Complexity in Emergency Management and Disaster Response Information Systems (EMDRIS)

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ABSTRACT

Today emergencies seem more complex than ever. Process of managing these emergencies also becomes more complex because of increasing number of involved parties, increasing number of people affected, and increasing amount of resources. This complexity, inherent in emergency management, brings lots of challenges to decision makers and emergency responders. Information systems and technologies are utilized in different areas of emergency management. However complexity increases exponentially in emergency situations and it requires more sophisticated IS and IT and it makes response and management more challenging. Thus analyzing the root causes of emergency management information systems complexity is crucial for improving emergency response effectiveness. This paper frames the issue of information systems complexity by focusing on the types of complexities involved in emergency management phases and explaining each complexity type. We propose 6 different complexity types: Human Complexity, Technologic Complexity, Event Complexity, Interaction Complexity, Decision Making Complexity, and Cultural Complexity.

Keywords

Complexity, emergency management and disaster response systems

INTRODUCTION

Complexity theory is highly relevant for disaster studies because it provides an entry point to describe disasters as the interaction between sub-systems of nature and society or hazard and vulnerability (Hilhorst, 2003). Complexity and complex systems have been studied for a long-time by different researchers from various disciplines. Along with increasing number of components, involvement of advance technology, increasing level of communication and large number of parties involved, today's socio-technical systems and processes in them are becoming more complex every day. Complexity increases exponentially in emergency situations which usually occur in socio-technical systems and it makes response and management more difficult. Information systems and information and communication technologies are often utilized in all phases of emergency management to improve results and safety. Thus complexity of emergency management and disaster response information systems (EMDRIS) is a multi-dimensional subject, and has important impacts on the success or failure of emergency management activities as well as on participating people and organisations. In this research, our goal is to describe the types of complexities which may be involved in information systems used in disaster management and emergency response phases. We first explain what is complexity and especially information systems complexity and what makes emergency management information systems more complex. Then, we propose 6 different complexity types for such systems as: Human complexity, Technologic complexity, Event complexity, Interaction complexity, Cultural complexity, and Decision making complexity. We propose a model to represent these complexity types and explain each one briefly.

LITERATURE REVIEW

Complexity and Complexity Definitions

Complexity is an undesired outcome of emergency situations. However, it is reality and we have to deal with it. Thus instead of ignoring it, it must be studied and be better understood to increase success level of emergency management and disaster response. Emergencies occur in societies which can be easily considered as tight coupled systems because of large number of interactions among nature, society, technology, and humans. Thus,

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understanding emergency management and disaster response complexity requires interdisciplinary approach because of inter-organizational action, real-time data and information flow, culture-based and society-based adjustments, and utilization of some simple and advance technologies. In addition to this natural complexity disaster represents the interdependent cascade of failure triggered by an extreme event that is exacerbated by inadequate planning and ill-informed individual or organizational actions (Comfort, 2005) and it makes it much more complex.

Synonyms for complexity are intricate and involved (Anneberg and Singh, 1993). Myers (1976) defines complexity as a function of the relationships among the components of the object. Both definitions indicate multiple relationships or interactions among two or more components of an entity. Morowitz (1995) also claims that complex systems share certain features like having a large number of elements, possessing high dimensionality and representing an extended space of possibilities. It makes systems inherently unstable, and causes the ways in which processes of ordering and change ocur to be unpredictable and non-linear (Hilhorst, 2003). Another facet of complexity is related to understandability. IEEE Standard Glossary (std. 610.12) defines complexity as the degree to which a system or component has a design or implementation that is difficult to understand and verify (IEEE, 1990). Alford also uses the word complex to mean difficult to understand (Alford, 1994). All these definitions and findings can be easily modified to apply for emergency management and disaster response information systems and are a good sign that complexity level is related to the understandability of objects, entities, systems or situations by humans. Complexity, thus, can be defined as a difficulty metric, particularly with respect to understanding multiple relationships or interactions among two or more components of an object, entity, system,or situation in emergencies.

Because understandability depends on several different factors and is a subjective measure, complexity is both difficult to define precisely and to quantify. Different disciplines use different approaches and characteristics to define complexity; considering these different approaches can offer insights into the complexity of emergency management and disaster response. Emergency management and disaster response and information systems carry characteristics of socio-technical systems because of humans, nature, technology, equipment, buildings, and environment play role in it. Thus, we primarily use social and technical approach to complexity in our research.

Characteristics of Emergency Management and Disaster Response Information Systems (EMDRIS)

EMDRIS must designed to be real-time. EMDRIS functionality and applications require them to communicate with many systems, to work on multiple tasks at the same time to process data and to produce results, and to do all their work in real-time to support decision-making process. They are embedded within an environment which they must sense important properties of that environment, and must be able to take actions by issuing instructions/commands to the resources that it can control, must be programmed by users to achieve a set of goals, and to execute the planned actions within the approval envelope given it by its human users.

As a result of above detailed literature review (can not listed here because of space limitation), we can say that in EMDRIS most important causes of complexity factors are humans which are operating the system and using the systems to make decisions, the characteristics of the event, technology infrastructure, culture of society and culture of organisations, interaction and communication among all components of the system and decision making in real-time. Thus, we summarize different aspects of emergency management complexity as illustrated in Figure 1.

RESEARCH MODEL

The objective of this study is to define and determine the complexity of information systems designed for emergency management and disaster response. After considering different disciplines' approaches to complexity, as well as the characteristics of emergency management and disaster response information systems explained in section 1.2, six different types of complexity can be identified for emergency management and disaster response information systems:

Human Complexity: The most two common components of emergency and disaster repsonse systems are humans and technology. As a result, human error (Meshkati, 1991; Grabowski & Roberts, 1996) is of vital importance in these systems and are studied by different disciplines in different ways. Previous studies show that one important cause of the accidents and incidents in large-scale systems is human error. For instance, human error has been shown to contribute 50 to 70% of the risk at nuclear power facilities (Trager, 1985), and 65% of catastrophic marine-related accidents have been the result of compounded human and organizational errors during operations (Moore, 1994).

Basically, thereare two types of human involvement in large-scale systems. Humans might be the operators of the complex system and can cause complexity because of wrong doings (such as pushing the wrong button, not following the instructions given by the system, incorrect use of system functions, etc.) or humans can be decision makers who get information from the systems and make decisions based on that information. Causes of error include fatigue, workload, and fear as well as cognitive overload, poor interpersonal communications, imperfect information processing, and flawed decision making (Helmreich and Merritt, 1998). These unsafe acts as arising primarily from aberrant mental processes such as forgetfulness, inattention, poor motivation, carelessness, negligence, and recklessness (Reason, 2000). Thus, human related complexity must be analyzed and in order to minimize human errors and required precautions must be taken. Human error is systematically connected to features of people tools, tasks, and operating environment. Progress on safety comes from understanding and influencing these connections (Dekker, 2002).

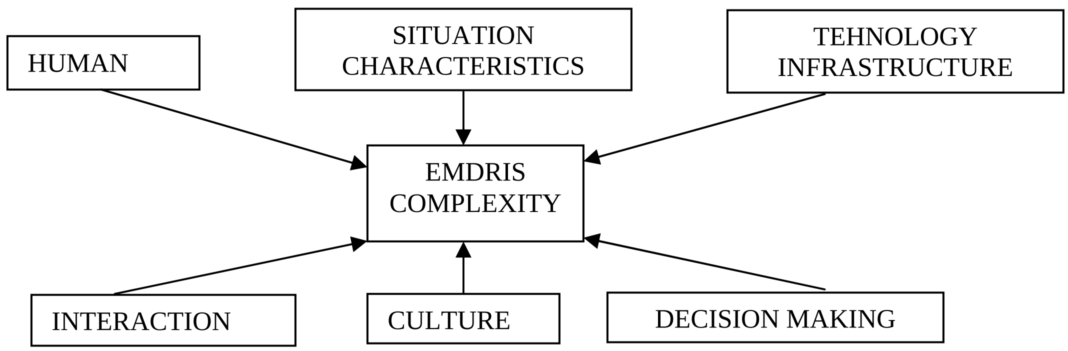

Figure 1 Representations of Complexity Factors in EMDRIS

Technologic Complexity: Another important component of emergency management system is technology. Almost all EMDRIS are using computer technology heavily. While some of them are being managed and controlled by software (nuclear power plants, airplanes), others are using computers and software as an auxiliary component (as, a decision support system) to help with some important system functions (operator decision- making, monitoring, and automation of some of the tasks). Computer technology and software can speed up tasks, decisions, information flow, and calculations, and make systems and operators aware of what is happening in real-time. At the same time because of tight coupling and large number of components and subsystems it increases complexity of the system.

Over the last decade, many disasters have shown that even in the most developed economies, catastrophic events can overwhelm communications grids. In fact, communications failures in New York City on September 11th 2001 contributed directly to the loss of the lives of at least 300 fire-fighters. Timely communication among responders relies on the establishment of robust and efficient communication infrastructures (Chen et al, 2009).

Event Complexity: In our research, event complexity refers to event which created the disaster and requires emergency response. This could be earthquakes, floods, tsunamis, storms, hurricanes, wild fires, nuclear power plant accidents etc. We propose that event-specific characteristics will increase the level of complexity in EMDRIS. Each event type may require different response types varying in amount and type of resources, personnel, technology as well as sophisticated tools, software, hardware, reasoning, database, etc. Especially early warning systems and technologies might be available in some disaster types and they must be incorporated to EMDRIS while for other no such systems may exist.

Interaction Complexity: In our model interaction covers organizational, coordination, and administrative (management) complexity. Organizations involved in emergencies have a mix of organizational structures and cultures, and, in order for the overall success, they must work together to achieve a number of competing and common goals. Despite the fact that these organizations and individuals share common goals in emergencies and disasters, their operating practices and values may conflict (Grabowski, 2010). Same is true for EMDRIS and involved systems.

Interaction happens between organizations, between systems, between people and these interactions make system complex. System and organizational support for flexibility is important because flexibility is required for creative problem solving (Plotnick et al, 2009). When a large-scale disaster happens, a great deal of information occurs in a short period of time (Atoji et al, 2000). The emergency starts out with a lack of information, which then turns into large amounts of imprecise information (Manoj and Baker, 2007). The need for integration intensifies as the number of organizations engaged in response operations increases and the range of problems they confront widens (Comfort and Kapucu, 2006). Thus, each one of above mentioned sub-complexities must be studied in detail.

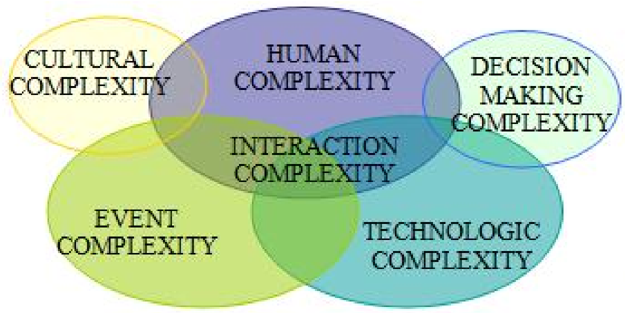

Figure-2 Proposed Complexity Types and Interrelations Among Them

Cultural Complexity: Societies are different than each other and every society has it's own characteristics, customs, beliefs, life styles, demographics, etc**.** For example some countries are multicultural in terms of population with different races, different languages, belief systems, etc. while some other are homogenous. Number of multicultural countries is increasing because of immigration. This also needs to be considered during emergency planning and disaster response. Number of single mothers, number of elderly people, number of disabled people, number of children must be considered. Belief systems may also affect post-disaster activities and how they must be handled. Other component of cultural complexity may come from organizations involved in emergency management. Every organization may have their own culture and this will effect their collaboration with other organizations. Thus, EMDRIS must consider all these factors and must be customized to handle country-specific cultural information and inter-organizational cultural issues.

Decision Making Complexity: Decision making is not easy during emergencies. Knowledge is an important source. During emergency response, individuals, teams, and organizations share and apply knowledge as they process information, make decisions, and act on existing knowledge (Chen et al, 2009). Coskun and Grabowski (2001) define two sub complexities for decision making. As user interface complexity and explanation complexity. Communication between EMDRIS and their user(s) is provided by user interfaces. In order to utilize the functions and available features of EMDRIS, users should be able to easily see, capture, and understand information on the screen (interface). The screen design must allow users to see all information with their related importance level to understand information easily, and to easily use all functions of EMDRIS. For explanation, EMDRIS provide information and support to users and/or decision makers. In order to make good decisions, user should be well informed about the situation, alternative decisions should be determined and evaluated, and the results of each alternative must be presented. EMDRIS must help users with information, alternative determination, alternative testing, and result prediction stages in order to improve the quality of decisions. Thus all the information must be explained to users.

CONCLUSIONS

If we can better define complexity types and study them in detail, this will help us to take necessary actions to reduce unnecessary complexities in emergency management and disaster response information systems, thus resulting with more effective and more productive solutions to handle disasters and decrease amount of losses. This study proposed 6 different complexity types for such situations thus opening a discussion platform for complexity of emergency response. Further studies must focus on how to measure or quantify each complexity type and to compare them to help decision makers.

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