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During-incident process assessment in emergency management: Concept and strategy

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ABSTRACT

An incident is normally composed of three stages: pre-incident, during-incident and post-incident. The assessment is a prominent composition in the lifecycle of emergency management for the purpose of quick and effective response. Present-day assessment methods mainly concern the pre-incident risk evaluation and the post-incident loss evaluation. However, during-incident process assessment is of crucial importance to assist the decision-making in emergency response and eventually achieve the goals of emergency management. This paper analyzes the influencing factors of during-incident process assessment and proposes a conceptual model of assessment. Three during-incident process assessment strategies, namely, "mitigability", "rescuability", and recoverability are illustrated which quantitatively characterize the evolution of incidents and corresponding responses, and hence contribute to appropriate decisions in practical applications.

1. Introduction

In recent years, various kinds of incident have frequently occurred over the world, including common incidents (e.g., fire, traffic accident), and catastrophic incidents (e.g., earthquake, mining disasters, large-scale infectious disease, terrorist attacks). Incidents in different diversity brought great damage to humanity, not only disrupting the normal life but causing casualty and property loss, and even menacing the national security. The "Southern Snow Storm", "3.14 violent incidents in Lhasa" and "5.12 Wenchuan Earthquake" are typical representatives taken place in China in 2008. As a worldwide public health incident, the A/H1N1 influenza caused many deaths in American, Europe and Asian Countries in 2009. Usually, incidents are sudden, unexpected, destructive, spreading and uncertain. Without timely and appropriate response, incidents probably develop to more destructive ones and cause more loss. The effective response is highly dependent on the accurate assessments which provide scientific decision-support for prevention, rescue and recovery of the harm caused by incidents.

Emergency management can be described as a responding process to incidents based on analysis of the mechanism, process, influence and consequence of incidents. It requires the effective integration of various social resources with the aim to decrease and diminish the harm through appropriate decisions (Chen et al., 2008a). Due to the increasing occurrence of incidents and great damage caused, research on emergence management continues to attract a lot of attentions in recent years.

Assessment is a vital composition of emergency management, referring to the determination of quantitative or qualitative value of the risk of potential incidents or the loss caused by incidents. The loss assessment can be called as result-oriented assessment in the sense that it focuses on the loss caused and serves for loss compensation, recovery and reconstruction after disasters. On the contrary, the future-oriented assessment intends to prevent disasters or reduce the potential loss before or during disasters. The present future-oriented assessment strategies comprise two categories: risk assessment and vulnerability assessment (Buckle et al., 2001; Mustafa, 2003; Bruneau et al., 2003; Paton et al., 2001). A large variety of assessment methods have been proposed and applied with success in various fields. In summary, the current assessment strategies mainly concern the risk evaluation before incidents or the loss evaluation after incidents. More important aspects of assessment during the evolvement of incident should be addressed, including the degree of incident mitigation, the possibility of rescuing trapped objects and the difficulty of recovery. Unfortunately, to the best of our knowledge no prior work has been reported on these issues except some primary attempts (Chen et al., 2008b, 2009b; Shangguan et al., 2009). In this paper, we extend our previous work by defining a unified

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conceptual model of three types of during-incident process assessments (short for DIPA) and discussing the specific formalization of the measurements.

DIPA and post-incident assessment are different in some aspects. A disaster or incident always happens at a fixed time point and continues for a period, which can be from several seconds to a few minutes (e.g., an earthquake), from several minutes to 1 or 2 quarters (e.g., a flood), or from one week to several months (e.g., an infectious disease). DIPA is conducted during the evolution of the disaster, aiming to evaluate the current situation and the future trend simultaneously. It can answer such questions as: Is it possible to mitigate the evolution of the incident? What's the probability to successfully rescue the victims? And which can be likely recovered in a given period? Most of these questions cannot be answered by post-incident assessment. That is to say, the emergency managers should emphasize more on making decisions to prevent the future possible loss and recover the damage to a normal situation. However, post-incident assessment always deals with a fixed-term circumstance of disaster with little possibility of enhancement and expanse. Take 9.0 East Japan Earthquake as an example. DIPA can help to make decisions on shutting down the nuclear power plant or informing people to flee away from the coast when the earthquake was observed, but post-incident assessment can only provide some information such as the quantity of victims and wealth loss, and the influenced areas.

In this paper, we analyze the influencing factors of during-incident process assessment and establish a conceptual model. Three novel during-incident process assessment strategies, namely, "mitigability", "rescuability", and recoverability are proposed to characterize the evolution of incidents and corresponding response. "Mitigability" defines the degree that human can impact the evolvement of incidents and reduce the expected loss through certain structures and measures. "Rescuability" evaluates whether the trapped objects are worth saving and how to rescue. Recoverability represents the degree of difficulty that recovers the destroyed objects to a given status. The during-incident process assessment strategies are capable to give good guidance for appropriate decisions during the evolution of incidents.

The rest of this paper is organized as follows. In Section 2, the related work about assessment strategies in emergency management is reviewed. The principle of during-incident process assessment is described in Section 3. In Section 4, the conceptual model is proposed and the influencing factors are analyzed. Afterwards, the strategies of "mitigability", "rescuability", and recoverability assessments are illustrated respectively in Section 5. In Section 6, the refinement and deployment of proposed assessments are discussed. Finally, the paper is concluded and future research directions are given in Section 7.

2. Literature review

Assessment is a widely studied topic in a variety of fields, such as education assessment, psychiatric assessment, tax assessment, and risk assessment. Nowadays, with the rapid development of computer technology, many practical methods have been proposed for assessment, including statistical analysis, analytic hierarchy process (AHP), heuristic methods, and Monte Carlo simulation. Among them, AHP is the most widely used assessment method for multi-criteria decision-making (MCDM) problems. It determines the priority of a set of alternatives and relative importance of criteria through a series of pair-wise comparisons (Hu et al., 2009).

Risk assessment is a process to identify the potential incident, analyze the likelihood and severity of adverse effects occurring, and determine appropriate ways to eliminate or control the incident. Risk assessment is regarded as the basis of decision making to remove or reduce the risk in emergency management. Among the tools of risk assessment, risk matrix approach (RMA) is frequently used due to the feasible way of risk expression and easy-to-use superiority. It was proposed by Electronic System Center, and developed by US Airforce and MITRE Corporation (Paul et al., 1998; Willhite, 1998). In order to overcome the disadvantages of RMA and improve its applicability, other mathematic approaches, e.g., Borda Method significantly improving the precision of RMA (Zhu et al., 2003), Rezoning of matrix cells (RMC) utilizing a more meticulous classification of risk index and reordering the distribution of different levels to make the assessment result less vague (Markowski and Mannan, 2008), are also incorporated. The basic RMA is extended with four arithmetic operations to enhance the applicability of the method (Ni et al., 2010).

Recently, fuzzy set, grey system theory, artificial neural network, genetic algorithms, information technique and other intelligent methods have been applied to risk assessment (Liu et al., 1999; Lin and Liu, 2004). Brown and Dunn (2007) described a quantitative risk assessment approach for hazardous materials transportation by means of consequence modeling. Jiang et al. (2009) adopted a fuzzy comprehensive assessment, combined with fuzzy classification and fuzzy similarity to predict the flood risk in Kelantan, Malaysia. Karimia and Hüllermeier (2007) presented a system to evaluate the risk of natural disasters using fuzzy set theory in conjunction with probability theory. Zhang (2004) estimated the risk of drought disaster to agricultural production in the maize-growing area of Songliao Plain of China based on Geographical Information Systems (GIS). Antonioni et al. (2009) developed a framework for the risk assessment of Na-Tech accidental events. A landslide hazard information management system and a real-time warning information releasing system were implemented on MapGIS platform (Yin et al., 2007). A variety of decision support tools have been implemented addressing the risk assessment of internal and external hazards in the chemical industry (Reniers et al., 2006). For example, MAX-CRED-III is an automatic tool to assess the chemical risks (Khan and Abbasi, 1999).

Vulnerability is the pre-event, inherent characteristics or qualities of social systems that mark the potential harm. It is defined as a function of the exposure (who or what is at risk) and sensitivity of system (the degree to which people and places can be harmed) (Cutter, 1996). Risk vulnerability assessment (RVA) stems from the engineering analysis focusing on the structural elements, e.g., buildings, facilities, and infrastructures. The present study of RVA has extended to a broad range of domains to evaluate the vulnerability of people, property, and resources. There are many studies of RVA recently, both on the model and on the application in different areas. Dai et al. (2002) summarized the vulnerability assessment in landslide disaster and analyzed four related impacting elements. Papathoma and Dominey-Howes (2003) gave a tsunami vulnerability assessment model (PTVAM), afterwards, they improved the model by adding spatial and temporal factors (Dominey-Howes and Papathoma, 2007). Ezell (2007) raised an Infrastructure Vulnerability Assessment Model (I-VAM) for qualitative treatment of vulnerability in a medium-sized clean water system. In emergency management, RVA tends to concern the susceptibility of an area at the presence of risks. It is used to identify hazard zones, thereby forming the basis of pre-impact and hazard mitigation planning in order to enhance the robustness and persistence of the region through better distribution and allocation of the resources (Brooks et al., 2005; Clark et al., 2000; O'Brien et al., 2004). Various methods have been proposed, including quantitative methods, qualitative methods, mathematical modeling methods, and dynamics simulation. Fedeski and Gwilliam (2007) studied hydrological and geological hazards of a region and