DISASTER LOGISTICS: HOW TO ESTIMATE THE EMERGENCY GOODS TO SUPPORT EARTHQUAKE RELIEF OPERATIONS

by

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ABSTRACT

Disaster logistics, or humanitarian supply chain management, has attracted research attention in recent years. This paper develops an estimation model to estimate the types and quantities of emergency goods necessary to support earthquake relief operations. It is crucial that the buffer stock for earthquake relief be well defined and ready to deliver to disaster areas when an earthquake occurs. This paper therefore serves as a guide to disaster logistics, especially how to estimate the emergency goods needed for earthquake relief operations. It not only reviews the literature to describe current practices and research trends in disaster logistics but also provides a model framework to estimate the emergency goods necessary in this regard.

KEYWORDS

Humanitarian Logistics, Disaster Logistics, Earthquake, Earthquake Relief, Emergency Goods, RADIUS Tool

INTRODUCTION

Indonesia occupies a very active tectonic zone, because it is located at the meeting point of three of the world's major tectonic plates and nine smaller plates (Bird, 2003 in Irsyam, et al., 2010). The existence of these tectonic plate interactions makes the region vulnerable to earthquakes (Milson, et al., 1992 in Irsyam, et al., 2010). Indeed, between 1897 and 2009, there occurred more than 14,000 earthquakes with a magnitude M > 5.0 (Irsyam, et al., 2010). In the past six years, various major earthquake activities have been recorded in Indonesia. These activities have included the Aceh earthquake accompanied by tsunami in 2004 with a magnitude M = 9.2, the Nias earthquake in 2005 (M = 8.7), the Yogya earthquake in 2006 (M = 6.3), the Tasikmalaya earthquake in 2009 (M = 7.4) and the West Sumatera earthquake in 2009 (M = 7.6). These earthquakes caused thousands of casualties and considerable damage to collapsed infrastructure and buildings and cost billions of rupiah in rehabilitation and reconstruction (Irsyam, et al., 2010). Based on these facts, it can be inferred that Indonesia should be prioritized for earthquake relief operations.

Earthquakes are a serious disruption for society, causing widespread loss of human life in addition to material, economic and environmental losses. These losses can exceed the capabilities of local communities to resolve them using their own resources, and thus locals frequently need help from other areas, which require a well-designed earthquake relief system. The earthquake relief system relies on demand management to allow the emergency response to be carried out quickly, precisely and accurately. The pattern of demand management in emergency relief is irregular with respect to quantity, time and place. Thus, prediction models for emergency goods that support earthquake relief operations are required. Examples of emergency goods included food and drink, medicine, milk for babies and diapers. This research develops prediction models that can predict the types and quantities of emergency goods necessary to support earthquake relief operations. Buffer stock for earthquake relief must be well defined and ready to deliver to disaster areas when an earthquake occurs so that emergency response activities can be carried out immediately.

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DISASTER LOGISTICS

Disaster logistics (also called humanitarian logistics) is defined as the process of planning, implementing and controlling the efficient and cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for alleviating the suffering of vulnerable people (Thomas and Kopczak, 2005). Two major streams of disaster logistics can be distinguished, namely continuous aid work and disaster relief. According to Ertem et al. (2010), the main objective of disaster logistics is to save lives and help beneficiaries in contrast to that of commercial logistics, which is to maximize profit. Kovács and Spens (2007) further stated that humanitarian logistics could be characterized by time delays, which may result in the loss of lives.

RESEARCH METHODOLOGY

This research develops a model to estimate and determine the types and quantities of emergency goods needed by disaster victims during the emergency response phase of an earthquake. The mapping of the research approach is illustrated schematically in Figure. 1.

FIGURE 1
RESEARCH APPROACH
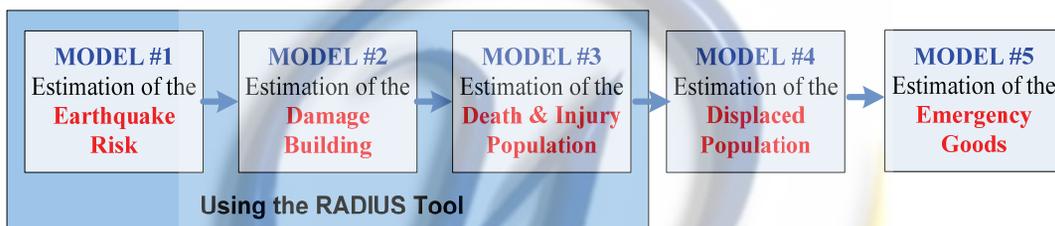
To this end, five main models should be considered:

- **Model #1: Estimation of Earthquake Risk**. The outputs from this model are the estimation of Peak Ground Acceleration (PGA) and estimation of Modified Mercalli Intensity (MMI) for the area analyzed.

- **Model #2: Estimation of Building Damage**. The output from this model is the damage to buildings following the earthquake, i.e. number of damaged residential buildings, schools, hospitals, shopping centers and industrial facilities.

- **Model #3: Estimation of Death and Injury**. This model consists of two models; the first one estimates injuries, while the second estimates fatalities.

- **Model #4: Estimation of Displaced Population**. This model estimates displaced populations by category, such gender and age. Specific categories of displaced populations are needed to estimate the specific emergency goods for children, adults and the elderly.

- **Model #5: Estimation of Emergency Goods**. This model is based on the estimations provided by Models 1–4. It determines the types and quantities of emergency goods needed by disaster victims in the emergency response phase.

The approach to this research is based on the already existing RADIUS (Risk Assessment Tools for the Diagnosis of Urban Areas against Seismic Disasters) tool. According to Okazaki et al. (2000), RADIUS is an initiative of the International Decade for Natural Disaster Reduction (1990–2000), which was launched in 1996. This promotes worldwide activities for reducing seismic disasters in urban areas, particularly in developing countries. RADIUS provides a methodology and guidelines for risk assessment based on the findings of case studies in nine selected cities. In particular, it offers a spreadsheet-based program for estimating earthquake damage and casualties in an area or city with limited information. The program can thus be used to evaluate the earthquake risk situation in a city. The output of RADIUS is the estimated damage caused by an earthquake, including number of deaths and injuries, based on the prevailing conditions, such as information on demographics, relative density of buildings, soil type and inventory information related to buildings. The results of RADIUS can be used to develop a mitigation plan to prepare the city to face future earthquakes.

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The mapping of the models described in Section 3 can be seen schematically in Figure. 2. First, an earthquake scenario for the disaster area should be agreed. The epicenter, magnitude and occurrence time (day or night) should also be determined. Ground shaking intensity or PGA at the site usually becomes greater as the magnitude becomes larger or the distance from the site to the epicenter becomes smaller. Ground shaking is also greatly influenced by the ground conditions of the site. Thus, an earthquake hazard value can be estimated from the parameters of the earthquake scenario and ground conditions. Damage is then estimated from this hazard value and existing structures in the area (i.e., number of structures as well as types of buildings or lifeline facilities) using vulnerability functions derived for each type of structure. Vulnerability functions reflect the relationship between seismic intensity and the degree of damage to a structure. Casualties such as deaths and injuries are also estimated if the population distribution is known. Then, the total amount and distribution of damage can be estimated if the chosen earthquake scenario were to occur. Thus, the displaced population can be predicted and the emergency goods necessary to respond estimated.

A seismic intensity scale is the most familiar index to indicate the strength of ground shaking and/or how an earthquake will affect an area. Several types of intensity scales exist and different types are used throughout the world. The most commonly used scale is the MMI scale, which is applied herein, although PGA is also used for the convenience of engineers since this parameter is adopted in the design and analyses of structures. In RADIUS, PGA can be calculated using one of four attenuation formulas: Joyner and Boore (1981), Campbell (1981), Fukushima and Tanaka (1990) and Young (1997). PGA is then converted into MMI using the empirical formula of Trifunac and Brady (1975). The estimations of PGA and MMI are calculated in Model 1.

The RADIUS Tool also adopts four ground classifications based on the surface soil, namely "Hard Rock," "Soft Rock," "Medium Soil" and "Soft Soil." For an effective estimation of damage to buildings, a building classification is necessary. Buildings can be classified according to various parameters. RADIUS adopts a simple building classification that categorizes buildings into the following 10 types: (1) RES-Informal construction, (2) RES2-URM-RC (URM = Unreinforced Masonry, RC = Reinforced Concrete) composite construction, height up to three stories, (3) RES - URM-RC composite construction, height four to six stories, (4) RES4-Engineered RC construction, newly constructed multi-story buildings, (5) EDU1-School buildings, up to two stories, (6) EDU2-School buildings, greater than two stories, (7) MED1-Low to medium rise hospitals, (8) MED2-High rise hospitals, (9) COM-Shopping Centers, and (10) IND-Industrial facilities, both low and high risk.
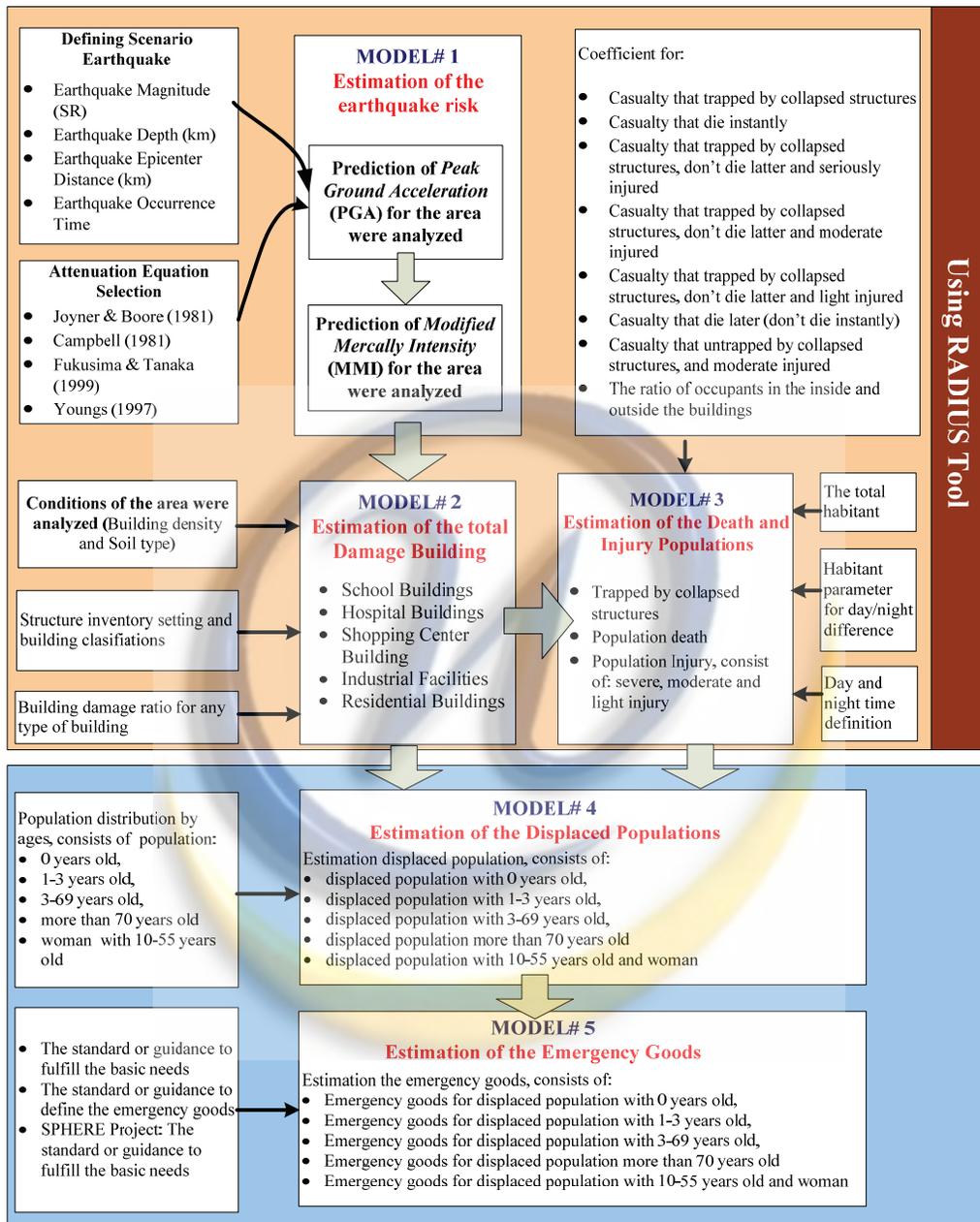
Building damage caused by earthquakes contributes to disasters and causes casualties and fires. Earthquake damage to buildings is greatly influenced by the types of buildings. The estimation of collapsed or heavy damage to buildings, which is considered to be the main cause of death and injury during an earthquake, is calculated in Model 2.

Casualties can be calculated based on the number of damaged buildings. Information on the number of people found inside buildings during the earthquake is necessary for casualty and injury calculations. The number of people inside buildings during the day and night is usually different since the ratio of building usage differs. For example, day population is smaller than night population in residential dwellings. Alternatively, school and office populations are higher during the day and almost non-existent during the night. In RADIUS, day and night populations are estimated individually for each type of building classification. Daytime is defined as from 6 am to 6 pm and nighttime from 6 pm to 6 am. The estimation of deaths and injuries during an earthquake is calculated in Model 3.

The next step is to estimate the displaced population based on the population distribution by age, estimation of building damage (from Model 2), average number of household occupants and estimation of deaths and severe injuries (from Model 3). The estimation of the displaced population during an earthquake is calculated in Model 4. The outputs of this model are divided into the following age categories: 0 years old, 1–3 years old, 3–69 years old, more than 70 years old and women aged 10–55 years old.

Finally, we must calculate the types and quantities of emergency goods necessary to support earthquake relief activities. This estimation should be well prepared to respond to devastating earthquakes, especially in the emergency response phase. The estimation of emergency goods is based on the displaced population output (from Model 4) as well as on standards or guidance to fulfill the basic needs for emergency goods. The estimation of emergency goods is calculated in Model 5.

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FIGURE 2
FRAMEWORK FOR THE DEVELOPMENT OF THE ESTIMATION MODEL

Defining Scenario Earthquake
- Earthquake Magnitude (SR)
- Earthquake Depth (km)
- Earthquake Epicenter Distance (km)
- Earthquake Occurrence Time

Attenuation Equation Selection
- Joyner & Boore (1981)
- Campbell (1981)
- Fukusima & Tanaka (1999)
- Youngs (1997)

MODEL# 1
Estimation of the earthquake risk

Prediction of *Peak Ground Acceleration* (PGA) for the area were analyzed

Prediction of *Modified Mercally Intensity* (MMI) for the area were analyzed

Coefficient for:
- Casualty that trapped by collapsed structures
- Casualty that die instantly
- Casualty that trapped by collapsed structures, don't die latter and seriously injured
- Casualty that trapped by collapsed structures, don't die latter and moderate injured
- Casualty that trapped by collapsed structures, don't die latter and light injured
- Casualty that die later (don't die instantly)
- Casualty that untrapped by collapsed structures, and moderate injured
- The ratio of occupants in the inside and outside the buildings

Using RADIUS Tool

Conditions of the area were analyzed (Building density and Soil type)

Structure inventory setting and building clasifiations

Building damage ratio for any type of building

MODEL# 2
Estimation of the total Damage Building
- School Buildings
- Hospital Buildings
- Shopping Center Building
- Industrial Facilities
- Residential Buildings

MODEL# 3
Estimation of the Death and Injury Populations
- Trapped by collapsed structures
- Population death
- Population Injury, consist of: severe, moderate and light injury

The total habitant

Habitant parameter for day/night difference

Day and night time definition

Population distribution by ages, consists of population:
- 0 years old,
- 1-3 years old,
- 3-69 years old,
- more than 70 years old
- woman with 10-55 years old

MODEL# 4
Estimation of the Displaced Populations
Estimation displaced population, consists of:
- displaced population with 0 years old,
- displaced population with 1-3 years old,
- displaced population with 3-69 years old,
- displaced population more than 70 years old
- displaced population with 10-55 years old and woman

- The standard or guidance to fulfill the basic needs
- The standard or guidance to define the emergency goods
- SPHERE Project: The standard or guidance to fulfill the basic needs

MODEL# 5
Estimation of the Emergency Goods
Estimation the emergency goods, consists of:
- Emergency goods for displaced population with 0 years old,
- Emergency goods for displaced population with 1-3 years old,
- Emergency goods for displaced population with 3-69 years old,
- Emergency goods for displaced population more than 70 years old
- Emergency goods for displaced population with 10-55 years old and woman

CONCLUSION

This paper not only reviewed the literature to describe disaster logistics but also provided a model framework to estimate the emergency goods necessary to support earthquake relief operations. Further research is needed to extend the mathematical formulation or equation in order to describe how to estimate emergency goods. The mathematic formulation should be considered to be a one-shot decision estimation, because the emergency response should be carried out as quickly as possible, as there is no chance to reorder emergency goods.

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