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Systems Engineering Procedia 5 (2012) 191 – 197

Procedia Systems Engineering

International Symposium on Engineering Emergency Management 2011

The optimization model in the disaster risk mitigation investment

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Abstract

The damage caused by the disaster impact the economy, society, and the environment evidently in recent years. The management of disaster risk is attached more importance. The cost-benefit analysis (CBA) and disaster risk analysis (DRA) are used gradually widely in the disaster risk management. In the disaster risk mitigation, the investment in the risk mitigation is considered as the cost, the reduction of the damage caused by the risk mitigation is considered as the benefit. In this paper, an optimization model is put forward based on the CBA and DRA. The model is helpful for the decision of the disaster risk mitigation investment, especially in the large engineering.

Keywords: disaster risk mitigation; optimization model; system; engineering

1. Introduction

Emergency incidents and disasters stem from a range of natural, biological, technological, industrial and other human phenomena, and induce significant social and economic costs to the nations. These costs include direct damage to property, infrastructure and facilities; financial costs and indirect economic losses; fatalities, injuries and illness; impairment of ecosystems and loss of biodiversity; and social and cultural losses.

Over the last several decades, the number of reported natural disasters and emergency incidents, with their impact on human and economic development worldwide has been increasing yearly. Existing records, while less reliable before 1980, can be traced back to 1900. This longer time period also shows a relentless upward movement in the number of disasters and their human and economic impacts. Earthquakes, storms, and other hazards killed about 3.3 million people between 1970 and 2010, an annual average of 82,500 deaths worldwide in a typical year, a small fraction of the roughly 60 million who die every year and of the 1.27 million killed in traffic accidents alone[1].

In the future, there are two powerful trend will induce the change of Emergency incidents and disasters: burgeoning cities and a changing climate. The latest United Nations (UN) estimates suggest that, globally, the urban population exceeded the rural for the first time in 2008[2]. The density of people and economic activity in growing urban area will change the risk impact. The cities work as the engine of economy growth, so work force and also the firms like to locate, which will make the asset value in the urban area growing higher. The exposure of economic assets to Emergency incidents and disasters in cities will also grow [3].

The recent studies suggest that a doubling of greenhouse gas concentrations could increase tropical cyclone damage by 54 percent to 100 percent in the United States and double tropical cyclone damage globally [4]. The climate change will also induce the population and economics assets exposed to the extreme events.

 doi:10.1016/j.sepro.2012.04.031

To reduce the consequence of the emergency incident or disaster, the resources are allocated. Among the responses to the emergency incident and disaster, prevention and recovery are the two main ways to the disasters. Prevention is the activities undertaken before crisis to control or mitigate its impact, so that the damage can be prevented or reduced. Recovery means the activities undertaken after a disaster to restore the economic or social system to former conditions before disaster. In many cases, the prevention of disaster is more effective than the recovery [5]. In most cases, the individual and government need to make decision to choose the proper measures among all prevention and all recovery based on the cost-benefit analysis.

In this paper, one theoretical decision model was put forward based on the disaster risk analysis (DRA) and cost-benefit analysis (CBA).

2. The frameworks of cost-benefit analysis(CBA) and disaster risk analysis(DRA)

2.1. The frameworks of cost-benefit analysis (CBA)

Cost-benefit analysis (CBA) is an assessment tool used to determine the economic efficiency of a potential or already implemented activity. If the economic returns produced by the activity (benefits) are more than the amount spent to implement the activity (costs), then the activity is considered economically efficient.

CBA generally involves three basic steps. Firstly, it is necessary to indentify the benefit and cost of an activity. Secondly, assigning monetary of the values to the benefit and cost was necessary. Thirdly, discounting all future benefits and costs to present values should be done. Then the decision makers can make decision based the net present value (NPV, discounted future benefits minus discounted future costs).

There are several limitations to CBA. One is the difficulty of assessing nonmarket values. Although methods exist, particularly regarding the value of human life. Another issue is the lack of accounting for the distribution of benefits and costs in CBA. The general principle underlying CBA is the Kaldor-Hicks-Criterion, which holds that benefit from a specific project should potentially be able to compensate those who are disadvantaged by it. Another issue is the question of discounting. It is difficult to choose the appropriate discount rate to discount the benefits and costs caused by the project. Although the cost-benefit analysis has some limitations, it still can be used as a powerful tool whose main strength is an explicit and rigorous accounting framework for systematic cost efficiency decision making. CBA also be used in disaster mitigation analysis in public sectors such as US and Australia and so on [6][7].

2.2. The frameworks of disaster risk analysis (DRA)

Risk management can be broken down into three components (Fig. 1. (a)). The first step is the identification of risks, followed by second step, an analysis of their potential impact. If a specific risk is considered large, the third step risk control measures should be considered. These may be mitigation measures that reduce risk or the transfer of risk to other parties.

For disaster risk management, it also follows the standard risk management process above. In general definition, risk is the probability of a harmful occurrence with a specific force at a specific location and at a specific time. It is well recognized that risk is related with the probability of the harmful occurrence and the impact it induced [8].

For the emergency and disaster risk, it is related with two elements- hazard and vulnerability. Hazard is related with the probability of occurrence of the harmful disaster event. And vulnerability is related with the susceptibility to injury or damage when the event occurs and the ability to protect against it. So the disaster can be expressed as the function of hazard and vulnerability as follows:

Disaster risk = Hazard $\times$ vulnerability

In the disaster risk analysis, it is necessary to take hazard analysis and vulnerability analysis. Hazard analysis involves determining the type of hazards affecting a certain area with specific intensity and frequency.

In hazard analysis, disasters and their causes and the resulting impact chains should be identified, analyzed and documented. Knowledge of the types of hazard is essential for analyzing and assessing risks. To be able to estimate and evaluate the degree of risk and the characteristics and scale of possible loss from disasters, it is necessary not only to estimate the probability of occurrence but also to investigate the force and duration of the event. It is necessary to establish how far the system is potentially affected by the event. If there is no vulnerable system at the