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Learning before the storm: Modeling multiple stakeholder activities in support of crisis management, a practical case

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ABSTRACT

The severe consequences of a Critical Infrastructure (CI) crisis demand continued research directed toward proactive and reactive management strategies. Despite the best efforts of governments and communities, the diversity of stakeholders, conflicting demands for resources, and a lack of trust among organizations create complexities that limit the effectiveness of the response. This paper identifies four specific problems that appear to reoccur when CIs are challenged: heterogeneity, multiple and inconsistent boundaries, resilience building and knowledge transfer and sharing. A combination of collaborative modeling and software simulation methodologies is proposed in order to identify the interrelationships among diverse stakeholders when managing the preparation for and reaction to a CI crisis. This approach allows experts to work together and share experiences through the modeling process which can lead them to a better understanding of how other organizations work and integrate different perspectives. In addition, simulation models enable domain experts to understand the consequences of certain policies in the short and long terms, thus improving the crisis managers' knowledge for future crisis situations. This paper presents a practical case of a hypothetical crisis in the CI sector and the approach used in order to deal with the four problems identified above.

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1. Introduction

Society's welfare is dependent on the effective performance of Critical Infrastructures (CIs) to provide our energy, water supply, transportation, sanitation and telecommunications [1]. When CIs fail, the consequences are enormously expensive and wide-ranging. The effects extend beyond their own domain and trigger subsequent emergencies in the economic and social systems that are built upon them. In the aftermath of recent intentional attacks and an arguably increasing rate of natural disasters, concerns about CI vulnerability and resilience are high, and interest in the topic is growing accordingly.

While there is no agreed-upon definition of emergency management in the literature, many sources refer to a four-stage activity cycle of mitigation, preparedness, response and recovery [2]. Other authors provide a time-based cycle of pre-event, event-focused, and post-event timing e.g., [3]. These proposals can be merged considering that mitigation and preparedness activities are related to the pre-event stage, response to the event and recovery to the post-event stage. Responsible emergency management includes the use of practiced and established plans that reduce the impact of the event on people and assets and provide insight into improvements for the future, linking recovery to future mitigation and preparedness. The severe consequences of a CI crisis demand continued search for proactive and reactive strategies to improve resilience when planning is found to be inadequate [4–6].

Crisis management is often conflated with emergency management, but there are important differences. Wybo [7] supplies a useful distinction: Emergencies become crises if the system's resilience and emergency preparedness is insufficient to manage the event response and recovery. In the Katrina crisis, for example, rehearsed routines were incompatible with the emergent reality. Plans gave way quickly to improvised and localized activities as the situation on the ground deteriorated,

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officials delayed taking decisive actions, and information varied in its timeliness, consistency and accuracy [8]. Large-scale events do not become crises if resources and remedies are adequate to maintain order. For example, winter storm power outages trigger rapid mobilization of resources for emergency response without devolving further.

Efficient development of crisis management tools and methods must take into account the existence of some significant complexities. Crisis management requires the cooperation of a diverse set of stakeholders who initially have divergent perspectives that need to be integrated. In addition to complexity due to interdependencies among CIs and the activities implemented to prepare for and respond to crises, there are also dynamic complexities caused by significant delays. Crisis management also necessitates that a variety of activities must be implemented simultaneously in a coherent way. Finally, crisis managers need to learn not only from the crises they have experienced, but also from the crises suffered by other entities, which constitute a challenging knowledge transfer and sharing problem.

The transition from CI emergency response to CI crisis is a dynamically complex problem, one where a systems perspective may be very valuable [1]. Dynamically complex problems arise in tightly coupled systems, are driven by endogenous causality, and often neglect the side effects and long term consequences of managerial decisions made by segments of the system [9]. In the context of CI, tight coupling of the system is based on irreducible interdependency between components, where a failure of one may cascade to others. The importance of endogenous causality becomes clearer as we expand the problem boundary beyond the provision of a single critical resource. The benefits of dialog among a wider group of stakeholders include operational savings, improved resource leverage, and more balanced outcomes [10], but it is difficult to move beyond reactive decision-making and analysis, particularly in crisis.

Adopting a system perspective for CI requires that we go beyond the focus on specific triggering events to one that recognizes how the success or failure of response is based on the development of relationships, resources, information and procedures during the preparation phase, as well as our ability to integrate lessons from the history of previous crises. Abrahamsson et al. [11] advocate a system framework for analyzing and evaluating emergency response, stressing the value of visualizing the links among stakeholders. Formal simulation models of critical infrastructure, such as those developed by Conrad et al. [12] provide insight into cascading problems and hidden side-effects and vulnerabilities. Formal simulation models also provide a test bed for scenario development and policy experiments in large-scale problems, particularly when field-based experiments are impractical [10].

In this paper we construct a formal simulation model of one possible CI crisis, based on a hypothetical large-scale power grid failure in the EU. The model is based on a series of workshops conducted with experts in power generation, CIs that depend on power to maintain their own services, and civil protection experts. We focus on four complexities of CI emergencies where scale has particularly aggravating effects: Heterogeneity, multiple and inconsistent boundaries, activities to build resilience, and information transfer and sharing. Each has been identified in multiple post-event analyses as a challenge to rapid and effective response. We complete our analysis with comparative simulations that show how consideration of these effects during crisis planning and preparation reduces the scope, size, and length of a future crisis.

2. The complexities of scale within CI crisis management

What makes CI crises unusual? There are obvious direct effects when many members of society are unable to perform their daily routines. When attempting to manage these crises, there are second-order effects that can have a severe effect on the response and restoration of normal activity:

2.1. Heterogeneity

The crisis management community consists of many organizations on the local, state, federal and private levels. Procedural conflicts and priorities create confusion and inconsistent actions. When a crisis occurs, points of failures are often found along the boundaries among the organizations and entities that need to support one another. Integration of stakeholder perspectives can be expected to improve the effectiveness and efficiency of future response. Crisis preparedness research is similarly diffused among engineering, business management, social science, public administration, public health and governance. Unfortunately, much of the research in these disciplines is focused with an inward-looking lens, ignoring the relationships and synergies among fields.

Heterogeneous perspectives generate multiple interpretations of key concepts in crisis management [13–15]. Collaboration and planning is limited by the lack of a common language and understanding of interdependencies and side-effects. Although several ontologies are defined, most of them are designed for a specific purpose in a particular domain such as disaster plans or emergency operation centers, and do not provide a general context [16–19]. Another difficulty is that there is no standard indicator for the measurement of potential and true costs, so comparative analysis is difficult. Emphasis is placed on operational and performance measures that are easier to estimate empirically than on soft variables, such as behavioral preferences, that provide insight into how preparation decisions are made and implemented [20–23].

2.2. Multiple and inconsistent boundaries

The interconnectedness of CIs leads to unanticipated extension and cascading effects during emergencies [24]. For example, the Canadian ice storm power outage of 1998 led to oil supply problems, which in turn affected transportation and health services [25]. The effects of CI outages are not limited by geography or political treaty, as evidenced by the Italian outage, the Canadian outage and the Russian–Ukrainian gas conflict [26–28]. Differences in law, regulations, crisis awareness levels, language and culture aggravate coordination and planning problems.

A dynamic and emergent perspective on crisis development introduces the effect of time into planning and mitigation. Delays create boundary challenges, as causes, effects and responsibilities may be masked if not proximal to the event. Differing perceptions of time pressure can lead to selection of rapidly applied actions with few short-term benefits [29] or

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