Second, a resource repository is implemented with a geosaptial database that enables spatial query of resources with a graphical interface. In addition, a GIS which enables automated decision making such as resource matching and route finding for resource distribution is presented. Integration of decision models into the framework to support complex decision making for equipment distribution is also proposed. With the framework in place, disaster response operations could become more efficient. Simulated test cases have been carried out for Champaign, IL, the City of Chicago and the New York City. Future research will be directed towards further expansion and validation of the framework through interaction with emergency management agencies in the US.

1. Introduction

Over the past few decades, large-scale natural and human-induced disasters have brought significant attention to the importance of disaster response. Examples of such eXtreme Events (XEs) are earthquakes, hurricanes and terrorist attacks, which cause extensive human casualties, economic loss, and infrastructure destruction. On September 11, 2001, the 9/11 terrorist attacks killed 2819 innocent people, injured more than 6290, and caused over 105 billion of economic loss [1]. The supply of equipment to first responders was insufficient during the disaster response operations [2]. On May 12, 2008, a magnitude 7.9 earthquake struck China. Disaster response operations such as civilian search and rescue were hampered, due to limited equipment not meeting the massive demand [3]. This forced first responders to dig for survivors with their bare hands [3]. The earthquake caused over 69,197 deaths, left 18,222 people missing, and injured 374,176 people [4]. On January 12, 2010, a magnitude 7.0 earthquake struck Haiti. Without the appropriate heavy-lifting equipment, search and rescue operations were hindered [5]. The death toll is approximately 230,000 [6]. Response operations for many disasters were challenged due to first responders' limited access to the necessary and appropriate equipment [7,8]. As a result, it is imperative to have an effective resource distribution in order to support the lifesaving operations.

There are many challenges in resource distribution during disaster response. The lack of access, standardization, coordination, and communication of critical information for situational awareness and decision making are obstacles that need to be addressed [9,10]. During Hurricane Katrina for example, the logistics management systems of the state and federal government did not have an electronic interface in between for communication and coordination. Resource requests from the state level to the federal level were input by hand. With no tracking mechanism in place, the state was unable to follow up on the resource requests, resulting in significant time delays [11]. An electronic interface, supporting collaboration among different jurisdictions, should be established for communication to reduce time delays in disaster response.

In addition to technical challenges, there are also organizational and managerial challenges. For example, cohesive inter-organization collaboration is needed for effective disaster response. Resources owned by different organizations need to be visible and available to the incident command. However, due to the lack of command and control during a major disaster, the coordination of resources across different organizations is difficult [12–14]. In addition, volunteers and response organizations outside of the disaster affected zone converge into the area to assist the response efforts. This is the resource

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doi:10.1016/j.autcon.2010.12.007