A Structured Equation Model of Collaborative Community Response

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ABSTRACT

This paper analyses the collaborative dynamic of community in response to urgent situations. Community emergencies arising from natural or man-induced threats are considered as exogenous events that stimulate community resources to be unified around the response, action, and recovery activities related to the emergency. A structured equation model is derived to depict the actions of the community system. The system is described in terms of its resources including the propensity to trigger community action and collaboration among diverse groups. The community is profiled with respect to its ability to respond. The system defines the trigger mechanisms that are considered to be the drivers of collaborative action. A simulation model is presented to enact the system emergencies, community profiles, and collaborative response. The results develop an improved understanding of conditions that engage community collaborative actions as illustrated by examples from community research in the EnRiCH and the C-Change community research projects.

Keywords

Adaptation, community collaboration, emergency response, community engagement, structured equation modeling (SEM), simulation, decision analysis, EnRiCH, C-Change, preparedness, risk analysis

INTRODUCTION

Community emergency situations arise from potential, predicted or actual events that have natural sources (e.g., severe storms, weather anomalies, floods) or are human-induced threats (e.g., exposure to dangerous goods, fires, accidents). These difficult and damaging interactions between people and nature generally occur as exogenous factors beyond the controllability of receptors, such as communities, that are impacted by them (Gunderson and Holling 2002). The consequences of urgent events stimulate community resources to act in response through humanitarian and resourceful recovery activities related to the emergency. Community collaborative response is generally recognized as a key ingredient in effective adaptation to emergency situations. However, research in this area is almost exclusively *ex post* and descriptive of observed behaviour. More work is needed to understand collaborative mechanisms and to provide prescriptive structures for improved community collaboration in the context of local emergencies.

The purpose of this paper is to model these collaborative interactions and the response mechanisms of community resources to react to emergency events. In so doing, the intent of this research is twofold: (1) to identify, through establishing measurable conditions, community preparedness and the community's capacity to adapt to emergencies; and (2) to describe the process by which the community becomes mobilized and the needed resources are applied to confront emergency events and their challenges. Our interest, like that of Berkes (2012), and Allen (2003), is in reducing community vulnerabilities and threats through the collaborative and collection action of community members, and the effective deployment of available community resources. It is understood that this can be better achieved if: (i) the threat is understood (FEMA 2012); (ii) the community has

compiled the necessary resources and inventory of people, materials, infrastructure, and institutional arrangements required to deal with the threat (Haque and Etkin 2012); (iii) the community has undertaken strategic planning steps to become prepared (Levac et al. 2011); and (iv) the community is in a position to act in order to deploy efficiently and effectively its resources collaboratively before, during, and after the event inducing emergency (Shapiro 2011; Kegler et al 2010; Lasker and Weiss 2003). To this end, the objective of the paper is to: (1) model and describe the emergency including its expected impacts; (2) profile the community under threat and the context of the emergency event; (3) characterize the community's social capital including leadership, resources, priorities, strategic plans, and level of preparedness; and (4) describe the deployment and effectiveness of community resources in response to the emergency situation with respect to the emergency impacts and changes to the community profile.

The paper uses data on collaborative practices and evidence from historical emergency circumstances and performance of community response for two community-based research projects at the University of Ottawa:

- EnRiCH ("Enhancing Resilience and Capacity for Health") - a community-based, participatory action research project for the implementation and evaluation of resilience-oriented interventions in 5 target communities in Canada. EnRiCH develops new knowledge to enhance preparedness, response and recovery for emergency events or natural disasters (O'Sullivan et al. 2012); and
- C-Change ("Managing Adaptation to Environmental Change in Coastal Communities: Canada and the Caribbean") – an International Community-University Research Alliance (ICURA) project whose goal is to assist participating coastal communities to share experiences and tools that aid adaptation to changes due to sea level rise, and increasing frequency of extreme weather events, e.g., hurricanes, seasonal storm surge. C-Change seeks to improve understanding of the impacts of changing climate on local assets, and to increase capacity for planning for adaptation (Lane and Watson 2012).

METHODS

Structured equation modeling provide the foundation for simulation modeling and analysis through the model components of the Community Emergency Event and Response system as depicted in Figure 1. Figure 1 includes the modules of the system model as identified above: (1) the exogenous emergency event; (2) the community context and profile; (3) the community's social capital, priorities, capacity to adapt, and resources; and (4) community response and actions to the exogenous event. Model modules are presented in detail below.

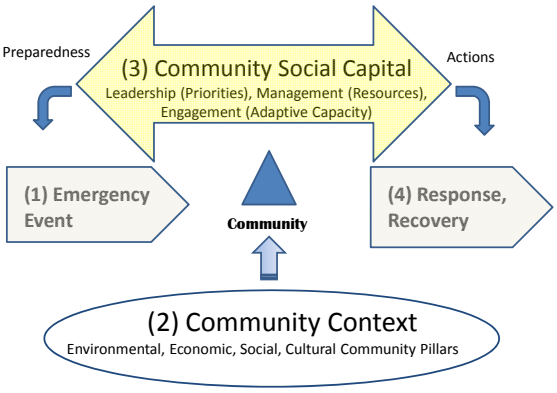

Figure 1. Community Emergency Event and Response System

(1) Emergency Event Module

An emergency is defined in the system model as a natural and/or human-induced event that induces an emergency situation on the community. For EnRiCH, emergencies are defined in general terms as chemical, biological, radiological, nuclear and explosive (CBRNE) events that cause trauma to community resources and individuals, especially vulnerable populations. In the case of C-Change, coastal communities experience

emergencies from extreme weather events, e.g., severe storms, hurricanes, that impact exposed and vulnerable infrastructure (bridges, roads, buildings) impacted by storm surge and flooding. Expected impacts from emergency events are modeled as value-based damages to the assets of the community. These assets are classified in categories that include: the environmental, economic, social, and cultural assets of the community. The extent to which these asset categories are prepared and protected, reflects the priorities of the community to adapt and be resilient, and to render it less vulnerable as a consequence. The Emergency Module accounts for the impacts as a function of: (a) the relative strength of the event, e.g., more severe versus less severe storm; (b) the resources of the community to project, accommodate, or retreat, in preparation for the emergency inducing event; and (c) the action of the community attributed to managing the event.

(2) Community Profile Module

Communities are defined in the context of the pending emergency situation and with respect to their value-based assets position. Communities are accounted for in the status quo of the event context with respect to their assets with respect to Environmental, Economic, Social, and Cultural categories that provide the inventory and resources associated with its physical and environmental attributes, the membership and involvement in the commercial economic sector, the elements of the social system (e.g., community demographics, social services, health care, etc), and the characteristics that identify the unique cultural perspective of the community (e.g., churches, community centres, etc.) (Lane and Watson 2012, Fisher 2011).

(3) Community Social Capital Module

The community is evaluated in terms of its social capital for emergency preparedness. This includes: (i) community social capacity for collaboration and community synergy (Lasker and Weiss 2003); (ii) resources for emergency relief (e.g., access to first responders, emergency services, clinics, etc.); and (iii) preparedness as measured by institutional arrangements, and collective community capability to be independent of food, water, energy and communication services and community members' ability to be self sufficient for a 72 hour period. This dimension of the community profile, "community social capital" (Figure 1), is expressed in terms of community attributes assigned to leadership (with respect to community priorities), management (of human and material resources), collaborative engagements and within-community communication (adaptive capacity) (O'Sullivan et al. 2012).

(4) Community Response and Action Module

Community capacity is a key component of the ability of the community to be prepared in the face of the pending emergency conditions. Community capacity and implementation of community response and action are separate but related elements of the system. The existence of action guidelines and plans, as well as evidence of ongoing community communication and engagement in monitoring and training for emergency events contributes to response and action effectiveness (BCI 2010; FEMA 2012; Shapiro 2001). Community capacity may be considered a necessary but not a sufficient condition to elicit effective emergency response and action. Unanticipated examples abound of the capacity of communities and individuals to act over and above their apparent means to overcome the challenges of traumatic events. These responses are modeled as a function of historically observed actual community responses. The modeling framework explores interaction opportunities that give rise to incidences of exceptional response. These incidences are modeled as a function of the event, community resources and capacities, and the cohesive synergies and collaboration among community groups (Eriksson and Lindström 2007; Kegler et al. 2010).

Functional Module Behaviour

The linkages and functional relationships between the modules of the Community Emergency Event and Response System (Figure 1) are developed using structural equation modeling (SEM) developed from the work of Goldberger (1972) and subsequent analysis (Bagozzi and Yi 2012). Interrelated module functions are described initially in Figures 2a, b, c, and d below as follows:

a) Emergency Event Urgency (i.e., severity) versus Community Response or mobilization – in the event of a more severe predicted or actual event, it is anticipated that the affected community will mobilize accordingly in direct relationship to its capacity and responsibility;
b) Community Social Capital (leadership, management, engagement, communication) as a function of the Community Profile assets by category (environmental, economic, social cultural) – defines the community's preparedness position as a function of its recorded value asset position, and its state of preparation prior to the onset of the emergency inducing event;
c) Emergency Event Impacts with respect to the Community Profile assets by category (environmental,

economic, social cultural) for alternative levels of urgency or severity – the higher the severity of the threat, the higher the impacts (damages) across the Community Profile as a function of historical emergency events and steps taken to adapt to pending events;

d) Community Response versus Social Capital for alternative levels of emergency event urgency – measures of community response are indicated as a function of community social capital and the community's capabilities of collaborating and communicating in the context of the event.

The system models the feedback between the mobilization of community response and the actual impacts on the community profile. The higher the effective community response, *ceteris paribus*, the lower the effective impacts on the community assets. Data from the EnRiCH and C-Change communities experience are used to define candidate functional forms, feedback, and response based on the limited emergency event experience (as illustrated in Figure 2). These data are used to investigate 'trigger values' in the response functions indicating changes in levels of impacts based on observations for mobilized community response.

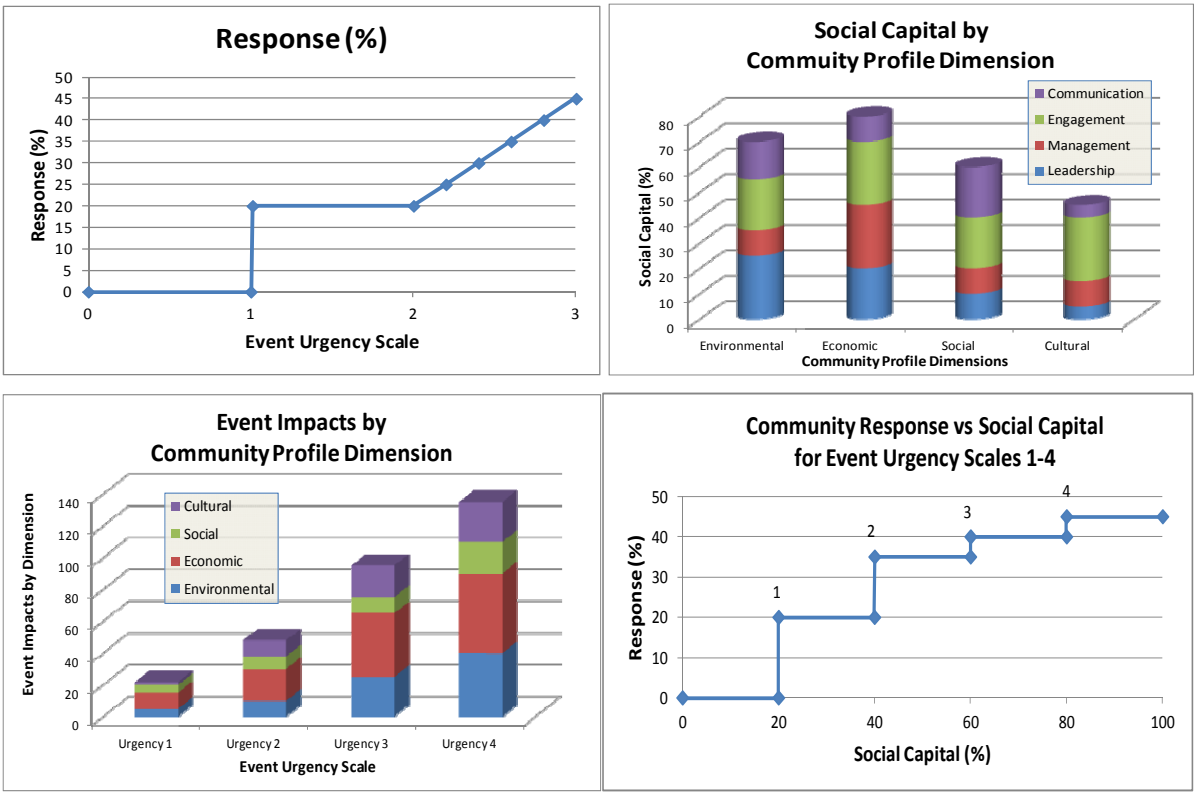

Figure 2. Events, Social Capital, and Response Functions; (a) Event urgency vs Community Response; (b) Social Capital by Community Profile Dimension; (c) Event Urgency vs Event Impacts by Community Dimension; (d) Social Capital vs Community Response.

ANALYSIS AND RESULTS

The functional system, illustrated above in Figure 2, is used as the basis for the development of a dynamic simulation model using the *Arena* simulation software (Kelton et al. 2007). The simulation model links the elements of the Community Emergency Event and Response System (Figure 1) in a dynamic framework indicating mechanisms for emergency event response and recovery. Randomized emergency events are modeled through their affects, durations and expected impacts. The community response is determined as a function of the social capacity and mobilized response. The *Arena* model is characterized by a linked model of component for: (1) community preparatory status; and (2) emergency inducing event and response as illustrated in Figure 3 below.

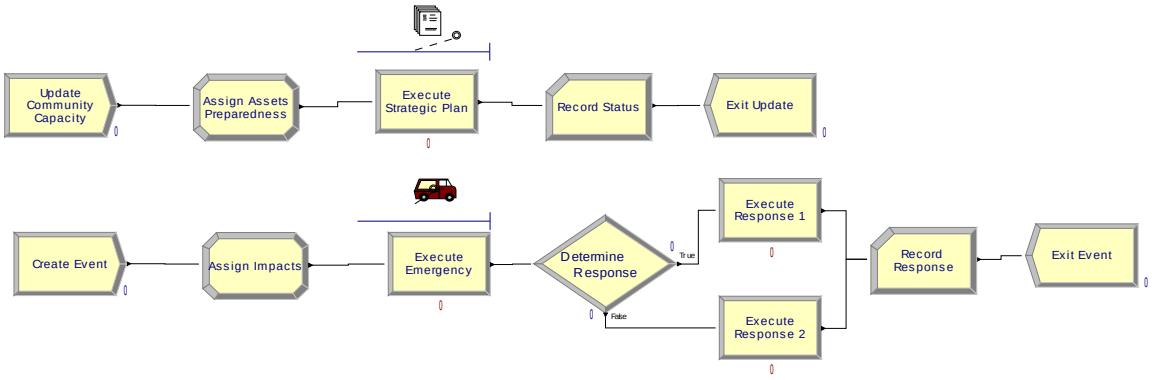

Figure 3. Arena Simulation Core Model

Manipulation of alternative levels and configurations of community social capacity and response are designed, tested, and validated using EnRiCH and C-Change observations from limited historical emergency response. The results of the simulation design are analysed to explore conditions, target levels, and indicators to summarize the mechanisms that are deemed most preparatory and effective in dealing with the crisis.

CONCLUSION

The modeling exercise of this paper is neither unique nor definitive. Rather, it explores the identification and measurement of elements of community response to emergencies. This requires building and constructing a representative response system characterized by community mechanisms that are judged to be more of less effective in the face of the impacts of modeled emergency situations. In so doing, the analysis, through practical observations from the EnRiCH and C-Change cases studies, develops insights into defining preparedness and effective response mechanisms. The exploratory results direct policy makers and community leaders to focus on the priorities of the community toward improving preparedness and response.

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