ICT Support and the Effectiveness of Decision Making in Disasters: A Preliminary System Dynamics Model

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ABSTRACT

A high level conceptual model is presented of factors hypothesized to be key determinants of the effectiveness of decision making in large scale disasters, grounded in the literature on disaster management. ICT robustness (including the use of social media) sensemaking, and the effectiveness of decision making processes by the multi-organizational Partially Distributed Teams that must cooperate are accorded key roles in the process model. The outcomes of the decision making processes modeled are decisions, in terms of timeliness and quality.

Keywords

Social media, system dynamics model, ICT, decision making, disaster management effectiveness

INTRODUCTION

There have been hundreds of articles produced in the last decade describing specific examples of new Information and Communication Technology (ICT) innovations that may improve the quality of decision making during disasters, and thus the outcomes of disaster management, such as the quality and timeliness of the decisions made and actions taken. There have also been many studies of what may be viewed as factors or processes that are part of the overall emergency management process, such as sensemaking (Weick, 1993), avoiding “threat rigidity” syndrome (Dörner, 1996), and building effective temporary organizations composed of subteams that must cooperate (Plotnick, Hiltz and Ocker, 2010). The purpose of this paper is to integrate previously separate strands of research, and to hypothesize the relationships among these factors, in the form of a model. We choose System Dynamics (SD) to express the causal relations among variables that can be considered key factors in disasters. The model positions ICT as playing a key role in the disaster management process. This first effort at an integrated model can not yet be tested with specific case data, but by identifying the expected key model relationships we hope that researchers will collect the data that would be necessary to test even parts of the model, during some future disaster simulations or actual cases of disaster management.

The next section of this paper introduces and the factors we include in our overall model. The third section presents and describes our initial model of the response phase process, starting with hypotheses about the relationships of pairs of factors and then the full model that results. We conclude with a discussion of possible future research.

DEFINITIONS OF FACTORS

The World Health Organization defines a disaster as an occurrence that causes damage, ecological disruption, loss of human life, deterioration of health and health services, on a scale sufficient to warrant an extraordinary response from outside the affected community or area. The factors in our proposed complete model are categorized as “*inputs*,” (things that happen before or as the disaster management process starts that affect the initial state of the management process), the disaster *management process* itself; including the effectiveness of the *actions* or decisions that occur, and the *outcomes* of the disaster management process. An overview of the complete set of factors included is shown in Figure 1. For our preliminary system dynamics model, however, we will include in this short paper only the italicized factors.

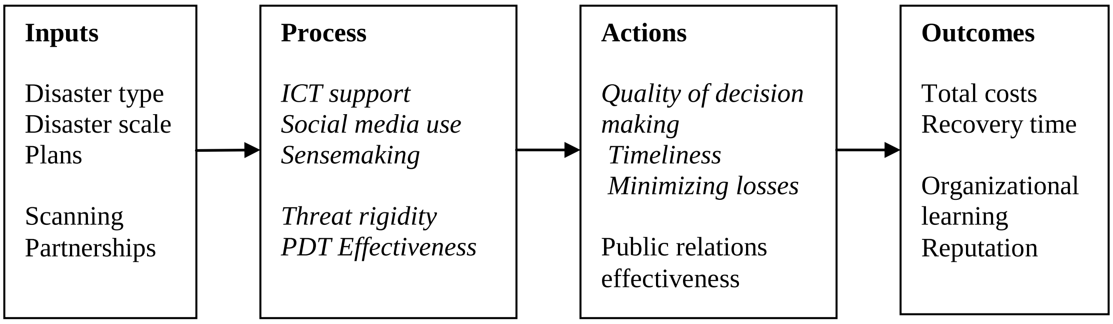

Figure 1: Factors in the complete model of Disaster Management Effectiveness

I. Process: During the Emergency

ICT support

a. ICT support robustness- Ideal would be both computer based information systems for disaster management, and functioning computer networks and communications networks such as the phone system. Levels onsite are dependent on bringing in equipment and trained personnel; electrical power for devices (that could be supplemented by generators); and whether communication networks (including those for mobile phones) are working well, poorly (e.g., saturated capacity) or not at all because the cell towers run out of power after a day or two. Another consideration is the ability to set up facilities to house and feed the workers onsite, which is dependent on a combination of pre-planning (e.g., setting up facilities and supplies before a hurricane hits) and the state of the transportation infrastructure after the disaster strikes. Thus, the level of ICT robustness is liable to fluctuate during the disaster. It could probably be rated on a 1 to 10 scale for modeling purposes.

b. Social media- In many accounts of disasters, it has been shown that social media contain important information about the nature, location and severity of specific incidents that need attention, e.g., where there are victims in need of rescue or medical attention or evacuation. For example, during the 22/07/2011 Norway terrorist attacks, many participants at the youth camp made contact with their family and friends using their mobile phones (calls, SMS, Twitter, Facebook). A great deal of useful information was disseminated via social media, but it was observed that better coordination between official and public information practices could have improved situation awareness regarding the coordination of response (Perng et al, 2012). The states for social media used to gather information and/or communicate among the team or with the public could be classified as (yes, effectively; yes, ineffectively, / no). This could change during the disaster.

Sensemaking vs. threat rigidity

Does the team involved share information and build a shared understanding? Or do they take action without understanding the actual situation or based only on routine plans and practices?

a. Avoiding Threat rigidity

This consists of over-reliance on rules and familiar procedures; inability to take unanticipated complexity into consideration (ignoring potential side effects and long term negative outcomes and possible actions "not in the plan; becoming unable to act as negative events cascade) (Dörner, 1996; Plotnick and Turoff, 2010).

When faced with a threat, organizations, groups, and individuals often react with well-learned behaviors or habitual responses (Staw et al., 1981) that may be maladaptive and may exacerbate the situation. This is because an unfamiliar threat may cause stress and anxiety; in response, a psychological coping mechanism is that information flow is restricted and new information is not sought.

b. Group Sensemaking

Sensemaking is made necessary by crisis conditions that constitute what Weick (1993) describes as a "cosmology episode" in which "both the sense of what is occurring and means to rebuild that sense collapse together." Especially at the onset of a crisis, the "surface" or presenting disaster is perceived, but the full set of underlying causes, the location and extent of damages, and most importantly, what subsequent related disasters may occur, are not known (Mitroff, 2004). Group Sensemaking involves a shared activity in which the team members try to make sense of things by addressing the questions, " 'what is happening out there?', `why is it taking place?', and `what does it mean?'" (Choo, 2006; Weick, 1995). Sensemaking is thus about how people give meaning to what is happening in order to reduce the equivocality and ambiguity that surrounds them.

Partially Distributed Team (PDT) Effectiveness

Most crisis management situations involve emergent temporary organizations that are Partially Distributed Teams (PDTs), consisting of subteams from different organizations and at different locations that must coordinate and cooperate to effectively deal with a disaster. PDTs have a unique, unbalanced communication structure in that the co-located subteams communicate mostly face-to-face but communication among subteams is mediated. Among the conditions for effective decision making in the PDT environment are:

a. **Shared identity** (vs. subgroup dynamics, or "us vs. them"). At the extreme, differences in organizational and national culture as well as possible time zone differences may lead to "faultlines" whereby conflict and distrust escalate to a condition of inability to work together and agree on anything (Polzer et al, 2006; Privman, Hiltz and Wang, 2013).
b. **Trust** among the subteams (Plotnick, Hiltz, and Ocker, 2011)
c. **Appropriate leadership**/authority structure (e.g. leader for each subteam able to make decisions based on local conditions, and not a single central leader who tries to dictate in a command and control manner) (Plotnick, L., Ocker, R., Hiltz, S.R. and Rosson, M.B. 2008).

II. Actions: Quality of Decision Making

In addition to having and using the important potentially available information, effective teams avoid heuristic errors in decision making, including: avoidance of interpretation problems (e.g., rumors and mis-communicated information); and the "MUM" effect (tendency to withhold or improve negative information (Coombs 2007). The criteria for a good decision is that it is timely and minimizes losses.

Timely decisions must be made on an ongoing basis during the crisis. Not acting at all is usually worse than making some sort of decision to use a resource to solve a problem. For example, one might not have enough generators or ambulances to meet all the needs, but if they are not sent somewhere on a timely basis they will not do anybody any good.

The losses that must be minimized include human lives and injuries; property and financial losses, including business shutdowns; disruptions to the public (e.g., evacuations, power losses and other infrastructure losses such as blocked highways or no clean water supply), that affect their ability to carry out normal work or family activities; environmental damage, present and future; and decrease in trust in and reputation of the organizations involved (e.g., FEMA's loss of public confidence after Katrina).

A PRELIMINARY MODEL OF THE DYNAMICS OF DISASTER MANAGEMENT

In this section, we present the hypothesized relationships among pairs of factors included in the response process phase and the model that results. We exclude public relations effectiveness to simplify the model as well as the separate components of PDT effectiveness.

Disaster Management Process hypotheses

1. The better the ICT support, the better the sensemaking
2. The better the ICT support, the better the quality of the decision making process
3. The better the ICT support, the less threat rigidity
4. The better the ICT support, the greater the PDT effectiveness
5. The better the sensemaking, the less threat rigidity
6. The more threat rigidity, the less the sensemaking (Note: these form a loop)
7. The better the sensemaking, the better the PDT Effectiveness.

8. The better the PDT effectiveness, the better the sensemaking (Note: these form a loop).
9. The better the sensemaking, the better the decision making process.
10. The better the PDT effectiveness, the better the decision making process.
11. The better the decision making process, the better the subsequent sensemaking.
12. The better the decision making process, the better the decisions in terms of both timeliness and quality.
13. Decision Quality in terms of minimizing losses affects infrastructure preservation or restoration, which in turn affects ICT robustness. (Timely and good decisions restore utilities and transportation, which in turn supports the robustness of the ICT support, including the ability to bring in more equipment and personnel and keep them healthy).

We present in Figure 2 the preliminary model of the key process variables proposed as especially important for the overall effectiveness of the disaster management process. These were generated using Vensim. For simplification, use of social media is not broken out separately in this model, but is included as one of the two components of ICT support. Social media use is separate from overall ICT support robustness, but we hypothesize that it is related to the other variables in the model in the same way.

In this diagram, the parallel hash marks mean that there is a delay in a cause-effect relationship. The loops are given short abbreviations for the subprocess they model, e.g. "Senseff" is the causal loop between Sensemaking and PDT Effectiveness. All of the causal loops are labeled with an "R," meaning that they are Reinforcing loops, also referred to as "positive" loops. This means that the decision process quality is either spiraling up as time goes on, or spiraling down. If in a downward spiral the team would eventually be making no decisions at all, or all bad decisions. This is obviously not sustainable. Eventually, other actors would step in as the disaster becomes worse and worse in its costs and no effective steps are being taken.

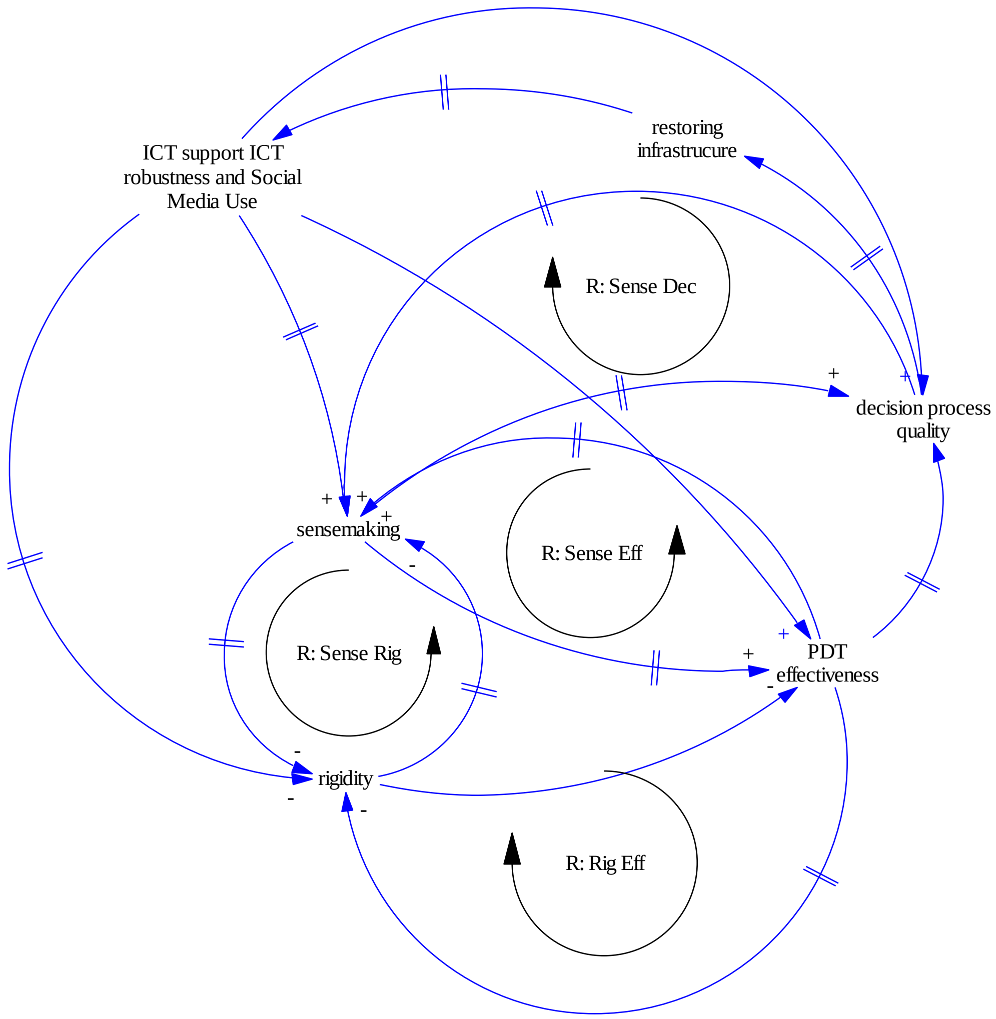

Figure 2 A Preliminary System Dynamics Model of Key Factors in Disaster Decision Making

DISCUSSION AND FUTURE RESEARCH

We have presented a proposed system dynamics model of key communication and decision process factors that will influence the quality of decision making during large scale crises that require the formation of a Partially Distributed Team made up of subteams from different organizations. Information and Communication support serves as a key driver in this model. Current efforts to improve the availability of ICT support (use of generators, local area networks that supplement the Internet) when utilities such as cell phones and electricity disappear are thus very important. In the socio-technical system presented, “the components influence each other by constantly shaping and changing each other” (Haavik, 2011, p. 99

The choice of system dynamics was not casual. SD has a strong record regarding its ability to express the causal structure of complex systems in terms of a high level (highly aggregated) causal diagram along with reinforcing and balancing mechanisms contained in the feedback loops of the causal diagram. Second, system dynamics views the changing dominance of feedback loops as the driver of the dynamics of the system (Richardson, 2011). Understanding the “dynamics” of a system, say of a disaster, that is, the behavior over time of the variables relevant for the disasters, and the drivers of such dynamics, are key requisites to improve disaster management – in fact, to improve the management of any complex system.). Thus, we suggest that a system dynamics model is a natural choice to model the process.

Of course, the major limitation of this model is that we have not tested it. We cannot offer such possibility yet, since the necessary data, the so-called “reference behavior” of key variables, to calibrate a system dynamics model of a generic disaster, or of a particular disaster for that matter, is not available. We intend to develop other parts of the model to encompass the factors excluded from the initial model in this paper. A next step is to try to work out measures for the ‘stocks’ and “flows” between variables that are entwined in causal loops in the model. Then we will try to find one or more cases where we can collect measures of several of the factors at several points in time, in order to be able to run the model and test its predictive power.

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ACKNOWLEDGMENTS

This research was partly supported by travel grants from the University of Agder.