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Assessing the Impact of a Geospatial Information System for Improving Campus Emergency Decision-Making of Novice Crisis Managers

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by

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We hereby certify that this dissertation, submitted by Adam Albina, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

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An abstract of a Dissertation submitted to Nova Southeastern University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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Adam R. Albina
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A significant increase in campus-based emergencies warrants the investigation into emergency management information systems that serve a novice crisis decision-maker. Institutions of higher education that are not large enough to have dedicated emergency management offices generally press novice decision-makers into emergency management roles. An investigation was conducted to assess the impact of an emergency management geospatial information system on the decision performance of novice crisis managers through the use of a scenario-based simulation.

A mixed method sequential explanatory method was used to collect quasi-experimental data on decision time, decision accuracy and situational awareness. Qualitative analysis was conducted through interviews with participants. Statistical results indicate the decision accuracy is positively affected by the use of an emergency management geospatial information system. Data Envelopment Analysis (DEA) is non-parametric linear programming method used to identify decision-making units in a data set that are optimal in their use of single or a set of resources (inputs) in delivering a set of expected results (outputs). DEA indicated that efficiency ratios from the geospatial information system group outperform the traditional group. Geospatial information systems hold much promise in providing systems that are easy to use, promote heightened levels of situational awareness and decision support.

Acknowledgments

First, a thank you to the professor who inspired my desire to research decision making under uncertainty, Dr. Glenn Browne. Dr. Browne was my advisor during my graduate work at UMBC and started a fire in 1994 that has burned brightly ever since. It is with great gratitude that I was afforded the opportunity to continue the journey 20 years later in a doctoral program with incredibly supportive faculty at NSU. Thank you to my dissertation advisor, Dr. Trudy Abramson without whom I would have never made it this far. She was encouraging, direct, and a great mentor to me. Allowing me to make my own decisions, good and bad, and helping me understand what it takes to cross the finish line. My committee, Dr. Maxine Cohen and Dr. Antonio Rincon provided valuable insight, feedback and rigor throughout the process and a sound backdrop of experience for which I am grateful. A special thanks to Dr. Sumitra Mukherjee for his wise council and Dr. Steven Terrell for his valuable assistance in research methods. A warm thanks to Dr. Kim Round for her support and guidance throughout the doctoral process and for putting up with my complaining almost every step of the way.

The inspiration for lifelong learning comes from my parents. Melvis A. Albina, Ph.D. and Rene B. Albina, J.D. have modelled a life with an unwavering commitment to education and personal growth. Both have been amazingly supportive in my doctoral journey and in my life. Much of what I have achieved and hope to be able to give back to the world in some way, is because of the love and support of my parents.

Finally, I share this moment, as I share all moments, with the love of my life. My wife, Mary, has never stood behind me, she has always been at my side or a good distance in front of me. Her patience, encouragement, and love has been the most important constant in my life. Without her support I would not be where I am today. She has created a wonderful supportive life and for her and our three sons: Nick, Tony, and Joe, I am forever grateful for their support. I love you all.

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Chapter 1

Introduction

Background

The greater subject is crisis management in institutions of higher education (IHEs). Worldwide, 6,457 weather-related disasters were recorded between 1995 and 2015. These disasters claimed a total of 606,000 lives and affected more than 4 billion people. Although annual economic losses from disasters are difficult to identify, the current estimates from UN Office for Disaster Risk Reduction (UNISDR) are $250-$300 billion annually (Wahlstrom & Guha-Sapir, 2015). Higher education continues to be impacted by both natural disaster crisis as well as those inflicted by their fellow man such as acts of terror, violent activism, and shootings. Natural disasters impact IHEs and surrounding communities concurrently, often limiting the intervention of civil emergency response personnel. These types of events, often termed extreme events, tax the organizational structure and the decision-making of the institution. Extreme events are most often associated with large scale natural disasters on the order of hurricane Katrina in the U.S. in 2005, the University of Iowa floods in 2008 (Fillmore, Ramirez, Roth, & Peek-asa, 2011), the 2011 earthquake and tsunami in Japan (Kushida, 2012), and hurricane Sandy in the U.S. in 2012. Smaller local events such as the 2001 tornado at the University of Maryland (FEMA, 2003), or the closure of the University of South Carolina due to flooding are more limited in scope but are crisis events with problems that are unique to smaller more localized areas (Reed, 2015).

Generally, smaller IHE lack dedicated emergency management departments and formally trained staff. Staff supporting the emergency management function are doing so as an additional duty and have very little or no experience in emergency management (Sullivan, 2012). Institutions are potentially entrusting the safety of students, institutional personnel and local community to inexperienced emergency managers.

Geospatial Information Systems (GIS) are increasingly used in professional emergency management and are gaining wider acceptance among non-professional users. Free web based tools allow greater familiarity with basic GIS operations (Yang & Lin, 2011) and have become ubiquitous in their use in personal navigation. A GIS, like any information system, is a combination of hardware, software, and communication medium, employed to generate, collect and disseminate useful contextualized information (Valacich & Schneider, 2010). As a natural extension of mapping and cartography in the digital age, the GIS represents the earth and multi-layers of related objects in a familiar map-based paradigm. In addition to representing traditional geographical/topographical features, a GIS can also overlay imagery, census data, road networks, weather data, and other thematic information as required by a particular context (Tomaszewski, 2015). The use of GISs may provide support for novice crisis managers and facilitate more timely and accurate decision-making in smaller IHEs faced with large-scale emergency situations.

The ideal environment for participants is a College or University in the United States with no established emergency management office and a resident population of students. As the research methodology is a quasi-experimental method, it was important to select participants who individually qualified as novice crisis management decision makers in a higher education context. The unit of analysis was the individual participant from the residence life staff or other staff members who did not hold a dedicated emergency management role. Two groups were used in the conduct of the experiment; one group was provided with training and the use of an emergency management GIS (the treatment) and the other group was provided training and used standard emergency management tools and operating procedures. Both groups had access to the same situational information.

Problem Statement

The problem is novice crisis managers in small IHEs without emergency management offices lack effective decision support and collaboration tools that facilitate decision-making and situational awareness. Small IHEs may benefit from geospatial, map based tools to support decision-making and foster collaboration with outside agencies when conditions prevent local emergency management teams from arriving on site.

Given the increase of campus based incidents and the high concentration of students in a small geographic area, IHEs are expected to maintain high levels of preparedness and appropriate levels of response to emergencies due to the presumed vulnerability of students in their care (Farris & McCreight, 2014). IHEs are unique in their emergency management vulnerability due to their lack of experience in the field. Nearly two-thirds of IHE emergency managers, 64.5%, have less than five years experience, and 41.3% have fewer than three years of experience in emergency management (Sullivan, 2012).

Novice IHE crisis managers possess valuable institutional information required for critical decision-making in the early stages of a crisis. Critical information may include the number of personnel potentially affected in a crisis, the organic support facilities available, air evacuation landing sites, and local emergency management plans and procedures. In addition, IHE emergency managers may have information relevant to hazardous material storage on campus, potential ground evacuation routes, as well as other situation dependent information. Perry, Wiggins, Childs and Fogarty (2012) indicate that although inexperienced decision-makers can be guided to attend to the same information to which experienced decision-makers attend, the decision accuracy of less-experienced decision-makers does not necessarily improve. Lack of decision maker experience appears to be an important limitation in decision performance (G. Klein, 1997; Lipshitz, Klein, Orasanu, & Salas, 2001; Todd & Benbasat, 1992). To exacerbate lack of experience, environmentally imposed time pressure, as in a crisis situation, contributes negatively to decision performance (Kahneman & Klein, 2009; G. Klein, 2008).

Dissertation Goal

The goal of this study is to investigate and disseminate the effects of using a geospatial information system for emergency management on the decision performance of novice higher education decision-makers in a simulated crisis event. The independent variable is the use of a geospatial information system for crisis management. The dependent variables are part of a multi-dimensional construct of decision performance defined by the time to complete a decision task, the accuracy of the decision, and an assessment of situational awareness. Constraints of the experimental environment include the moderating variables of low decision-maker experience and time pressure (see Figure 1).

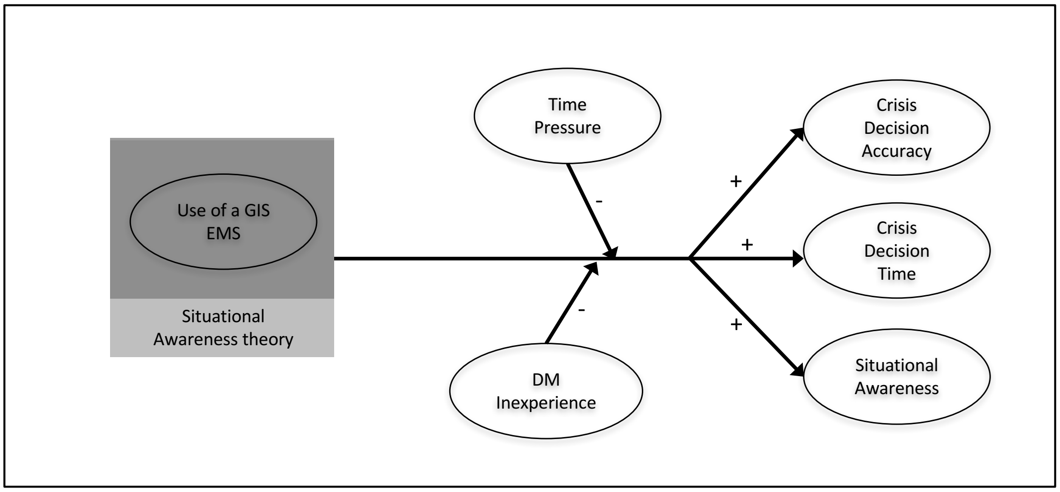


Figure 1. Research model for effect of GIS Emergency Management System on Decision Performance using the underlying theory of Situational Awareness.

Research Questions and Hypotheses

A scenario based simulation (Parker, Srinivasan, Lempert, & Berry, 2014) was conducted using a quasi-experimental research design methodology (Salkind, 2012) applied through a prototype Emergency Management GIS based system to test the following hypotheses (Hs):

- H1: Use of an Emergency Management GIS based system by a novice decision-maker reduces critical decision-making time during a simulated crisis response.
- H2: Use of an Emergency Management GIS based system by a novice decision-maker increases accuracy in critical decisions during a simulated crisis response.
- H3: Use of an Emergency Management GIS based system by a novice decision-maker increases situational awareness during a simulated crisis response.

Additionally, the following research questions (RQs) will be addressed qualitatively through analysis of literature, DEA and a phenomenological qualitative approach:

- RQ1: What is known about novice decision-making in a higher education emergency management context?
- RQ2: How does the use of an Emergency Management GIS based system by a novice decision-maker affect decision-making performance, as a function of time, accuracy and situational awareness during a simulated crisis response?
- RQ3: What are the perceived benefits and drawbacks of an Emergency Management GIS for the novice decision-maker in a higher education context?

Relevance and Significance

The Higher Education Equal Opportunity Act of 2008 requires an IHE to have emergency notification and response plans and dictates a minimum of one annual exercise in order to test the plan, and conduct assessment and evaluation. An IHE must publish the procedures for communicating emergency information to the larger community (HEOA, 2008). The ability for IHE to prepare for an emergency, respond adequately to protect life and infrastructure, recover from the damage and mitigate the local and societal impact is the primary mission of emergency management. Research in this area has focused on the professional field of emergency management such as fire brigades, emergency medical services, law enforcement, municipal emergency management as well as non-governmental organizations (NGO) such as the Red Cross (Heard, Thakur, Losego, & Galluppi, 2014; Ley, Pipek, Reuter, & Wiedenhoefer, 2012b; Lukosch, Lukosch, Datcu, & Cidota, 2015).

The issues challenging effective inter-organizational collaboration and decision-making during extreme events include barriers to shared situational awareness (Ley et al., 2014; Mishra, Allen, & Pearman, 2013), a common language and symbol adoption in the domain and the marked differences in normal service operation and operations during extreme events (Wu, Convertino, Ganoe, Carroll, & Zhang, 2013). Finally, extreme events generally contain high levels of uncertainty making preplanning and training less important than improvisation and quick thinking (Ley, Pipek, Reuter, & Wiedenhoefer, 2012a; Mendonça, 2007). Crisis management is a unique discipline where stakes are generally very high, the situation is fluid, rapidly changing, and full of uncertainty. Multiple agencies are generally involved in crisis management and decision-making is often distributed (Rittel & Webber, 1973; Skertchly & Skertchly, 2001). Emergency management as a profession contains various levels of expertise, training, exercise and professional development. Much of the research on information systems support for emergency management is focused on the experts who work in the field.

There is a potentially important gap of research focused on novice crisis manager decision support, collaboration and information sharing with outside agencies during extreme events especially in a higher education context (Murchison, 2010). During events of this nature, it is likely local emergency response organizations such as police, fire and emergency medical service (EMS) may be fully engaged in the most serious centers of the incident or be spread quite thin over a geographically large response area. Limited resources due to destruction, prioritization, uncertainty as to continued or follow on dangers, and potential geographic or incident based impediments to movement may leave smaller organizations struggling to cope with a crisis without immediate or even medium term local, state, or federal assistance. Under such conditions, it is likely that novices who are on the scene by virtue of their positions in affected organizations will be forced into roles for which they are ill equipped, untrained, and unprepared.

There is a general finding that a GIS context is implicit in emergency management situational awareness. It appears to be a natural vehicle in which to contextualize an emergency situation (Heard et al., 2014) and support crisis decision-making. Using a geospatial reference and augmenting familiar mapping constructs with annotations that externalize situational artifacts such as road blockages, flooded areas, weather related phenomena etc. reduces cognitive burden needed to process such contextual information (Wu et al., 2013). Disasters are inherently spatial in nature and using a GIS for emergency management provides a natural toolset for thinking spatially and making effective decisions (Tomaszewski, 2015). Understanding the impact, requirements and design considerations for technologies that foster situational awareness and decision support to assist novice crisis managers is an area of research that is under explored.

A recent higher education emergency management survey (Sullivan, 2012) found that colleges and universities vary widely in their practices and organizational structure with respect to emergency management. The organizational location of emergency management units varies with 32% reporting locations other than Environmental Health and Safety, Public Safety, or stand-alone units. Thirty percent of IHE's have fewer than one full time equivalent (FTE) and 43% have between one and two FTE staff members assigned to emergency management. For small colleges and universities with limited staff, it is unlikely that there is an emergency management office staffed with trained personnel. The personnel exercising emergency management responsibility are often performing the role as an additional duty (Farris & McCreight, 2014). It is time for research focused on novice crisis managers in small IHEs exploring the use of GISs to foster situational awareness and provide decision support. Such endeavors will help start the conversation around bringing smaller entities into the larger emergency management picture. Proposing potentially transformative tools and evaluating their impact on crisis decision-making for non-expert campus crisis managers is the current research focus.

Barriers

As novice emergency management decision makers are the focus of this work, the task of finding enough participants who qualify as novice emergency management decision makers presented a barrier. In order to ensure that participants where not trained or certified in emergency management, a selection questionnaire was developed to qualify participants for the study. Two slightly different sample populations were identified as potential populations. The first and most preferable sample was professional staff members working in higher education who are novices in emergency management from different areas of the country. A national level professional conference that brings together these individuals would have provided a single source for participants and mitigate threats to external validity caused by a selection-treatment interaction (Creswell, 2014b) and provide for greater generalizability of results. Application was made for the conduct of a study as supported research during a national conference of student affairs professionals in higher education at the Association of College and University Housing Officers International Conference (ACUHO-I). Unfortunately, the application to conduct the study at the national conference was denied. The second potential sample population consisted of professional staff members working in higher education who are novices in emergency management located in the New England region of the north eastern United States. These participants would be found at institutions of higher education geographically accessible for the study. Although such a sample population does increase the threat to external validity, such a limitation was necessary. Saint Anselm College, Manchester New Hampshire was chosen as the site for the study as it met the selection criterion. Finding enough qualified participants at the institution was a challenge.

Limitations

In order to conduct the simulation experiment in a timeframe that maximized subject participation, the participation was held to roughly 45-60 minutes. The scenario was accelerated in order to meet the timeline and potentially deviated from what a participant might consider a realistic sequence of chronological events. Threats to external validity include the experimental environment of a laboratory setting and the interaction of setting and treatment (Creswell, 2014b). These threats may limit the generalizability of results to on the ground decision-making in an actual emergency response.

Definitions of Terms

Acute Exposure Guidelines: AEGLs are an estimate the concentrations at which most people experience health effects if they are exposed to a hazardous chemical for a specific amount of time. AEGL-3 is the airborne concentration, expressed as parts per million, of a substance above which most people experience life-threatening health effects or death. AEGL-2 is the airborne concentration above which most people experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape the affected area. AEGL-1 is the airborne concentration above which most people experience discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and usually reversible if exposure is removed. (NOAA, 2017).

Command, Control and Communication: The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission and the techniques and technologies used to communicate the direction (Chairman of the Joint Chiefs of Staff, 2017).

Constant Return to Scale: If output grows at the same rate as inputs, holding all else constant, the production function exhibits constant returns to scale (Basu, 2008).

Data Envelopment Analysis: A non-parametric linear programming method used to identify decision-making units (DMUs) in a data set that are optimal in their use of single or a set of resources (inputs) in delivering a set of expected results (outputs). DEA computes both the “best practice” or efficiency frontier, in the set of DMUs, and the relative inefficiencies of those DMUs not on this frontier as compared to the optimal performing DMU. Mathematically, a DMU at the top or edge of the frontier will have an efficiency ratio of one, and those DMUs further away from the frontier will have a ratio less than one but not less than zero (Dilts, Zell, & Orwoll, 2015).

Incident Command System: A standardized approach to the command, control, and coordination of emergency response providing a common hierarchy within which responders from multiple agencies can be effective (FEMA, 2008).

Material Safety Data Sheet: Also known as a Safety Data Sheet (SDS), it is a document that includes information on the properties of a chemical; the physical, health, and environmental health hazards; protective measures; and safety precautions for handling, storing, and transporting the chemical (OSHA, 2018).

National Response Framework: A guide to how the United States responds to all types of disasters and emergencies. It is built on scalable, flexible, and adaptable concepts identified in the National Incident Management System to align key roles and responsibilities across the Nation (DHS, 2016).

State Emergency Response Commissions: The Governor of each US state designates a State Emergency Response Commission (SERC) that is responsible for implementing the Emergency Planning and Community Right-to-Know Act (EPCRA) provisions within its state (99th United States Congress, 1986).

Tribal Emergency Response Commissions: The Chief Executive Officer of each US tribe designates a Tribal Emergency Response Commission (TERC) that is responsible for implementing the Emergency Planning and Community Right-to-Know Act (EPCRA) provisions within its tribe (99th United States Congress, 1986).

United Nations/North American Hazardous Materials Code: Four-digit numbers used world-wide in international commerce and transportation to identify hazardous chemicals or classes of hazardous materials (United States Department of Transportation, 2016).

Virtual Table Top Exercise: A technology enabled tabletop exercise where team members meet in an informal, classroom setting to discuss their roles during an emergency and their responses to a particular emergency situation. A facilitator guides participants through a discussion of one or more scenarios. The duration of a tabletop exercise depends on the audience, the topic being exercised and the exercise objectives. Many tabletop exercises can be conducted in a few hours, so they are cost-effective tools to validate plans and capabilities.

Acronyms

ACUHO-I: Association of College and University Housing Officers International

AEGLs: Acute Exposure Guideline Levels

ANOVA: Analysis of Variance

API: Application Programming Interface

ATS: Applied Training Solutions, LLC

C2: Command and Control

C3: Command, Control and Communication

CAMEO: Computer-Aided Management of Emergency Operations

CEM: Certified Emergency Manager

CITI: Collaborative Institutional Training Initiative

CMTS: Consequences Management Training System

CRS: Constant Return to Scale

DEA: Data Envelopment Analysis

DHS: Department of Homeland Security

DMU: Decision-making Unit

EMGIS: Emergency Management Geospatial Information System

EMI: Emergency Management Institute

EMS: Emergency Medical Service

EPA: Environmental Protection Agency

FEMA: Federal Emergency Management Administration

FTE: Full time equivalent

GIS: Geospatial Information System

HAZMAT: Hazardous Material

HAZUS: Hazard United States Software

HCI: Human Computer Interaction

HSEEP: Homeland Security Exercise and Evaluation Program

ICS: Incident Command System

IC: Incident Commander

IHE: Institution of Higher Education

IRB: Institutional Review Board

LEPC: Local Emergency Planning Committees

MANOVA: Multiple Analysis of Variance

MLB: Major League Baseball

MSDS: Material Safety Data Sheet

MSEL: Master Situational Events List

NGO: Non-governmental Organization

NIMS: National Incident Management System

NOAA: National Oceanic and Atmospheric Administration

NRF: National Response Framework

OA: Option Awareness

SA: Situational Awareness

SAGAT: Situational Awareness Global Assessment Technique

SART: Situational Awareness Rating Technique

SERC: State Emergency Response Commissions

TERC: Tribal Emergency Response Commissions

UNISDR: United Nations Office for Disaster Risk Reduction

UN/NA: United Nations/North American Hazardous Materials Code

VTTX: Virtual Table Top Exercise

Organization of the Study

The background, problem statement, research goals, hypotheses and research questions are addressed in the current chapter. The research goal and research questions are further expanded in the following four chapters. Chapter 2 reviews the relevant literature in emergency management, geospatial information systems, situational awareness theory, decision theory and decision-making in emergency contexts. In Chapter 3, this synthesis is operationalized and applied in the mixed methods proposed research methodology in order to answer the research questions and test the research hypotheses. The research model is presented, along with the research plan, instrumentation, measurements and conduct of the experiment. Chapter 4 presents the results of the analysis and chapter 5 provides conclusions, implications and recommendations for future research.

Chapter 2

Review of the Literature

To establish the research foundation, literature and practice is reviewed to 1) determine the appropriate cycle in disaster management for the implementation of an Emergency Management GIS (EMGIS), 2) investigate the known potential benefits and impediments to the use of an EMGIS in higher education crisis context, and 3) understand the effect of inexperience in time critical crisis management as it relates to decision support. The related theoretical principles found in Situational Awareness (SA) theory are also reviewed as they relate to decision support.

Emergency Management

Operational and academic differences exist in the terms emergency, disaster, crisis and catastrophe. Distinctions are found largely in scope and are important in understanding how an EMGIS can be applied to each case. Emergencies are smallest in scope and are usually handled by local agencies such as emergency medical services (EMS), police, and fire (Haddow, Bullock, & Coppola, 2014). In the higher education context, an emergency may be handled by campus authorities such as campus police, campus based EMS, and/or Health Services with coordination of local authorities if required. EMGIS requirements for such events are fairly minimal as emergencies rarely play out over long periods of time and geospatial information includes only the immediate vicinity in order to gain an awareness of the complete situation (Tomaszewski, 2015).

Disasters can be made up of several emergencies occurring at the same time, whether from the same root cause or different related causes. A disaster exceeds the ability of local authorities to effectively respond and state level authorities are engaged to provide needed assistance. Sometimes, even national assets are required if the state emergency management capabilities are over taxed by a disaster (Haddow et al., 2014). In 2008, the Federal Emergency Management Agency (FEMA) created the National Response Framework (NRF) which “describes additional specific Federal roles and structures for incidents in which Federal resources are involved” (FEMA, 2008, p. 12). When disasters are declared at the national level, federal departments and agencies adhere to the roles and responsibilities defined in the NRF in support of the local emergency management, non-governmental organizations (NGO’s) and the private sector which includes IHEs. Implementation of an EMGIS is more complex due to the scope of the situation, the data required for the GIS, and the interagency coordination necessary in such a large-scale event.

A crisis is generally referred to as a point in time event, perhaps within the context of a disaster, as events unfold and lead to a potential increase in a dangerous situation (Haddow et al., 2014). An example might be a critical care hospital whose back up generation is disabled due to water damage during a hurricane. The hurricane disaster risk is further exacerbated by the hospital crisis. A crisis is an excellent candidate for an EMGIS if the system is already employed in the management of the disaster as it provides excellent information about the larger context that may impact the operational needs of the crisis.

Finally, there is much debate in the academic community over definitions, for the purposes of this research a catastrophe is a larger scale and more socially impactful disaster. Catastrophes may induce social conditions that are potentially different from disaster environments including long term transportation disruption, health care issues, housing concerns, economic impacts and movement or relocation of affected people (Wachtendorf, Brown, & Holguin-Veras, 2013).

Managing, responding and reacting to emergencies, disasters, crises and catastrophes are all considered part of the emergency management domain. Emergency management as a discipline can be defined quite simply as a "discipline that deals with risk and risk avoidance" (Haddow et al., 2014, p. 2). Early history in the discipline begins with the Flood Control Act of 1936 and the subsequent merger of the Federal Civil Defense Administration and the Office of Defense Mobilization into the Office of Civil Defense and Mobilization in 1958. The current federal organization, FEMA was established in 1978 under President Jimmy Carter. The 1993 World Trade Center bombing in New York City and the Oklahoma City Federal Building bombing ushered in a new era of emergency management as terrorism became a national priority. FEMA published a new community-based approach called Project Impact: Building Disaster-Resistant Communities (Haddow et al., 2014). The project called for communities to establish partnerships across the community to include all stakeholders and private sector business entities and NGOs (FEMA, 1993) which includes both private and public IHEs. FEMA established a disaster management cycle consisting of preparedness, response, recovery and mitigation (see figure 2).

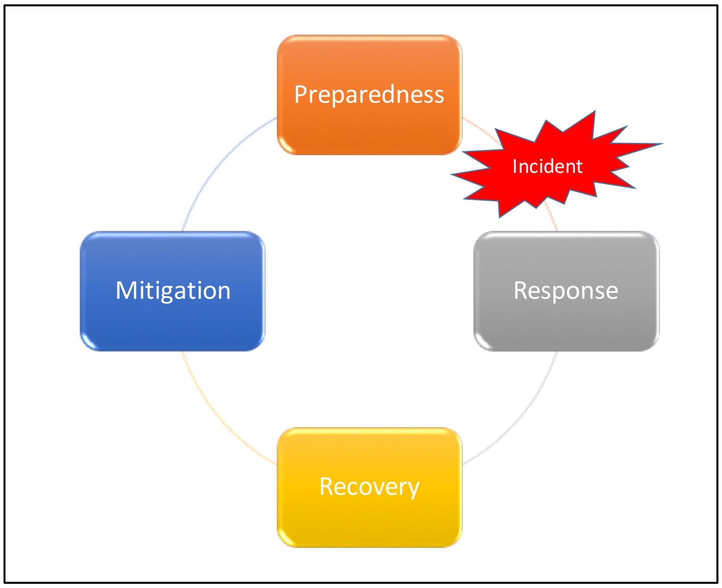


Figure 2. FEMA Disaster Management Cycle adapted from "FEMA (1993). Building disaster-resistant communities: Project impact guide book."

After the terrorist attacks of 9/11 on the World Trade Center and the Pentagon, the Department of Homeland Security (DHS) was created by executive order under the Homeland Security Act of 2002. Unification of many disparate agencies under an Incident Command System (ICS) proved successful during the attack on the Pentagon (Harrald, 2012). Creation of the DHS formalized the relationships bringing together 22 Federal agencies (107th Congress, 2002). Subsequently, a number of Presidential Policy Directives (PPD) were issued including PPD-5 which directed the formation of a National Incident Management System (NIMS). The NIMS framework included the ICS (PPD-5, 2003). NIMS was designed to provide a common organizational structure to facilitate incident command, operations, planning, logistics, and finance regardless of what might be multiple internal organizational structures involved in an incident. As of 2004, all organizations in the United States were expected to use the ICS structure to guide response efforts regardless of the incident's cause, size, or complexity (Jensen & Waugh, 2014). IHEs are expected to implement the NIMS based ICS during an incident.

In 2003, FEMA, now under the DHS published a guidebook on building the disaster-resistant university. The guide extended the whole community approach to emergency management into the university setting. The guide underscored the millions of dollars in disaster assistance provided by FEMA to both private and public universities and colleges in the United States. It further solidifies national interest in protection of IHEs through the $15 billion dollar annual research grant investment by the federal government (FEMA, 2003). The guide provided a four-phased approach to developing a disaster resistant university:

1. organizing resources,
2. hazard identification and risk assessment,
3. developing the mitigation plan and
4. adoption and implementation.

Several of the phases rely on detailed campus wide and local community mapping technologies to inform related activities. GIS systems were recommended as an appropriate tool for creating detailed hazard profiles, predicting scope and extent of potential damage associated with a particular hazardous incident, as well as identifying potential vulnerabilities. The FEMA guide book specifically detailed the type of information needed in a GIS (2003):

> The base map should extend beyond the campus boundaries to include campus-related facilities such as residential areas, local fire stations, transportation facilities, and fraternity and sorority buildings. Coordinate this activity closely with surrounding local officials. Placing this map on a geographic information system (GIS) will make it more useful as the project progresses and the data

> become more complex. GIS can be used to store and access the mapping information, displaying the areas, systems, and functions that are at risk and graphically depicting potentially damaged areas and buildings, costs of repair, and concomitant threats to operations that will assist in setting mitigation priorities (p. 23).

GIS systems were recommended for use during remaining phases but have to be appropriately prepared with the necessary information and overlays in the hazard identification and risk assessment phase. FEMA provides Hazard United States (HAZUS) software for free which uses GIS technology to estimate physical, economic, and social impacts of disasters. HAZUS graphically illustrates the limits of identified high-risk locations due to earthquake, hurricane and floods. Users can download state specific information to use within the GIS and enable visualization of the spatial relationships between populations and other geographic elements for the type of incident being modeled (FEMA, n.d.). FEMA Publication 386-2: Understanding your risks - Identifying Hazards and Estimating Losses (2001) states, “maps produced with GIS can help to explain hazard events, predict outcomes, visualize scenarios, and plan strategies” (p. 6).

Geographic Information Systems in Emergency Management

Command and control have been of interest to the Human Computer Interaction (HCI) community for many years (Heath & Luff, 1992; Roth et al., 1998; Scott, Wan, Rico, Furusho, & Cummings, 2007) with special attention to the technologies designed to foster situational awareness and collaboration. More recent research has taken advantage of the technological advances in ubiquitous connectivity and readily available geospatial information system application programming interfaces (API). These APIs provide standards based tools such as content object replication kit (CORK) and GeoTools for the development of research vehicles in geospatial systems and subsequent use in crisis management contexts (Wu et al., 2013). Through two iterative prototypes, a set of design guidelines for geo-collaboration supporting systems was developed. Following on this work, Ley et al. constructed an Inter-Organizational Situational Assessment Client (ISAC) paired with an Inter-Organizational Information Repository (IOIR) based on several Open Geospatial Consortium (OGC[2]) tools and Google Maps (2014). They focused on the mechanism of improvisation at work in real world crisis management and their work encompasses inter-organizational crisis management as well as geo-collaboration and expertise sharing. Cuevas et al. developed PinPoint™ using similar open source technologies to provide coverage planning, and response coordination with a shared annotated GIS basis for Red Cross Disaster Action Teams (Cuevas, Jones, & Mossey, 2011). Similar research in distributed synchronous collaboration for emergency response in extreme weather scenarios also capitalized on open source products. Products included the Renaissance Computing Institutes (RENCI) open source Geoanalytics System (RENCI, n.d.), MongoDB, Django and PostGIS in the development of BigBoard (Heard et al., 2014). BigBoard supports both mobile and desktop interfaces for collaboration over a shared map-based paradigm with situational annotations and overlays.

Prior research efforts have much in common, although slightly different in their approaches as well as the specific research questions. In practice, a map or GIS based display is an effective tool for fostering situational awareness (SA), confirming earlier research into decentralized command and control environments. In a crisis, the novice will be more easily overwhelmed with information and this could hinder their ability to process relevant information and result in a decrease in decision performance (Perry et al., 2012).

Using a geospatial reference and augmenting familiar mapping constructs with annotations externalizing situational artifacts such as road blockages, flooded areas, weather related phenomena etc. provides a reduced burden on cognitive overhead needed to process such contextual information (Wu et al., 2013). Research to date has confirmed that SA is a critical and ongoing activity that informs decision-making and subsequent action in emergency response (Ley et al., 2014) and that a geospatial paradigm is an effective technology for SA in a distributed environment (Gorman, Cooke, & Winner, 2006; Wu et al., 2013). Recent studies lean quite heavily on Situational Awareness Theory.

Situational Awareness Theory

Situational awareness has long been a staple construct of the HCI community and codified in 1995 with a long standing theory by Endsley (1995) who recently defended it (Endsley, 2015a, 2015b). SA for an individual in an emergency management context is composed of three levels: perception, comprehension and projection. Perception, or Level 1 SA, involves attending to the important attributes and information in the affected emergency environment. Level 1 SA requires monitoring the situation, cue detection, and recognition of relevant situational elements and their current condition. Comprehension, or Level 2 SA, of the situation is achieved through synthesis of the relevant elements recognized in Level 1 SA and an understanding of their significance in light of the goals of the crisis manager. A novice crisis manager may not be able to extract the broader meaning of the Level 1 elements as well as a more experienced one. Finally, a crisis manager is able to project the future actions or states of the relevant elements recognized in Level 1 and operationalized in Level 2 in order to be actionable in the projection, or Level 3 SA (Endsley, 1995b, 2004; Kaber & Endsley, 2004). The crisis manager seeks necessary information and balances information seeking against the goal driven requirements of the crisis, protecting life, protecting property, adhering to time constraints, etc. Extreme situations are most often very time sensitive and characterized by significant uncertainty compounding the achievement of Level 3 SA for a novice. The theoretical framework for shared or team situational awareness is the largely the same as that for individuals with differing team members having responsibility for different Level 1-3 artifacts. The extent to which shared SA is gained is the extent to which members of the team have SA with respect to the elements of the situation for which they are responsible and that are communicated effectively to the team (Endsley, 1995b, 2012).

A more recent extension of situational awareness in decision-making is the idea of Option Awareness (OA). OA is a compliment to SA and is defined as the perception and comprehension of the relative desirability of the available options in a decision scenario. This comprehension extends to the underlying factors and trade-offs that explain that desirability (M Pfaff et al., 2013). Similar to SA, OA is described as a series of levels of deeper comprehension of options, their relationships and subsequent future projection for creative option generation. Level 1 is the perception of the relative robustness of alternative options, Level 2 is deeper comprehension of relationships between factors underlying the option outcomes, and in Level 3 OA decision makers modify options or creatively generate new options (G. L. Klein, Drury, Pfaff, & More, 2010). These three levels of perception, comprehension, and creative revision of options can be paralleled with the three levels of SA. SA, however, is concerned with awareness of elements in the situation space, OA is concerned with awareness of elements in the decision space. OA has been largely investigated with visualization tools to increase comprehension and has been applied to collaboration in emergency response operations and public health crisis management (Liu, Moon, & Pfaff, 2011; Mark Pfaff, 2015).

Decision-making in Emergency Management

Laakso and Palomäki define three simplified questions all emergency management decision-makers face: "1. What has happened and what is happening? 2. What should be done now (and next)? and 3. How can we gather the necessary resources available to do that?" (p. 1712). In the early stages of a crisis or disaster, the first people on the scene are generally from the affected organization. Assuming the role of an incident commander, making appropriate decisions, acting as effectively as possible and communicating with those affected and emergency services is vital (2013).

The research into decision support for emergency management to date has largely been conducted using emergency management teams that have a fairly high level of experience. Perry et al. (2012) found that although inexperienced decision-makers can be guided to attend to the same information to which experienced decision-makers attend, the decision accuracy of less-experienced decision-makers does not necessarily improve. It is the lack of experience in the decision-maker that appears to be an important limitation in decision performance (G. Klein, 1997; Lipshitz et al., 2001; Todd & Benbasat, 1992). To exacerbate the lack of experience, environmentally imposed time pressure, as in a crisis situation, contributes negatively to decision performance (Kahneman & Klein, 2009; G. Klein, 2008). Mishra et al. (2013) confirm prior research that suggests quite strongly that novices make decisions in entirely different ways than do experienced decision-makers. They conclude that it is imperative to study the information practices of novice and experts separately when working under environments that are time constrained, complex and uncertain. Novices tend toward normative decision-making strategies and experienced decision-makers tend toward more intuitive recognition primed models (G. Klein, 1997; Lipshitz et al., 2001; Todd & Benbasat, 1992). The models to which experts have access are developed over time as decision-makers. These models are born of exposure to a history of events and decision outcomes. Experts match the current scenario with scenarios that are similar in their history and select the model that most closely matches and may only need minor adjustments to apply to the current situation (G. Klein, 1989, 2008). Exacerbating the problems faced by a novice emergency manager is the difficulty in accepting the recommendations of an outside agency without the ability to comprehend at a Level 2 SA and therefore be unable to reach the Level 3 SA that calls for an action. They simply lack the appropriate situational history available to a more experienced decision-maker to successfully operationalize the elements present and validate the recommendations. Additionally, decision-makers often discount the advice of more experienced decision-makers (Bonaccio & Dalal, 2006) often preferring their original decision choices above those recommended by experts (Dalal & Bonaccio, 2010; Fischer & Jungermann, 2014; Yaniv, 2004).

The area of emergency management information systems and emergency management decision support systems is a difficult one. In order to study the context adequately, field studies of real crisis management or reasonable simulations of scenarios are necessary. This type of research is either inaccessible or often cost prohibitive. In a recent review of 8,408 papers over two decades in the knowledge management domain there were only fifty-one (0.6%) papers that investigated applied-Knowledge Management Systems for disaster/emergency management (Dorasamy, Raman, & Kaliannan, 2013). Thankfully, crisis situations on even a medium scale do not occur with great frequency so the practical application of even the best research is limited by the nature of the problem. However, the incredibly high stakes and potential impact of a crisis situation on the loss of life and property should make the research stream a much more worthwhile pursuit in an applied context.

Chapter 3

Methodology

Overview

Investigating a potential solution to the lack of effective decision support and collaboration tools that facilitate decision-making and situational awareness faced by novice crisis managers in small IHEs suggests the following research methodology. It is hypothesized that a novice decision maker may benefit from geospatial, map-based tools to support decision-making and foster collaboration with outside agencies when conditions prevent local emergency management teams from arriving on site in the early moments of a crisis.

A scripted simulation of an emergency event was conducted with one participant at a time. Although two participants were in the same simulation at the same time, they were unaware of the other and there was no interaction between them. Each of their actions and decisions were independent and in different rooms. From the participants' perspective, they were conducting the study alone. At specified decision intervals in the scenario, computer automated dialogs appeared and the participant was instructed to choose the best decision based on the situational knowledge they had at that time in the scenario problem. The scenario continued on an automated timer until completion. Time required to make the decision was measured, the decision itself was recorded, and a post simulation instrument was administered immediately following the scenario conclusion to assess situational awareness. Two groups were formed by random assignment from the participant list for the experiment. The first group was the treatment group and was trained on and used an EMGIS during the simulation. The second group did not have an

EMGIS available for use. Instead, the second group had the 2016 Emergency Response Guidebook, paper maps of the scenario area, and an information binder about the buildings and the incident site. Qualitative follow up in the form of structured interview questions were conducted for the treatment group.

Research Design

The research design was a mixed methods sequential explanatory design (Creswell, 2014a). Mixed method research designs have gained wide acceptance in social science research (Creswell, 2014a, 2014b; Johnson, Onwuegbuzie, & Turner, 2007; Onwuegbuzie & Wilson, 2003; Tashakkori & Creswell, 2007; Tashakkori & Teddlie, 2010). Neither a post-positivist philosophy leaning toward purely quantitative research methods (Phillips & Burbules, 2000) nor a constructivist philosophy leaning toward purely qualitative methods (Lincoln, Lynham, & Guba, 2011) are appropriate for the research questions articulated here. A pragmatic worldview was espoused not committed to any single philosophy, but focused on the research problem itself and open to whatever methods will best arrive at a solution or greater understanding (Tashakkori & Teddlie, 2010). The design was quantitative dominant as the research relied on a quantitative method for initial experimental data collection while concurrently recognizing that the addition of qualitative post experimental data collection and subsequent analysis to yield a greater depth of understanding of the research problem and potential solutions. The quantitative strand of research was concerned with the measurable impact of an EMGIS on decision time, decision accuracy and situational awareness. Comparison of treatment vs no-treatment groups may or may not yield statistical significance, hence the qualitative follow up. The qualitative strand was concerned with a richer explanation of the interaction between the variables and the impact of the treatment in addition to the quantitative statistical result. The specific design for the quantitative research strand was quasi-experimental. The specific design for the qualitative research strand was a combination of non-parametric statistical method in the form of Data Envelopment Analysis and phenomenological method using structured interviews. Data analysis was the point of mixture of the methods in order satisfy the quantitative and qualitative goals of the research (Creswell, 2013; Salkind, 2012; Tashakkori & Teddlie, 2010).

Approach

A simulation, more specifically, a computer based virtual table top exercise similar to those used for training at the FEMA Emergency Management Institute, was conducted with one participant at a time acting as the incident commander during the scenario based simulation (Parker et al., 2014). Simulation has been used quite effectively in the emergency management field for training and evaluation (Dugdale, Saoud, Pavard, & Pallamin, 2015). The crisis scenario was as realistic as possible for the participant as well as sufficiently specialized to require information seeking and good SA. Throughout the course of the simulation, a set number of decisions were required of the participant at specific and consistent times. The scenario required that decisions be made prior to moving on in the scenario although events continued to progress in order to realistically simulate decision time pressure (See Appendix A). No geospatial data were collected during the research. All field data points were simulated. Although participants were told that weather conditions were automatically updated through the EMGIS connection to the National Oceanographic and Atmospheric Administration (NOAA), the connection was simulated. Additionally, participants were told that the

EMGIS was connected to the state GIS system and that the state would be updating incident locations and road closures, the connection was also simulated. For both groups, the non-emergency management GIS (nonEMGIS) group and the EMGIS group, the same information relevant to the decision scenarios was provided. The manner in which the information was provided was different for each group. The EMGIS group was able to select layers in the EMGIS using custom coded intuitive buttons to overlay information on the GIS system and select informational attributes from the GIS artifacts (See Appendix B). The non-EMGIS group had the 2016 Emergency Response Guidebook and aforementioned informational binders (See Appendix C). Each group had a period of training designed by the researcher, and conducted by previously trained undergraduate research assistants to familiarize them with the resources they had available to them in the conduct of the simulation. The EMGIS group received training on the EMGIS. The non-EMGIS group received training on the use of the Guidebook, and an orientation of the other informational assets available to them. Training took approximately 15 minutes with the non-EMGIS participants usually taking slightly less time to complete the training. The training provided was specific to the operation of the EMGIS or use of the materials provided. Training did not include emergency management nor crisis response training. The scenario from start to finish took between 23 and 30 minutes and five decision choices were required of the participant. No outside agency coordination was required as all events were simulated.

Research Questions

In order to test H1, that decision time is positively affected by an EMGIS, the time to make a decision was measured during the experiment. Decision time is a fairly straightforward construct and is defined as the time required to reach a decision outcome (McGrath, 1990, 1991). A software based timing application was developed to allow research assistants to accurately collect decision time information for each of the five required decisions in the scenario. Time was started when the decision was required in the simulation and stopped when the decision was rendered. The decision time was recorded by the research assistant on a timing sheet.

In order to test H2, that decision accuracy is expected to increase through the use of EMGIS, the accuracy of each required decision during the scenario was measured. In the definition of decision accuracy, it is useful to understand the type of task in order to define the construct. Strauss (1999) suggest that the type of task has a significant effect on performance. McGrath (1984) proposed a task circumplex that has since been widely used. McGrath proposed that the majority of tasks conform to specific categories created around four fundamental processes: *generate*, *choose*, *negotiate*, and *execute*. Creative tasks found often in marketing, such as brainstorming, planning etc. involve processes of idea generation. Intellective or problem-solving tasks involve processes such as selecting correct answers, and judgment or decision-making tasks involve processes needed to reach consensus on a ranked answer. Conflict resolution involves processes around negotiation, and execute tasks actually require physical processes such as moving to a location or engaging environmental conditions. The research design is concerned with *choose* tasks, which McGrath categorizes into *intellective* where a problem has a correct answer and *judgment* where there is no absolute correct answer and decision-makers settle on a preferred answer. As intellective tasks have a correct answer, the decision accuracy construct is defined as the difference between the decision-maker's choice and the prior choice determined from the answers of experts. As judgment tasks have no absolute correct answer, the decision accuracy construct is defined as the difference between the decision-maker's ranking and the prior ranking determined from a panel of experts (Adams, 2005). There was always a *best* answer for each decision point. Prior expert rankings were used to rank order the four choices for each of the five decisions. A decision booklet was developed that contained the exact verbiage of the system-generated dialog for decision choices and participants simply circled their preferred answer in the booklet. Decision time stopped when an answer was selected, and decision accuracy was recorded as a numeric decision value on a scale of one to four with four being the best decision and one being the least optimal. Participants were not allowed to look ahead in the decision booklet prior to the request for rendering the next decision.

In order to test H3, that SA will increase through the use of an EMGIS, SA was measured using a standard rating scale. SA was measured using the Situational Awareness Rating Technique (SART) (Taylor, 1990) administered post scenario (See Appendix D). The SART responses were calculated and score for each SA component (understanding, attentional demand, and attentional supply) as well as the single composite SART score were recorded for each participant.

In order to answer RQ1, what is known about novice decision-making in a higher education emergency management context a literature review was conducted and presented in chapter 2.

In order to answer RQ2, does the use of an EMGIS affect decision-making performance, as a function of time, accuracy and situational awareness, a Data Envelopment Analysis (DEA) was performed with the input of decision time and the outputs of decision accuracy and situational awareness. A relative efficiency frontier was constructed from the efficiency scores for each participant. DEA is used to identify what are referred to as decision-making units (DMUs) in a data set that are optimal in using a single or a set of resources (inputs) in delivering a set of expected results (outcomes). DEA has been called *balanced benchmarking* and is supported by several software packages including benchmarking libraries in R as well as Microsoft Excel™. The heart of DEA is nonparametric linear programing methods. DEA computes both the *best practice* or efficiency frontier, in the set of DMUs, and the relative inefficiencies of those DMUs not on this frontier as compared to the optimal performing DMU. Mathematically, a DMU at the top or edge of the frontier will have an efficiency ratio of one, and those DMUs further away from the frontier will have a ratio less than one but not less than zero (Dilts, Zell, & Orwoll, 2015). DEA has been used to determine between group effects of a restaurant chain's use of an information system with others in the chain that did not use an information system (Banker, Kauffman, & Morey, 1990). Group comparisons were investigated around software programmer productivity for projects with and without a structured development methodologies (Banker & Kauffman, 1991). DEA has been used to compare operational efficiencies of bank branches with PIC (personal investment center) versus those without, national trading banks compared to regional banks, online shopping efficiencies under two different web site designs, comparison of different R&D programs, economic efficiencies of banks in Brazil with those in Europe and even the performance of the MLB (Major League Baseball) in regular season and post-season (Avikiran, 2000; Golany & Storberg, 1999; J. Hahn & Kauffman, 2002; Lee, Park, & Choi, 2009; Lewis, Lock, & Sexton, 2009). Much research has been published espousing the use of DEA efficiency scores in a two-step analysis process where parametric measures are used with the DEA efficiency score (Banker, Zheng, & Natarajan, 2010). There is disagreement on the efficacy of such approaches and more research is required (Hirschauer & Musshoff, 2014; Sinuany-stern & Friedman, 2016). A DEA model based on a constant return to scale (CRS) was used as a non-parametric measure in answering research question two in recognition that decision time, decision accuracy and situational awareness are likely related in non-trivial ways.

In order to answer RQ3, and understand the perceived benefits and drawbacks of an Emergency Management GIS for the novice decision maker in a higher education context, a qualitative assessment of the use of an EMGIS was measured through structured interviews with EMGIS group participants immediately following the conclusion of the simulation and the SART administration. Questions were structured in terms of evaluation of the overall impact, issues or concerns with EMGIS use in a higher education context, and positives and negatives with EMGIS. Thematic analysis was conducted through an open coding method followed by an axial coding method of the interviews (Creswell, 2013).

Procedures

IRB approval from both NOVA Southeastern University and Saint Anselm College (the site) was received (See Appendix E and F). A convenience population of Student Affairs and other College employees from the site who could potentially find themselves forced into service during a campus incident was compiled with the assistance of Student Affairs leadership (See Appendix G). Forty-nine invitations to participate were sent via email. The email contained a link to the qualification questionnaire that collected relevant demographic data and experience assessment (See Appendix H). Thirty-two questionnaires were completed and screened to ensure that participants were novices in emergency management (65% response rate). Two respondents were screened out as unqualified leaving 30 qualified participants. Participants were assigned a participant identification number from one to 30 and the identification numbers were randomly assigned to two experimental groups using an online program from GraphPad (GraphPad Software Inc., 2017). Participants were scheduled over a four-week period attempting to schedule two at a time where possible. Four undergraduate research assistants where chosen and subsequently CITI certified using the guidelines from the hosting institution and Nova Southeastern University IRB. Research assistants were provided scripts for training and the conduct of the experiment and several test runs were conducted with the research assistants.

The experiment employed two complete participant computer systems for the simulation and treatment located in different rooms. The rooms were sufficiently far away from one another to disallow sound and conversational bleed over but close enough to easily move between. Each computer system was outfitted with dual monitors, a single keyboard, mouse and audio speakers. Each participant was provided a notepad and pen for note taking if desired. Each system contained identical software to include a web based simulation using an automated Master Situational Events List (MSEL), training video, and a pre-loaded operational EMGIS. The MSEL simulation and exercise control construct is a common software planning and execution tool for the conduct of emergency management, law enforcement and military command, control and communication (C3) exercises. The MSEL contains all of the scenario information to be presented to the participant along with the necessary timing of the events. The MSEL software implementation, provided by a third-party company, uses a message-centered approach to present the scenario and the events that occur as the simulation moves forward in time. In the military and FEMA exercise domain, each message or piece of information provided to participants throughout the scenario is called an "inject". Given a particular scenario, information critical to the participant is injected into the scenario at predetermined times or at predetermined situational event triggers. The inject list, verbiage and timings were developed and validated in advance. A short three-and-a-half-minute training video was developed using Camtasia that provided an overview of using the simulation software (TechSmith, 2017). Use of the software was very straightforward requiring only that the participant click on the messages as they arrived to read them.

Each computer system was also pre-loaded with an operational EMGIS. The EMGIS was a commercially available product, ESRI ArcMap™ version 10.5.1, that lacked any of the emergency management features required. Software development was conducted using the provided Python language extensions for ArcMap™ (arcPy libraries) and several Arc add-ins were created. The add-ins included a button to launch a chemical database, a chemical danger zone predictor, and a chemical danger zone layer toggle button. The buttons were aggregated into an EMGIS toolbar and installed on the main screen. The EMGIS was loaded with street, municipal and aerial imagery of the scenario target school, Saint Joseph's College of Maine. This simulation location was chosen to ensure that all participants had roughly equal knowledge of the geography. Using the site as the simulation school could have unfairly advantaged participants who had spent many years at the site over relatively new personnel. Each building was overdrawn with a polygon and color coded based on its usage. The GIS database was updated to carry attributes about each building accessible by the user with the ArcMap™ identify tool.

For the non-EMGIS group, binders were created with street level and aerial imagery from Google Maps of the target school with three different levels of zoom for a total of six maps. A Campus map from the school website was included with building names in the legend. Additionally, the same data provided in the ArcMap™ attribute tables was included in the binder. A photograph of each building with the attribute data below was included in the binder. Two color printed and spiral bound copies of the 2016 Emergency Response Guidebook were also created. With two identically configured experimental workstations and two copies of all materials required for the experiment, random assignment to groups and scheduling of participants was facilitated. If a participant was in the non-treatment group (no EMGIS), one of the two monitors was simply turned off and the Guidebook and Binder were provided. As it was preferable, for expediency, to run two participants at the same time it didn't matter what group the participant was in as the simulation and timings were the same and both experimental stations could handle either group.

Participants arrived at their scheduled time and were introduced to their research assistant. Consent forms were reviewed and signed by the participant and the research assistant began the experimental protocol. Participants were oriented to the environment and the materials they had available to them during the simulation. The training video for use of the simulation tool was played and any questions answered. Training on the use of the tools available, dependent on the group, was provided using a standard script provided to the research assistants. Research assistants indicated when they were ready to begin the simulation. Training and orientation generally took about 10 to 15 minutes with the treatment group taking slightly longer on average. The simulation began with general background information about the target school and was followed by information about the developing incident. The target school was a small residential college in Maine with classes in session. A distracting event of a major tractor trailer accident and fire well east of the campus provided rationale to the participants as to why local emergency response personnel were occupied with this adjacent mass casualty accident leaving them with responsibility for immediate response on campus. The major highway accident also provided a plausible story about a re-routed tractor-trailer coming close to campus on back roads in an effort to go around the major accident which closed the highway. The incident progresses with the tractor trailer attempting to turn around on a small road near campus, overturning and throwing four 55 gallon barrels of cargo from the truck bed. Injects begin to come more frequently with reports coming in from Campus Safety, local Police and Fire authorities, students in the form of tweets with imagery and state HAZMAT assets. The simulation was largely text based with supporting graphics but was not graphic in nature nor disturbing in its imagery. There were no images containing human beings or animals, only overturned vehicles and vapors. Several superfluous pieces of conflicting information were provided around local blueberry fields prune burning, reports of serious smoke in the sky from the highway incident and potential smoke from the local crash site. Inject timing was roughly sixty seconds between injects. The scenario progressed quickly and participants where pressed for time.

All injects are accompanied by a sound. There was a loud bell for bulletins, a cell phone ringer for calls, a two-tone sound for email and a loud door knocking sound for someone delivering a message in person. At five specific times in the scenario, a bulletin was presented with a question and four possible choices for an answer. The question instructed the participant to choose the best answer given what they knew about the situation at that time. The first decision was around notification to campus to stay clear of the crash site. Prior to decision point two, information had been provided that allowed the participant to identify the leaking barrels as potentially 200 gallons of chlorine liquid. Decision point two was a decision on whether to prepare to evacuate or shelter in place. As the scenario progressed participants had all the information they needed to plot a danger zone around the spill location and the downwind evacuation zone regardless of treatment group. Decision point three required a decision about the best evacuation destination for the students. Decision point four required a decision on whether to move students only or all of campus to the evacuation site. Finally, decision point five required a decision requested by the local HAZMAT authority for a location best suited for a decontamination site (See Appendix A for the complete scenario and decision points). The scenario was a fairly standard HAZMAT training scenario modified to fit higher education.

The use of a chlorine liquid presented some unique challenges to novice participants. Chlorine liquid turns to a gas at a temperature of 70 degrees F. The gas is heavier than air and therefore seeks out low ground. While people at a higher level in a building may be unaffected, people at ground level may receive toxic levels of exposure. Air handling systems may become a factor in a decision to evacuate or shelter in place. Chlorine is an oxidizer and can cause rapid corrosion. The use of chlorine liquid in the scenario provided enough required expertise that novice decision makers were likely unaware of its dangerous properties. The scenario concluded shortly after the Director of Campus Safety arrived at the Communications Center and assumed the IC role. As soon as the scenario ended, all participants were presented with the SART instrument to measure situational awareness. For the treatment group, the participants were interviewed by the research assistants following the interview protocol. Interviews were recorded for subsequent transcription and analysis.

Instrumentation

Instrumentation for the experiment included a qualification questionnaire, the simulation scenario, an EMGIS system, simulation software and SART instrument. Instrumentation was tested during pilot experimental trials and modified as necessary. Where such modifications were required, threats to validity were evaluated.

In order to determine if a potential participant was actually a novice crisis manager, a simple questionnaire was developed to assess the experience level of the potential participant in the area of emergency management (See Appendix H). The questionnaire was developed in Qualtrics™ to facilitate distribution. Additionally, a structured interview guide and structured interview questions were developed with expert review by Dr. Hui-Ling Chen, Director of Institutional Research at Saint Anselm College and Dr. Kim Round, Professor and Director of Instructional Technology at Saint Anselm College (see Appendix J).

Potential scenarios and situation manuals were provided by a Program Manager at FEMA Emergency Management Institute. The Program Manager is the Virtual Table Top Exercise Program (VTTX) Manager and an expert in the development and execution of scenario based exercises for training and evaluation in emergency management. From the scenarios and materials provided by FEMA, the Hazardous Material (HAZMAT) spill of chlorine requiring evacuation and mitigation was selected. HAZMAT spill of chlorine was selected as it is sufficiently unique as to be novel to most novice emergency managers and sufficiently complex to require specialized knowledge. The scenario was modified to fit the higher education context and the time allotted for the experiment. The candidate scenario was developed based on the materials provided from FEMA EMI. Two experts in emergency management and one expert in University Residence Life validated the correctness of the scenario information, the decision outcomes against which participants will be evaluated and the realism and authenticity provided by the scenario. EMI also reviewed the final scenario and made only minor recommendations on the content. After some discussion, their review also endorsed a suggestion to administer the SART instrument mid-scenario and post-scenario. As the scenario was self-correcting, meaning that after a decision was selected by the participant, the scenario did not branch based on that decision. Instead, the scenario provided a subsequent situational update that included the appropriate action having been implemented in order to ensure that all participants had the same information and all decisions were atomic. Although a self-correcting scenario was necessary, it is possible that the corrections could influence the end of scenario measurement of SA. Mid-scenario and post-scenario recording of SA could provide an instrument to compare the SA and perhaps discover any affect. Nine pilot runs of the experiment were conducted with a convenience sample of novice decision makers and the SART instrument was administered mid-scenario and post scenario. There was no significant difference in the SART rating for a participant comparing mid and post scenario scores and a post exercise method for administration was adopted. The qualifications of the experts who have reviewed the scenario are included below (See Table 1). The results of the validation process for the scenario where recorded and changes and feedback are included as an appendix (See Appendix K).

Initially, selection of the EMGIS included the Computer-Aided Management of Emergency Operations® (CAMEO) software suite. CAMEO is a system of software

Table 1

Scenario and decision accuracy expert reviewers

Expert	Qualifications
Director of Campus Safety	BS Criminal Justice. Graduate of the Command Training Institute, Babson College. 27 year career in law enforcement in a New Hampshire Police Department. Captain, Director of Operations. NIMS/ICS trained. Incident Commander for numerous law enforcement and natural disaster incidents. 13 years as a Director of Campus Safety & Security.
Former law enforcement Special Response Team and Boston EMS member.	BS Criminal Justice. MBA. 22 year career in law enforcement Manchester, New Hampshire Police Department. Detective Lieutenant. 16 year Special Response Team (SRT) member. 27 year State and Nationally Registered AEMT. State EMT Instructor. State EMT Examiner Basic and Advanced. NIMS certified. 6 years Boston EMS.
Resident Life and Education Director	Ed.D(c), M.Ed. 10 year Director of Residence Life and Education
FEMA EMI Program Manager MEP, PCP, PACEM	Program Manager, Virtual Exercises at the Federal Emergency Management Agency. Firefighter and Hazardous Materials Technician, Gettysburg Fire Department. 20 years of Air Force, Law Enforcement, and Emergency Management Experience.

applications developed through a collaboration between the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA). The suite of applications is used widely to plan for and respond to chemical emergencies. The suite is in use by firefighters, State Emergency Response Commissions (SERCs), Tribal Emergency Response Commissions (TERCs), Local Emergency Planning Committees (LEPCs), industry, schools and environmental organizations (United States Environmental Protection Agency, 2017). The suite provides tools to look up Material Safety Data Sheets (MSDS) for a myriad of hazardous materials (Cameo Chemical database). The suite provides a tool for generating an atmospheric dispersion model to estimate the downwind dispersion of a chemical cloud based on characteristics of the released chemical and other environmental factors (Aloha software). Threat zones can be displayed on GIS portion of the suite to help users assess geospatial information, such as vulnerable locations (MARPLOT software). Together, these tools made a powerful EMGIS and HAZMAT response suite for a professional emergency manager. However, ease of use of the toolset was quite poor and proved to be well beyond the expertise of novice decision maker in a crisis situation. A significant amount of training and expertise was required to appropriately plot the downwind chemical dispersion. The Aloha tool was somewhat integrated into the MARPLOT GIS software but getting the plot to show in the GIS proved clunky and inconsistent. Mistakes were easy to make and not necessarily noticeable. ESRI ArcMap™ was subsequently selected as the appropriate software given that it has a Python API library (arcpy) that allows add-ins to be developed for specific geospatial applications. The ArcMap™ interface can be complicated with a Table of Contents tree structure containing all of the layer information typically on the left side of the screen. The Catalog window typically occupies the right side of the screen and many ribbon menus occupy the top navigation bar. In order for the interface to support a novice user, only the simplest elements were to be allowed on the screen. Basic map navigation was all that was required. Four custom add-ins buttons were developed in Python, installed into ArcMap^{TM} and aggregated into an EMGIS toolbar that was positioned alongside the basic navigation toolbars in the ribbon menu. Almost all of the screen real-estate was dedicated to the mapping function.

The EMGIS toolbar contained four buttons. There was a custom add-in button that launched the Cameo Chemical Database as a sub-process of ArcMap^{TM} and allowed the participant to search for a hazard by name or United Nations/North American Hazardous Materials (UN/NA) Code typically found on a vehicle placard. Once found the participant was able to read the MSDS for the hazard which included isolation guidance as well as downwind protection guidance. A second custom add-in button was developed that launched a chemical danger zone predictor tool and provided a dialog box that accepted the name of the chemical, the type of spill and the amount of the spill. Since the EMGIS was automatically updated in terms of weather conditions, no weather information was required. The danger zone predictor was simulated but participants were not aware that it was simulated. The third custom add-in button was a toggle for the danger zone overlay. Clicking this button effectively turned on the downwind dispersion of the chemical cloud hidden layer with the accident site automatically selected as the point of origin for the spill. The Aloha tool was previously used to plot an actual downwind dispersion layer in the MARPLOT application using all of the scenario information as inputs. The layer was then exported from MARPLOT and imported as a layer in ArcMap^{TM}.

Since all Table of Contents layer information was hidden from the participant to reduce interface complexity, the danger zone predictor and danger zone overlay buttons were used to simulate actual downwind dispersion calculations and presentation of the downwind overlay. The dispersion overlay contained four zones of differing colors from green to red. The danger zones reflected the wind confidence lines and the Acute Exposure Guideline Levels (AEGLs). AEGLs are an estimate of the concentrations at which most people experience health effects if they are exposed to a hazardous chemical for a specific amount of time. There are generally three AEGL values, each of which corresponds to the severity of the health effect. AEGL-3 is the airborne concentration, usually expressed as parts per million (ppm) of a substance above which most people experience life-threatening health effects or death. AEGL-2 is the airborne concentration above which most people experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape the affected area. AEGL-1 is the airborne concentration above which most people experience discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and usually reversible if exposure is removed (NOAA, 2017). Using the identify tool in ArcMap™ participants were able to click on the zones and read a description similar to the above for each color band. The overlay was presented in color, superimposed on top of the geography that was affected. The participant could see what buildings, roads and features were in a particular downwind danger zone. The final custom add-in button was a tool that reset environment variables back to their original state. These variables were used to track what the user had done with the GIS in order to ensure that appropriate information had been entered into the danger zone predictor prior to allowing the toggle of the dispersion overlay (See Appendix B).

An agreement with Applied Training Solutions, LLC (ATS) provided free use of the Consequences Management Staff Trainer™ (CMST) for the experiment. CMST is a simple-to-use, interactive, web-based exercise platform used by commercial, government and military organizations to prepare for a wide range of natural and man-made emergency situations (Applied Training Systems, 2017). CMST is Homeland Security Exercise and Evaluation Program (HSEEP) and NIMS compliant (See Appendix L for system screen shot). Use of the system was provided in exchange for feedback on the usability and design considerations for use of such a system in a higher education context. The scenario was developed using the CMST software system entering each inject and setting the timing for when each inject would fire. Exercise start time is whenever the facilitator begins the exercise from the facilitator console. Participants log into the CMST system from anywhere they have a network connection. For the experiment, both experimental computers were logged in with pre-created user ids of participant_one and participant_two. Both participants were assigned roles in the system of Incident Commander. Since there was no interaction allowed as chat, shared white board, and shared mapping services were disabled for the exercise, participants were unaware that more than one person was in the simulation. When the exercise started, participants were notified with a banner message and a quiet sound. The exercise runs on what is known as simulation time. If the simulation is supposed to take place starting at 17:00, the simulation shows the time now as 17:00 on the bottom of the simulation screen. The first inject fired at 17:00 immediately after exercise start. Initial timings started at 17:00 and ran through 17:43 with approximately fourteen injects of information including five decision points. After running nine pre-experimental trials, times were systematically lowered and more injects were added as participants had too much idle time and did not feel like they were under pressure. Final trials successfully created a feeling of time pressure as reported by the trial participants and SART scores were dramatically lower. The final simulation contained twenty injects, five decision points and a compressed timeline of twenty-three minutes that could be automatically extended to 30 minutes if needed for a participant. No participants required longer than 30 minutes.

A timing tool was created in order to record decision time for participants for each discrete decision required in the simulation. Trials revealed, as the time was compressed, that there was a possibility that a participant could be working on answering a decision question as the scenario progressed and another decision was required before the previous decision had been rendered. A spreadsheet application was developed in VBA that used five buttons labeled DP1 through DP5. Clicking the button started a timer and changed the label of the button to "STOP". Clicking the button again stopped the timer and recorded the time in a cell in the spreadsheet for that decision. Timers were independent of one another so a research assistant could start the timer for decision point one and then start the timer for decision point two while the first timer continued to run in case the condition described above arose. Laptops or tablets were provided to the research assistants with which to conduct decision timing. Additionally, a timing sheet was developed that included all of the inject start times as it was important for the research assistant to follow along in the scenario and be prepared for the audible sound when a decision was required (See Appendix M). Decision time was defined as the amount of time elapsed between when a decision was required and a decision was rendered. If the participant was busy with an information seeking task and ignored the decision sound, the time started when the decision was required not when the participant knew that the decision was required. Research assistants also instructed participants to render the decision, or decisions, that were required prior to moving on in the scenario. Moving on consisted of clicking on any new information that was provided since the decision was requested. This prevented participants from gaining insight into the situation as it developed prior to making the current decision that was based on the information provided up to that point in the simulation.

SA was measured using the Situational Awareness Rating Technique (SART) (Taylor, 1990) administered post scenario. The most popular measurement, Situational Awareness Global Assessment Technique (SAGAT), was rejected due to its intrusive implementation and potential threat to external validity over concerns of experimenter effect (Kintz, Delprato, Mettee, Persons, & Schappe, 1965). SAGAT is based on information-processing theory. Endsley considers situation awareness as an internal model that is derived from the environment prior to decision-making and subsequently performance (Endsley, 1995b). The implementation requires freezing the experimental scenario and blanking the simulation screens in order to query participants on questions related to SA. SART is less obtrusive and is generally administered as a questionnaire post trial. Both SAGAT and SART have been applied in a number of areas, including military aviation (Endsley, 1995a), air traffic control (Endsley & Kiris, 1995), military operations (Matthews, Pleban, Endsley, & Strater, 2000), driving (van den Beukel & van der Voort, 2017) and process control (Hogg, Folleso, Strand-Volden, & Torralba, 1996). The SART instrument provides a high – low rating scheme on a scale of 1-7 and rating are combined in order to arrive at a single composite measure of participant SA (See Appendix D). SART is focused on ten dimensions grouped into three domains to measure SA. Familiarity with the situation, information quantity and information quality make up the domain called understanding (U). Division of attention, concentration of attention, arousal and spare mental capacity make up the domain called attentional supply (S). Instability of the situation, complexity of the situation and variability of the situation make up the domain called attentional demand (D). A composite SART score was calculated using the following formula:

$$SA = U - (D - S)$$

where: U = summed understanding, D = summed demand, S = summed supply (Taylor, 1990). The post scenario SART score was calculated and each domain score as well as a single composite SART score recorded for each participant.

Sample

A priori power analysis for independent groups was conducted in G*Power to determine a sufficient sample size using an alpha of 0.05, a power of 0.75, and an effect size (d = 1) (Faul, Erdfelder, Buchner, & Lang, 2013) (See figure 3). Based on the assumption of normal distribution as well as the assumption that the two groups will have similar variance, the desired sample size was 30 participants with random assignment to the EMGIS (15) and non-EMGIS (15) groups.

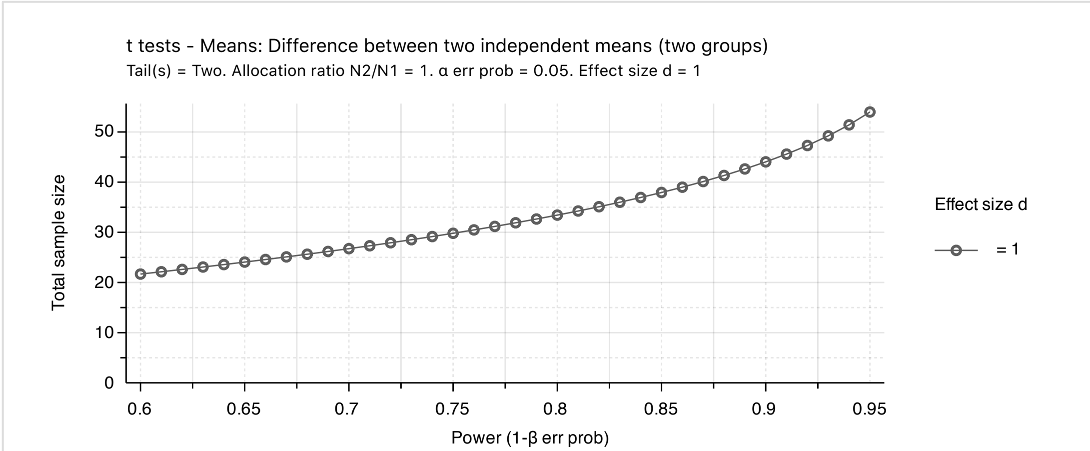


Figure 3. G*Power graph for sample size and statistical power.

The population source was a geographic convenience sample of staff from the site with no established emergency management office. A call for individual participation was conducted via email to include a link to a short questionnaire to collect contact and demographic information, briefly describe the study, and establish the experience level of the potential participant. A total of 30 qualified participants were randomly assigned to two experimental groups. Potential participants were contacted via email to coordinate their participation for the dates of the experiment with the goal of scheduling 30 participants. The local IRB process was followed for the site to allow a local experiment. Coordination was conducted with the site to secure two rooms for the conduct of the experiment with the necessary equipment.

Data Collection

The decision time variable for the decisions required during the experiment were recorded by the research assistants using the developed timing application. The CMST system provided a decision dialog at the appropriate time in the scenario and the decision choice of the participant was recorded in a paper booklet. Total decision time was summed in seconds for analysis. Decision accuracy for each participant was calculated post experiment and recorded as a numeric value for each decision. The decision choices were rank ordered by experts from least optimal to most optimal on a scale of one to four with four being the most optimal decision. Total decision accuracy was summed for each participant. The SART responses were calculated and a single composite SART score recorded for each participant. Interviews were recorded, anonymized, and uploaded to TranscribeMe transcription services for transcription. All data for participants was recorded using only the participant ID number in the research database.

Data Analysis

Statistical data analysis was conducted using Statistical Package for the Social Sciences™ (SPSS) for normality, homoscedasticity, and between group effects. Outliers were identified and each hypothesis was tested using appropriate parametric statistical methods. Non-parametric measures were analyzed and qualitative analysis was conducted for research questions.

Hypothesis 1: *Use of an Emergency Management GIS based system by a novice decision-maker reduces critical decision-making time during a simulated crisis response.* The time required to make a decision was recorded as the total decision time variable. The first hypothesis was tested through independent sample t-test to include the decision time as a dependent variable to analyze mean differences in the two groups.

Hypothesis 2: *Use of an Emergency Management GIS based system by a novice decision-maker leads to higher accuracy in critical decisions during a simulated crisis response.* The total decision score of the participant was recorded as decision accuracy. The second hypothesis was tested through independent sample t-test to include the decision accuracy score as a dependent variable to analyze mean differences in the two groups.

Hypothesis 3: *Use of an Emergency Management GIS based system by a novice decision maker increases situational awareness during a simulated crisis response.* At the conclusion of the scenario a SART instrument was administered and a SART score calculated. The third hypothesis was tested through independent sample t-test to include the SART score as a dependent variable to analyze mean differences in the two groups.

Research Question 1: *What is known about novice decision-making in a higher education emergency management context?* A literature review was conducted in order to answer research question one. Information was categorized, reviewed, and synthesized to provide a rich background of relevant research and thought into which the current research is situated and is included as chapter 2.

Research Question 2: *How does the use of an Emergency Management GIS based system by a novice decision maker affect decision-making performance, as a function of time, accuracy and situational awareness during a simulated crisis response?* Using time as the input value and decision accuracy and SART scores together as outputs, a Data Envelopment Analysis (DEA) was conducted using a Constant Return to Scale model (CRS). A relative efficiency frontier plot was created and color coded to visually represent the multi-criterion decision problem. Mean analysis was subsequently conducted to understand between group effects.

Research Question 3: *What are the perceived benefits and drawbacks of an Emergency Management GIS for the novice decision maker in a higher education context?* In order to answer research question three, a structured interview with each of the 15 EMGIS participants was conducted post simulation. An open coding method followed by an axial coding method was used to conduct thematic analysis of the interviews (Creswell, 2013).

Summary

A mixed methods sequential explanatory design (Creswell, 2014a) was selected in order test the research hypotheses and answer the posited research questions. The design was quantitative dominant. The research relied on a quantitative method for initial experimental data collection while concurrently acknowledging that the addition of qualitative post experimental data collection and subsequent analysis could yield a greater depth of understanding. The quantitative strand of research was concerned with the measurable impact of an EMGIS on decision time, decision accuracy and situational awareness. The qualitative strand was concerned with the interaction between the variables and the perceived impact of the treatment. The specific design for the quantitative research strand was quasi-experimental. The specific design for the qualitative research strand was a combination of non-parametric statistical method in the form of Data Envelopment Analysis and phenomenological method using structured interviews. Data analysis was the point of mixture of the methods in order satisfy the quantitative and qualitative goals of the research (Creswell, 2013; Salkind, 2012; Tashakkori & Teddlie, 2010).

Participants were pre-screened for qualification as novice crisis managers and randomly assigned to two groups. A computer based virtual table top exercise was conducted with participants acting as the incident commander during the scenario-based simulation. One group used an EMGIS and the other group used more traditional paper-based resources. For both groups, the non-emergency management GIS (nonEMGIS) group and the EMGIS group, the same information relevant to the decision scenarios was provided. Each group had a period of training designed by the researcher, and conducted by previously trained undergraduate research assistants to familiarize them with the resources they had available to them in the conduct of the simulation. The EMGIS group received training on the EMGIS. The non-EMGIS group received training on the use of traditional paper based tools, and an orientation of the informational assets available to them. Decisions were required at specific times throughout the scenario and decision accuracy, and decision time were recorded. Situational awareness was evaluated post experiment using SART.

Statistical data analysis was conducted using Statistical Package for the Social Sciences^{TM} (SPSS) for normality, homoscedasticity, and between group effects. Outliers were identified and each hypothesis was tested using appropriate parametric statistical methods. Non-parametric measures were analyzed and qualitative analysis was conducted for research questions. Outliers were not removed for the qualitative analysis as it is not required for the methods. DEA and axial coding were employed for the qualitative analysis.

Chapter 4

Results

This chapter provides the results of the mixed methods used in the satisfaction of the research goal. The chapter is organized with a brief summary of the problem under investigation, a summary of the experimental process, exploration of the participant demographic information, presentation of the results and hypothesis testing, qualitative analysis and chapter summary.

The goal was to investigate and disseminate the effects of using a geospatial information system for emergency management on the decision performance of novice higher education decision-makers in a simulated crisis event. There is a lack effective decision support and collaboration tools to facilitate novice decision-making and situational awareness in small IHEs (Murchison, 2010). The notable lack of experience in IHE emergency management underscores the need to provide decision support that is effective for novice decision makers (Sullivan, 2012). Research suggests that small IHEs may benefit from geospatial, map based tools to support decision-making and foster collaboration with outside agencies when conditions prevent local emergency management teams from arriving on site (Tomaszewski, 2015).

Thirty participants were qualified as novices in activities related to emergency management and crisis response who work at an institution of higher education without an office of emergency management. Participants were randomly assigned to two groups: a treatment group that used a prototype emergency management geospatial information system, and a non-treatment group that used traditional tools normally found in a higher education emergency operations center. Both groups used a web based computer simulation software product to participate in a 30-minute time scripted HAZMAT scenario that included a 200-gallon liquid chlorine spill in dangerous proximity to their residential college campus. Atmospheric conditions where such that the ambient temperature quickly vaporized the liquid and a 5mph wind drifted a dangerous amount of chlorine gas toward the northern portion of campus where a large concentration of student residence halls were located. Participants received information from a variety of sources to include student tweets and associated pictures, local police, campus safety, local fire department officials and HAZMAT teams. Time between information presentation was quite short, simulating time pressure. Throughout the simulation, at consistent and precise times, participants were asked to make decision choices around notifications to campus, shelter in place or evacuate, evacuation locations, scope of evacuation and HAZMAT decontamination site selection. Data was collected on participant decision time, decision accuracy and situational awareness.

Decision time was defined numerically as the time, in seconds, between when a decision was required and a decision was rendered. Decision times for each of five decision points was summed for a total decision time variable in seconds for each participant. There was no missing data for the total decision time variable. Decision accuracy was defined as a numeric score on a scale of one to four with four being the most optimal decision and one being the least optimal as defined by experts during the research design. Decision accuracy for each of the five decision points was summed for a total decision accuracy variable for each participant. There was no missing data for the total decision accuracy variable. It is interesting to note that that no participant received a perfect decision accuracy score. This is to be expected, and desirable, as participants were novices with little familiarity with the scenario. Situational awareness was measured immediately after the simulation concluded using the SART instrument. A composite SART score was calculated using the following formula:

$$SA = U - (D - S)$$

where: U = summed understanding, D = summed demand, S = summed supply (Taylor, 1990). The SART score was recorded for each participant and there was no missing data for the SART variable.

Summary of Demographic Information

Responses to the qualification questionnaire for qualified participants indicated that none of the selected participants had any formal emergency management training. Formal training was described in the questionnaire as college level curricular course work, professional certifications, academic degrees, or FEMA certifications such as Certified Emergency Manager (CEM). Thirty-three percent of selected participants indicated that they had received some form of informal training in their careers (33.3%). Informal training was described in the questionnaire as on-line NIMS training, local workshops, or professional development seminars. There were varying levels of participation in training exercises in emergency management or crisis response. Exercises were described in the questionnaire as sand table, virtual tabletop, full physical simulations with local emergency agencies, or campus wide on-the-ground simulations. Sixty percent of selected participants had no exercise experiences, 16.7% had participated in some way in one or two exercises and 20% had participated in three or four exercises. One selected participant had been involved in six or seven exercises in a former job but was involved in document management contingency planning and not emergency response. Several selected participants indicated on the questionnaire that they had been an incident commander. Follow up conversations revealed that they had misunderstood the question and had never actually been an incident commander. No selected participant had ever been an incident commander. Incident command was described in the questionnaire as being the primary manager of a crisis response such as a flood, tornado, hurricane or other natural disaster, campus shooter, facility collapse, mass casualty, or chemical disaster. No selected participant had ever served in the armed forces or was currently serving, nor had ever been in law enforcement or emergency medical services. Demographic information is provided below (See Table 2). About a quarter of the participants were between the ages of 20 and 29 that is typical of residence life staff. The majority of the participants were 40 or older (56%). There were slightly more female participants than male (57%) and overwhelmingly participants held an academic degree of bachelor's or higher (93%) with slightly more than half holding at least a master's degree (60%). All of the participants served in positions at the site where it was typical of their daily duties to interact with students either formally as part of their job duties such as residence life staff or informally such Director of Physical Plant or Director of Student Activities.

Preliminary Data Analysis

Data were consolidated into a Microsoft Excel spreadsheet and imported into SPSS software for analysis. Data were also imported into R for DEA analysis (R CoreTeam, 2017) and the Benchmarking package implementation was used for calculation of the DEA efficiency as well as the relative efficiency frontier (Bogetoft & Otto, 2015). In SPSS the group variable was coded 0 and 1 for EMGIS and non-EMGIS

Table 2

Demographic Characteristics of Participants (N = 30)

Characteristic	*n*	%
Age at the time of the study		
20-29	8	27
30-39	5	17
40-49	7	23
50-59	4	13
60-69	6	20
Gender		
Male	13	43
Female	17	57
Highest education level completed		
Less than high school degree	0	0
High school graduate (high school diploma or equivalent including GED)	1	3
Some college but no degree	0	0
Associate degree in college (2-year)	1	3
Bachelor's degree in college (4-year)	7	23
Master's degree	18	60
Doctoral degree	3	10

Note: Total percentages are not 100 for every characteristic due to rounding

groups respectively. The data for all variables were pre-screened for quality, missing data, outliers and normality. Analysis showed there were no bad or missing data elements. Mahalanobis distance was calculated on all raw data items to discover any outliers (see Figure 4). A chi-square statistic was calculated for each respondent based on Mahalanobis distance and evaluated against an alpha level of 0.05. There were two cases classified as outliers in the data set ($p < 0.05$) and both cases were excluded from parametric analysis. Conveniently, there was one outlier in each group therefore group sizes remained equal for subsequent analysis. All variable distributions were sufficiently normal for the purposed of conducting the *t*-test (i.e., skew < |2.0| and kurtosis < |9.0|; Schmider, Ziegler, Danay, Beyer, & Buhner, 2010). Total decision time exhibited skewness and kurtosis of -0.876 and 0.392 respectively, total decision accuracy

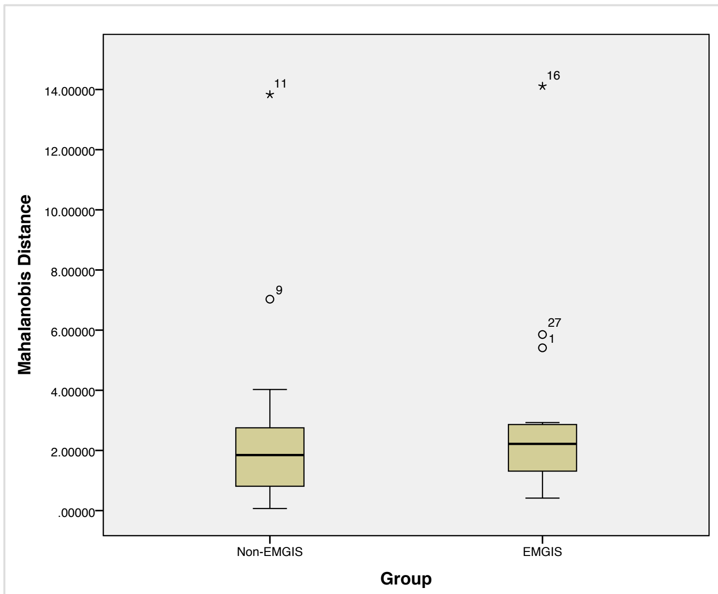


Figure 4. Mahalanobis Distance outliers are marked by an * (p<0.05*)*

exhibited skewness and kurtosis of -0.605 and .925 respectively, and SART exhibited skewness and kurtosis of -0.876 and .392 respectively.

A two-tailed bi-variate Pearson Correlation (using an alpha level of 0.05) for the dependent variables for all hypotheses indicate there is a strong negative correlation between decision time and decision accuracy (r = -0.502, n = 28, p = 0.007). This indicates that as decision time increased, decision accuracy decreased. The correlation holds if groups are separated for analysis although the correlation is not statistically significant for the non-EMGIS group (r = -*0*.274, n = 14, p = 0.344) as opposed to the EMGIS group analyzed separately (r = -0.543, n = 14, p = 0.045). This correlation will be considered in the DEA analysis. It is not unexpected that decision time and decision accuracy are related. More difficult decisions potentially require more time and analysis then less complex decisions.

Data Analysis

The EMGIS group (N = 14) was associated with shorter overall decision time M = 392.79 (*SD = 100.09).* By comparison, the non-EMGIS group (N = 14) was associated with numerically longer overall decision time M = 472.07 (SD = 154.85). To test H1 that use of an Emergency Management GIS based system by a novice decision-maker reduces critical decision-making time during a simulated crisis response, an independent sample t-test was performed. The assumption of homogeneity of variance was tested and satisfied via Levene's F test, $F(26) = 3.353$, $p = 0.079$. The independent sample t-test was not associated with a statistically significant effect, $t(26) = 1.609$, $p = 0.120$. Cohen's d was estimated at 0.608 with an effect size of 0.30 which is a moderate effect size (Cohen, 1988). There is little statistical support for H1 and therefore requires a failure to reject the NULL hypothesis. The EMGIS group was not associated with a statistically significant improvement in decision time over the non-EMGIS group.

The EMGIS group (N = 14) was associated with higher overall decision accuracy M = 16.64 (*SD = 1.59).* By comparison, the non-EMGIS group (N = 14) was associated with numerically lower overall decision accuracy M = 15.29 (SD = 1.77). To test H2 that the use of an Emergency Management GIS based system by a novice decision-maker increases accuracy in critical decisions during a simulated crisis response, an independent sample t-test was performed. The assumption of homogeneity of variance was tested and satisfied via Levene's F test, $F(26) = 0.003$, $p = 0.959$. The independent sample t-test was associated with a statistically significant effect, $t(26) = -2.127$, $p = 0.043$, significant at the $p<0.05$ level. Cohen's *d* was estimated at 0.7999 with an effect size of 0.371 which is a moderate effect size (Cohen, 1988). There is statistical support for H2 and the NULL hypothesis is rejected. The EMGIS group was associated with a statistically significant improvement in decision accuracy over the non-EMGIS group.

The EMGIS group (N = 14) was associated with higher overall situational awareness scores M = 20.57 (*SD = 4.831).* By comparison, the non-EMGIS group (N = 14) was associated with numerically lower overall situational awareness scores M = 19.86 (SD = 3.634). To test H3 that use of an Emergency Management GIS based system by a novice decision-maker increases situational awareness during a simulated crisis response, an independent sample *t*-test was performed. The assumption of homogeneity of variance was tested and satisfied via Levene's *F* test, $F(26) = 0.065$, $p = 0.800$. The independent sample *t*-test was not associated with a statistically significant effect, $t(26) = -.442$, $p = 0.662$. Cohen's *d* was estimated at 0.166 with an effect size of 0.082 which is a small effect size (Cohen, 1988). There is little statistical support for H3 and therefore requires a failure to reject the NULL hypothesis. The EMGIS group was not associated with a statistically significant improvement in situational awareness over the non-EMGIS group. All results are summarized in Table 3.

Intuitively, the three variables under analysis appear to be related. The time required to make a decision may be influenced by the complexity/difficulty of the decision. The accuracy of the decision may be influenced by one's understanding of the situation and perhaps the time one has to make a decision. The level of situational awareness likely influences both decision time and accuracy. The previous Pearson

Correlation indicated that decision time and decision accuracy where correlated when evaluated ($p < 0.05$). In order to explore the relationship of these three variables a DEA

Table 3

Group differences for decision time, accuracy and SA

	EMGIS		Non-EMGIS				
Measure	*M*	*SD*	*M*	*SD*	*t*(26)	*p*	Cohen's *d*
Time	392.79	100.09	472.07	154.85	1.60	0.120	0.60
Accuracy	16.64	1.59	15.29	1.77	-2.12	0.043*	0.79
SA	20.57	4.83	19.86	3.63	-0.44	0.662	0.16

*Note: * Significant at the p<.05 level.*

analysis was conducted using R-Studio and the Benchmarking library. The original idea behind DEA was to provide a methodology for comparing (DMUs), and those exhibiting best practice or optimal efficiency were identified and formed an efficiency frontier. DEA enables a measurement of the level of efficiency of non-frontier units against benchmarks which inefficient units can be compared (Charnes, Cooper, & Rhodes, 1978; Cook & Seiford, 2009). Rather than comparing groups across metrics of central tendency that use the mean as the measure of variance, DEA can be used to compare groups by combining multiple inputs and outputs and using the top performers as a means to compare groups. DEA requires values for both input and output and considers the variables together. The inputs generally consist of metrics that tend be considered optimal as their value decreases. The outputs are generally metrics that tend to be considered optimal as their value increases (Banker et al., 1990). The decision problem including the three decision variables under investigation fit the DEA model quite well. Decision time is considered optimal if its value is lower or it takes less time to make a decision in a crisis. The other two variables are considered more optimal if they are higher. Higher decision accuracy and higher situational awareness are optimal.

Thirty participant records to include total decision time, total decision accuracy and SA score were loaded as a data frame into R. As DEA is a non-parametric method, there was no need to remove outliers. In DEA, each of the records constitutes a single DMU to be compared to all other DMUs in the data set. The *y* axis was defined as a matrix consisting of total decision time and the *x* axis was defined as the combination of total decision accuracy and total SA. DEA efficiency scores were generated based on a Constant Return to Scale (RTS) known as the CCR model named so for its authors (Charnes et al., 1978). The most efficient DMU receives an efficiency score of 1. All other DMUs are scored between 0 and less than 1. The objective function of the DEA is to find the DMU with lowest decision time as a ratio of the highest decision accuracy and highest situational awareness score considered together. The optimal performing DMU is considered to be on the relative efficiency frontier and all other DMUs are located below the frontier or, as it were, enveloped by the frontier.

DEA efficiencies were analyzed in terms of mean relationships in order to answer RQ2, how does the use of an Emergency Management GIS based system by a novice decision maker affect decision-making performance, as a function of time, accuracy and situational awareness during a simulated crisis response. Again, as DEA is a non-parametric method, there was no need to remove outliers. The EMGIS group ($N = 15$) was associated with higher overall efficiency ratios $M = 0.583$ ($SD = 0.178$). By comparison, the non-EMGIS group ($N = 15$) was associated with numerically lower overall efficiency ratios $M = 0.466$ ($SD = 0.170$). Participant efficiency ratios were compared to the overall mean for both groups *M* = 0.525 (*SD* = 0.184) with a finding that nine participants in the EMGIS grouped scored above the mean while only five participants in the non-EMGIS group scored above the mean. This represents a 17% improvement in efficiency scores in the EMGIS group when considering decision performance as a ratio of decision time and the combined values of decision accuracy and situational awareness (See Table 4).

Table 4

Group Differences for Efficiency Ratios

	EMGIS			Non-EMGIS		
Measure	*M*	*SD*	*Total > M*	*M*	*SD*	*Total > M*
Efficiency ratio	0.525	0.184	9	0.525	0.184	5

The DEA relative efficiency frontier graphic visually demonstrates the improvement (see Figure 5). DMU number 7 is the optimal efficiency ratio with low decision time and a high combination of accuracy and situational awareness. Using the DEA frontier provides insight into the interaction between the variables. This analysis mitigates conclusions from parametric analysis that may reward a quick but sub-optimal decision over a more optimal decision that took a slightly longer time to render. The DMUs clustered at top edge of the frontier also confirm the statistical analysis that showed that the EMGIS group demonstrated a statistically significant difference in decision accuracy.

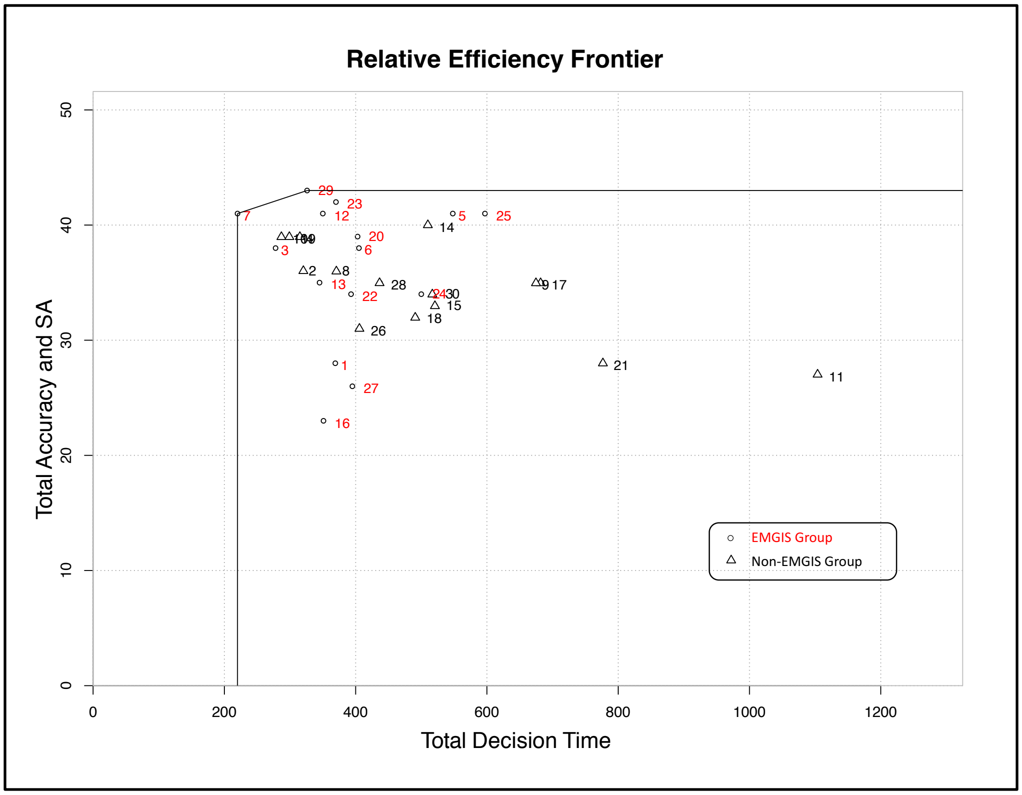


Figure 5. Relative Efficiency Frontier

Immediately following the conclusion of the experiment and administration of the SART instrument, EMGIS participants were interviewed following the interview protocol. In order to answer RQ3, as to the perceived benefits and drawbacks of an Emergency Management GIS for the novice decision maker in a higher education context, open coding was first conducted using all interviews in order to capture participant stories and get a sense for the essential shared experience of using an EMGIS during the simulation. Axial coding was completed synthesizing the related open coding and capturing themes related to participant experiences. NVivo v11 software was used to record the coding and generate the coded transcripts for thematic analysis (QSR International Pty Ltd, 2011). Two independent coders compared and consolidated their work after coding separately. The second coder was a CITI certified undergraduate research assistant who did not participate as an experimental research assistant but only participated in the qualitative analysis. The undergraduate student was an English major taking a Human Computer Interaction course for honors credit and qualitative analysis was covered in the course content. Additional training on the NVivo software was also provided to the student. Open coding to include textual examples of participants language are included as an appendix (See Appendix N), axial coding and thematic analysis are presented below (See Table 5).

Table 5

Axial coding and Thematic Analysis of Participant Interviews.

Open code	Axial code	Thematic Description
Ease of decision choices. Higher decision confidence. Better decisions. Faster decisions. Usefulness in an emergency. Geospatial context. HAZMAT information. Option awareness. Weather visibility.	Benefits of an EMGIS	An EMGIS eases the burden of decision-making, providing geospatial and HAZMAT information that results in the perception of better, faster, more information driven decision-making in a simulated crisis event.
Realism. Geospatial contextual understanding. Expensive. Power reliance. Mobility. Over reliance.	Challenges with an EMGIS	An EMGIS requires significant training and familiarization with geospatial concepts, relies on power and network availability, could be prohibitively expensive, may be limited in high mobility situations and could create an over reliance problem.
Situational Awareness. Understanding. Feature Benefits.	Situational Awareness	An EMGIS provides good context in a crisis situation with respect to population locations and hazard danger zones and provides beneficial features to improve understanding of a complex situation and the efficacy of potential actions.

Participants generally agreed that the EMGIS eases the burden of decision-making in the simulated crisis event. They found that the geospatial and HAZMAT presentation provided by the EMGIS helped them make better, faster, and more informed decisions. A consistent theme was that of training or familiarization with the EMGIS. Clearly, such a system requires significant training and familiarization. Drawbacks included a lack of understanding of geospatial concepts and need for power and network availability in the event of a crisis, which may not be available if the crisis includes a wide spread power outage. No participants considered battery backup capability or generators in their discussion. Participants listed expense and limited mobility as potential challenges with a computer-based system. There was some fear that an over reliance on such a system could be problematic if the system were unavailable. In terms of situational awareness, there was general agreement the EMGIS provides good context in a crisis situation. The geospatial nature of the system provides a unique view into population locations and hazard danger zones in the HAZMAT scenario. Participants agreed that their understanding of what was happening and how it would affect the campus was improved by the EMGIS and helped them evaluate the effectiveness of potential protective actions.

Summary

A mixed methods sequential explanatory research design was undertaken and results were analyzed using parametric statistical techniques for hypothesis testing as well as non-parametric techniques in DEA and qualitative interview analysis for exploration of the research questions. Statistical significance was found to support H2, and a failure to reject the NULL hypothesis was found for H1 and H3. Using DEA techniques, combining inputs and outputs in the multi-criterion decision problem yielded an improvement in decision performance for the EMGIS decision-making units and insight into the interaction of the variables. Qualitative analysis of interviews from the EMGIS yielded some potential explanations of the results and insights into the use of an EMGIS by novice crisis decision makers in a higher education context.

Chapter 5

Conclusions

This chapter explores the conclusions to be drawn from the results with respect to the research questions. The chapter is organized with a brief summary of the problem under investigation, implications, recommendations and future research, and chapter summary.

The goal was to investigate and disseminate the effects of using a geospatial information system for emergency management on the decision performance of novice higher education decision-makers in a simulated crisis event. Results indicate that there is benefit to the implementation of geospatial decision support tools for novices confirming related results suggested by previous studies (Tomaszewski, 2015; Wu et al., 2013). Two randomly assigned groups of 15 participants each were qualified as novices in activities related to emergency management and crisis response. Both groups used web-based computer simulation software, and tools provided to navigate and make decisions throughout the scenario. The tools consisted of an EMGIS for one group and standard paper-based maps and crisis response guides for the other group. Experimental data was collected on decision time, decision accuracy, situational awareness and analyzed using parametric, non-parametric and qualitative techniques. Each research question is reviewed and the point of mixture between qualitative and qualitative research strands was evident as qualitative findings, where applicable, are used to illuminate quantitative result.

The first research hypothesis, that use of an Emergency Management GIS based system by a novice decision-maker reduces critical decision-making time during a simulated crisis response was not supported by parametric statistical method. A significant negative correlation was found between decision time and decision accuracy. For the experiment, as decision time increased, decision accuracy decreased. This may seem counterintuitive but is in line with previous studies on decision complexity. As decisions increase in complexity and require greater expertise, decision makers rely on strategies that reduce information processing load and potentially lead to “satisficing” or making decisions that seem good enough when compared to the work necessary to arrive at them (Chu & Spires, 2000; Kahneman & Klein, 2009; Simon, 1997; Speier, 2006). It is not a surprising result that as decision time increases decision accuracy decreases. This finding underscores the complexity of the decisions and the need to seek out appropriate information in order to choose a decision. Information seeking simply takes time. The longer times might suggest an unfamiliarity with the decision, higher complexity, and the need to seek out more information, which is to be expected in a novice, and lower decision accuracy is a result. Between groups, results suggest that the EMGIS did not have a significant effect on decision time. Qualitative analysis may provide some insight into this finding. There was a consistent theme in the interviews that participants desired more time to become familiar with the EMGIS. Several statements made by participants indicated that they thought they may have done better if they had more familiarity with the EMGIS. Observationally, there were a few EMGIS participants who did not effectively use the EMGIS in any of their decision-making when compared with the other members of the EMGIS group. Interviews from these participants suggest that they were aware of the lack of use and desired more training on the EMGIS. Potentially, the EMGIS was simply too complex for a novice to operate effectively given the already increased cognitive load caused by the lack of familiarity with the scenario and the imposed time pressure. This is consistent with previous research on the effects of time pressure and complexity on cognitive load (M. Hahn, Lawson, & Lee, 1992; Jackson & Farzaneh, 2012). These participants, had significantly longer response times than others in the treatment group by an average of 150 seconds when compared with those who did effectively use the EMGIS potentially skewing the results of the EMGIS mean analysis in the *t*-tests. Perhaps the complexity of the situation for a novice over rides the potential time benefit in information processing that could have been gained by the use of an EMGIS. It can be concluded that the prototype EMGIS used in the experiment may have required too much effort for a novice to learn and effectively use given the increased cognitive load brought on by the scenario itself.

The second research hypothesis, that the use of an Emergency Management GIS based system by a novice decision-maker increases accuracy in critical decisions during a simulated crisis response was supported by the results. A significant statistical result was observed between the EMGIS group and the non-EMGIS group. Decision accuracy was measurably higher in the EMGIS group. This finding supports the idea that not only do geospatial information systems positively affect the decision-making of experts (Barkhi & Kao, 2010; Convertino, Mentis, Slavkovic, Rosson, & Carroll, 2011; Murchison, 2010; Simons, 2013; Wu et al., 2013) but also that of novices in situations with which they are potentially unfamiliar. Qualitative results suggest that there is a perception that a geospatial information system was critical in the decision-making of the participants.

However, had interviews been done with the nonEMGIS group, it may have been found that the Emergency Response Guidebook occupied a similar position of criticality in decision-making. There was a strong perception that the EMGIS made decision-making faster and more accurate. Certainly, the nature of the problem has a significant impact on the tools used to address it and this problem was largely geospatial in nature. However, most emergency management situations are geospatial in nature (Heard et al., 2014). An improvement in the accuracy of critical decisions by higher education novice crisis managers through the use of an EMGIS is a first step in the research to provide better decision support systems for novices in these unique environments.

Observations of both groups as they participated in the experiment uncovered a unique aspect of the experimental design that may have shaped some participant behavior. Participants tended to search for information without prompting prior to receiving the first decision point. Most participants looked for road names, building names, and searched for the location of the main highway where a large accident had occurred. Most participants were fairly active in their information seeking prior to the first decision. Once the first decision was required, participants were subsequently less active in their information seeking behavior. Although they read the descriptions of the events that were unfolding, it seemed as though they were not actively using either information source, EMGIS or manual binders, to familiarize themselves with the situation until the next decision was required. There was very little projection of current events into the future and preparing for eventualities. It is possible that this observation was due to the lack of experience of the participants and the inability to be able to operationalize synthesized information (Level 2 SA) and then project appropriately into the future never achieving Level 3 SA (Endsley, 1995b, 2004; Kaber & Endsley, 2004). It is possible, however, that once participants realized that they would be provided options in the decision-making process, they could simply wait and evaluate those options one at a time and use a process of elimination to arrive at the best decision. This may be part of coping strategy of decision-making under uncertainty, known as reduction. One method of reduction is to defer uncertain decision-making until more certain information is available (Lipshitz & Strauss, 1997; van den Heuvel, Alison, & Power, 2014). As the situation was unfamiliar and participant knowledge very low, there may have been a compelling desire to reduce the mental load of conceiving and evaluating potentially large numbers of contingencies (Nadav-Greenberg and Joslyn 2009). Simply waiting to see what the potential "answers" might be in the next required decision provides a simple mechanism for the conservation of cognitive resources. It is likely that time pressure and unfamiliarity with the scenario contributed to the necessity of using a strategy to conserve cognitive resources. It is just as plausible that the fairly standard test taking strategy, process of elimination, was employed in order to achieve better performance on the task. Further research into these possibilities is needed. As both groups exhibited the same behavior, the effect on the comparison of performance across groups was negligible.

The third research hypothesis, that use of an Emergency Management GIS based system by a novice decision-maker increases situational awareness during a simulated crisis response was not supported by the parametric method. SART score is a calculated score subtracting summed understand (U) from the result of subtracting summed attentional demand from summed attentional supply. It is interesting to note that in an independent sample *t*-test ($a < 0.05$), there was a statistically significant difference in the nonEMGIS group ($N = 14$, $M = 15.93$, $SD = 1.77$) when compared with the EMGIS group ($N = 14$, $M = 14.07$, $SD = 2.20$) on the attentional demand variable (D), $t(26) = 2.458$, $p = 0.021$. The self-reported attentional demand of participants was statistically significant at a lower level than the nonEMGIS group. Although there was not enough variance in the overall SART score to be statistically significant, lower attentional demand for those participants using the EMGIS underscores an important finding. Perhaps the lower attentional demand provided more cognitive resources for decision-making given that there was no significant difference between groups on attentional supply and understanding. It is likely that this lower attentional demand contributed to the higher decision accuracy result of the EMGIS group. The finding that the scores for understanding were very close for the nonEMGIS group ($N = 14$, $M = 13.07$, $SD = 2.86$) when compared to the EMGIS group ($N = 14$, $M = 13.71$, $SD = 2.23$), was not surprising. In order to make each decision atomic, all participants had to start from the same level of understanding prior to each subsequent decision. In essence, the participants were provided with near perfect understanding of the situation from a decision outcome perspective after each decision was rendered through information provided as the scenario progressed. It makes sense that understanding between groups would be equivalent and that standard deviations would be relatively low. It is likely that this mean threshold was mathematically influential on the calculation of SART scores and subsequent finding of no statistical significance between groups. Qualitative results indicate the perceptions of understanding of the situation in the EMGIS group were high, but it is not clear if the qualitative result is also due to the self-correcting scenario. Additional research without a self-correcting scenario is needed in this area.

The first research question, what is known about novice decision-making in a higher education emergency management context was reviewed in chapter 2. The area of emergency management information systems and emergency management decision support systems is difficult to study. Field studies of crisis management in live scenarios are either inaccessible, cost prohibitive or operationally ill advised. In a recent review of 8,408 papers over two decades in the knowledge management domain there were only fifty-one (0.6%) papers that investigated applied-Knowledge Management Systems for disaster/emergency management (Dorasamy et al., 2013). Very few studies undertake the crisis management context of higher education and novice decision makers. Research has confirmed that lack of experience in a decision-maker appears to be an important limitation in decision performance (G. Klein, 1997; Lipshitz et al., 2001; Perry et al., 2012; Perry, Wiggins, Childs, & Fogarty, 2013; Todd & Benbasat, 1992). Mishra et al. (2013) suggests that novices make decisions in entirely different ways than do experienced decision-makers. They conclude that it is important to study the information practices of novice and experts separately when working under environments that are time constrained, complex and uncertain. Novices tend toward normative decision-making strategies and experienced decision-makers tend toward more intuitive recognition primed models (G. Klein, 1997; Lipshitz et al., 2001; Todd & Benbasat, 1992). These findings led to the creation of a study focused on novices and finding ways of supporting their unique decision-making processes.

Perhaps the most striking result was in the investigation of research question two, how does the use of an Emergency Management GIS based system by a novice decision maker affect decision-making performance, as a function of time, accuracy and situational awareness during a simulated crisis response. It is intuitive that situational awareness, decision time and decision accuracy are related in some complex ways. The DEA analysis is sensitive to the relationship between multiple inputs and multiple outputs. A review of the graph of the relative DEA frontier reveals some interesting results from which some conclusions can be made (See Figure 5). First it is interesting that the slowest four times between both groups were all in the nonEMGIS group. Although it is likely that the EMGIS was more complicated than the manual materials, the complexity did not seem to slow down the EMGIS group and revealed lower standard deviations in the EMGIS group. The five top performers in the experiment were all from the EMGIS group with two of them essentially creating the efficiency frontier. Decision performance as a function of time as an input and decision accuracy and situational awareness as outputs, indicate that the EMGIS group had better efficiency scores than the nonEMGIS group. While parametric measures reveal linearity and mean variance of each of the dependent variables, DEA provides a unique view into the data that suggests that perhaps the relationships of the dependent variables are best viewed with non-parametric techniques. From the DEA results, it is clear that there are measureable gains in decision performance of a novice with the use of an EMGIS in a simulated crisis scenario.

The third research question explored the perceived benefits and drawbacks of an Emergency Management GIS for the novice decision maker in a higher education context. Analysis suggests three themes that emerged from the 15 participants interviewed. The first theme was that an EMGIS eases the burden of decision-making in a crisis event. The information system provided geospatial features that enhanced the participants ability to better understand the HAZMAT situation as it unfolded. The affect was a perception of better, faster, more information driven decision-making in a simulated crisis event.

The second theme was that there are some drawbacks to an EMGIS, specifically that its effective use requires significant training and familiarization. Geospatial concepts are somewhat new and require some time and familiarity in order to become comfortable with them. Additionally, any information system relies on power and network availability. Cost was identified as a potential concern for adoption as well as a possible over reliance on the technology to the exclusion of on ground information gathering.

The final theme was that an EMGIS provides good context in a crisis situation with respect to population locations and hazard danger zones and provides beneficial features to improve understanding of a complex situation and the efficacy of potential actions.

Implications

Especially in the area of decision accuracy and timeliness, an EMGIS has a positive impact on decision performance of novice crisis managers in a simulated HAZMAT scenario in a higher education context. While training on the use of an EMGIS is as necessary for effective implementation as it is for any new system, the implications for the use of such a system in higher education are very positive. Prior research on the use of GIS systems in emergency response and disaster management have been focused on experts (Heard et al., 2014; Ley et al., 2012b; Lukosch et al., 2015). There is clearly a need to increase the research around the study of GIS based information systems impact on the novice crisis manager. Although there are significant challenges to overcome for the novice thrown into a crisis management situation, it is clear that an EMGIS can have a positive impact on decision quality and total decision performance. Implications in the area of decision theory suggest that although novices and experts make decisions in completely different ways (G. Klein, 1997; Lipshitz et al., 2001; Todd & Benbasat, 1992), an EMGIS could potentially mitigate the differences and increase decision performance of novices in crisis situations.

Implications in practice suggest that IHEs can implement a GIS system for their campus with relative ease using open source tools such as QGIS or commercial products such as ESRI ArcGIS or the Cameo Suite of tools. As a first step in the use of a GIS in an operational higher education context, this relatively low-cost effort can easily be extended to support emergency management. Including an EMGIS in an overall plan to build a Disaster Resilient University extends the FEMA Guidebook to include emergency management tool sets appropriate for higher education (2003).

For small IHEs, the impact of an EMGIS could be considerably greater. It is unlikely that a small IHE will have an Office of Emergency Management staffed with trained professionals. The lack of emergency management experience in these organizations (Sullivan, 2012) could potentially be mitigated through the implementation and training of an EMGIS. Participants were able to make better decisions using a prototype EMGIS with 10 to 15 minutes of training during a complex chemical hazard and evacuation simulation. Implementation of a production EMGIS coupled with sufficient training could better prepare novice decision makers to protect life and property in the event of a crisis situation.

Recommendations

In practice IHEs can implement a GIS to establish the basic information needed for effective use. Based maps should extend beyond the geography of the university to any known hazard areas such as flood plains, wild-fire prone areas, urban centers etc. Maps should include local facilities that may be part of a business continuity or disaster management plans. Maps should include markings and overlays for local fire stations, transportation facilities, medical services, potential evacuation sites, and assembly areas for emergency response staging. Campus facilities should be included along with relevant information stored as attributes to include, potential occupancy, building type, air handling systems, etc. Campuses should include locations of natural gas and water main shut off valves, electrical sub stations and other critical utility information that may be needed by response personnel. If enough information is included in the GIS it will be useful for creating detailed hazard profiles, predicting scope and extent of potential damage associated with a particular hazardous incident, as well as identifying potential vulnerabilities.

Coordination with local GIS based resources at the state or federal level can provide a wealth of information and the opportunity to collaborate in real time. There is a significant research effort to explore the use of web based geospatial information systems as a community tool for planning, crisis management and sharing of information (Haworth, Whittaker, & Bruce, 2016; Houston et al., 2015; Kar, Sieber, Haklay, & Ghose, 2016; Soden & Palen, 2014). A cross organizational collaborative effort between state and regional entities could create a network of GIS based information that could prove vital in the protection of life and property in the event of an emergency.

Future Research

Future human computer interaction research into the design and usability of an EMGIS could potentially yield usability results that increase the effective use of the system potentially mitigating the finding that the EMGIS required more training and familiarization. The usability of such a system is critically important due to the nature of the situations for which it will be used. Crisis situations do not happen very often, are unpredictable in their scope and impact, and are often quite novel in their presentation. Focusing on usability will decrease the cognitive resources necessary to use the decision support system and potentially free up resources to apply to the crisis situation.

Situational awareness is a difficult construct to measure. In the experiment, it was necessary to provide a scenario that self-corrected in order to get atomic, measurable decisions for all participants. The side effect of appropriate measurement of decision accuracy was a skewed measurement of situational awareness in the area of understanding. Future research could explore a method of branching the scenario to allow for a wider range of decisions that are not corrected. Decision accuracy could be measured in terms of outcomes rather than discrete measures along a scale of optimal to sub-optimal decisions. Additionally, exploring the effect of option awareness (G. Klein, Pfaff, & Drury, 2011; Liu et al., 2011; M Pfaff et al., 2013) on the decision performance of novice decision makers may provide a more complete theoretical picture.

A valuable extension of this research to include collaborative efforts with other entities could potentially provide a novice access to expertise that may not otherwise be brought to bear on a crisis situation. The collaborative possibility of connected GIS systems requires further research as it relates to assisting novice decision makers in a crisis event.

Summary

The ability for IHE to prepare for an emergency, respond adequately to protect life and infrastructure, recover from the damage and mitigate the local and societal impact is paramount in our higher education communities. The Higher Education Equal Opportunity Act of 2008 requires an IHE to have emergency notification and response plans and dictates a minimum of one annual exercise in order to test the plan, and conduct assessment and evaluation. An IHE must publish the procedures for communicating emergency information to the larger community (HEOA, 2008). Research in this area has focused on the professional field of emergency management such as fire brigades, emergency medical services, law enforcement, municipal emergency management as well as non-governmental organizations (NGO) such as the Red Cross (Heard et al., 2014; Ley et al., 2012b; Lukosch et al., 2015). The problem addressed was that novice crisis managers in small IHEs without emergency management offices lack effective decision support and collaboration tools that facilitate decision-making and situational awareness. Based on a literature review it was posited that small IHEs may benefit from geospatial, map-based tools to support decision-making and foster collaboration with outside agencies when conditions prevent local emergency management teams from arriving on site.

A mixed methods sequential explanatory research design was undertaken and results were analyzed using parametric and non-parametric techniques combined with qualitative analysis in order to achieve the research goal. A prototype EMGIS was developed for use in a custom developed simulation of a HAZMAT crisis affecting a campus. Thirty participants were randomly assigned to a treatment group and a non-treatment group. The treatment group was trained on the use of the EMGIS for the simulation, the non-treatment group was trained on the use the 2016 Emergency Response Guidebook, paper maps of the scenario area, and an information binder about the buildings and the incident site. Several hypotheses were formulated to determine if the use of such a system by novices in a higher education context decreases critical decision-making time, increases decision accuracy and increases situational awareness when examined separately. Additionally, a research question was posed to explore how the use of an EMGIS impacts decision-making performance, as a function of time, accuracy and situational awareness taken together. Finally, a qualitative strand of research was pursued to gain an understanding of the perceived benefits and drawbacks of an Emergency Management GIS for the novice decision maker in a higher education context. A quasi-experimental approach was used for the conduct of the experiment and 30 of 49 participants were qualified as novice emergency management decision makers through a qualification questionnaire. Data was collected over a four-week time period and subsequently analyzed. A strong negative correlation between decision time and decision accuracy was found, indicating that as decision time increased, decision accuracy decreased. Parametric statistical techniques found a significant effect for the EMGIS group when compared to the nonEMGIS group on decision accuracy. Decision time nor situational awareness parametric tests yielded a significant difference in effect between groups.

DEA analysis was undertaken and the EMGIS group was associated with higher overall efficiency ratios. By comparison, the non-EMGIS group was associated with numerically lower overall efficiency ratios. Participant efficiency ratios were compared to the overall mean for both groups with a finding that more participants in the EMGIS grouped scored above the mean than the non-EMGIS group. This represents a 17% improvement in efficiency scores in the EMGIS group when considering decision performance as a ratio of decision time and the combined values of decision accuracy and situational awareness. Integration of the qualitative analysis of EMGIS participant interviews provided some insight into key issues for the EMGIS group in the use of the prototype system. Participants generally agreed that the EMGIS eased the burden of decision-making in the simulated crisis event and increased their understanding of the situation. Consistently, the theme of training or familiarization with the EMGIS was found. Potentially, the lack of familiarity and the complexity of the system mitigated the results of the experiment. However, given the obvious disadvantage of a lack of familiarity/usability, the EGMIS group outperformed the non-EMGIS group. Such a result may be magnified with longer training times with the EMGIS or better usability of the prototype system itself.

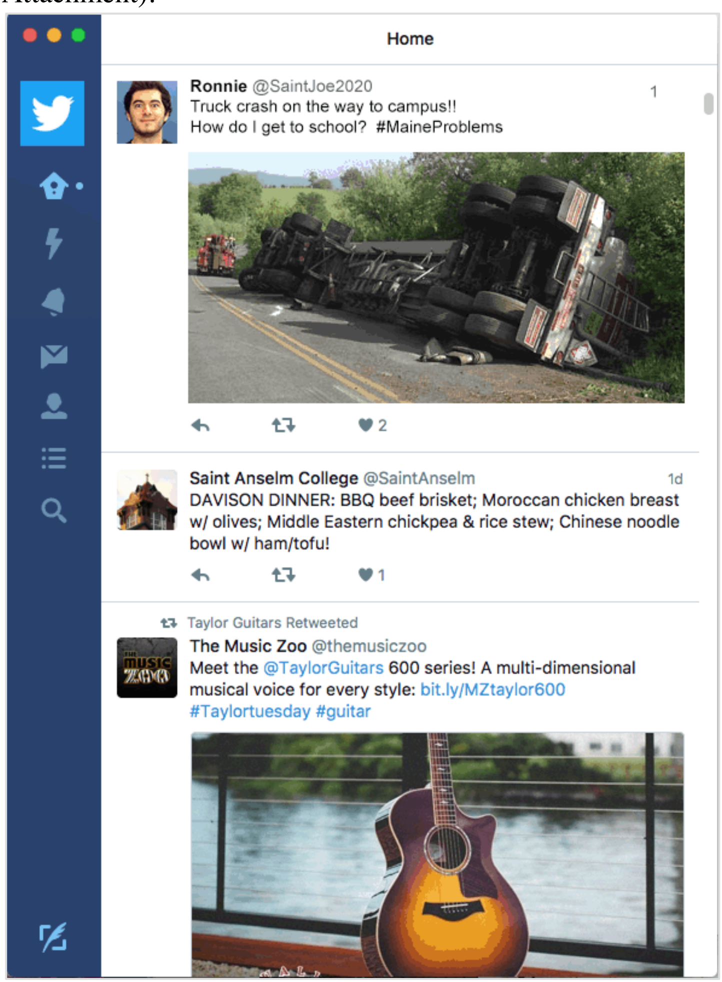
Novice crisis managers in small IHEs without emergency management may benefit from geospatial, map-based tools in the critical area of decision accuracy to support decision-making and foster collaboration with outside agencies when conditions prevent local emergency management teams from arriving on site.

Appendix A

Complete simulation scenario master situational event list.

Inject Properties	Inject Description
Inject #1 17:00:00 5/19/17 Bulletin Background	Background Information St. Joseph's College of Maine is a small, residential liberal arts college. The student population is 97% residential. The campus houses approximately 1,000 students in residence halls. You are the on call, on campus, Resident Director for St. Joseph's College Office of Residential Life tonight. Currently, half way through the semester, the College is a bustling place after classes with numerous student activities, athletic events and residence life programs in full swing. St. Joseph's College of Maine is located on 474 acres along the shore of beautiful Sebago Lake just north of Standish, Maine. It is eighteen miles northwest of Portland, Maine. Portland is the largest city in Maine and covers 68 square miles in geography. The Greater Portland metropolitan area is home to over half a million people, more than one-third of Maine's total population. Portland's location as the southern port of the state enhances its function as an industrial and residential hub with a significant amount of commercial zoning and light-industrial zoning. Because of its gateway location, Portland's transportation system also serves as a pass-through to counties to the North. A north-south Interstate, 95 runs to the West of Portland with a bypass, 295, running through downtown Portland. At the closest point, 95 is approximately 8 miles from the College. A popular route to points north west of Lake Sebago is 302. 302 and 202 form a path commonly used as a bypass route around potential traffic issues on 95. 302 is often used as route from 95 to points North and West of Sabego Lake and passes within 2 miles of the College. Numerous local side roads such as 35, and 115 connect with Route 302, which also serves as a major commuter route through the Sebago Lake region.

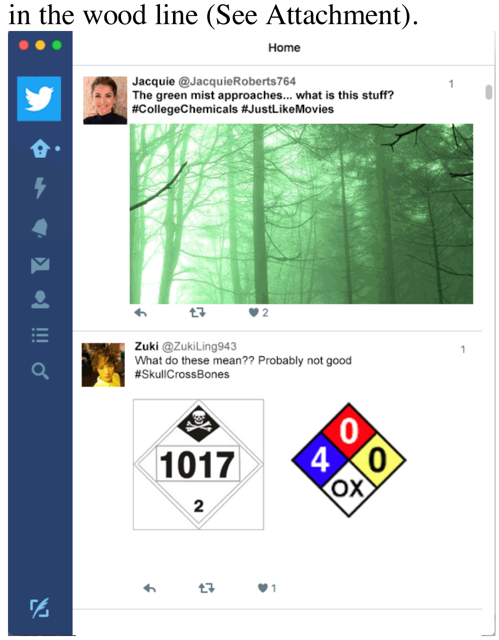
Inject Properties	Inject Description
2 17:02:00 5/19/17 Bulletin Incident Scenario	Incident Scenario It is 5:02 p.m. on Friday, April 19. The temperature is a warm 79 degrees, the sky is clear and sunny, and the humidity is 78 percent. The weather forecast for Portland calls for evening thunderstorms developing from the east. Wind speed is currently about 5mph blowing from the south east to the north west from about 180 degrees. There has been a major accident and fire on interstate 95 east of the College, Portland municipal assets as well as mutual aid assets from surrounding towns are responding and local hospitals are preparing for a mass casualty incident. Traffic has been rerouted from Northbound 95 to multiple side streets including route 302. A tractor trailer, unfamiliar with the 302 to 202 bypass route has missed the turn for 202 and has proceeded up 302 and turned onto 35 southbound looking for a place to turn around. The driver attempts to turn around at Nicholas Drive and Chadbourne Road (35) and jack knives the vehicle. The truck tips over the downward slope of the shoulder violently slamming the truck bed into the ground as it rolls onto its side off the road. The driver is uninjured and has radioed to his dispatcher to request offload assistance. The location of the tractor trailer is approximately 5000 feet (1 mile) from the north eastern most housing units (the uppers) on campus through a residential area and a wood line. The Uppers house approximately 600 students.
3 17:04:00 5/19/17 Phone Report of a vehicle accident in proximity to campus (M1)	It is 5:04 p.m. This is Campus Safety. The Local Police department just radioed me that a tractor trailer has overturned on Nicholas road and Chadbourne road not far from the College separated by the wood line. Our students often use the road to get to and from campus. The Police Department wants us to keep students away from the scene because it will be a while before they can get there due to the accident/fire on interstate 95. Since you are the on-duty Resident Director, I'd like to request that you spread the word through RAs to the residence halls. I am going to take a safety vehicle down White Bridge road, but as I'm the only safety officer on duty, I will need to make my rounds. The accident aftermath on I95 appears to be growing, I'm hearing chatter over police bands about smoke causing limited visibility and more accidents. They are closing 95 quite a ways south of the accident to redirect traffic. I hear there are some people in the area are moving toward the scene of the accident on Nicholas road to see what is happening.

Inject Properties	Inject Description
4 17:05:00 5/19/17 Phone Update from Campus Safety (M2)	It is 5:06 p.m., this is Campus Safety. Everything appears to be fine approaching the scene and there were a few small groups of students traveling the road leaving or coming to campus. Some of them had passed the accident scene. I intend to go closer to the vicinity of the crash site to check if any students are there. I can see the smoke in the sky to the East from whatever is happening on I95. I heard on the news that they were re-routing all north and south bound traffic. I recommend you relocate to the Communications Center on campus where you have access to phones, radios, local news, and informational materials. I'll keep you updated.
5 17:06:00 5/19/17 Bulletin Situation Update (M3)	It is 5:06 p.m., Campus Safety has moved some students along back to the residence halls that were near the scene. Several local residents near the crash site have also told students to stay away from the site. Some of the barrels from the truck are strewn about one of the property owner's land from the overturned tractor trailer. Students are beginning to post comments on social media (See Attachment). 

Inject Properties	Inject Description
6 17:06:00 5/19/17 Phone Local Police dispatch information bulletin (M2a)	It is 5:06pm. The local wild blueberry farm will be burn pruning the fields today, you might expect some mild smoke drifting over Saint Joseph's today based on the wind direction. The field is just East of Pearson's Town Farm. The farm has the required gallons of water on hand along with experienced personnel and the appropriate permits from the town of Standish. Some local residents have complained and we wanted to assure the school that the farm has the permits to burn.
7 17:07:00 5/19/17 Phone Director of Residence Life Calling (M2b)	It is 5:07pm. This is the Director of Residence life. I finally got through to you - I've been trying for 15 minutes but cell calls aren't going through. I'm on my way back in but I've run into a lot of traffic, I heard on the radio that there was bad accident on I95. I should be there shortly and I meet you in the Communications Center. Call drops...
8 17:08:00 5/19/17 Bulletin News Media Reports (M3a)	Some News crews have begun to report about a turned over tractor trailer on local news stations but are overshadowed by the major accident and fire on 95. News reports that there were at least 2 tractor trailers involved in the accident on 95, and multiple car pile ups. The highway has been shut down for emergency service crews in the middle of rush hour. There is a lot of thick smoke coming from the accident scene on I95.
9 17:08:00 5/19/17 Phone Campus Safety observation (M3b)	It is 5:08p.pm., On the way back to campus I noticed that there is some smoke coming through wood line south of Whites Bridge road , I suspect the tractor trailer may have caught fire or something after I left the area. Police will probably be there soon if they can break away from the I95 traffic control.
10 17:09:00 5/19/17 Bulletin DECISION POINT (1)	Instruction: Given what you know about the situation at this point, choose the BEST course of action below: A. Call 911 and report the incident information. B. Wait until more information is available. C. Call the Resident Assistants on duty in the Residence Halls to have them make sure that students stay away from the accident scene. D. Call Campus Safety to have an emergency notification go out over the load speaker and text messaging warning students to stay away from the accident scene.
11 17:10:00 5/19/17 Bulletin Situation Update (M4)	News media begin to report that there is some smoke emanating from the overturned truck and residents in the area are rushing away from the scene indicating they smell a mildly pungent odor. News media reports that it appears that at least four 55 gallon barrels have broken and are leaking their contents onto the ground. Campus Safety is stationed at a crossroad along the common entrance to campus and warning students to return to the

Inject Properties	Inject Description
	Campus via alternate routes. Campus Safety calls you to report the smoke appearing in the wood line east of campus and is currently directing student traffic away from the site. They are having trouble reaching you over cellular service as the lines appear to be jammed due to the accident and the fire on the interstate. The smoke from the I95 incident is clearly visible to the East of campus and concerning students. You have already called into the Director of Residence life. They did not answer but you left a voice mail message explaining what you currently know about the situation. Several students tweet photos containing the placards on the vehicle (See Attachment). 

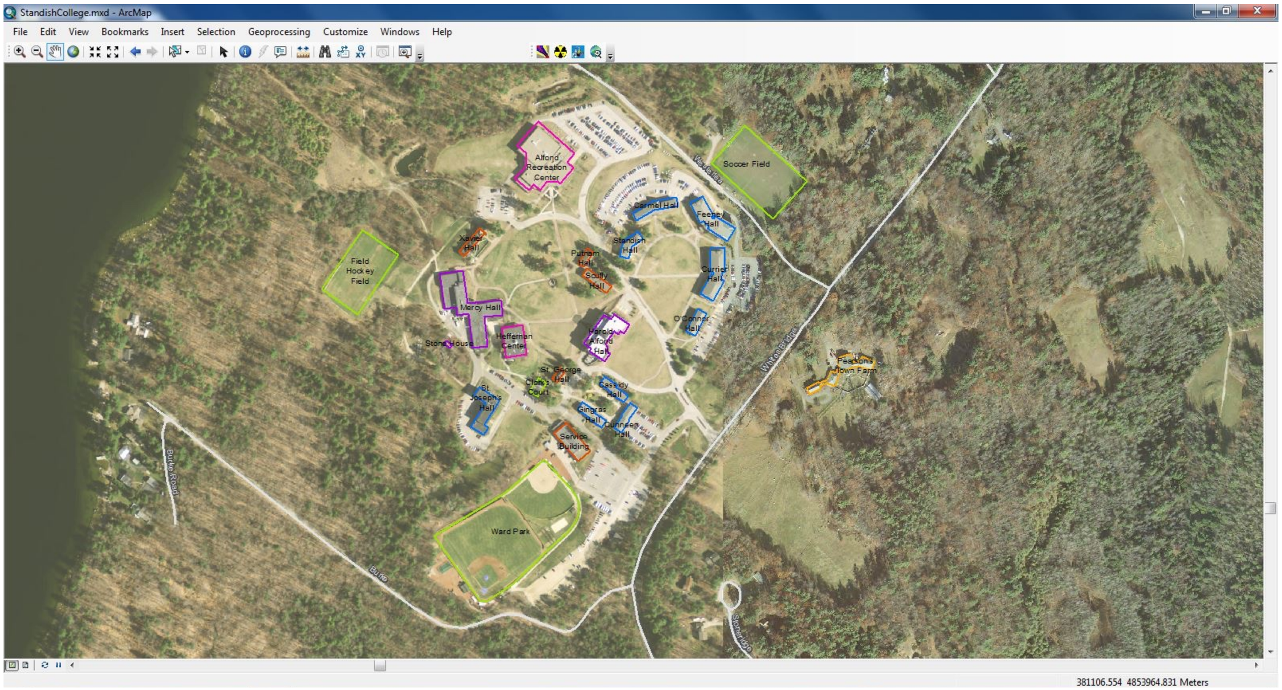
Inject Properties	Inject Description
12 17:11:00 5/19/17 Bulletin DECISION POINT (2)	Instruction: Given what you know about the situation at this point, choose the BEST course of action below: A. Send out a campus alert over the emergency notification system to have all students in the upper residence halls return to their residence halls and shelter in place. Instruct facilities to turn off resident hall air Handling systems. B. Send out a campus alert over the emergency notification system to have all students prepare to evacuate the upper residence halls. C. Wait and monitor the situation, there is not enough information to take action. D. Wait and monitor the situation, there is no threat to students at this time.
13 17:14:00 5/19/17 Phone Situation update (M5)	It is 5:14 p.m., The emergency on 95 has diverted resources but the Deputy Fire Chief is on scene at the tractor trailer accident site. The Deputy Chief has relayed to Campus Safety that the truck was carrying liquid chlorine and at least three barrels were thrown from the vehicle and are leaking. Given the prevailing winds, they recommend moving students out of the upper residence halls and getting them to a safe place. Potentially, around 200 gallons of chlorine could be leaked from the 4 fifty-five gallon barrels, producing a cloud plume that could reach campus. The Deputy Chief has called the state HAZMAT team. The local Emergency Operations Center in town is coordinating busses to move affected people out of the area. The state HAZMAT team will be on site in 20 minutes. Two additional Resident Directors have reported to your location in the Campus Communications Center.
14 17:15:00 5/19/17 Bulletin DECISION POINT (3)	Instruction: Given what you know about the situation at this point, choose the BEST course of action below: A. Send out a campus alert to have all students in the upper residence halls evacuate to Richard Ward Bailey Field/Park. B. Send out a campus alert to have all students in the upper residence halls evacuate to the green space between Alfond Hall and Heffernan Hall and wait further instructions. C. Send out a campus alert to have all students in the upper residence halls evacuate to the Field Hockey fields West of Mercy Hall. D. Wait and monitor the situation, there is no threat to students at this time and no need to cause panic.

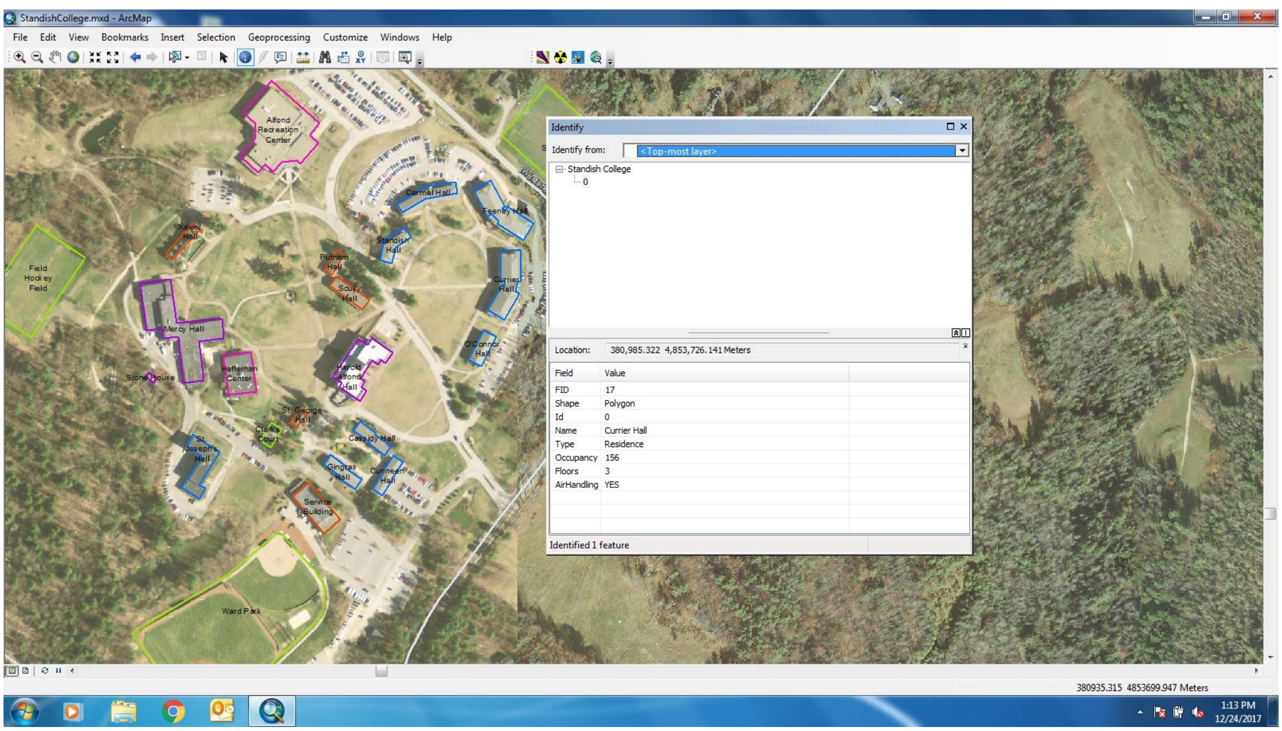
Inject Properties	Inject Description
15 17:17:00 5/19/17 Bulletin Situation Update (M6)	At 5:17 p.m., A campus wide alert was issued to have all students in the upper residence halls evacuate to the Ward Park fields. Students are moving to Ward Park athletic fields, there is confusion and some of the students who were moved away from the scene by Campus Safety are complaining that they are experiencing some stinging of the eyes and some difficulty breathing. Parents who are watching the media reports are calling the College and asking for information. Some parents are indicating that they belief the two incidents are connected. Many parents are indicating that they are having a hard time reaching their student by cell phone. The news media are gathering at the perimeter of the scene. Reports of what is happening are unclear. The HAZMAT team has not yet arrived. News personnel are reporting conflicting information. Some reporters state that the smoke is caused by a fire in the overturned tractor trailer and some are reporting that there is a chemical leaking and vaporizing. Several reports are indicating that residents are evacuating themselves and there are reports of people wheezing and having difficulty breathing. The buses that were coordinated by the Emergency Operations Center in town are arriving at Richard Ward Bailey Field/Park parking area. The drivers indicate that they have instructions to take passengers to Windham High School off route 202 which is southeast of the spill by about 3 miles. Tweets from the scene show the following mist in the wood line (See Attachment). 

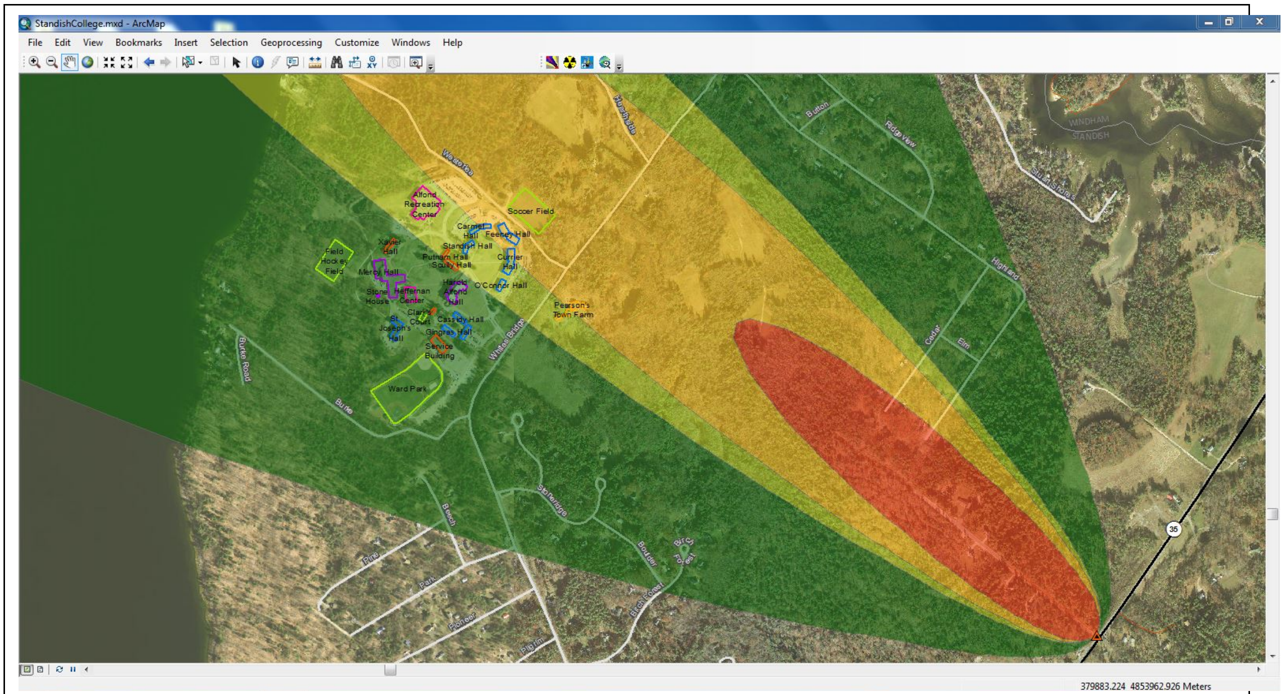
Inject Properties	Inject Description
16 17:18:00 5/19/17 Bulletin DECISION POINT (4)	Instruction: Assuming collaboration with Campus Safety, given what you know about the situation, choose the BEST course of action below: A. Send out a campus alert to have all non-emergency personnel on campus evacuate to the Richard Ward Bailey Field/Park and not to evacuate in their personally owned vehicles. B. Send out a campus alert to have only students on campus evacuate to the Richard Ward Bailey Field/Park if they do not have a vehicle. C. Send out a campus alert to have only students on campus evacuate to the Richard Ward Bailey Field/Park and not to evacuate in their personally owned vehicle. D. Wait and monitor the situation until local authorities, or the Director of Residence Life arrives to take over.
17 17:20:00 5/19/17 Phone HAZMAT Team Requests assistance (M7)	It is 5:20p.m., The HAZMAT team has arrived at the accident scene and confirmed that the chemical spill is liquid chlorine that has vaporized and is being drifted toward the northern portion of campus by the wind. There is not much time left before it could potentially reach campus. They are asking for a location on campus, away from the affected area, suitable to setup a decontamination station for any students or local citizens exposed to the chlorine gas.
18 17:21:00 5/19/17 Bulletin DECISION POINT (5)	Instruction: Given what you know about the situation, choose the BEST course of action below: A. Recommend the HAZMAT team setup in the south parking lot near Richard Ward Bailey Field/Park across from the Service building. B. Recommend the HAZMAT team setup at Richard Ward Bailey Field/Park. C. Recommend the HAZMAT team setup on the green space between Harold Alfond Hall and the Cassidy residence hall. D. Recommend the HAZMAT team setup at the Field Hockey field west of Mercy Hall.
19 17:23:00 5/19/17 Door Campus Safety Assume Incident Command (M8)	It is 5:23p.m., The Director of Campus Safety arrives at the Communications Center and assumes the Incident Commander role. You provide the Director with a briefing of all of the information you have and move to Richard Ward Bailey Field/Park to assist in the evacuation and possible decontamination of students.
20 17:30:00 5/19/17 Bulletin EXERCISE CONCLUSION	The exercise is concluded.

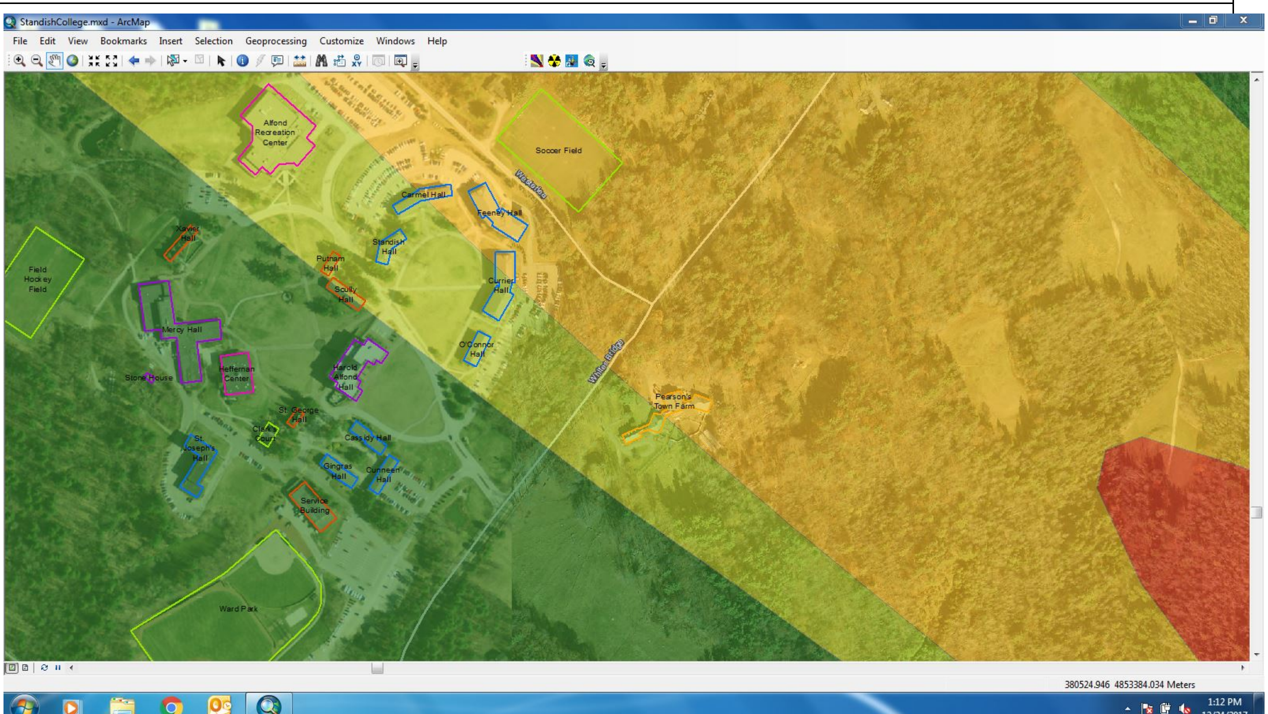
Appendix B

EMGIS Screen shots



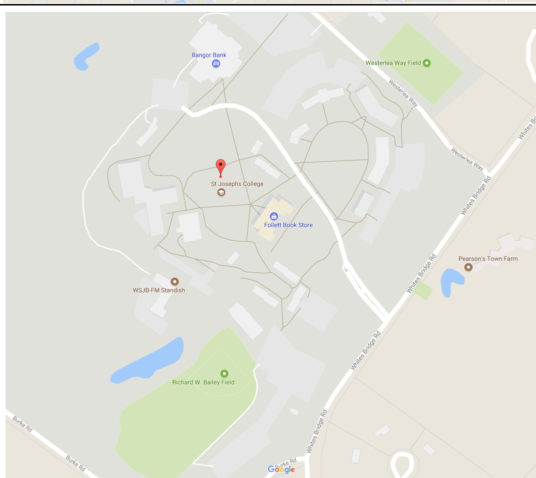


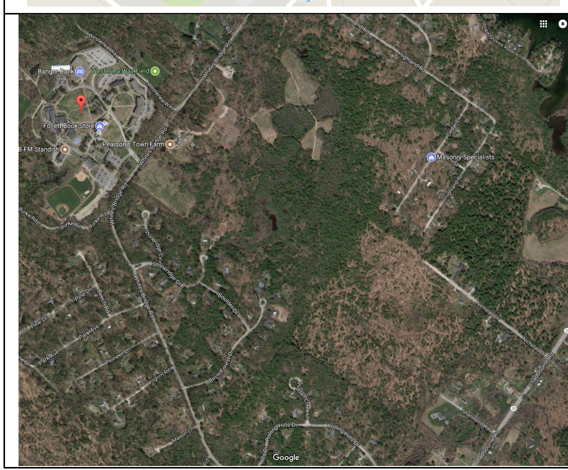

StandishCollege.mxd - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Alfond Recreation Center
Soccer Field
Carmel Hall
Feeney Hall
Standish Hall
Field Hockey Field
Mercy Hall
O'Connor Hall
Pearson's Town Farm
Ward Park
379883.224 4853962.926 Meters

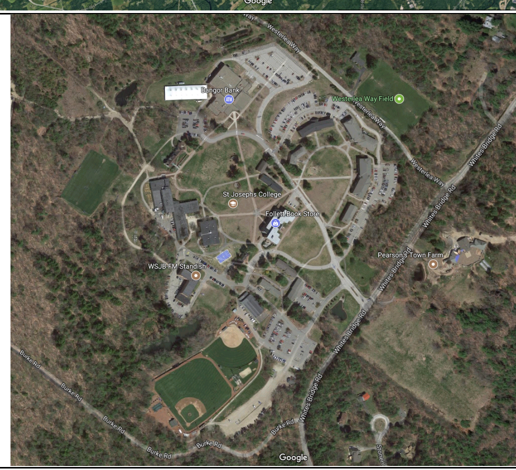

StandishCollege.mxd - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
Alfond Recreation Center
Soccer Field
Carmel Hall
Feeney Hall
Standish Hall
Putnam Hall
Scully Hall
Currier Hall
Field Hockey Field
Mercy Hall
Stone House
Heffernan Center
O'Connor Hall
Harold Alfond Hall
Pearson's Town Farm
St. Joseph's Hall
Cassidy Hall
Gingras Hall
Service Building
Ward Park
380524.946 4853384.034 Meters
1:12 PM
12/24/2017

Appendix C

Non EMGIS group Binder Sample







O'Connor Hall

O'Connor Hall features three floors of double rooms for students and a lounge, perfect for studying or hanging out with friends.

Building Name	Type	Occupancy	Floors	Air Handling
O'Connor Hall	Residence	83	2	YES

Xavier Hall

Historic Xavier Hall houses the president's and deans' offices, as well as the Alumni and Human Resources offices. This historic property also features a luxurious meeting space for College and community events. At the western edge of campus, Xavier Hall overlooks expansive Sebago Lake.

Academic Deans Office
207-893-6643

Human Resource
207-893-7757
sjcemployment@sjcme.edu

President's Office
207-893-7711

Building Name	Type	Occupancy	Floors	Air Handling
Xavier Hall	Administration	15	1	NO

Appendix D

Situational Awareness Rating Technique

Instability of the Situation

How changeable was the situation? Was the situation highly unstable and likely to change suddenly (High) or was it very stable and straightforward (Low)?

Low High

1 2 3 4 5 6 7

Complexity of the Situation

How complicated was the situation? Was it complex with many interrelated components (High) or was it simple and straightforward (Low)?

Low High

1 2 3 4 5 6 7

Variability of the Situation

How many variables were involved in the situation? Were there a large number of factors that required attention (High) or were there few factors that required attention (Low)?

Low High

1 2 3 4 5 6 7

Arousal

How aroused were you in the situation? Where you alert and ready for activity (High) or did you have a low degree of alertness (Low)?

Low High

1 2 3 4 5 6 7

Spare Mental Capacity

How much mental capacity did you have to spare in the situation? Did you have sufficient capacity to attend to many variables (High) or did the situation required your full mental capacity with nothing left to spare (Low)?

Low High

1 2 3 4 5 6 7

Concentration of Attention

How much were you concentrating in the situation? Were your thoughts intently focused in the situation (High) or not very intently focused in the situation (Low)?

Low High

1 2 3 4 5 6 7

Division of Attention

How much was your attention divided in the situation? Were you attending to many aspects of the situation at the same time (High) or were you attending to only a few aspects at a time (Low)?

Low High

1 2 3 4 5 6 7

Information Quantity

How much information did you gain about the situation? Did you receive and understand a great deal of knowledge (High) or very little (Low)?

Low High

1 2 3 4 5 6 7

Information Quality

How valuable was the knowledge you gained in the situation? Was the information very valuable to the situation (High) or not very valuable (Low)?

Low High

1 2 3 4 5 6 7

Familiarity with the Situation

How familiar were you with the situation? Did you have a great deal of relevant experience (High) or was the situation relatively new (Low)?

Low High

1 2 3 4 5 6 7

Appendix E

Nova Southeastern IRB Exemption Letter

NSU

MEMORANDUM

To: **Adam Albina**

From: **Ling Wang, Ph.D.,**
Center Representative, Institutional Review Board

Date: **June 9, 2017**

Re: **IRB #: 2017-377; Title, "Assessing the Impact of a Geospatial Information System for Improving Campus Emergency Decision-Making of Novice Crisis Managers"**

I have reviewed the above-referenced research protocol at the center level. Based on the information provided, I have determined that this study is exempt from further IRB review under **45 CFR 46.101(b) (Exempt Category 1)**. You may proceed with your study as described to the IRB. As principal investigator, you must adhere to the following requirements:

1) CONSENT: If recruitment procedures include consent forms, they must be obtained in such a manner that they are clearly understood by the subjects and the process affords subjects the opportunity to ask questions, obtain detailed answers from those directly involved in the research, and have sufficient time to consider their participation after they have been provided this information. The subjects must be given a copy of the signed consent document, and a copy must be placed in a secure file separate from de-identified participant information. Record of informed consent must be retained for a minimum of three years from the conclusion of the study.

2) ADVERSE EVENTS/UNANTICIPATED PROBLEMS: The principal investigator is required to notify the IRB chair and me (954-262-5369 and Ling Wang, Ph.D., respectively) of any adverse reactions or unanticipated events that may develop as a result of this study. Reactions or events may include, but are not limited to, injury, depression as a result of participation in the study, life-threatening situation, death, or loss of confidentiality/anonymity of subject. Approval may be withdrawn if the problem is serious.

3) AMENDMENTS: Any changes in the study (e.g., procedures, number or types of subjects, consent forms, investigators, etc.) must be approved by the IRB prior to implementation. Please be advised that changes in a study may require further review depending on the nature of the change. Please contact me with any questions regarding amendments or changes to your study.

The NSU IRB is in compliance with the requirements for the protection of human subjects prescribed in Part 46 of Title 45 of the Code of Federal Regulations (45 CFR 46) revised June 18, 1991.

Cc: Gertrude Abramson, Ed.D.
Ling Wang, Ph.D.

3301 College Avenue • Fort Lauderdale, Florida 33314-7796
(954) 262-0000 • 800-672-7223, ext. 5369 • Email: *irb@nova.edu* • Web site: www.nova.edu/irb

Appendix F

Saint Anselm College IRB Exempt Letter

SAINT ANSELM COLLEGE 1889

INSTITUTIONAL REVIEW BOARD

100 Saint Anselm Drive, Manchester, New Hampshire 03102-1310 • 603-641-7000 • www.anselm.edu

Adam R. Albina
Chief Information Officer
Saint Anselm College

June 22, 2017

Dear Mr. Albina,

I have reviewed your application to the Saint Anselm College Institutional Review Board (IRB) regarding your project *Emergency Management in Higher Education.* Since the project has already been reviewed by the Institutional Review Board at Nova Southeastern University (NSU) they will be the IRB of record. Their review indicated that the project was exempt under 45 CFR 46.101 (b) and further review by the Saint Anselm College IRB is therefore not necessary. I assume that any amendments to the project or unanticipated events or problems that affect the risks to human subjects will be reported to the IRB at NSU as indicated in their letter of exemption.

Sincerely,

Erik Cleven, PhD
Chair, Institutional Review Board
Saint Anselm College

Appendix G
Study Site Permission Letter

SAINT ANSELM COLLEGE
1889

STUDENT AFFAIRS

100 Saint Anselm Drive, Manchester, New Hampshire 03102-1310
Phone: 603-641-7000 • www.anselm.edu

May 31, 2017

Saint Anselm College
100 Saint Anselm Drive
Manchester, NH 13012

Subject: Site Approval Letter

To whom it may concern:

This letter acknowledges that I have received and reviewed a request by Adam R. Albina to conduct a research project entitled "Emergency Management in Higher Education" at Saint Anselm College and I approve of this research to be conducted at our facility.

When the researcher receives approval for his research project from the Nova Southeastern University's Institutional Review Board/NSU IRB, and the Saint Anselm College IRB,, I agree to provide access for the approved research project. If we have any concerns or need additional information, we will contact the Nova Southeastern University's IRB at (954) 262-5369 or irb@nova.edu.

Sincerely,

Joseph M. Horton, Ed.D.
Vice President of Student Affairs
jhorton@anselm.edu
603-641-7600

Appendix H
Qualification Questionnaire

Emergency Management Systems in Higher Education

Dear Potential Participant,

I am contacting you because of your experience in higher education and your potential involvement in handling emergency or crisis situations which may or may not be part of your normal work duties.

This decision support research participation survey which you are being asked to complete will serve as guide for the random selection of participants for a study. The study is focused on the technology and tools that might assist a decision maker in an emergency situation in a higher education context. The purpose of this study is to gain a better understanding of the relationships between technology and decision making in a simulated scenario based emergency management situation.

If you are selected for the study to be conducted in the Fall of 2017, your participation in this study will consist of taking part in a computer based scripted simulation of an emergency situation in a higher education context. The simulation will be text based in terms of events with visual aids to clarify the situation. Content will not be graphic or disturbing and visualization will not include any virtual reality visualization or gaming constructs. Participation is expected to take between 30 and 45 minutes, although there is no time limit. You are required to complete the questionnaire below to qualify for the study. All participants selected for and subsequently participating in the study will receive remuneration of twenty-five dollars in the form of a gift card. During the actual study you may discontinue your participation at any time. Your participation is strictly voluntary. There is no penalty for discontinuing participation and remuneration will still be provided if you opt out during the study.

Your name and identifying information will not be associated with any part of the written report of the research. All of your information, results and interview responses will be kept confidential. All data will be assured of anonymity, stored in an encrypted format, and destroyed when no longer required.

By continuing below, you acknowledge that you have read and understand the above information. You are aware that you can discontinue your participation in the study at any time. Participants selected will be notified in order to schedule your participation.

Thank you for your participation.

Adam R. Albina
Ph.D. Candidate in Information Systems
College of Engineering and Computing
Nova Southeastern University

How many full time resident students live at the campus at which you work?

- ○ 1-500
- ○ Greater Than 500 less than 1,000
- ○ Greater than 1,000 but less than 2,000
- ○ Greater than 2,000 but less than 3,000
- ○ Greater than 3,000 but less than 5,000
- ○ Greater than 5,000 but less than 10,000
- ○ Greater than 10,000
- ○ Click to write Choice 8

Does your institution have a dedicated Office of Emergency Management separate from Campus Safety or Security?

- ○ Yes
- ○ No

Do you work in the Office of Emergency Management at your institution?

- ○ Yes

- No

Block 1

Have you had any formal emergency management training? (Formal training consists of College level curricular course work, professional certifications, academic degrees, FEMA certifications such as CEM).

- Yes
- No

Have you had any informal training in emergency management? (Informal training consists of on-line NIMS training, local workshops, or professional development seminars and the like.)

- Yes
- No

How many training exercises in emergency management or crisis response have you participated in? (Exercises include sand table, virtual table top, full physical simulations with local emergency agencies, or campus wide on-the-ground simulations.)

- None
- 1-2
- 3-4
- 5-6
- More than 6

How many emergency management situations have you managed in your career as the incident commander? (A qualifying event would be a flood, tornado, hurricane, or other natural disaster, campus shooter, facility collapse, mass casualty, or chemical disaster.)

- None
- 1-2
- 3-4

- 5-6
- More than 6

Block 2

Have you ever served in US or other country's Armed Forces and received training in combat operations, combat support or emergency management?

- Yes
- No

Are you now serving in the Armed Forces?

- Yes
- No

Have you ever worked as a police officer, emergency medical technician (EMT), paramedic, or firefighter?

- Yes
- No

What is your year of birth?

What is the highest level of school you have completed or the highest degree you have received?

- Less than high school degree
- High school graduate (high school diploma or equivalent including GED)
- Some college but no degree
- Associate degree in college (2-year)
- Bachelor's degree in college (4-year)

- Master's degree
- Doctoral degree
- Professional degree (JD, MD)

What is your gender?

- Male
- Female

Appendix I

NonEMGIS and EMGIS Group Consent Forms

NOVA SOUTHEASTERN UNIVERSITY
College of Engineering and Computing

Consent Form for Participation in the Research Study Entitled
Emergency Management in Higher Education

Funding Source: None.

IRB protocol # 2017-377

Principal investigator
Adam R. Albina
100 Saint Anselm Drive
Manchester, NH 03102
(603) 641-7266

Co-investigator
Gertrude Abramson, Ed.D.
3301 College Avenue
Fort Lauderdale, FL 33314
(954) 262-2070

For questions/concerns about your research rights, contact:
Human Research Oversight Board (Institutional Review Board or IRB)
Nova Southeastern University
(954) 262-5369/Toll Free: 866-499-0790
IRB@nsu.nova.edu

Site Information
Saint Anselm College
Office of Information Technology
100 Saint Anselm Drive
Manchester, NH 03102

What is the study about?

The study is focused on the technology and tools that might assist a decision maker in an emergency situation in a higher education context. The purpose of this study is to gain a better understanding of the relationships between technology and decision making in a simulated scenario based emergency management situation.

Why are you asking me?

We are inviting you to participate because of your experience in higher education in potentially handling emergency or crisis situations as part of your work duties. There will be between 30 and 40 participants in this research study.

Initials: ________ **Date:** ________

What will I be doing if I agree to be in the study?

Your participation in this study will consist of taking part in a computer based scripted simulation of an emergency situation in a higher education context. The simulation will be text based in terms of events with visual aids to clarify the situation. Content will not be graphic or disturbing and will not include any virtual reality environments nor any video gaming activities. Participation is expected to take between 45 and 60 minutes, although there is no time limit. You will be asked to make decisions during the simulation based on the information provided. You will answer a 10-question survey during and after the simulation. You will not be graded on your decisions.

Is there any audio or video recording?

No.

What are the dangers to me?

Risks to you are minimal, meaning they are not thought to be greater than other risks you experience every day. If you have questions about the research, your research rights, or if you experience an injury because of the research please contact Mr. Albina at (603) 641-7266. You may also contact the IRB at the numbers indicated above with questions about your research rights.

Are there any benefits to me for taking part in this research study?

There are no benefits to you for participating.

Will I get paid for being in the study? Will it cost me anything?

You will receive a payment of 25.00 dollars for your participation in this study, there are no costs associated with participating in the study.

How will you keep my information private?

The questionnaire will not ask you for any information that could be linked to you. Your decision responses during the scenario will not have any information that could be linked to you. All information will be encrypted when not in use and will be destroyed 36 months after the study ends. All information obtained in this study is strictly confidential unless disclosure is required by law. The IRB, regulatory agencies, or Dr. Abramson may review research records.

What if I do not want to participate or I want to leave the study?

You have the right to leave this study at any time or refuse to participate. If you do decide to leave or you decide not to participate, you will not experience any penalty or loss of services you have a right to receive. If you choose to withdraw, any information collected about you **before** the date you leave the study will be kept in the research records for 36 months from the conclusion of the study and may be used as a part of the research. Remuneration will be provided even if you choose to leave the study after the simulation has begun.

Other Considerations:

Initials: ________ **Date:** ________

3301 College Avenue • Fort Lauderdale, Florida 33314-7796
(954) 262-2000 • 800-541-6682, ext. 2000 • Fax: (954) 262-3915 • Web site: *www.cec.nova.edu*

If the researchers learn anything which might change your mind about being involved, you will be told of this information.

Voluntary Consent by Participant:

By signing below, you indicate that

- this study has been explained to you
- you have read this document or it has been read to you
- your questions about this research study have been answered
- you have been told that you may ask the researchers any study related questions in the future or contact them in the event of a research-related injury
- you have been told that you may ask Institutional Review Board (IRB) personnel questions about your study rights
- you are entitled to a copy of this form after you have read and signed it
- you voluntarily agree to participate in the study entitled *Emergency Management in Higher Education*

Participant's Signature: ___________________________ Date: ________________

Participant’s Name: ______________________________ Date: ________________

Signature of Person Obtaining Consent: _____________________________

Date: ___________________________

3301 College Avenue • Fort Lauderdale, Florida 33314-7796
(954) 262-2000 • 800-541-6682, ext. 2000 • Fax: (954) 262-3915 • Web site: *www.cec.nova.edu*

NOVA SOUTHEASTERN UNIVERSITY
College of Engineering and Computing

Consent Form for Participation in the Research Study Entitled
Emergency Management in Higher Education

Funding Source: None.

IRB protocol # 2017-377

Principal investigator
Adam R. Albina
100 Saint Anselm Drive
Manchester, NH 03102
(603) 641-7266

Co-investigator
Gertrude Abramson, Ed.D.
3301 College Avenue
Fort Lauderdale, FL 33314
(954) 262-2070

For questions/concerns about your research rights, contact:
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Nova Southeastern University
(954) 262-5369/Toll Free: 866-499-0790
IRB@nsu.nova.edu

Site Information
Saint Anselm College
Office of Information Technology
100 Saint Anselm Drive
Manchester, NH 03102

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We are inviting you to participate because of your experience in higher education in potentially handling emergency or crisis situations as part of your work duties. There will be between 30 and 40 participants in this research study.

Initials: ________ **Date:** ________

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Your participation in this study will consist of taking part in a computer based scripted simulation of an emergency situation in a higher education context. The simulation will be text based in terms of events with visual aids to clarify the situation. Content will not be graphic or disturbing and will not include any virtual reality environments nor any video gaming activities. Participation is expected to take between 45 and 60 minutes, although there is no time limit. You will be asked to make decisions during the simulation based on the information provided. You will answer a 10-question survey during and after the simulation. You may also be interviewed by the researcher, Mr. Adam Albina. Mr. Albina will ask you questions about your experience with the simulation and technology tools provided. You will not be graded on your decisions, and interview questions will be about your experience not the scenario. The interview will last no more than 15 minutes.

Is there any audio or video recording?

This research project will include digital audio recording of any interviews. This audio recording will be available to be heard by the researcher, Mr. Adam Albina, personnel from the IRB, and the dissertation chair, Dr. Gertrude Abramson. The recording will be transcribed by professional transcription service into a text document. The transcription service will not be provided with your name nor will your name appear in the audio recording. Audio recordings will be encrypted by the researcher Mr. Adam Albina when not in use. The recording will be kept for 36 months from the end of the study. The recording will be destroyed after that time by digital shredding. Because your voice will be potentially identifiable by anyone who hears the recording, your confidentiality for things you say on the recording cannot be guaranteed although the researcher will limit access to the tape as described in this paragraph.

What are the dangers to me?

Risks to you are minimal, meaning they are not thought to be greater than other risks you experience every day. Being recorded means that confidentiality cannot be promised. If you have questions about the research, your research rights, or if you experience an injury because of the research please contact Mr. Albina at (603) 641-7266. You may also contact the IRB at the numbers indicated above with questions about your research rights.

Are there any benefits to me for taking part in this research study?

There are no benefits to you for participating.

Will I get paid for being in the study? Will it cost me anything?

You will receive a payment of 25.00 dollars for your participation in this study, there are no costs associated with participating in the study.

How will you keep my information private?

The questionnaire will not ask you for any information that could be linked to you. The transcripts of the audio recording will not have any information that could be linked to you. Your decision responses during the scenario will not have any information that could be linked to you. The interviews will not

Initials: ________ **Date:** ________

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have any information that could be linked to you. As mentioned, the recordings will be encrypted when not in use and will be destroyed 36 months after the study ends. All information obtained in this study is strictly confidential unless disclosure is required by law. The IRB, regulatory agencies, or Dr. Abramson may review research records.

What if I do not want to participate or I want to leave the study?

You have the right to leave this study at any time or refuse to participate. If you do decide to leave or you decide not to participate, you will not experience any penalty or loss of services you have a right to receive. If you choose to withdraw, any information collected about you **before** the date you leave the study will be kept in the research records for 36 months from the conclusion of the study and may be used as a part of the research. Remuneration will be provided even if you choose to leave the study after the simulation has begun.

Other Considerations:

If the researchers learn anything which might change your mind about being involved, you will be told of this information.

Voluntary Consent by Participant:

By signing below, you indicate that

- this study has been explained to you
- you have read this document or it has been read to you
- your questions about this research study have been answered
- you have been told that you may ask the researchers any study related questions in the future or contact them in the event of a research-related injury
- you have been told that you may ask Institutional Review Board (IRB) personnel questions about your study rights
- you are entitled to a copy of this form after you have read and signed it
- you voluntarily agree to participate in the study entitled *Emergency Management in Higher Education*

Participant's Signature: ___________________________ Date: ________________

Participant's Name: ______________________________ Date: ________________

Signature of Person Obtaining Consent: _____________________________

Date: ___________________________

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Appendix J

Interview Protocol: Post Experiment Interview Guide.

Time of interview: _________

Date: _________

Location: ____________________________

Interviewer: ________________

Subject_ID: [ ]

Questions:

- What were your general impressions of the map based information system you used in the scenario?
- How do you think the map based system affected your understanding of the situation?
- How did the use of the map based system affect your decision-making?
- Do you think there would be advantages to a map based information system in a higher education emergency? What might they be?
- Are there disadvantages to a map based information system in a higher education emergency? What might they be?

Appendix K

Scenario Validation Expert Feedback

Validation of the HAZMAT scenario

Inject	Source	Feedback	Mitigation Action
Incident Scenario			
	Director Campus Safety	Insufficient information to plausibly explain why local resources are unable to provide assistance.	Expanded the scope of the distracting fire and accident up on a nearby highway.
	SRT/EMS Member	Incorrect placement of distracting fire and accident for plausible re-routing of the HAZMAT tractor trailer.	Corrected distraction location to better support traffic re-routing.
	Director of Residence Life	There is no mention of the number of students housed in the residence halls that are affected.	Added 300 students to the as the number of students in housed in the residence halls affected.
Message 1			
	Director Campus Safety	Local Police wouldn't call Residence Life to report the overturned tractor trailer.	Changed student to Campus Safety Officer who was contacted. Campus Safety then contacted Residence Life.
Message 3			
	Director of Residence Life	On duty Resident Directors (RD[b]) would probably spread the word for RAs[a] to assist in getting students away from the over turned truck.	Changed the inject o include RAs spreading the word to students.
Decision Point 1			
	Director of Campus Safety/SRT EMS member	Although C is the best answer, RDs will likely choose A to call 911 forgetting that the Police called them in the opening of the scenario.	No Action
	Director of Residence Life	Disagreed that RDs would choose A, it's just a vehicle accident at this point. Agreed that C is the best answer.	No Action
Message 4			
	Director of Campus Safety	Indicated most communication would now be taking place over cellular – consider	Added suggested statement. Explained that the participants will have access to materials in

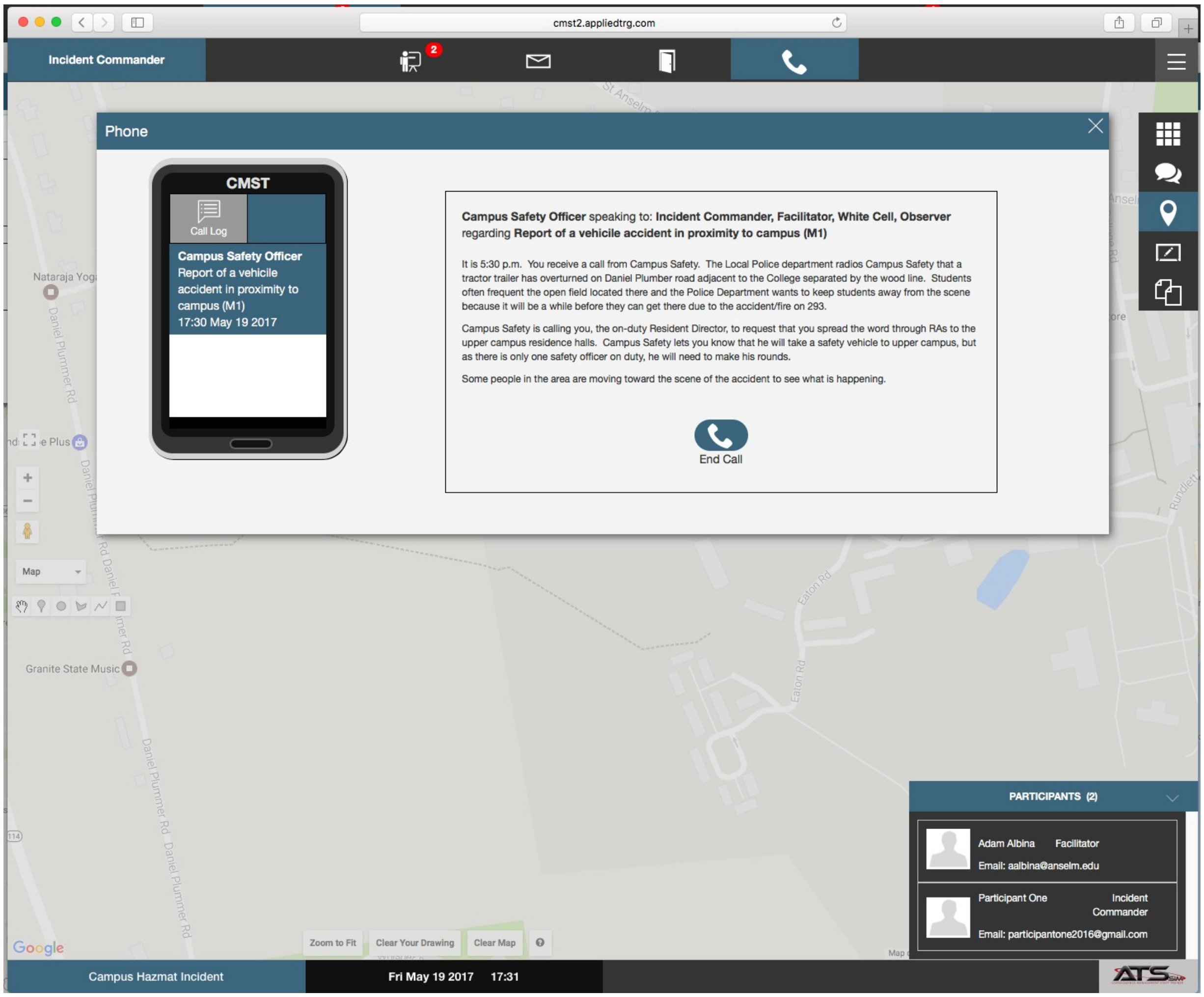
		jammed lines. Most staff won't know that the placard means chlorine.	which they can look up the information.
	Director of Residence Life	Noted that at this point, the RD would have reported up the chain of command looking for help. Stated that most staff would not know what the placards mean but they would know it's bad.	Added that the RD has tried to reach the Director of Residence Life and left a message. Explained that the participants will have access to materials in which they can look up the information.
	SRT/EMS Member	Immediately asked if the wind speed and direction had been provided. Suggested that the wind be further North or we would need to do an immediate evacuation of all of campus.	Pointed out the information in the incident scenario brief. Changed the wind direction slightly.
Decision Point 2			
	All	Agreed the best choice was B.	No Action.
Message 5	Director of Campus Safety	Indicated that the Fire would likely be first on the scene and they would call HAZMAT. Indicated that Fire might coordinate transportation for affected people but not specifically for students.	Modified the inject to have the Deputy Fire Chief on scene issuing instructions. Changed students affected to personnel affected.
	Director of Residence Life	Indicated that other staff members would be assisting at this point.	Added other staff members to the inject.
Decision Point 3			
	All	Agreed that A was the best answer.	No Action.
Message 6			
	Director of Campus Safety	Indicated that parents would probably not be driving to campus at to pick up students at this point.	Removed the sentence from the inject.
Decision Point 4			
	All	Agreed that A was the best answer.	No Action
Message 7			
	Director of Campus Safety	Commented that a triage point would likely be setup and EMS for treatment, we would probably need to accommodate more than decontamination.	Modified the scenario to specify that the decision was for decontamination only.

	SRT/EMS Member	Commented that any treatment concerns would be a transport immediately – they would not be equipped to treat on site for HAZMAT.	No Action.
Decision Point 5			
	All	Agreed that A was the best answer.	
General Comments			
	FEMA EMI Program Director	Indicated that a self-correcting scenario may affect post-scenario SA. Recommended an additional SART measurement mid-scenario.	Modified methodology to include mid-scenario measurement of SART.
	SRT/EMS Member	Commented that sometimes there are 2 choices that could be correct. Each Decision Point should state choose the *best* answer.	Noted.

Note: [a] Resident Assistant are students. [b] Resident Directors are staff members.

Appendix L

Consequences Management Staff Trainer Software Screenshot



Appendix M

Experimental Timing Sheet

Stat	#	Information Inject
	1	**Background** 17:00
	2	**Incident Scenario** 17:02
	3	**Report of vehicle accident in proximity to campus (M1)** 17:04
	4	**Update from Campus Safety (M2)** 17:05
	5	**-Local Police dispatch information bulletin (M2a)** 17:06 **-Situation Update M3)** 17:06
	6	**Director of Residence Life Calling (M2b)** 17:07
	7	**-News Media Reports (M3a)** 17:08 **-Campus Safety Observation (M3b)** 17:08
	8	***DECISION POINT 1 (17:09): Time:*** *Reset Timer*
	9	**Situation Update (M4)** 17:10
	10	***DECISION POINT 2 (17:11): Time:*** *Reset Timer*
	11	**Situation Update (M5)** 17:14
	12	***DECISION POINT 3 (17:15): Time:*** *Reset Timer*
	13	**Situation Update (M6)** 17:17
	14	***DECISION POINT 4 (17:18): Time:*** *Reset Timer*
	15	**HAZMAT Team Requests assistance (M7)** 17:20
	16	***DECISION POINT 5 (17:21): Time:*** *Reset Timer*
	17	**Campus Safety Assumes Incident Command (M8)** 17:23
	18	**Exercise Conclusion** 17:30
	19	***Administer SART Instrument***

Appendix N

Open Coding EMGIS Group Interviews

Open code	**Properties**	**Examples of participant's words**
Impact on Decision-making	Ease of decision choices.	"easier for me to make decisions" "helped me know where to send people"
	Higher decision confidence.	"I became more confident in my decision-making"
	Good visual aid for decision-making.	"the area of effect thing was definitely helpful" "it makes it very clear where the most danger is"
	Better decisions.	"better decision-making" "increasing information-driven or data-driven decisions in an emergency" "big impact on every decision made"
	Faster decisions.	"helped make decisions quicker"
System Challenges	Training and Familiarity.	"if I had been more familiar with it" if I had more time to be familiar with it – it would have been more helpful" "had more time with it" "People would need to be trained on using it" "it slowed me down a little initially because I was trying to find where the tuck actually had tipped over"
	Realism.	"you're not going to be sitting at a computer in an emergency" timing – what kind of time do you have" "All those systems are already in place to tell you what to do"
	Geospatial contextual understanding	"granted that north, south, east, west is a challenge" "trying to see where everything is and getting the full scope of it, was a little bit of a challenge" "getting precise coordinates in an event ... would probably be difficult" less useful.. "inside a building as opposed to outdoor activity"

Open code	Properties	Examples of participant's words
		"take me a long while to figure out where the accident did take place"
	Expensive.	"if it's really expensive"
	Power reliance.	"if there's a power outage" "internet outage" "servers go down…" "Power surge…" "like last week when none of us had power…"
	Mobility	"spending a little too much time working on a screen instead of getting into action" "or even if it's a laptop – you're not going to be sitting…"
	Over reliance.	"may shift the thinking... simulation vs actuals… and tools at your fingertips" "you don't have access to it…" "rely too much on this information without listening to authorities…" "so locked in that you're taking forever to try to make the absolute best decision that you can"
System Efficacy	Usefulness in an emergency	"helpful" "But overall, I thought it was very helpful" I thought it was very helpful" "having something that's pretty clear cut and helpful is important" "It was definitely very useful" "you can use to determine the best course of action from there" "informative, useful, flexible" "I think the map information was very helpful" "I think that it would give crisis management coordinators the opportunity to project what might happen…" "help a lot of lower level people make decisions if they had to make decisions" "I think there's more pors than cons to it"
	Feature Benefits	

Open code	**Properties**	**Examples of participant's words**
		"the colors were beneficial in order to kind of see the severity" "able to see your whole campus" "to be able to determine the most appropriate place to get your students to…"
	Geospatial context	"giving you and aerial view of where everything is" "gives you lots of relevant information" "it gave me a lot of context around where everything was in relation to where I was" "where the accident was in relation to the campus and the potential placement of our students" "our campus facilities in relation to the potential chemical exposure" "based on where the accident was" "being able to see the map there"
	HAZMAT information	"helpful to see where the pools of the chlorine were going to flow" "to see where the possibilities of contamination would be" "able to identify what chemicals were happening and how that would affect our camps" "Danger zones in relation to both where the students are living and what options are for moving students away" "the green area definitely, obviously, it's the safe zone for where students could go and that kind of helped me understand what areas were safe." "being able to overlay the chemical data and the cloud area for the hazard was nice to be able to see"
	Option awareness	"it does give you an overview of what your options are" "what's out there for possibilities"
	Weather visibility	"being able to kind of see how much of a presence weather really played in the situation, that was very very helpful"

Open code	Properties	Examples of participant's words
		"where the chemical fumes would be spreading based on the weather conditions"
Situational Awareness	Understanding	"it definitely helped" "I would have no idea what was going on without it" "gave me a lot greater understanding of the situation" "without the idea of wind direction affecting how the incident was unfolding, I wouldn't have had the wherewithal to understand that…" "a good idea of how severe the situation... it could have been" "easiest to kind of understand where students should be going" "helped kind of understand where this issue is going to go" "where my people would be safe and far enough away that if something did change we could be in a better situation" "I'm a visual person so seeing it on screens is much better"

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