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Understanding The Decision-Making Process of Local Level Emergency Managers and Future Impacts of Social Data

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Understanding The Decision-Making Process of Local Level Emergency Managers and Future Impacts of Social Data

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Abstract

During the course of a natural disaster, affected populations turn to different avenues to attempt to communicate their needs and locations while emergency managers are faced with the task of making quick decisions to aid in the response effort. The decisions that emergency managers face are affected by factors such as available resources, responder safety, and source of information. In this research, we interview emergency managers about the 2009 North American Ice Storm and a flooding event in late April of 2017 to understand the decisions made and the factors that affected these decisions. Using these interviews, a list of interview questions using the Critical Decision Method were created that could be used to more deeply understand the decisions and decision-making process of a local-level emergency manager during a disaster response event. Additionally, animations were created to illustrate the comparative effectiveness of disaster response routing plans developed with and without the consideration of social data based on data inspired by a real event.

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1. Background and Motivation

Every year around the world, approximately 60 volcanoes erupt [1], 50 tropical storms reach hurricane status [2], 120 magnitude 5.5+ earthquakes occur [3], and more than 1200 tornadoes touch down [4]. Between the years of 2004 and 2013, events such as these affected over 1.9 billion people, causing over 1.6 trillion US dollars (USD) in damages and almost 1 million deaths [5]. Figure 1 and Figure 2 break down the cost and causality of natural disasters by the type of event between 2004 and 2013.

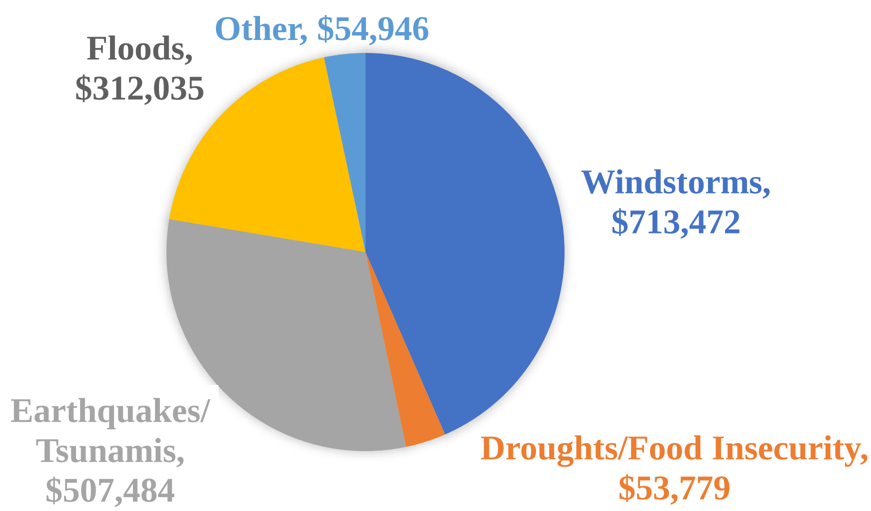

Figure 1. Economic impact of natural disasters from 2004 to 2013 in millions of USD

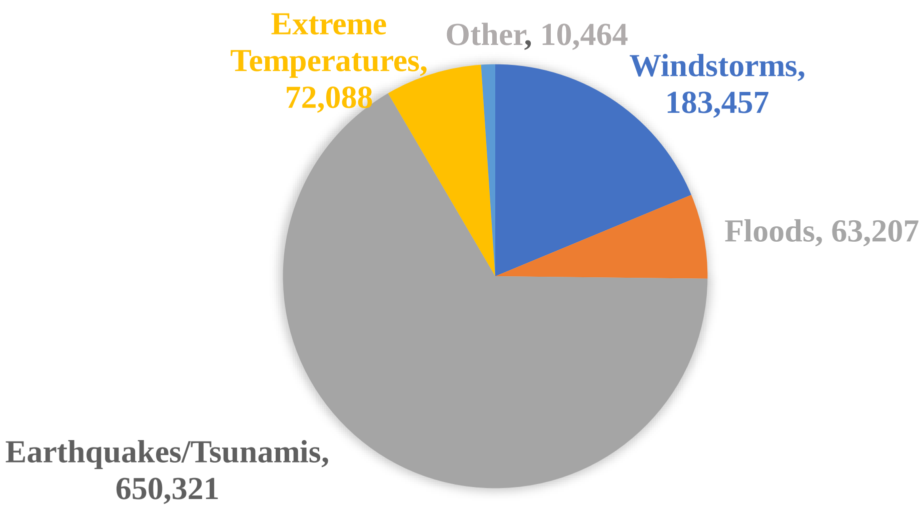

Figure 2. Death toll of natural disasters from 2004 to 2013

Situational awareness refers to how aware an emergency manager is of the needs and locations of a population that has been affected by a disaster. To obtain situational awareness, emergency managers must collect information about the situation on the ground during and after a disaster. Traditional sources for gathering this information in past disasters have included emergency telephone numbers, like 9-1-1 in the United States, and rapid assessment teams. These methods, however, sometimes fail to capture a comprehensive view of needs in a timely manner. Emergency telephone numbers may be overwhelmed by a surge in call volume, and rapid assessment teams may have insufficient capacity to visit every site to assess needs. Social data has emerged as an alternative information source in recent disasters. Here, we use the term *social data* to refer to information posted to social media and other crowdsourcing platforms. Emergency managers may enhance their situational awareness by incorporating social data, but they also open themselves up to the risk of possibly inaccurate information. Survey data has shown this risk has discouraged some emergency managers from using social data for situational awareness [9].

The 2012 National Preparedness Report from the U.S. Department of Homeland Security found social media has played an increasingly important role in disasters as a situational awareness tool [6]. However, the report also found emergency response organizations are more likely to use social media to transmit information than gather data. Organizations that restrict the use of social data during response operations forego the potential benefits of enhanced situational awareness that it affords. On the other hand, organizations that allow social data to inform their planning efforts report becoming overwhelmed with the amount of data, and being unable to efficiently use it [6].

As an example of the overwhelming amount of information social data can provide, from October 27th to November 1st when Hurricane Sandy made landfall on the U.S. East Coast, over 20 million tweets were sent about the storm [7]. A report from the Pew Research Center's Project for Excellence in Journalism found 34% (about 6.8 million) of the tweets about the storm during this time period "involved news organizations providing content, government sources offering information, people sharing their own eyewitness accounts and still more passing along information posted by others," and 25% (about 5 million) of the tweets were photos and videos that demonstrated the damage to affected areas [7]. The report found both text-based and picture-based tweets were susceptible to be from past disasters or false, and users on Twitter attempted to point out any false images or tweets.

While the volume of social data may be large, organizations have extrapolated useful information successfully. For example, in December 2012, the UN Office of Coordination of Humanitarian Affairs created their first-ever official crisis map solely from social media data in response to Typhoon Pablo in the Philippines [8]. The crisis map displayed the situation on the ground, such as damaged infrastructure or displaced populations, and the impact severity.

Social data can also bring attention to vulnerable populations. In August 2017, Hurricane Harvey hit the coast of Texas, and led some to call "Hurricane Harvey the first major natural disaster of the social media age" [23]. During Harvey, some social media posts went viral, bringing attention to populations who had encountered difficulties in reaching local authorities. One example is a tweeted photo of a flooding assisted living center that, after being retweeted over 4,800 times, caused emergency responders to move the center to the top of the priority list [23]. In addition to social media, sites like "Houston Harvey Rescue" were created by citizens as a way to centralize crowdsourced information about affected populations [24]. However, like during Hurricane Sandy, misinformation was spread during the event. For example, a report of an electrocution was posted on Facebook, but firefighters arriving to the scene where the incident was reported to take place determined the information was false [24].

Research regarding emergency managers and their use, concerns, and processing capabilities of social data has been conducted in the past.. One of the most comprehensive studies is the joint National Emergency Management Association and CNA Analysis & Solutions survey, which garnered over 500 responses from emergency managers at state, county and local levels [9]. Among the respondents, 64% of state, 42% of county and 44% of local level emergency managers reported having "enhance[d] situational awareness by gathering, filtering and analyzing" social data during past emergencies [9]. Additionally, over half of the state level participants and less than 20% of county and local level participants reported having a social media policy enacted in their agency. However, 85% of state, 83% of county, and 75% of local level emergency managers responding to the survey reported they "would not act on [social data] unless it was verified by a response agency or other trusted sources" [9]. This indicates some level of distrust of social data.

Social data has the potential to be useful during emergency response decision-making, but the potential benefits have not yet been quantified. Additionally, social data currently has not been widely adopted by emergency managers as part of their decision-making process. This thesis makes preliminary steps towards understanding the usefulness of social data for disaster response decision making. As a first step, the decisions required during a disaster response operation, as well as factors influencing how those decisions are made, need to be understood. Topics such as the allocation of resources (e.g., how does one decide whether a vehicle, first responder, etc. should be committed to a particular need?), the resources emergency managers have at their disposal, and the process by which information is or is not considered are of interest. Only with a strong grasp of the decision-making environment can we begin to understand how incorporating social data could influence those decisions. For simplicity of scope, this thesis focuses on disaster response decision making at the local level.

There are two main objectives of this research. The first is to develop a set of Critical Decision Method (CDM) interview questions to elicit decision-making processes employed by emergency managers during a disaster response operation, with the hope that the questions can be used to further this research agenda in the future. The research team conducted exploratory interviews with a county level emergency manager and three city level emergency managers. The purpose of these interviews was to build content knowledge to inform the development of a set of CDM interview questions. The second objective of the research is to construct a set of animations to illustrate the comparative effectiveness of disaster response routing plans developed with and without the consideration of social data. To be consistent with the local-level scope of the research, these animations represent an event magnitude commensurate with a local-level response. To create instances that may be encountered by emergency managers at the local level, data from past local events was collected and analyzed. The events selected for the research were the 2009 Ice Storm in Arkansas and Kentucky and the 2017 late April Floods, which affected the city of Fayetteville in Washington County, Arkansas.

In this paper, an overview of the organizational structure of emergency responders and a literature review in decision-making models is provided in Section 2. Then in Section 3, a summary of the events and information gathered from the exploratory interviews are provided. In Section 4, the two CDM question sets are explained and reflected on based on information from the interviews. In Section 5, the animations and their possible applications are discussed. Finally, Section 6 summarizes findings and presents potential future research topics.

2. Literature Review

First, the structure of emergency response hierarchy in the United States is defined. Second, a survey of literature in the field of decision-making models and eliciting expert knowledge is provided. This survey is meant to define what experts in the field of decision-making models see as the current best practices for eliciting expert knowledge.

During an emergency response effort, the Incident Command System (ICS) is used as a framework to organize responders. The framework is depicted in Figure 3. The ICS is comprised of five functions: Command, Operations, Planning, Logistics and Finance & Administration. The Command function is comprised of the Incident Commander, who is the head emergency responder, the Public Information Officer, who relays information to the public, media and other agencies, the Safety Officer, who is in charge of safety of emergency responders, and the Liaison Officer, who is the "point of contact for… other government agencies, nongovernment agencies and/or private entities" [10]. Operations performs the tactical operations, Planning creates plans of action and manages resources, Logistics is responsible for providing resources needed, and Financial & Administration tracks the cost of response including what can and can't be reimbursed [10].

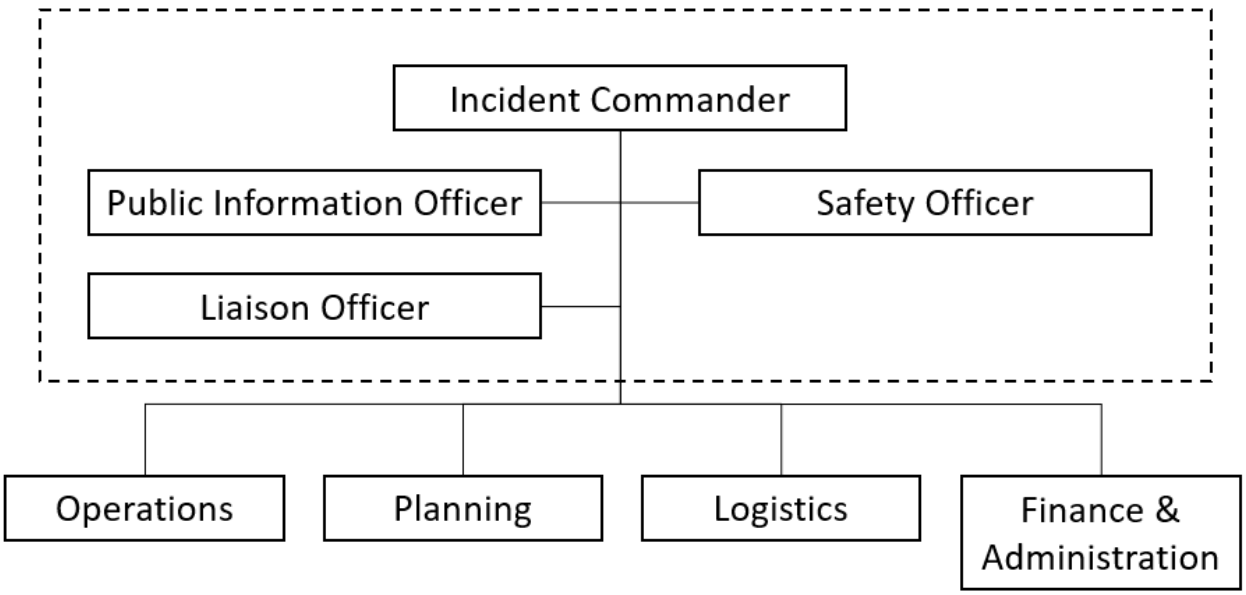

Figure 3. Incident Command Structure

Naturalistic Decision-Making (NDM) "is a descriptive model which gives a detailed representation of how experts actually make decisions in the real world, using their experience" [11]. Before the development of NDM, researchers would create models of the decision-making process in a controlled situation where the decision maker was making the optimal decision [13]. NDM differentiated itself by focusing on how experienced decision makers make decisions in a time-sensitive, ever-changing environment. By focusing on how environmental factors affected the decision-making process of experienced decision makers, these experiential models would eventually be "accepted as the standard account of decision-making by most practitioners" [13].

Inside the umbrella of NDM, there are decision-making models, and methods to elicit expert knowledge. For the purpose of this research, the methods to elicit expert knowledge were of most interest.

The elicitation methods are often referred to as cognitive task analysis methods which "are used to determine and describe the cognitive processes" of people during the decision process [16]. The five main elicitation techniques that are used are: Applied Cognitive Task Analysis, Cognitive Walkthrough, Cognitive Work Analysis, the Critical Incident Technique and the Critical Decision Method [16]. Since the Critical Incident Technique and the Critical Decision Method have both been used successfully to elicit expert knowledge about dynamic, high-stake events, which disaster response operations are, these two methods were further analyzed. The other three methods were not furthered analyzed as they are not as useful for eliciting specific knowledge about desired situations as the Critical Incident Technique and the Critical Decision Method.

The Critical Incident Technique (CIT) uses a semi-structured interview to elicit the decisions and decision-making processes from experts for non-routine situations [16]. To conduct these interviews, the incident is first defined, the interviewee walks through the timeline, and finally the interviewer uses a set of probing questions to understand the decision process. While CIT uses probes to understand the decision process of the interviewee, these probes have been rejected in favor of the cognitive probes of the Critical Decision Method [16].

The Critical Decision Method (CDM) is a refined version of the Critical Incident Technique [12] that uses cognitive probing questions during interviews to elicit information about decision-making in changing environments. The US Department of Health & Human Services Agency for Healthcare Research and Quality has defined a set process for CDM interviews [12]. These interviews typically start with the establishing the situation the expert will analyze, then a construction of a timeline of the situation and of the decisions being made. When the interviewer understands the timeline and decisions, cognitive probing questions are then used to understand the decision-making process of the expert for each decision point. CDM has been used in the past to understand the decisions fire ground commanders make during operations [11], the debugging process of computer programmers, and the decision support systems of military operations [15]. While CDM appears to help understand at a deeper level the decision-making processes of the interviewees, concern has been raised about the accuracy of the technique due to memory degradation [16].

3. Summary of Events and Exploratory Interviews

Interviews were conducted with the Washington County, Arkansas (AR) Emergency Manager, the Fayetteville, AR City Emergency Manager, the Assistant Fayetteville Emergency Manager and an Assistant Fire Chief of the Fayetteville, Fire Department. These interviews lasted from one half-hour to an hour. During these interviews, the emergency manager were asked to describe any emergency events they had participated in, as well as their role in it. An additional interview was conducted with the Parks & Recreation Director for Fayetteville, AR about the process to set up shelters.

3.1 Timeline of the 2009 Ice Storm

The 2009 Ice Storm in Arkansas and Kentucky is considered to have been the third worst ice storm in the history of the United States [17]. While several states were affected by the ice storm, Northern Arkansas and Kentucky were the most affected areas. The storm caused 1.3 million residents across the United States to lose power, and over 300,000 power poles to be knocked out in Arkansas [17]. The storm also caused the death of 18 people in Arkansas and 24 in Kentucky, with the reasons being "traffic accidents, hypothermia, and carbon monoxide poising" [17]. Specifically, in the Northwest Arkansas area, "over 100,000 people [were left] without power," and almost two weeks were required to restore power to affected populations [18]. The storm caused almost $80 million in damages in the Northwest Arkansas area [18], with cleaning efforts continuing through the summer for some of the affected areas [17].

A week prior to the event, emergency management personnel in Washington County and Fayetteville had conference calls with the National Weather Service's Tulsa office about the forecasted severity of the storm. These calls would continue up until the night before the storm. In preparation for the response effort, the city of Fayetteville took a variety of actions. The city created a list of essential personnel and reserved hotel rooms downtown for these personnel. The city also shifted personnel schedules to have 24/7 coverage. Generators were tested at the dispatch center and main offices, and fuel supplies were inventoried. Lastly, vehicles were pre-chained and limits on the city's credit cards were removed so that city personnel would be able to purchase supplies. However, there were a few lessons learned from the experience. First, while the Emergency Operations Center (EOC) was allocated one power generator, the EOC needed two generators to satisfy its electricity demand, which was one factor contributing to the EOC not being usable during portions of the event. Second, the backup power sources for pre-approved shelter locations across the city were not catalogued in advance. It was discovered in real-time that some of the pre-approved shelter locations were inoperable due to insufficient backup power. Because of this, the city now has a list of prequalified locations that can be used as shelters and have verified backup power sources.

In the days leading up to the event, rain saturated the ground making trees unstable. Around 2:00 pm on the event start date, the temperature plunged, the rain changed to freezing rain, and powerlines and trees started to fall over. As a result, the emergency call volume to increase drastically. By 3:00 pm, most businesses closed leading to a rush hour as the weather continued to worsen. Between 5:00 and 6:00 pm, power outages started and the concern of falling trees was elevated. The city of Fayetteville bought as many chainsaws as they could to cut trees that fell. During the initial response to the event, when utility crews were dispatched to handle a situation, like a downed power line, the street would have to be cleared going to and from the destination. Once nighttime came, worker safety became a large concern. Work crews would hear trees crack and fall, and if the area the workers were in was heavily wooded, the area either had to be served by a large crew or wait until daylight. Also, during this time Fayetteville emergency management contacted Washington County to help set up shelters, as well as request more generators.

By the third day, Ozark Regional Transit (a local public transportation company) vans and Razorback Transit (a transportation service by the University of Arkansas) buses were used to transport the population, taking the place of ambulances which were used when not needed for hospital transports. On the fifth day, fuel ran out for the sanitation system, causing an immediate need for the system to be refueled. During this time, Fayetteville also started discussions with FEMA to see what could be reimbursed as part of the emergency response effort. The population also started to go downtown as cabin fever was kicking in, however some restaurants were out of food due to not getting food deliveries from the storm. On the 7th day power was restored to all buildings within one mile from the city center, and power was restored to all populations by the 10th day. On the 14th day all shelters were closed.

3.2 Calls, Communication, and Resources for the 2009 Ice Storm

A Central Dispatch Center (CDC) is the point where emergency calls are received and are then allocated to the correct response agency (e.g. a medical emergency would be sent to EMS). During the event, the CDC was responsible for triaging calls by learning about the affected caller's condition and supplies to determine their prioritization of need. Calls during the event ranged from vehicle accidents to fallen trees on property to health emergencies to people being trapped outside. In general, prioritization is given to any life risk before property damage. As for the order of prioritization within a group of similar calls, special consideration was given to vulnerable populations, but all else equal, the prioritization depended on when a call was received.

For the first two and a half days, press events were held on the TV and information was sent out on social media, but the population was not receiving the information. After emergency managers learned that the population was using radios, as radios are not as dependent on a working power source, managers switched to broadcasting messages over the radio, which increased the number of people receiving information. Once charging stations were opened at shelters and community buildings, the revival of mobile phone activity led to an increase in call volume and higher engagement with social media.

As for the allocation of resources, vulnerable populations were targeted with help first. The fire department was dispatched to senior living centers, and additional concerns were raised for disabled populations. Fayetteville worked with the local power company to make sure that the hospitals and shelters in the area were powered. Two of the most important resources during the event were fuel and generators, which were in short supply. Generators were needed to power essential buildings that were without power, and fuel was needed to power these generators, as well as generators for the sewage system.

3.3 Timeline of the 2017 Late April Floods

The 2017 late Aprils Floods caused flooding from Oklahoma to Ohio [19]. Rainfall in certain areas hit 12 inches within two days, causing historic flooding. In the Northwest Arkansas region, the storm caused power outages, and left many roads flooded [20]. For Fayetteville, the city received about 7 inches of rain in one day.

Like the 2009 Ice Storm, emergency managers had calls with the National Weather Service. However, there was some level of doubt among local officials that the storm would have much impact on the area. As a result the staffing levels for response personnel were not increased. By midday, the area received about one to two inches of rain. The decision was made not to open the EOC. However, by 6:00 pm, the area received between 6 to 7 inches of rain and emergency managers had to call off-duty personnel to help with the response effort. Across the two days of response, a total of 80 people needed rescue in Fayetteville, with about 50 people being rescued from one neighborhood that was being flooded.

3.4 Calls, Communication, and Resources for the 2017 Late April Floods

During the two days of the incident, there were a total of 57 calls. These calls included responding to 2 structure fires, a gas leak, 24 rescue calls, 1 swift water rescue, 1 accident, 1 vehicle fire, 12 medical assistance, 11 alarm activations, and 2 power lines downed. Throughout the event, the fire department had to respond to these calls and help blockade roads as the state Department of Transportation personnel were delayed in their response due to difficulties in getting to the affected area. Whether calls were for a fire or a downed power line, the fire department had to respond to the call, and in this circumstance, personnel were taken off blockade duty to respond.

A single shelter was set up for the event, however, the process had a few problems. First, the person calling to set up the shelter was in the field responding to calls, while the person who would help run the shelter had difficulties getting to the designated shelter. Once the shelter was set up, it was noticed that the pets in the shelter were causing problems with the population, so a separate room for people with pets was created.

3.5 Social Data

During these two incidents, social media was used primarily as a push strategy (pushing information to the public), but was also used to gather information. For example, during the 2009 Ice Storm, social media activity was used in conjunction with dispatch call volume and information from the local power company to learn about where power was out at, as well as the number of people who may be affected. A point was raised during the interviews that using social data and elevating a person’s priority from this data may both calm the affected population and restore confidence in the response effort as it shows emergency managers are being responsive to the situation. However, there is the risk of observers viewing emergency managers responding to a viral post as just a political maneuver to restore trust in local officials.

Responders seemed open to using social data in response efforts, with one commenting that capturing data from social media would be valuable considering how the usage of social media has increased. One way that the responders wanted to use social data was to scan for key words that are related to someone being injured. This could allow for faster response times for these situations. Another use of social data responders wanted was the ability to leverage what the population was seeing with the conditions of infrastructure, as being able to quickly identify dangerous roadways and/or bridges would allow officials to inform the public faster. Finally, using location data (geotagging) from social media posts would allow responders to know exactly where a social media user was, and allow for responders to pin down locations faster. However, retrieving accurate social data is still a concern. Having a way to verify social data was viewed as important, with one responder saying they would pay for the ability to check for accuracy.

While social data would increase the situational awareness of emergency responders, it could come at a decline in the use of the 911 system. One responder emphasized that hearing and/or seeing someone injured is important, as it can be used to understand how badly injured a person is. An aspect of the 911 system which would be lost in an exclusively online system is reach-back. Having the ability to reach-back for the 911 system allows for an operator to get back in contact with a caller, and the prosecution of fake calls, and is a reason that information from the 911 system is generally viewed as trustable. If there was a system to reach-back for social media, information coming in could become more trustworthy. Another positive of the

911 system is that there is always a person on duty to collect the information, unlike social data. This means that information at any time can be processed on the 911 system, and the proficiency of operators may be better as they constantly interact with the system. However, an advantage of social data over the 911 system is the speed with which the information can be collected. For the 911 system, an operator must have a conversation with the affected person, and the duration of the conversation is variable. For social data, there is usually a text post and/or picture someone can view to immediately gather information. To summarize whether information should go to the 911 system or social data, one responder believed that critical information should stay within the 911 system, but all other information could go through social data.

3.6 Other Topics

During the response to Hurricane Harvey, the volunteer organizations, like the Cajun Navy, participated in efforts to help rescue people who were stuck due to the flooding. While these freelancing responders mean well, they can also cause trouble as rescue operations can become dangerous. During two of the interviews, the topic of freelancers was brought up, and the emergency managers emphasized that if there are enough trained professionals helping with response efforts, they would rather freelancers not assist. Or, if there is a need for extra help, that freelancers should coordinate with response agencies during a response. Professional emergency responders typically study the area that is forecasted to be affected and know what is considered to be an acceptable risk, meaning they usually have a good judgement of a situation. Freelancers, on the other hand, could ignore risks for the sake of helping and in turn need to be rescued.

During one interview, the topic of PODs was brought up. A POD, or Point of Distribution, is a location that provides supplies and/or information to the affected population of a disaster. PODs can be classified as either open or closed, with open PODs serving the public and closed PODs serving a pre-specified subset of the population (e.g., a company can establish a closed POD to serve their employees and their families). For this interview, the discussion focused on open PODs and where they could be located. The responder talked about how supply PODs are usually fire departments or churches, but schools could also be used. If a fire department is used as a POD, then supplies can be moved across the city via fire trucks, and fire trucks could be used to transport food to homes in need during an event. However, for a fire department the staffing level may need to be increased as they would still respond to calls. For schools, information could be distributed by giving students paperwork to give to their guardians. Additionally, supplies could be sent home with students that are in a family that may be vulnerable to the event. While police departments can also be used as a POD location, negative connotations about police could prevent some portions of the population from using a POD there.

When a shelter is to be set up, a series of phone calls from responders to the CDC then to the Red Cross takes place. While it is possible for a local government to create a shelter, by having the Red Cross create the shelter, the local government can relieve itself from legal problems. Additionally, the Red Cross typically has more experience than local governments in creating shelters. As to where a shelter is set up, for Fayetteville, there are pre-approved buildings that can be converted to shelters. Inside of the shelters, items such as cots, showers, medications, clothing, food, and power outlets are provided to the temporary residents. One of the biggest problems shelters face is the closing down process. While an event may have concluded, there may be portions of the population that require additional time for the effects to recede, or may need help getting back home. The Red Cross can then get hotel rooms for affected populations, and help organize transportation for vulnerable populations.

4. Critical Decision Method and Social Data Questions

4.1 Question Creation

As part of this research, a set of CDM questions that employ the probes introduced in [16] are developed, as well as a set of questions regarding social data that do not follow CDM structure. The questions can be found in the Appendix. During the creation of both sets of questions, the word "social data" was used over the word "social media" as during previous interactions with emergency managers "social media" appeared to be a trigger word that elicited negative responses, which could taint the interview data.

The set of questions for CDM interviews focus on the decisions and decision processes of emergency managers during a response event. Six probing areas were identified, with some areas having sub-probes. These sub-probes were meant to further explain topics which may have affected the decision. For example, question seven shown in Figure 4 is asking if a particular decision is typical for the scenario, while the sub-probe follows up by asking if the responder has responded to a situation similar before. If they have responded to a similar situation, the previous situation may influence how they responded to the current one. For question six (about goals) and question nine (about options), wording from existing probes introduced in [16] was changed to fit the situations and for question eight (about situational assessment) an additional sub-probe was added. All other questions were either heavily adapted from [16] or created using the same established principles.

> 7. [Standard Scenarios] Does this decision point fit a standard or typical scenario?
>   a. [Analogues] Were you reminded of any previous experiences?

Figure 4. CDM question seven

The questions over social data were created to understand how social data was used in past response efforts, as well as how the expert feels about social data. Unlike the previous set of questions, those regarding social data do not follow the CDM structure. However, the concept of probing is carried over. For example, question two in Figure 5 is exploring what reservations an emergency manager has regarding social data and has two sub questions that assist in understanding where these reservations are from.

> 2. What reservations do you have regarding social data?
>   a. Have any past experiences from yourself or others shaped how you view social data?
>   b. Have any news articles or research shaped your view on social data?

Figure 5. Social data question two

The first two questions of the series are used to understand the organization's policies and experts' feeling about social data. This will yield insights into the willingness of the expert and organization to use social data in a disaster response operation. The third question is used to identify the experts' past experiences with social data, and the process by which social data was included – or excluded – from a logistics plan or situational awareness. The fourth question focuses on how the type of data (traditional or social) and social data characteristics (time from post, location, type of content, etc.) affect prioritizations in logistics planning, for example in determining in which sequence to visit requests (i.e., route planning).

4.2 Analysis of Questions

The insights from the elicited knowledge during the interviews allowed for the question set to be revised based on a stronger understanding of what happens during an emergency response effort. In reviewing the current question list, two topics seem to be missing from the decision-making sub questions. First, responder safety was overlooked. In reviewing the ICS, the Safety Officer is responsible for decisions made about responders' safety, and in the 2007 Ice Storm, there was concern about safety when cutting trees in the dark. This led to a sub-question being included about responder safety. Second, during the conversation about the 2007 Ice Storm, there was concern about what could and could not be reimbursed, and what actions had to be done in a specific order to qualify as a reimbursable expense. Because activities must be paid for somehow, minimizing the cost of the response to local governments is a topic of concern. The question of reimbursement was also added to the basis of choice question. Finally, for the sub-questions about resources in the decision-making topic, resources were defined to include responders as a resource, as the number of responders is limited during response efforts.

5. Animations

Before conducting the interviews, a set of 6 animations were created. These animations contained 60 points, with the proportion of traditional data being either 50% or 67%, and the accuracy of the social data being 25%, 50%, or 75%. These parameter values were selected randomly and had no basis in a past event. For each animation, two different routing strategies were depicted, using the methodology from Kirac et. al. [14]. The first routing strategy is if an emergency manager plans on visiting all points on a tour, regardless of whether it came from a traditional or social data source. The second routing strategy is if an emergency manager plans on visiting all traditional data points on the first tour, waits for each social data point to be categorized as accurate or inaccurate, and then plans a second tour visiting only the accurate social data points. For these initial animations, whether a point was traditional, accurate social, or inaccurate social data was randomly assigned. Concorde TSP solver was used to develop the routes for each strategy. For each animation, two counters are displayed which provide elapsed time and the number of people served. A screenshot of one of the animations is provided in Figure 6, with the top picture being taken before the animation ran and the bottom upon its conclusion. From the interviews, there was a desire not only to create future animations based on historical data, but to also find if/when a situation occurs when an emergency manager has the freedom to choose between alternative routing strategies for points that have the same or no priority.

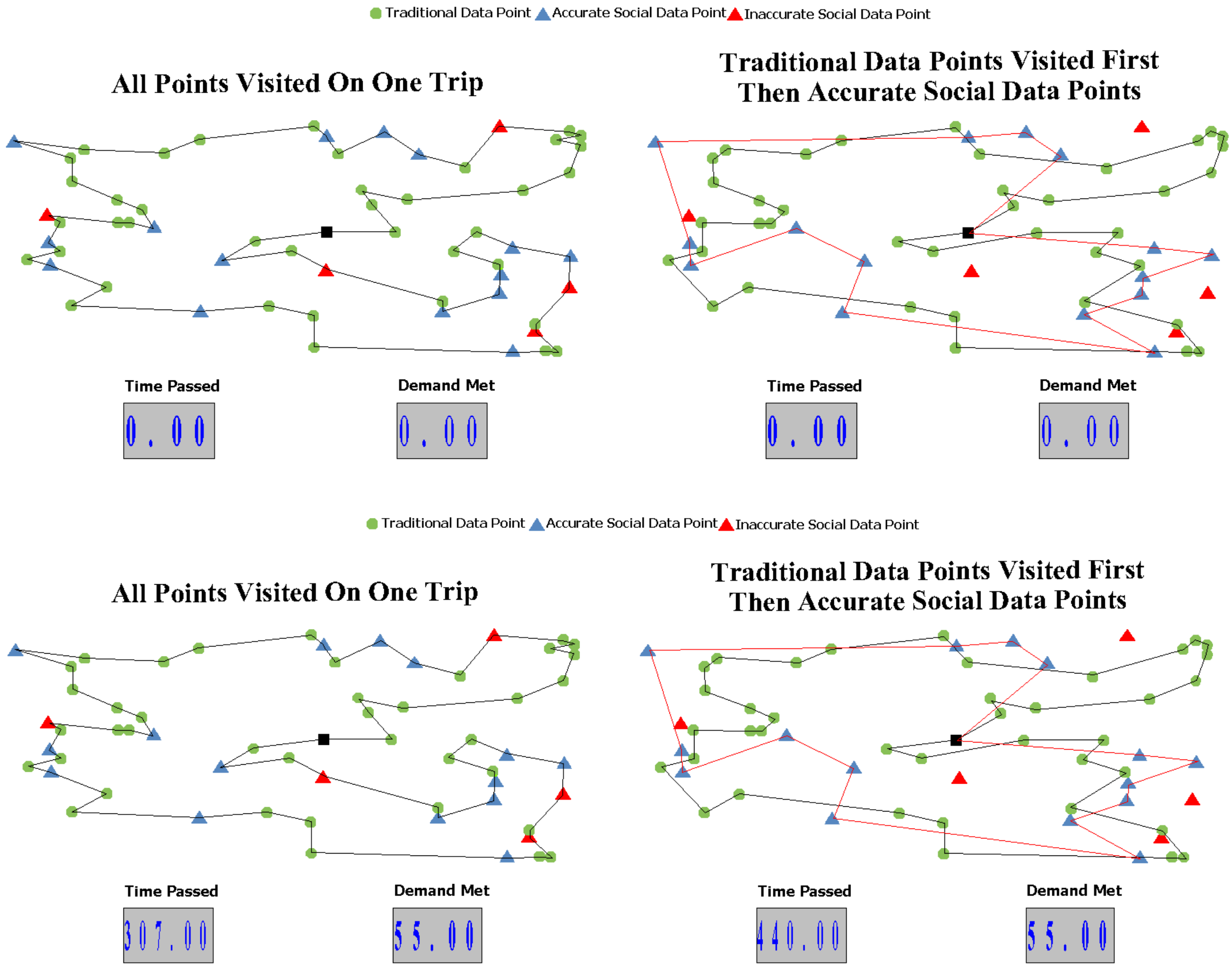

Figure 6. Example of created route animations

After the interviews, a new set of animations were created, modeled from call data collected about the 2017 Late April Floods. From the call data collected from the fire department, 57 calls were placed during this event. Of these 57 calls, 25% of these calls were false alarms or wellness checks, and 23% of these calls had no description about the incident the call was for. From this data, the accuracy of social data for the animations were picked to be either 25% or 50%, and the proportion of data to be from traditional data sources to be 67% to 75%. While the call volume during this event was 57 calls, the animations created only have 40 points due to Mathematica, the program used for these new animations, having difficulties to animate instances having more than 40 points. The points selected for the animations are based on the Dumas TSPTW[21] instances, and are solved in Mathematica using the Clarke Wright algorithm for one vehicle with a capacity of 40. Each point was randomly assigned to be a traditional, accurate social, or inaccurate social data point. For four of the Dumas TSP instances, the instance contained 41 points, and the 41st point was picked as the depot. One of the instances contained 61 points, with the 61st point selected as the depot, and the 41st to 60th points eliminated. A picture of an animation is provided below in Figure 7. The animations are available in the online open-source repository Mendeley at https://data.mendeley.com/datasets/x8w9vzp4vx [22]. Table 1 provides the number of points of each type and the distance travelled for each scenario. On average, visiting all points on one tour reduces the distance travelled by 31%.

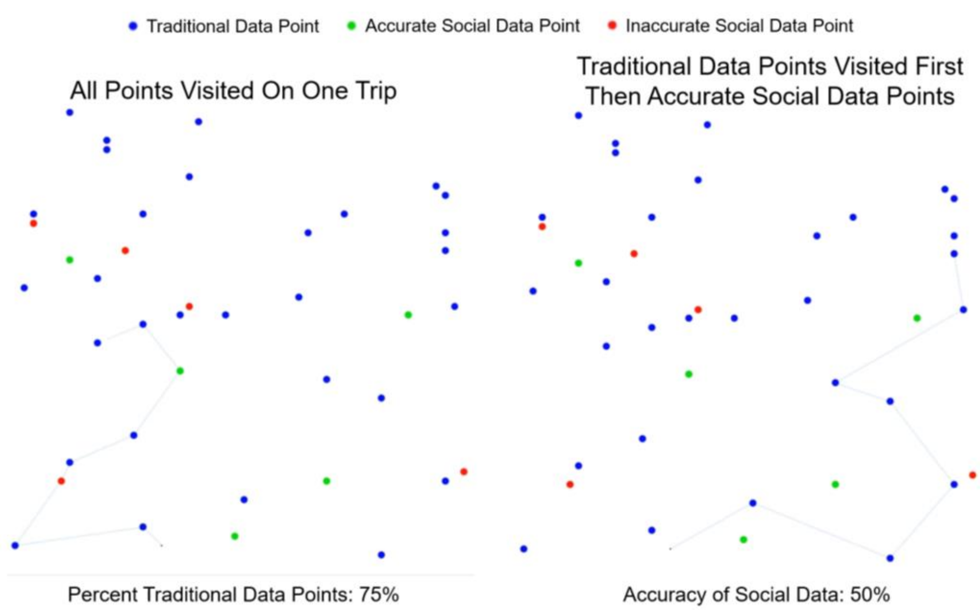

Figure 7. An animation for a Dumas n40w40.001 TSP instance

Table 1. Allocation of Data Points and Distance Traveled By Animation Instance

Data Name	Traditional Data Points	Accurate Social Data Points	Inaccurate Social Data Points	All Visited Distance	Traditional First Distance
n40w20.002	30	7	3	270	354
n40w20.002	30	5	5	270	382
n40w20.002	27	10	3	270	346
n40w20.002	27	7	6	270	339
n40w20.003	30	7	3	257	371
n40w20.003	30	5	5	257	344
n40w20.003	27	10	3	257	381
n40w20.003	27	7	6	257	371
n40w20.004	30	7	3	274	385
n40w20.004	30	5	5	274	366
n40w20.004	27	10	3	274	364
n40w20.004	27	7	6	274	349
n40w40.001	30	7	3	243	336
n40w40.001	30	5	5	243	319
n40w40.001	27	10	3	243	334
n40w40.001	27	7	6	243	316
n60w20.001	30	7	3	263	363
n60w20.001	30	5	5	263	358
n60w20.001	27	10	3	263	374
n60w20.001	27	7	6	263	381

For both animation sets, three assumptions were made. First, it is assumed that the population is distributed uniformly on an x-y coordinate plane. Real-life populations, however, are typically not distributed uniformly across space. Second, the animations assume that Euclidean movements are possible. In real-life, roads would be used to move from one point to another, and there is not always a straight path between points. Third, it is assumed that there are no expiration times on the demand for the points. During urgent situations, people can only wait so long for help to arrive. If it takes a long time for help to arrive, people may leave to try and find help or die.

In one of the interviews, the created animations were shown to the responder. While the animations focused on the impact of social data on response time, the responder suggested that the routing plans shown could be used for damage assessment and/or POD location. For damage assessment, efficiently routing vehicles to points of interest could reduce the distance these vehicles needed to travel to survey the damage. While the topic of PODs in this instance was not discussed thoroughly, the routing of vehicles to deliver supplies to PODs could be of interest.

6. Conclusion

The primary results of this research are a list of questions that follow the Critical Decision Method to understand the decisions and decision-making strategies of emergency responders during a disaster, and a set of animations inspired by collected call data. An original set of questions were created based on interviews with one county level and three city level emergency managers.

In addition to the list of questions, the use of social data in emergency response was explored. In the two incidents, social data was primarily used as a push strategy, but paired with other information sources, could be used to supplement the information supply. Responders were willing to use social data as an information source, but accuracy of the information, as well as the potential for the 911 system to be less utilized, caused concern.

Two future research topics were also identified. First, the traveling salesman problem variants may be useful for modeling damage assessment during emergency response when the demand points have uncertain accuracy. By minimizing the time needed to travel to all points, information about dangerous or concerning areas could be collected faster. Second, there currently are no well-established solutions for transporting affected populations during a winter event. Due to the needs of the population, such as wheelchairs or stretchers, transporting populations to a shelter can be difficult. Given that few vehicles can be used in the initial stage of a winter event, transporting people in these conditions limits how many people can ride on a vehicle. This question, however, may fall more into transportation engineering and urban planning.

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Appendix

ORIGINAL DISASTER RESPONSE PLANNING QUESTIONS

The purpose of this interview is to understand the decisions being made in a disaster response operation, and the factors affecting the decision-making process. During this interview, you are asked to think of one of the largest events your organization responded to in the last two years. We will first ask you to walk us through the event and your organization's response to it, from start to finish, to the best of your recollection. Based on your description of the event, we will note key points in time when decisions were made. We will follow up with detailed questions regarding those decision points.

1. [EVENT SELECTION] Our interview will center around the decision-making process during a non-routine event. It should be an event that was challenging, and one in which your expertise played a critical role, meaning that someone with less experience than you may have made different decisions. We are particularly interested in large events. Which event best meets this criteria?

2. Please walk us through the event and your organization's response to it, from start to finish, to the best of your recollection. By start, we mean the time your organization was alerted to the event, or began to anticipate it (e.g., a weather forecast). And by finish, we mean the time that the immediate response phase concluded and the situation was deemed under control.

3. [CONSTRUCT INCIDENT TIMELINE] Interviewer reconstructs a timeline and verifies it with the interviewee. This establishes a shared understanding of the event. The timeline may be updated and/or clarified as a result of this process.

4. Identify decisions for further probing. These decision points include times the interviewee would agree that several courses of action were possible, or that someone else with less experience might have taken a different approach.

5. What were the information sources that you had access to during this event?

For each decision point that requires probing:

6. [Goals] What were your specific goals and objectives at the time?

7. [Standard Scenarios] Does this decision point fit a standard or typical scenario?
    a. [Analogues] Were you reminded of any previous experiences?

8. [Situational Assessment] Did you use all of the information sources available to you for this decision point, or just a subset?

    a. (If a subset) Which sources did you use?
    b. Can any of this data you are describing be shared with us?

9. [Options] What courses of action were considered or were available?

10. [Decision-making] Were there any priorities (like first-come first-serve) that affected the decision?
    a. Did you use any software to support the decision-making process?
    b. Did time and pressure impact your decision-making process?
    c. [Resource] Did you allocate any available resources to respond to this decision point?
        i. Were there concerns at the time of making the decision that these resources may be needed at a later time?
        ii. Were any of these resources provided by another organization?
            1. Was there a certain amount of time you had with these resources?
            2. Did this impact how you used these resources?
    d. Were there any other organizations that responded to this event?
        i. Was there coordination between yours and the other organizations?

11. [Basis of Choice] What course of action did you choose? How was this option selected / how were other options rejected?

SOCIAL DATA QUESTIONS

1. Does the organization currently have, or is the organization willing to adopt specific policies that regulate the use of social data in disaster response plans? If so, what are these policies?
    a. Were there factors that affected the creation of the policies?
    b. How do you feel about the incorporation of the policies?

2. What reservations do you have regarding social data?
    a. Have any past experiences from yourself or others shaped how you view social data?
    b. Have any news articles or research shaped your view on social data?

3. Has the organization had previous experience of using social data in disaster response plans? If so, how important of a role did the social data play?
    a. Must social data be verified from an outside source (like an external agency or a VOST), before use?
    b. Are there particular characteristics that must be met for social data to be integrated into disaster response plans?
    c. Must a post from social media meet all of the characteristics above, or just a combination of a few?
    d. Are there any characteristics that would immediately make a post not be incorporated into a route plan?

4. What are the sources that the organization traditionally gets data from for disaster response plans?

    a. Does information from traditional data sources take priority over social data sources? In other words, do all of the data points from traditional data sources need to be visited before visiting any points from social media?
    b. Does the characteristics of that the social data affect when the data point is visited? For example, if a tweet is posted before another tweet, will the one that was posted first be visited before the other one? Or will the one that is closer be visited first?
    c. Does the type of post affect when it would be visited? For example, would a photo-based post be visited before a text-based post?

REVISED DISASTER RESPONSE PLANNING QUESTIONS

The purpose of this interview is to understand the decisions being made in a disaster response operation, and the factors affecting the decision-making process. During this interview, you are asked to think of one of the largest events your organization responded to in the last two years. We will first ask you to walk us through the event and your organization's response to it, from start to finish, to the best of your recollection. Based on your description of the event, we will note key points in time when decisions were made. We will follow up with detailed questions regarding those decision points.

1. [EVENT SELECTION] Our interview will center around the decision-making process during a non-routine event. It should be an event that was challenging, and one in which your expertise played a critical role, meaning that someone with less experience than you may have made different decisions. We are particularly interested in large events. Which event best meets this criteria?

2. Please walk us through the event and your organization's response to it, from start to finish, to the best of your recollection. By start, we mean the time your organization was alerted to the event, or began to anticipate it (e.g., a weather forecast). And by finish, we mean the time that the immediate response phase concluded and the situation was deemed under control.

3. [CONSTRUCT INCIDENT TIMELINE] Interviewer reconstructs a timeline and verifies it with the interviewee. This establishes a shared understanding of the event. The timeline may be updated and/or clarified as a result of this process.

4. Identify decisions for further probing. These decision points include times the interviewee would agree that several courses of action were possible, or that someone else with less experience might have taken a different approach.

5. What were the information sources that you had access to during this event?

For each decision point that requires probing:

6. [Goals] What were your specific goals and objectives at the time?

7. [Standard Scenarios] Does this decision point fit a standard or typical scenario?
    a. [Analogues] Were you reminded of any previous experiences?

8. [Situational Assessment] Did you use all of the information sources available to you for this decision point, or just a subset?

    a. (If a subset) Which sources did you use?
    b. Can any of this data you are describing be shared with us?

9. [Options] What courses of action were considered or were available?

10. [Decision-making] Were there any priorities (like first-come first-serve) that affected the decision?
    a. Did you use any software to support the decision-making process?
    b. Did time and pressure impact your decision-making process?
    c. [Resource] Did you allocate any available resources, including response personnel, to respond to this decision point?
        i. Were there concerns at the time of making the decision that these resources may be needed at a later time?
        ii. Were any of these resources provided by another organization?
            1. Was there a certain amount of time you had with these resources?
            2. Did this impact how you used these resources?
    d. Did responders' safety impact this decision? If so, how?
    e. Was the cost of this action reimbursable? Did this affect when you did this action?
    f. Were there any other organizations that responded to this event?
        i. Was there coordination between yours and the other organizations?

11. [Basis of Choice] What course of action did you choose? How was this option selected / how were other options rejected? If an action was reimbursable, did this affect what course you took?