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USING DISASTER SCENARIOS TO CREATE A STRATEGIC PLAN FOR A MOBILE GIS-BASED EMERGENCY RESPONSE SYSTEM

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ABSTRACT: *Hurricane Sandy hit an unprepared New York City and Long Island on October 29, 2012. Unlike previous disasters that have hit the tri-state area since 2001, GIS technologies were more widely used for managing this disaster. Unfortunately, the usefulness of GIS during the response and recovery period immediately following was lessened by the lack of preparedness by local governments and their agencies. This paper will describe how GIS was used during Hurricane Sandy to respond and mitigate its impact in the New York area. This research, and the lessons learned from it, will be used to present a strategic plan for a new GIS system that leverages new technological and social trends as part of a new emergency management system. A disaster scenario will be presented that mimics disaster conditions, and demonstrates how mobile technology and crowdsourcing can be used in a crisis situation.*

Keywords: *Emergency management, mobile WiFi, emergency response, emergency recovery, disaster scenarios, strategic plan*

INTRODUCTION

Geographic Information Systems have proven themselves in recent decades to be immensely useful for all four key stages of emergency management. However, one critical drawback is that even today, the Geographic Information Systems (GIS) deployed in most city agencies are primarily desktop-based. While this works well for everyday computing, as well as planning, preparing, and mitigating disasters, there are serious concerns with a stationary base of operations when considering disaster response and recovery. In particular, situational awareness for first responders in the field can pose a significant problem. Lessons learned from September 11, 2001—when New York City lost its Office of Emergency Management when the Twin Towers collapsed—have inspired many agencies to consider integrating mobile platforms as well.

Since 2001, many innovations in GIS have been developed that can be applied to emergency response, including wearable and portable technology, web-based mapping and cloud based computing, unmanned aerial vehicles, 3d mapping and gamification, geofencing, social media, and mobile WiFi. Emergency management and response systems can be greatly improved by leveraging GIS to its fullest capacity, which includes incorporating new technological developments and social media trends. This paper has one overarching goal: to present a rationale for the development of a strategic plan for a new GIS emergency management and response system that leverages new technological and social media trends. To meet this goal, this paper will accomplish the following objectives:

- Present a likely disaster scenario mimicking actual disaster conditions
- Using this scenario, demonstrate how mobile technology (tablets, cloud storage, web maps, mobileWiFi, geofencing, wearable computers) can help

BACKGROUND

GIS has proven itself to be useful in all key stages of emergency management: Planning and Mitigation, Preparedness, Response, and Recovery (Mondschein 1994; ESRI 2000; ESRI 2012; FEMA 2015d; FEMA 2015e). The events of September 11, 2001, significantly changed the applications and use of GIS for emergency management (Cutter 2003). The disaster destroyed the Emergency Operations Center, and all supporting equipment and data. Emergency responders had not considered such a scenario, but the lessons learned from the quick mashup of data stored at Hunter College, and the daily real-time aerial and thermal imaging and field data collection techniques became the foundation from which current GIS emergency response systems have been developed (Committee on Planning for Catastrophe: A Blueprint for Improving Geospatial Data, Tools, and Infrastructure, National Research Council, 2007; ESRI 2002; Robinson 2015; Stevenson *et al* 2010; Tomaszewski 2015).

By the time Hurricane Sandy hit the tri-state area on October 29, 2012, many newly-developed advancements in technology were in use and were being applied to emergency management with mixed success (Google 2012; Maplecroft 2015; Risk Frontiers 2015). A study conducted by Gartner, Inc, lists media tablets, mobile centric applications and devices (Brin 2003; Intel Software 2013; Knight 2011; Hay 2013), contextual and social user experiences (MapRoulette 2015; Priebatsch 2010; Wright 2012), connection of physical items to the internet via scanners, and cloud computing as some of the top 10 strategic technologies (Schwalbe 2014). Additional strategies under consideration include geofencing (Case 2012), unmanned aerial vehicles (i.e. drones, ND National Guard 2011; OReilly 2012; senseFly 2013), volunteered geographic information (Goodchild 2007; Meier 2011; OpenStreetMap 2015; Ushahidi 2015), mobile-deployed WiFi (Hintz 2007), and dashboards for non-expert users (Pacific Northwest National Laboratory 2010; SpatialKey 2015; Tableau Software 2013). There are strengths and weaknesses to consider with each of these new technologies, not the least of which is providing rapid, uninterrupted situational awareness for field technicians who are largely untrained. Additionally, there are needs of the stakeholders, who may be motivated by political and economic restrictions.

Mobile cloud-based GIS allows for the continuance of normal operations when normal circumstances are compromised. Operations that are not tied to a physical space can be reconstructed anywhere in the field should the operations center be compromised. Such a GIS can provide efficient use of resources and minimal downtime, convert the digital data accumulated in the field into products that field technicians can then use to continue their work, and can perform inspections more quickly and with less redundancy. Data and webmaps can be prepared and training for the new system can be completed in advance of implementation.

There are many advantages to implementing mobile cloud-based GIS for emergency management and response. Backups in more than one location allow for valuable information to be accessible in the event the operations site is compromised. Virtual Machine Images allow employees to login in remotely and access necessary data. Webmaps and dashboards put all relevant data in one up-front display for field techs. Mobile WiFi allows for field techs to be able to access the webmap while cellular and cable WiFi services are down. Real-time data processed as model input allows better situational awareness.

However, implementing this new system is not without its pitfalls. Employees must be aware of these backups and store vital information on the appropriate servers, and not on their local machine. Multiple logins are taxing on cloud servers, leading to compromised data speeds. This system also requires that all staff in the field are familiar with the interface and that it is easy to use. Also, mobile WiFi will not be available in all areas where field techs will be inspecting, so managers need to establish a procedure for handling data off-line, and syncing data when WiFi again becomes available. In addition, large amounts of data take time to process and verify, so products might not be available in a timeframe useful for field techs.

STRATEGIC PLAN

This study proposes that emergency planners adopt a strategic plan that relies heavily on preparedness prior to response and recovery. It is hypothesized that this proposed plan, if implemented, would both decrease response time and increase efficiency and accuracy of data collection by field technicians and first responders, with minimal training needed. This data will become particularly important both during the response phase, when data analysis can provide immediate feedback to first responders, and also during the recovery phase, as the agency gains a clearer picture of the damage. Additionally, it is proposed that a strategic plan can increase the effectiveness of future mitigation efforts, and can be applied agency-wide to increase the efficiency of everyday tasks and reduce training time.

FEMA recommends a Hazard Analysis Process (FEMA 2011) that develops a list of threats to the community (such as FEMA's Risk Map (2015a) and data feeds (2015b)). They also recommend that said plan profiles the type, probability, past history, and potential consequences of each threat, and combines threat profiles with community profiles to determine vulnerability by quantifying risk and developing response priorities.

The World Meteorological Organization (2015) recommends a strategic planning process that begins by gathering inputs and then conducts a Strengths Weaknesses Opportunities Threats (SWOT) Analysis in order to come up with strategic issues. Both the inputs from all stakeholders and the SWOT analysis are then reviewed in order to define three or four key statements. A strategic matrix is then constructed to address Opportunities v Strengths, Opportunities v Weaknesses, Threats v Strengths, and Threats v Weaknesses. Strategies, short and long term goals, and operational plans are then defined. After final reviews are conducted, adjustments are made as necessary.

The National Research Council's Committee on Planning for Catastrophe suggests that each threat profile should contain a scenarios describing the initial warning, potential impact and consequences, and response actions needed (Amram *et al* 2011; Committee on Planning for Catastrophe: A Blueprint for Improving Geospatial Data, Tools, and Infrastructure, National Research Council, 2007; CronosGroep 2014; Cutter 2003; ESRI 2006; Guven *et al* 2012; Pacific Disaster Center 2015a; Pacific Disaster Center 2015b; Pacific Northwest National Laboratory 2015; USGS 2015; Stevenson *et al* 2010; Wagner *et al* 2015).

This study recommends that a strategic planning process takes place as a combination of the FEMA, World Meteorological Organization, and National Research Council's methodologies described above.

DISASTER SCENARIO

Focusing on problem-solving without considering real-world applications of emergency management systems can lead to premature commitments to the first design, oversimplification of the problem to be solved, and an inadequate analysis of alternatives. Scenarios can help address emergency system design concerns by providing rough sketches of real-world applications, assessing user-appropriateness of design by emphasizing user experience, and highlighting areas where the design is incomplete.

A scenario-based design is a simplified description of the end-user's future possible experiences with a computer system as a story with characters, plot, and outcome. Using scenarios such as the ones Rosson and Carroll describe (2002) article allows an individual with limited technical knowledge to quickly understand how a new mobile GIS-based emergency response system can be used in a crisis, and thus the usage can be communicated to all stakeholders.

The following scenario describes a possible interaction between decision makers, technicians, and emergency workers and the proposed technological solution to emergency management.

> *BEFORE THE STORM: It's October in New York. Many years have gone by since Hurricane Sandy made landfall, and many local residents, businesses, and government agencies-not being accustomed to yearly storms as they are in the Southern US-have downgraded their concern about the threat of hurricanes. Unbeknownst to the residents, the National Weather Service is monitoring the formation of a tropical storm, and is predicting that this storm will be declared a hurricane. Like many hurricanes, its path curves northwards as it approaches North America. Unlike many hurricanes, its path just misses landfall with the Carolinas, allowing it to travel up the east coast towards New York City and Long Island unimpeded, gradually increasing in strength. The New York Metropolitan area must once again prepare for a disaster and evacuate its residents from low-lying areas.*

> *DURING THE STORM: One agency keeps their backup generators on the lower levels of a building in the flood zone. Several of the lower levels flood when the storm surge hits. This flooding destroys the generators and thus the building's backup power source. Data was backed up on servers, but these servers were kept on a higher floor within the now powerless building. Employees could not log into their machines to work remotely from data on the servers because*

the machines could not be turned on. This meant that data would need to be pieced together from ad hoc sources, and reports from field technicians entered by hand, creating redundant effort and limiting its use for response and recovery.

AFTER THE STORM: The agency created backups on servers in more than one location through the city. Weekly backups of ArcGIS SDE servers were instituted, and employees with communal data would add it to the SDE server on a regular basis. They created Virtual Machine Images of all software that GIS technicians would need and hosted those images on Amazon EC2. Webmaps with dashboards were created using ArcGIS Online for use in the office and the field. The GIS team purchased tablets for its field technicians that would need to travel to remote locations. These technicians could use the maps with built in dashboards for real time navigation and hazard updates, and they could edit the features and enter new damage information into a form as they inspected the roadways and bridges for damage. The agency connected these inspectors' mobile WiFi to these tablets so that technicians would be able to access the web map in areas where WiFi was not available due to storm damage, and web caching for times when WiFi was not accessible, so that any changes made to the feature datasets would be uploaded as soon as WiFi connection was reestablished. This real time data can be processed to become a model input (such as how emergency responders can input data verbally (CronosGroep 2014, ESRI 2002, Guven et al 2012,)), so that other inspectors know the best routes of travel to a site, and if a site has already been inspected. This greatly reduces redundant effort, and it allows field technicians to capture data and images in the field, reducing the number of additional visits needed. Contractors in the field have GPS enabled devices in their trucks, so their routes can be monitored, allowing the agency to better picture of the time between trips. The data collected from these inspections provides a more complete picture for future planning strategies.

DISCUSSION AND CONCLUSION

This paper presents the rationale for the development of a strategic plan for a new GIS emergency management and response system that leverages new technological and social media trends. This plan is presented in a disaster scenario format mimicking past hurricane conditions, but can readily be applied to other disaster scenarios that can affect New York City. The disaster scenario demonstrates how traditional and web-based GIS, emerging technology, and real-time data can be used to improve planning, mitigation, response and recovery. It is the recommendation of this study that local and state agencies consider implementing a strategic plan for emergency management that leverages desktop GIS and new emerging mobile, web-based technologies to create a more efficient system that provides better situational awareness during the response phase.

The goal of this strategic plan proposal is to create an emergency management planning and response system that is both resilient enough to be used in the described emergency, and flexible enough to be applied in all types of emergencies facing the New York area. It should be scalable so that that it can be updated daily by field technicians—thus reducing the time needed for training a person on the system—as well as during crisis or disaster situations. This scalable system for daily use would also assist in the data gathering needed to improve the system, such as gathering feedback to improve dashboards and locate mobile WiFi issues. Real time imagery will still be a concern. Since many low lying areas are affected by New York City will be affected by a ban on unmanned aerial vehicles, there is little hope that amateurs flying UAVs can provide the high quality and accurate immediate imagery that is vital to emergency managers. There is some hope, though, that commercial startups can secure federal permits prior to disasters so that these flights can take place in the immediate aftermath unimpeded (Black, 2015). Also, while in urban areas volunteered geographic information can rival that collected by government agencies, there exists information deserts in rural areas, and there is no clear motivational mechanism in place to encourage volunteers to map these areas (Goetz and Zipf 2012).

The addition of this data to the emergency management system will greatly improve situational awareness—specifically, goal selection, attention to critical cues, future predicted scenarios, and the interaction between awareness and actions as described by Endsley (1995). Office personnel will still be faced with a deluge of information to process, which is a strain on resources, and could also be a setback to timely data turnover. In all, however, these innovations will have the potential to significantly augment the usefulness of the system.

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