



Population behavioral scenarios influencing radiological disaster preparedness and planning

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ABSTRACT

Considerable attention is focused on plans for sheltering or evacuating the population of the US national capital region in response to a regional emergency such as a terrorist attack or natural disaster. Such planning engages multiple disciplines spanning infrastructure engineering, emergency management, health care, mass communication, water and food supply, logistics, and others. Knowledge of population behaviors should influence the many dimensions of protection, prevention, response, and recovery. Of particular interest are the behaviors and needs of the resident and non-resident populations in the aftermath of a regional disaster, including those at home, at work, and traveling. The authors deployed a 30-min telephone survey to 2700 residents of the region to gain knowledge of their intended behaviors in the event of a variety of potential dirty bomb attacks. The survey provides a unique foundation for the current paper. The paper will identify and model the assumptions of population behaviors that most affect agency priorities for emergency planning including regional sheltering and evacuation following a radiological disaster such as a dirty bomb. The technical approach assessed several planning initiatives across performance criteria derived from strategic plans and applied combinations of behavioral assumptions to vary the relative importance of each criterion. The results reveal the behavioral scenarios that are most significant to the prioritization of planning initiatives and identify the highest and lowest priority initiatives across the criteria used.

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1. Introduction

Emergency planners are confronted with a multifaceted problem for regional disaster recovery in that plans must take agency performance goals and criteria, possible actions, and incident-specific objectives into consideration while accounting for a variety of uncertainties in gathered data and assumptions. Sources of uncertainties that are present for a regional emergency include the emergent and future behaviors of the public who are affected by the incident. In the aftermaths of the Japan earthquake and tsunami, the Katrina hurricane, and the 9/11 attacks, interest in the behaviors and needs of populations has increased significantly, stemming from the belief that failure to address the associated uncertainties may cause emergency plans to become unrealistic or ineffective.

The US Department of Homeland Security collaborated with other federal departments, federal agencies and state, local, and territorial governments to develop fifteen National Planning Scenarios

in response to major terrorist attacks, natural disasters and other emergencies that have the greatest risk of mass fatalities, injuries or property loss and major social disruption (DHS, 2007a). Radiological dispersion device (RDD) attacks are considered one of these scenarios. A dirty bomb is a type of radiological dispersion device that combines conventional explosives (e.g., dynamite) with radioactive materials. The terms *dirty bomb* and *radiological dispersion device* are used interchangeably (NRC, 2010). In addition to immediate explosive effects, dirty bombs have radiological effects that usually do not cause immediate fatalities but can cause long term contamination of the affected area and its surroundings. Combined with its physical impacts, the psychological impacts of a dirty bomb on a society should not be underestimated.

This paper will integrate scenario planning with multicriteria analysis for the prioritization of initiatives that comprise regional disaster emergency plans. Primary focus centers around sheltering, evacuation, and related population behaviors and needs in the aftermath of an attack by a radiological dispersion device. Following published methods of the authors among others, a multicriteria analysis tool will be enhanced by scenario planning in order for emergency planners to better understand (i) what the highest priority initiatives are and (ii) which initiatives are robust

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with respect to the variety of behavioral scenarios. The use of scenario planning in a multicriteria analysis enables decision makers to systematically prioritize emergency planning initiatives under several behavioral scenarios. By identifying and analyzing scenarios related to population behaviors, the effort aims to mitigate or eliminate key uncertainties and knowledge gaps of emergency planners. The methodology is demonstrated in the case of a radiological dispersion device, or dirty bomb, attack. The effort will use data collected by the authors via a 2009 telephone survey of 2700 US national capital region residents to discover how populations might react following a dirty bomb attack (Guterbock et al., 2010). Performance criteria are defined and emergency planning initiatives aiming at preparedness, response, recovery and mitigation are assessed across the criteria under a variety of scenarios. Different scenarios are shown to influence an agency to vary the relative importance of criteria (following Karvetski et al., 2009; Schroeder and Lambert, 2011). This change in importance across criteria affects the priority-based order of planning initiatives. A key contribution of the paper is to aid emergency planners at the regional level to better understand and address population behaviors in a radiological emergency such as a dirty bomb attack. Applications of related methodology to different planning situations are demonstrated by Karvetski et al. (2011a), Karvetski et al. (2011b), Karvetski et al. (2011c), Martinez and Lambert (2010), and Martinez et al. (2011).

The next section summarizes related literature of multicriteria analysis, scenario planning, and population behaviors in emergencies with the relevant findings of the behavioral survey and also explains how knowledge of potential behaviors of the affected population is critical for emergency planning. The third section presents the technical approach used to integrate multicriteria decision analysis with scenario analysis for the prioritization of emergency planning initiatives. The fourth section describes an example based on a hypothetical radiological dirty bomb attack in the US national capital region. The final section synthesizes the results of the paper and needs for future effort.

2. Background

Multicriteria decision analysis and scenario planning provide a systematic approach to managing the complexities and the uncertainties associated with emergency or disaster planning problems. In risk assessment, scenarios represent what can go wrong in the most basic sense (Kaplan and Garrick, 1981). Scenario planning enables the characterization of possible threats and opportunities related to a system (in this case, related to population behaviors). Unlike forecasting, scenario planning does not typically include calculation of probabilities (Karvetski et al., 2011b). Although it is not possible to fully characterize the potential futures, scenario planning provides aid to reduce the uncertainties to a reasonable number of states that most matter to decision making. Ultimately, the decision maker is able to define strategies that are robust over a range of different possible outcomes (Belton and Stewart, 2002). Furthermore, scenario planning enables the observation of joint impacts of various uncertainties, simultaneous changes in various variables, and uses subjective interpretations beyond the reach of objective analysis (Schoemaker, 1995). The benefits of using multicriteria decision analysis in emergency planning are extensive. First, multicriteria decision analysis provides an appealing allocation of shared resources by enabling the involvement of a variety of stakeholders in the decision process. Second, the multifaceted nature of emergency decision problems makes it harder for decision makers to simultaneously process different information (Miller, 1956). This characteristic of multicriteria analysis helps decision makers process information such that it ensures consideration of

all encompassing criteria and factors (Belton and Stewart, 2002). The US National Incident Management System (NIMS) is harmonious with a multicriteria decision analysis for establishing incident objectives and strategies as part of the incident planning process. NIMS defines the process of determining the most appropriate strategy for the situation at hand as: identifying, analyzing, and evaluating reasonable alternative strategies that will accomplish overall objectives (DHS, 2008a).

Multicriteria decision analysis and scenario planning have been applied to a variety of practical situations including infrastructure development, natural disasters, accidents, and terrorism. Lambert and Patterson (2002) identify a set of dependency scenarios for disaster recovery. A categorical analysis is used to measure the interdependency of scenarios. Lambert and Sarda (2005) explore the risk of terrorism to critical infrastructure systems by first defining risk and various terrorism scenarios, and then using historical data, surveys, and expert opinion. Fisher and Garay-Vega (2012) compare driver performances in multi-threat scenarios. Lambert et al. (2006) provide a multicriteria framework for selection of transportation projects for highway planning. Lambert et al. (2003) evaluate guardrail needs along a corridor using multiple criteria. Tsang et al. (2002) define extreme event scenarios for the preliminary design of infrastructure projects in order to address the vulnerability of infrastructure systems to extreme events. Badri et al. (2011) use multicriteria analysis for selection of actions to manage risks related to occupational health and safety. Mulder et al. (2001) use multiple criteria to set priorities for home and leisure related accidents. Durbach and Stewart (2003) incorporate scenario planning with goal programming, a type of multicriteria optimization, in order to account for possible uncertainties. Tsai and Su (2004) use scenario analysis on freight vehicle accidents. Ram et al. (2011) incorporate twelve diverse scenarios with a multicriteria framework to evaluate food supply security options using a different additive value function for each scenario. Other studies use a multicriteria approach specialized for emergency management of nuclear transportation incidents and for the management of community incidents (Quarantelli, 1997; Lindell and Perry, 1980; Lindell and Prater, 2007). An overview suggests that the literature would benefit from a systematic assessment of criteria importance in light of uncertain behavioral scenarios, particularly for managing the needs of regional populations. Such assessment would be partially relevant to nuclear incidents and disasters as well as radiological dispersion device attacks.

Significant research about radiological attacks and the resultant sheltering and evacuation behaviors of affected populations utilizing physical models has been undertaken. Wein et al. (2010) analyze the impact of shelter-in-place evacuation decisions following an improvised nuclear device attack to the Washington, DC area. Carter et al. (2007) analyze the implications of a hypothetical improvised nuclear device attack on Washington, DC from multiple perspectives based on a workshop with experts. Dombroski and Fischbeck (2006) assess the risks of RDD events by considering both the physical effects of RDD's and the behavioral response factors in such an attack in Pittsburgh, PA. Dombroski et al., 2006 predicted compliance with shelter-in-place directions in case of a RDD event in Pittsburgh, PA, based on expert elicitation.

If emergency plans for sheltering and evacuation following RDD attacks are to be realistic, they must be based on projections of how people obtain their information in an emergency. These projections should include what sources they trust, the degree to which they have planned or prepared in advance, and the decisions and actions they will make under various possible emergency scenarios (Guterbock et al., 2010). However, emergency planners and researchers have little reliable guidance in terms of how they should expect residents to behave in the event of a regional disaster. The behavioral survey has been useful for collecting this type

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