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Information Science and Technology in Crisis Response and Management

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INTRODUCTION

Emergent technological innovations in robotics and miniaturization of robotics, drone technologies, acoustical sensors, and others are revolutionizing the effectiveness of crisis response and management efforts, on smaller local events, and in combination, may be applied to larger disaster events such as major community or regional crises. These have also been supported by advances in tracking, communications, information dissemination, identity verification, and location technologies developed over that past decade since Hurricanes Katrina and Rita devastated the central populated region of the United States and Central North America. The combination of these technologies show promise of rapid intervention and rescue, within the most devastated areas affected by major environmental and man-made disasters as they are scaled up to address larger population supports. Location and allocation of resources to the individuals, families, and populations of need may occur nearly unimpeded by obstacles, debris, contaminants and human first responder high risk environments. As these technologies are systematized and develop some level of autonomy in technological problem solving, they are likely to improve overall survivability of populations at risk in the most disaster fragile of environments.

BACKGROUND

Early efforts to link crisis management and information technology were concerned with the protection and maintenance of data within private business organizations. Businesses' have become dependent on technology to perform work, distribute products and improve productivity and efficiency. Loss of technology functions and critical information could cause irrevocable damage to a business. Therefore crisis management in the business sense has meant anticipatory planning for disruptions and protecting data and process critical for business success. The use of experts within a domain of business services coupled with domain decision makers and gathered into crises management teams; has been highly useful in considering critical scenarios of information or other critical processes disruption or loss. Constructing anticipatory action plans has proven to be a key part of adequate preparation for response, though these must be updated as situational contexts and key personnel change (Esbensen & Krisciunas, 2008).

Approximately a decade ago, in North America the major disasters of Hurricanes Katrina and Rita (Hurricanes: Science and Society, 2015) and there combined effects on a region of the south central United States were heavily televised, in part because of the urban location of the disaster in a modern and well known city. Major humanitarian service providers such as FEMA and the American Red Cross began to grapple with the scale of information needed and service provision possible for such large scale disasters and began seeking community and academic partnerships with corporate information technology providers, the defense industry, uniformed military service providers (especially those engaged in search and rescue efforts) and governmental agencies to improve crises response and management, for disasters of scale (Hurricane Katrina Disaster Relief, 2015).

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Since this time several additional cataclysms have increased awareness for the need to look at international and global response systems involving information technology, relative to preparedness, systemization, planning, pre-positioning of resources and equipment, logistics and distribution capacity in the management of crisis and disaster management. Public attention has been galvanized by devastating natural disasters such as; earthquakes in Pakistan in 2005 and in Sichuan China in 2008 and again in Haiti in 2010, the Tohoku earthquake and tsunami striking Japan in 2011, Cyclone Nargis that struck Myanmar in 2008 and by recent recollections of earlier but recent large scale disasters prior to the North American hurricanes of 2005 such as; the Sumatra tsunami of 2004, and the Iran earthquake of 2003, and several earlier to these and many others since (Lists of Disasters, 2015).

CRISIS RESPONSE AND MANAGEMENT: TECHNOLOGY CONSIDERATIONS

Crises and disasters are sudden and unforeseen. Each is serious, disruptive, overwhelming and often exceeds capacity to restore order and normalcy in any expected time frame. However, crisis or disaster events may occur with some frequency and predictability, and standardized responses may be thoughtfully and consistently applied. Others may be anticipated to occur occasionally but irregularly, and require a level of creativity and innovation over a short period in response. There are of course, improbable and unexpected crises and disasters which occur infrequently, but of which there are no precedents or examples to follow, and for which we have little or no prior experience. These are often widespread and devastating occurrences, requiring longer term determination and resolve to manage and to overcome or restore some level of normalization. Technology and information based systems may be designed to address each, as these relate to specific probabilities for their occurrence, and with attention to scalability of responses as needed for each type of crisis or disaster.

SWOT (Strengths, Weaknesses, Opportunities, and Threats) Analysis for Institutions

Though there are a number of possible and foreseeable crises that may affect any organization, information science technology is emerging as a critical crisis response consideration. Economic downturns, loss of funding, loss of physical and human assets, and employee litigation (Crisis Management, 2016) may all be tied to the consistency sustainability and privacy issues associated with information technology management protocols and continuity. A strategic planning method that may be quickly used by employees not fully familiar with an organization is to develop a simple SWOT plan of key and critical inquiries relative to information technology management or other strategic plan, crisis response initiative of the organization. Some possible lines of inquiry and planning for information technology management are given in Table 1 below, these should be strategically prioritized and determined both internally and externally:

Information Science Technology: Institutional Crisis Response and Management

Crisis response and management as related to institutions, or business, information science and technology requires crisis management teams are often designated in advance of a crises and focus crisis and recovery plans on avoiding a crisis, preparing and planning for crises, identifying threats and critical systems for protection, training key personnel for crisis events and recovery, communicating plans to organizational members, and reviewing and updating plans and disseminating crisis response guidelines. Phases of institutional Crises Stages (Fink, 1986) involving information technology have been identified as:

- **Prodromal Stage:** The first time those potential crisis symptoms occur. Early warnings may be missed, or may not occur creating unexpected crisis and causing decision makers to revert to a damage control process rather than preventing or limiting damage (Fink, 1986).
- **Acute Stage:** There is no preventative recovery, or turning back. The crisis begins and the eruption is noticeable. The crisis ends when the damage or disruption becomes unnoticeable (Fink, 1986).
- **Chronic Stage:** The recovery phase includes investigations, audits, explanations, self-analysis, self-doubt and healing. This phase is often used to analyze what went wrong and how to improve response in future (Fink, 1986).
- **Resolution Stage:** The crisis is resolved by managing the three prior phases of crisis. Alerts or prodromes are taken seriously in anticipation of avoiding or reducing the effect of any upcoming potential or foreseeable crises (Fink, 1986).

Most institutions with crisis management experience relative to information technology develop contingencies to suppress the destructive potency of a crises or critical event.

Key Theories Underlying Crisis Response and Disaster Response

At the institutional level crises are perceived as situational threats that may affect institutional reputation which may be moderated by application of communication theory, to minimize reputational harm (Coombs, 2007). Though larger scale disruptions external to the institution that may require disaster response are influenced by chaos theory and the perceived need to restore normalcy (Kiel, 1995). Similarities in each of these approaches to retain stability, or restore stability during periods of extreme stress to the institution or greater environment may be identified in classic crisis intervention theory as conceived by Aguilera and Messick as early as 1970. Crisis Intervention Theory maintains, that pre-existing equilibrium may be disrupted and result in disequilibrium among human organisms at the onset of extreme or prolonged stress. There is a pressing need to restore equilibrium. If there are sufficient balancing factors present, then no crisis occurs, or is sustained. Though, if sufficient balancing factors are absent, then a crisis will occur, or be sustained, though a lesser or less adequate level of equilibrium may still be possible (Aguilera, Messick, & Farrell, 1970).

Developing Crisis and Disaster Prevention and Response Infrastructure

A number of organizations and corporations are actively engaged in developing the technological architecture for preventing both institutional and non-institutional crises and disasters that occur with some frequency, and require standardized responses. These are preventable crises and probable disasters, or those of which a known infrastructure may be developed to rapidly and efficiently respond, so as to reduce loss of control. The costs of development are justifiable, and incidence rate may be statistically tracked with some accuracy for prediction of occurrence. These include those events that may be anticipated, and allow sufficient time to prepare for. Preparation is based upon what is known and what may be known, of which, there is an ability to take preventative action, and that there is an ability to plan to act to maintain or regain control where possible. Recent information technology advances related to crisis or disaster response capacity may be seen in Table 2 below:

Individual Hazards Reduction: Disaster Response and Management

Disaster response and emergency management may be related to single institutions as causal (i.e. Bhopal India, Chemical Spill in the 1980's), though the effects are often experienced community wide or regionally, whether manmade or natural. A single natural event may also be causal, but cause unexpected community and regional effects across institutions and technologies. These disrupt daily living and livelihoods, and cause loss of life, community structures, and normalcy, are widespread, and last for longer periods. Emergency Management Phases (U.S., FEMA, 2015) involving local or regional recovery, but those focuses upon individual or small group responses have been identified as:

- **Mitigation Phase:** Preventing future emergencies or minimizing their effects. Includes any activities that prevent an emergency, reduce the chance of an emergency happening, or reduce the damaging effects of unavoidable emergencies. Buying flood and fire insurance... (U.S., FEMA, 2015).
- **Preparedness Phase:** Preparing to handle an emergency. Includes plans or preparations made to save lives and to help response and rescue operations. Evacuation plans and stocking food and water are both examples of preparedness. Preparedness activities take place before an emergency occurs (U.S., FEMA, 2015).
- **Response Phase:** Responding safely to an emergency. Includes actions taken to save lives and prevent further property damage in an emergency situation. Response is putting preparedness plans into action. Seeking shelter from a tornado or turning off gas valves in an earthquake… (U.S., FEMA, 2015).
- **Recovery Phase:** Recovering from an emergency. Includes actions taken to return to a normal or an even safer situation following an emergency. Recovery includes getting financial assistance to help pay for the repairs. Recovery activities take place after an emergency (U.S., FEMA, 2015).

Most individuals, families, small groups, or some communities with disaster or crisis management training or experience develop contingencies to suppress the destructive effects of an emergency or disaster, including preparing for disruptions in information and media access, and energy, transportation, and communications disruptions. However, larger scale disasters may overwhelm these individual efforts.

Fragile and At Risk Systems and Environments

Within fragile, or at risk, business, manufacturing, or service systems, or within geographically defined areas such as a neighborhood, community, nation, or region, infrastructure to resist various forms of crisis or disaster effects, either natural or manmade is often inadequate for the risk profile of the institution or area (ReliefWeb International, 2015). Technology may be defined differentially, based upon the specific crisis prevention and response infrastructure needed for recovery. For example, regional risks may include inadequate roads, transportation, water supplies, food, or agricultural supports, weather reports, available media, energy access, shelter or insulation from the elements, access to money, or commercial goods needed for survival, medication, medical care, hygiene supplies, information, and communication, though this listing is not exhaustive. Each facility, institution, community, or geographic area or environment has a uniquely definable fragility, or risk profile. Planning, pre-positioning of equipment, services, or supplies and the systematic addressing of infrastructure limitations may attenuate the devastating effects of a crisis or disaster. Information technology is an essential part of and critical requirement in the evaluation of fragility and the provision of effective decision supports to responders and disaster response organizations. Recent device technology advances related to crisis or disaster response capacity may be seen in Table 3, below:

Humanitarian Action in Crises and Disaster Response

Whether the crisis is of smaller scale or more broadly distributed and classified as a disaster, local people such as: organizational volunteers, employees, or available citizens, with or without adequate supportive equipment or training, are most likely first responders. Approximately 90% of lives saved in a life threatening disaster are saved by local people (Calhoun, 2015). These first responders are themselves vulnerable to the same threats and losses as those they are attempting to rescue. These responders often have limited access to adequate and timely information, communication capacity, and needed health care services and medical expertise, or medications and medical supplies. In smaller crises, lack of information, communication and available but needed equipment and expertise are common. Smaller crises however, if unattended may increase risks for the development of full blown disasters if unresolved, within a risk reduction time frame (Author, 2006).

Post Crisis or Disaster: Resilience Engineering

The quote attributed to George Santayana, *Those who cannot remember the past are condemned to repeat It* (Internet Encyclopedia of Philosophy, 2015) with a variant frequently used by Sir Winston Churchill *Those who fail to learn from history are doomed to repeat It (*National Churchill Museum Blog, 2015*)* provide in their historical contexts sufficient example and justification to improve conditions following crises and disasters that could not be reasonably predicted to assure that they are less likely in the future.

Engineers and decision makers are increasing reliance on the principles and practices of resilience engineering for strengthening infrastructures and to reduce fragility and risk, due to potential damages from crisis or disaster.

Resilience engineering (Resilience Engineering Association, 2015) is an emerging and non-conventional approach to risk management, especially in engineering that examines methods to improve the ability at all levels of organizations to create processes that are robust yet flexible, to monitor and revise risk models, and to use resources proactively in the face of disruptions or ongoing production and economic pressures. Relative to information science and technology, the concept of information technology, communication technology, or computing technology failures, by robust design, are not due to the breakdown or malfunctioning of normal system functions, but are more likely to represent the limitations of human operators to anticipate adaptations necessary to changing conditions in the real world.

Issues, Controversies, Problems

Improving the saving of life and the limitation of longer term adverse effects during disaster is in part due to recent advances in strategic hardware devices such as remote telemetry, surveillance, multipurpose vehicles, including amphibious vehicles, and aerial unmanned surveillance and package delivery vehicles (drones). The capacity to gather situational awareness information remotely through acoustic sensors and bio monitors, ground and object penetrating scanning devices have greatly improved critical information gathering for crisis and disaster management. Additionally, mechanical or robotic search devices, and the interconnectivity of these between multiple information systems and operators, either human or computing, are also reducing barriers to rescue and recovery efforts.

SOLUTIONS AND RECOMMENDATIONS

Often technologies that have intelligence gathering capacity, logistical capacity, risk evaluation capacity and autonomous decision making ability are used for defensive and military purposes. However, these same technologies show great promise of being able to ameliorate the damage and destruction created by both natural and manmade disasters, as well as crisis response at the institutional level. Deploying these technologies and a wide scale and imaginative engineering focused upon improving the hardiness or resilience of civil, municipal, transportation, communication, information science and related structures will also mitigate the effects of crisis and disasters and improve overall response, and recovery.

FUTURE RESEARCH DIRECTIONS

Improved information science driven mapping and location technologies, including, for persons at risk or endangered, in a crises or disaster, automated deployment of assets, at a threshold level of early warning, improved logistics in planning and prepositioning and distribution of needed resources, are all critically needed areas for additional research. Rapidly self-correcting decision making software or applications for critical information systems restoration (financial, energy, information, etc.) would reduce legacy losses of vital knowledge needed to continue organizational, institutional, community or regional functions.

Advanced light weight composite material with protective and insulating properties that may be used as wearable information science interface platforms as clothing and with embedded bio sensors and others focused upon external environmental or risk conditions need further additional inquiry and would likely enhance the effectiveness of response personnel. Miniaturization, stable energy source, and autonomous functioning and sensing capacities for robots, drones and others would rapidly reduce risks in locating those in need and reducing risks. Networked visual (camera systems) through damages areas either urban or rural would also contribute to crises response.

CONCLUSION

Crisis response and management have improved steadily with access to improved situational awareness and information distribution. Satellite systems have improved weather prediction, and advanced warning alerts for some naturally occurring disasters. Emerging sensor technologies may improve earthquake and tidal wave or tsunami predication as previously difficult to predict natural events. Global positioning satellite systems have improved mapping and location technologies to enhance disaster location and improve logistical responses. Satellites have also improved knowledge of slowing developing disasters such as droughts, or water level and availability changes. These have assisted in providing additional supports to affected regions over time. The transmission of vital information over the internet and in combination with satellite technology, media broadcasting globally, and the advent of cloud storage or off site storage of critical information and redundant information archives have limited data and information loss and improved consistency and availability of access to both decision makers and affected populations during an emergency. Indeed the emphases on crisis response or disaster response and management knowledge for corporations, other institutions, helping organizations, the military services and governments have led to widespread and more focused levels of preparation and likelihood of limiting damages during a crisis, information based, or physical.

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KEY TERMS AND DEFINITIONS

Crisis Management: The application of strategies designed to help an organization, or community, deal with a sudden and significant negative event.

Crisis Response: The methods used to offer short term immediate help to individuals who have experienced a crisis, disaster or catastrophic event.

Device Technology- Crisis/Disaster Response: Mobile devices and technology enhanced mechanical devices with computing and problem solving capabilities, networked communication capacity, remote sensing and transport abilities to provide, alerts, response assistance and rescue assistance.

Fragility – Fragile, At Risk, Environments: Easily broken, shattered, or damaged; delicate; brittle; frail: a fragile ceramic container; a very fragile alliance, also applies to communities, regions or nations with limited capacity or infrastructure to recover from calamity.

Information Science: The study of processes for storing, organizing, retrieving or recovering information, especially scientific or technical information.

Information Technology- Crisis/Disaster Response: The study or use of systems (especially computers and telecommunications) for storing, retrieving, and sending information; routinely or in special event circumstances, or condition.

Manmade Disaster: Anthropogenic hazards or human-made hazards can result in the form of a human-made disaster. In this case, anthropogenic means threats having an element of human intent, negligence, or error; or involving a failure of a human-made system. This is as opposed to natural hazards that cause natural disasters.

Natural Disaster: A natural event such as a flood, earthquake, or hurricane that causes great damage or loss of life.

APPENDIX 1

Table 1. SWOT Analysis for IT Management and Crisis Response (Situation being analyzed: Information Technology Loss or Disruption)

Strengths What is the company doing well, relative to information technology management? What information technology resources does the company provide that are important to continuity, sustainability and crisis response? Is the company making best use of available information technology?	**Weaknesses** What resources or services could the company improve, relative to information technology management? What areas does the organizational competition have a technological edge relative to information technology management? What adverse information technology should the organization actually avoid?
Opportunities How will information technology change? What are the interesting trends in technology that could be exploited? What needs in the information technology market tare not being addressed by others?	**Threats** What is the competition doing well, relative to information technology? What information security threats should the business be most concerned about? What new innovations are others bringing, that would affect information technology management?

APPENDIX 2

Table 2. Information science and technology: crisis or disaster information technology advance

Information Technology Advance	Crisis/ Disaster Response Capacity
Satellite and transmission technology (including radio, video, ham radio, etc.)	Satellite conveyed information has become the primary conveyance system for information, communication, and geographic location data. Though satellites were originally designed to serve military and entertainment roles, over time they have become a tool for humanitarian and educational transfer of knowledge.
Computing capacity	Communications, information dissemination, data archiving, automation of routine tasks such as sending or updating alerts, automated calling or text messages
Data archiving capacity	Cloud based archiving of data, large hard drives, large servers, portable memory devices, data backup services and devices, etc.
Graphical user interface	Windows and Macintosh operating systems and proprietary corporate and other derivations, including a mouse or similar device, to select and display information rapidly
Global positioning data, global imaging data	GPS location, Google Earth and similar photo mapping applications (Google Earth, 2015).
Environmental data server, geographic information systems	Mapping, weather, and available distinguishing features, services available, terrain and available transportation routes (Google Crisis Response, 2015).
Mobile technology, personal and configurable, connectivity to information systems	Cellular phones, paging systems, text message, and email or automating phone message delivery upon detection of any predetermined activating event; capacity to archive directories of contacts and key services locally; capacity to access the internet to search for information or help; capacity to download customized application on rendering first aid, locating transportation, etc.
Crisis informatics	Continuous situational updating and risk parameter information either queries or automatically updated and displayed, or communicated
Crowdsourcing of data.	Matching or linking applications, that match available supplies to need within an area, match volunteers to disaster area, match perspective labor with available work, etc. (Google Person Finder, 2015).
Identity verification	Online financial and membership application that confirm, or authenticate identity
Tracking technologies	RFID chips, embedded in credit cards, or ID cards and GPS applications located in mobile phones, vehicles, or with assigned personnel or emergency broadcasting device
Post disaster reunification of children with families	(The National Center of Missing and Exploited Children; Unaccompanied Minors Register, 2015), (USA)
Simulators	(Search and Rescue Optimal Planning System, 2015). US Coast Guard (SAROPS) is made up of the Graphical User Interface (GUI), the Environmental Data Server (EDS) and the Simulator (SIM) which can predict: 1. probability of containment, 2. probability of detection, and 3. probability of success
Social networking	Provide an online location for family members, friends or contacts to check in and locate each other, update news, or share alerts: Facebook, Twitter, and similar networks

APPENDIX 3

Table 3. Information science and technology: interdependent crisis or disaster technology devices

Device Technology Advance	Crisis/ Disaster Response Capacity
Remote and portable sensors and transmitters; acoustic, biological, chemical, infrared, microwave, motion, thermal, radiation, visual, and others	Depending upon energy supply, sensors may be connected to computing and tele communications networks to provide continuous or situational monitoring and updating broadcasted to any configured receiver at distance.
Smart clothing, insulating and protective fabrics, sensor and transmission devices, exoskeletons, etc.	Clothing may be configured as shelter, protective device against injury, as a technology platform for sensing and communication; with designs currently available; exoskeletons permit the wearer to reduce limitations of some disabilities and increase body strength or endurance
Biological and health sensors; on person, in location	Exposure to specific contaminants, Wi-Fi enabled health monitoring software (cardio, pulse, EKG, EEG, kinesiology, etc.).
Linked camera systems, municipal and other	Traffic cams, sport event cams, accessible, security and weather cams, etc.
Water purification and transport devices and distribution	Solar powered portable mobile water purification systems, mobile dispatch software for water transport supplies, logistics tracking and volume
Food preservation and long term storage devices and distribution	Pulsed electric and magnetic field treatment to inactivate bacteria and limit quality loss in transport and storage, packaging and oxygen removal, mobile dispatch software for food transport supplies, logistics tracking and volume
Energy storage and production and distribution	Long term marine batteries that hold charge up to 10 years, mobile fuel powered generators, portable solar panel, mobile power plants, etc.
Portable and temporary shelter	(ShelterBox, 2015), an international disaster relief agency along with Rotary International, provides inexpensive relief shelters. The organization has tracking systems to monitor weather systems, the likely scale of hurricanes and cyclones and earthquake alert system. Other temporary shelter companies provide similar.
Advanced extraction, evacuation and hazard clearing tools	Devices or mechanical appendages often networked and monitored which are attached to multipurpose transportation devices and have specialized functions. Example; chain saws to clear hazards or obstacles, mobile battering ram, bomb detection, etc.
Transportations systems (unmanned) and human responder interface, or independent function	(Lynxx, 2015) Multipurpose vehicles, amphibious vehicles, drone technologies, etc.
Robotics and human responder interface, search, burrowing, medical, etc.	Larger automated and frequently mobile mechanical devices with some computing and communication capacity and other specialized functions or capacities such as: traversing difficult and hazardous terrain and gathering risk and other information, transporting supplies, digging or repetitive manualized labor tasks, and performing human supervised medical procedures at a distance
Miniaturization of robotics, and human responder interface, or independent function (disaster response micro robots)	Remote sensing devices, including miniature cameras attached to miniaturized robots to perform search or information gathering functions in high risk environments