Redefining and Measuring Resilience in Emergency Management Systems

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Inherent limitations of controlling risks in complex socio-technical systems were revealed in several major catastrophic disasters such as nuclear meltdown in Fukushima Daiichi nuclear power plant in 2011, well blowout in Deepwater Horizon drilling rig in 2010, and Hurricane Katrina in 2005. While desired risk management leans toward the prevention of such unwanted events, the mitigation of their impact becomes more important and emergency response operations provide the last line of protection against disasters (Kanno, Makita, & Furuta, 2008). In response to September 11 terrorist attack at World Trade Center in New York, U.S. Government launched the National Incident Management System (NIMS), an integrated national and multi-jurisdictional emergency preparedness and response program (Department of Homeland Security, 2008). The NIMS framework is characterized by a common operating picture, interoperability, reliability, scalability and portability, and *resilience* and redundancy (Department of Homeland Security, 2008). Among these characteristics, effective emergency response operations require resilience because planned-for actions may not be implementable and therefore the emergency response organizations must adapt to and cope with uncertain and changing environment (Mendonca, Beroggi, & Wallace, 2003).

There have been many attempts to define resilience in various disciplines (Hollnagel, Woods, & Leveson, 2007). Nevertheless, such attempts for emergency management systems (EMS) is still scarce in the existing body of resilience literature. By considering traits of EMS, this study proposes the definition of resilience as '*a system's capability to respond to different kinds of disrupting events and to bring the system back to a desired state in a timely manner with efficient use of resources, and with minimum loss of performance capacity.*' In order to model resilience in EMS, the U.S. NIMS is chosen because it allows for investigation of resilient behavior among different components that inevitably involve both human agents and technological artifacts as joint cognitive systems (JCSs) (Hollnagel & Woods, 2005). In the NIMS, the largest JCS comprises five critical functions: *Command, Planning, Operations, Logistics and Finance & Administration (F&A)* (Department of Homeland Security, 2008). External stimuli or inputs to this JCS are events that occur outside of its boundary such as uncontrolled events. When these events do occur, they are typically perceived by the 'boots-on-the-ground' in the Operations function. The perceived data are reported and transported to the Planning function in which such data are transformed into useful and meaningful information. This information provides knowledge base for generating a set of decisions. Subsequently, Command function selects some of those decisions and authorizes them with adequate resources so that Operations actually take actions for such decisions to the uncontrolled events. This compensation process continues until the JCS achieves its systematic goal which is to put the event under control. On the other hand, Logistics feeds required and requested resources such as workforce, equipment and material for the system operations and F&A does the accounting of resources as those resources are actually used to execute its given missions. Such JCS utilizes two types of memory: a collective working memory (CWM) can be manifested in the form of shared displays, document or whiteboards used by teams; similarly, collective long-term memory (CLTM) can take forms of past accident reports, procedures and guidelines.

Based on this conceptual framework for resilience of emergency operations, five Resilient Performance Factors (RPFs) are suggested to make resilience operational in EMS. Such RPFs are adaptive response, rapidity of recovery, resource utilization, performance stability and team situation awareness. Adaptation is one of the most obvious patterns of resilient performance (Leveson et al., 2006; Rankin, Lundberg, Woltjer, Rollenhagen, & Hollnagel, 2014). Another factor that typifies resilience of any socio-technical system is how quickly or slowly it bounces back from perturbations (Hosseini, Barker, & Ramirez-Marquez, 2016). In most systems, resources are constrained. Hence, resilience requires the effective and efficient use of resources to varying demands. As such demands persist over time, the system's performance level tends to diminish. For the EMS to remain resilient, its performance should be maintained in a stable fashion. Finally, EMS is is expected to possess the ability to perceive what is currently taking place, to comprehend what such occurrence actually means, and to anticipate what may happen and decide what to do about it. When this occurs within a team, it is often referred to as team situation awareness (Endsley, 1995; McManus, Seville, Brunsden, & Vargo, 2007).

This resilience model for EMS needs validation and many assumptions and simplifications made in this work require further justification. This model will be discussed and validated by using subsequent data collection from Emergency Operations Training Center operated by Texas A&M Engineering Extension Service (TEEX) and will be reported in future publications.

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