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Implementing a web-based decision support system for disaster logistics: A case study of an evacuation location assessment for Indonesia

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ABSTRACT

Decision support systems have increasingly played a critical role in disaster logistics. This study outlines the processes required to build an effective and reliable decision support system to assess the feasibility of public facilities during an evacuation after a disaster has occurred. The purpose of this study is to build a model of a web-aided decision support system to assess the extent to which public facilities can be used as evacuation centers for the victims of an earthquake and/or tsunami. An outcome from this research is an innovative system with direct web-based accessibility, involves many decision-makers and employs multiple criteria and inputs. Even though the system has been specifically designed for evacuation scenarios in Indonesia, the system can be used for disaster scenarios in other countries as well. There are several stages in this study where the first stage identifies and selects attributes, assembles a comprehensive computer application, and employs object-oriented programming (OOP), verification and validation of the system. The role of information systems and decision support systems are critical when informing decision-makers about evacuation location alternatives and to assess their feasibility immediately after a disaster occurs. The results from this study confirm that this system can provide critical and timely insights into complex evacuation scenarios. An additional benefit of this system is the user-friendly web-based application ensuring data access from any global location with internet access.

1. Introduction

Indonesia is acknowledged as a country vulnerable to natural disasters that can adversely affect heavily populated areas. For example the earthquake and subsequent tsunami in Aceh on December 24, 2004 resulted in the death of 105,262 people according to the Department of Social Affairs of the Republic of Indonesia [17]. Natural disasters are relatively common from a global perspective where increasing levels of global urbanization have created highly populated areas as opposed to previously dispersed rural areas with lower population levels. According to Ergun et al. [14] there were 6637 global natural disasters between 1974 and 2003 which affected more than 5.1 billion people; this resulted in approximately 182 million residents becoming homeless and caused 2 million deaths with a global economic loss of approximately USD 1.38 trillion. The total number of

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natural disasters affecting people has increased by an average of 55% between 2000 and 2004 with catastrophic disasters affecting 33% additional people during the corresponding period. For example,the earthquake in Port-au-Prince resulted in more than 3 million people being injured, homeless, or without access to food, and water; subject to a substantial amount of controversy it was estimated that between 100,000 and 316,000 people died from this earthquake alone [8].

Indonesia has been recently subject to widespread natural disasters where West Sumatra is one of the most disaster-prone provinces in this country. An earthquake in West Sumatra on 30 September 2009 measuring 7.6 magnitude on the Richter scale caused approximately 1100 fatalities across 13 districts/cities. The worst affected areas were Padang City, Pariaman City and the Pariaman District. The direct damage and losses were estimated at IDR 21.6 trillion being equivalent to approximately U.S. $2.3 billion. Disasters also cause substantial damage to roads, government offices, health facilities, educational facilities, trade facilitation and tourism resorts according to the National Agency for Disaster Management (BNPB), Republic of Indonesia. A subsequent natural disaster in Western Sumatra on October 25, 2010 was another earthquake located in the Mentawai islands which recorded as 7.2 on the Richter scale. According to data supplied by the post BNPB and Disaster Operations Control Centre West Sumatra on 22 November 2010, the aftermath of this earthquake and subsequent tsunami in the Mentawai islands was the death of 509 people, injuries to 17 others and displacement of 11,425 people scattered across different evacuation points.

It is accepted that natural disasters such as earthquakes and tsunamis cannot be prevented as they are inevitable natural occurrences. Community and relevant government bodies have sought to reduce the impact of disasters through the implementation of an effective evacuation process and planned post-disaster logistics but with limited success. Clearly the selection of the optimal evacuation site/s is one of the most important decisions when seeking to reduce the number of casualties directly resulting from the disaster. The role of information systems and decision support systems are critical when informing decision-makers about evacuation location alternatives and to assess their feasibility immediately after a disaster occurs.

The purpose of this study is to develop a reliable and effective decision support system to facilitate evacuation immediately after a disaster has occurred. This software is very useful and will assist to reduce exposure to risk when the victims and/or the local government have decided to evacuate to a safer location. The scope of this study is limited to an earthquake and/or a tsunami disaster. The software behind the model provides information about various types of buildings identified as potential evacuation sites. In addition the decision support system can undertake hypothetical scenario planning for different evacuation sites after varying categories of disaster.

2. Previous studies into post-disaster planning

According to Rickard [9] the logistics required for post-disaster planning from both commercial and humanitarian perspectives have much in common; nevertheless humanitarian logistics managers usually operate in an environment with limited infrastructure and poor communication capability. In disaster situations the control center for disaster relief operations play a pivotal role as the primary center for storing data and information required to carry out emergency responses in a timely manner. There are four phases in an emergency management cycle, namely *preparedness*, *response*, *recovery* and *mitigation* [1], where each phase is an integral part of an action plan and justifies further discussion. *Preparedness* refers to activities to enhance the ability to respond immediately after an incident including the response procedure development, design and installation of warning systems, evacuation planning and also training for emergency operations. *Response* is an activity which occurs during or immediately after a disaster to meet the immediate needs of disaster victims including mobilization and positioning of emergency supplies, equipment and personnel, undertaking time-sensitive operations such as search, rescue and evacuation as well as providing emergency medical care, food and housing programs. *Recovery* is an action which commences after the disaster when the urgent needs have been initially met including the repair of roads, bridges and other public facilities, restoration of electricity, water and other city services as well as undertaking other activities to help restore normal operation to a community. Finally, *mitigation* is an activity that partly or fully prevents disasters reducing the likelihood of the disaster occurrence, or otherwise lessens the damaging effects of disasters such as ensuring buildings are structurally sound and educating the public about the potential dangers and identifying ways to reduce risk.

Within the context of disaster logistic theory there are four important terms: hazard, emergency, disaster and catastrophe [12]. *Hazard* refers to an event that is a potentially damaging phenomenon within a specified time frame. *Emergency* is a situation that poses an immediate risk to health, the life of the property or alternatively the environment. *Disaster* is the disorder of the normal functioning of a system or society which in turn has a substantial impact on people, structures and the environment whilst also exceeding the maximum capacity of local resources. *Catastrophe* refers to the occurrence of a disaster in terms of the level of an extraordinary or catastrophic impact. Disaster response is a relatively complex process typically involving an extremely short time frame, a high level of uncertainty and also includes many stakeholders. A fundamental characteristic of natural disaster logistics is reference to a relatively complex situation with multiple stakeholders. Earlier studies concluded that some of the tools and methods developed for the commercial supply chain can be successfully adapted to logistics associated with an emergency response [5,3,18].

The concept of supply chain management is directly reliant on the effectiveness of material flow which is adversely affected by the level of information flow.