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HOW UNIVERSITY ADMINISTRATORS MADE DECISIONS DURING NATIONAL WEATHER SERVICE TORNADO WARNINGS IN THE SPRING OF 2011

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HOW UNIVERSITY ADMINISTRATORS MADE DECISIONS DURING NATIONAL WEATHER SERVICE TORNADO WARNINGS IN THE SPRING OF 2011

A THESIS APPROVED FOR THE
DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL SUSTAINABILITY

BY

Dr. John Scott Greene, Chair

Dr. Eve Gruntfest

Dr. Laurel Smith

To all those affected by the tornadoes of 2011.

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Abstract

This research examines how public university officials made decisions during National Weather Service tornado warnings in the Spring of 2011, how weather information and non-weather factors influenced decision making, and how new tornado warning practices may affect their decision making process. New tornado warning paradigms are under development by NOAA's Hazardous Weather Testbed and Warn-on-Forecast groups that will increase tornado warning lead times.

Universities placed under tornado warnings were identified during the Spring 2011 tornado season. Interviews with emergency managers and officials at five public universities were conducted to address four main research questions:

1. How and when do key decision makers use weather information in decision making about notifying the campus during tornado warnings?
2. How do non-weather related contexts affect the decisions made about emergency notification of the campus during tornado warnings?
3. What sources of information do key decision makers at universities access during tornado warnings?
4. What decision support tools would improve operations, with particular focus on changes in lead time with probabilistic warning information?

This research found that National Weather Service tornado warnings acted as a trigger to activate most emergency notification systems but multiple decisions and actions occur prior to the issuance of the tornado warning, including communication with other departments on campus, weather monitoring, and situational assessment. The main non-weather factors that influenced decision making were the time of day or

year and the location of people on campus. The most common and important sources of weather information used to make decisions were public or private radar sources and personal communication with weather information providers and local or neighboring emergency management.

Weather information preferences included increased spatial and timing specificity and the development of relationships with National Weather Service Weather Forecasting Offices. This research found that longer lead times with low probabilities would result in less decisive calls to action than shorter lead times with higher probabilities. This research also found that lead time for tornadoes may include the advanced notice provided by outlooks, forecasts, and watches provided by the National Weather Service from the perspective of university emergency managers.

Chapter 1: Introduction and Background

Different stakeholders have different hazardous weather information needs, and developing forecasting information products in ways that meet the needs of weather sensitive decision makers requires an understanding of these decision makers' current warning response processes, decision-making contexts, and weather information needs. The technical National Weather Service (NWS) definition of tornado warnings may change when longer lead times[1] associated with probabilistic hazard information come into being. Longer lead times will be available in the future due to the development of new technologies and increased meteorological understanding of convective scale storms (Kuhlman et al., 2009; Stensrud et al., 2009). This study considers how university decision makers, including emergency managers and administrators, made decisions about activating emergency notification systems (ENS) for their campuses during NWS tornado warnings in the Spring of 2011. This thesis poses four main questions

1. How and when do key decision makers use weather information in decision making about notifying the campus during tornado warnings?
2. How do non-weather related contexts affect the decisions made about emergency notification of the campus during tornado warnings?
3. What sources of information do key decision makers at universities access during tornado warnings?

[1] Tornado warning lead time is defined as "the amount of time between the issuance of a tornado warning and time the tornado hits" (Schumacher et al., 2010).

4. What decision support tools would improve operations, with particular focus on changes in lead time with probabilistic warning information?

Background

Tornado Warnings

As of 2012, the National Oceanic and Atmospheric Administration's (NOAA's) Storm Prediction Center (SPC) and National Weather Service (NWS) release tornado information in the form of outlooks, watches, and warnings (Golden & Adams, 2000). Outlooks are provided one to two days in advance of forecasted severe convective weather. Watches, issued four to six hours in advance (Stumpf et al., 2008), are distributed by the SPC when there is "significant potential to experience severe thunderstorms capable of producing tornados" (Golden & Adams, 2000). Outlooks and watches are released based on forecast information from numerical weather models and forecaster analysis (Stensrud et al. 2009).

NWS tornado warnings, as of 2012, are issued based on what is known as a “warn on detection” paradigm when a tornado is reported by a trained spotter or favorable conditions are recognized on radar (Stensrud et al. 2009). Prior to 2007, these were released as county-based warnings where NWS Weather Forecast Offices (WFOs) issued warnings for entire counties within their County Warning Area (CWA). Advances in the late 1990’s allowed forecasters to issue warnings that included latitude and longitude coordinates that formed polygons (Waters 2004), and allowed for the ability to generate graphical displays of these polygon warnings (Waters 2004, Waters & Settelmaier 2004), but other warning infrastructure, including NOAA Weather Radio

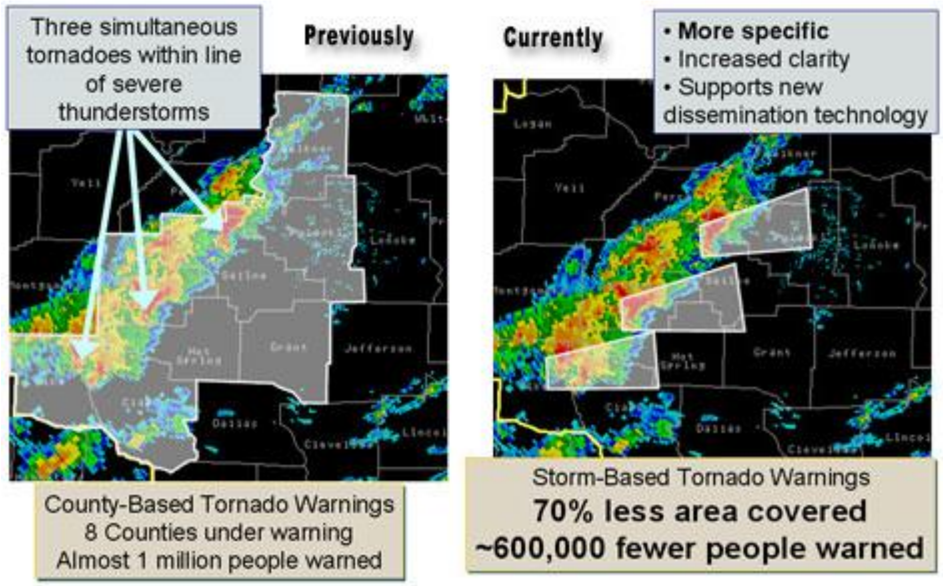

Figure 1: County-based and storm-based tornado warnings (Warning Decision Training Branch Webmaster, 2008).

(NWR) and sirens, were built to accommodate the county based warning paradigm. Because of this, NWS forecasters cropped warnings to county borders (Waters et al. 2005). The NWS began to train forecasters to create polygon based warnings that do not stop only at county boundaries (See Figure 1). These storm-based warnings were implemented in 2007 (Sutter & Erickson 2010), with potential benefits of fewer people placed under warnings, increased focus of emergency response resources to specific affected areas, and decreased time spent under warnings by those unaffected (U.S. Department of Commerce, 2007).

The change from county-based warnings to storm-based warnings offers an example of how changes to the warning system were not made collaboratively with stakeholders. League et al. (2012) found that 44% of Oklahoma emergency managers and 66% of Texas emergency managers have the capability of sounding sirens by subregion under the storm based warning system. However, only 48% of those in Oklahoma and 19% of those in Texas that have that capability use it 80% or more of the time and 33% in Oklahoma and 48% in Texas use the capability less than 20% of the time. NWR also continues to issue warnings based on county and is not equipped to issue warnings based on latitude and longitude. Despite nearly five years of using storm-based warning polygons, the system has not been adopted for some of the major notification sources for tornado warnings.

Probabilistic Hazards Information and Warn-on-Forecast

NOAA's Hazardous Weather Testbed (HWT) at the National Weather Center helps forecast software developers understand how people use weather forecasting tools. Part of the HWT program consists of the Experimental Warning Program (EWP). The EWP mission is to develop tools that will expand storm-based warning systems to improve communication of hazardous weather information. Part of this program is the Probabilistic Hazard Information (PHI) project, which is developing new products with the possibility of providing increased information to users (Kuhlman et al., 2008). These products include more specific temporal, spatial, and intensity information, increased lead time, stated probabilities, and continuous updates (see Figure 2).

PHI is one part of a larger project called Warn-on-Forecast (WoF), a NOAA initiative to increase lead times for short term hazards like tornadoes. The goal of WoF is to fill the current gap between forecast based watches and detection based short term warnings by providing forecasted warnings based on forecaster analysis of numerical weather prediction models (Stensrud et al., 2009). These forecasted warnings will display probabilistic information and provide longer lead times for tornadoes.

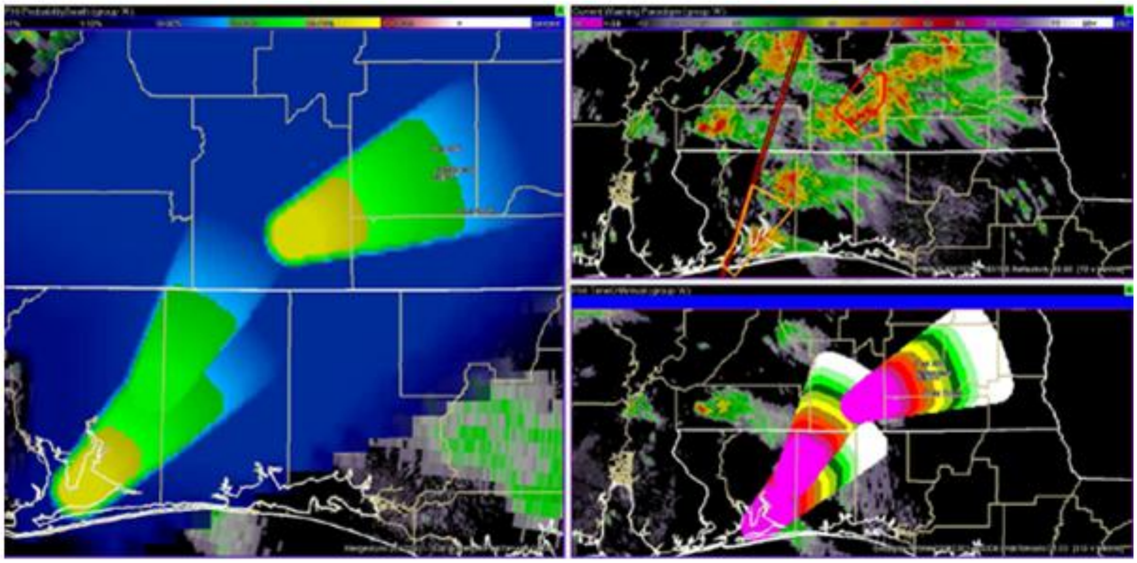

Figure 2: Probabilistic hazard information for tornados (left), current storm-based warning products from the NWS (top right), and estimated time of arrival (bottom right) (Kuhlman et al., 2009).

Social Science Woven Into Meteorology

Social Science Woven Into Meteorology (SSWIM), part of the University of Oklahoma and NOAA's Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), from 2008-2012, is an initiative to integrate social science research methods into meteorological research and product development. To develop these PHI products and the WoF project in ways that are useful to key stakeholders, agencies that provide weather information need to understand how specific stakeholders use current sets of information during warning response and what products will meet stakeholder needs. The goal of this study is to examine the perspective of university officials on NWS tornado warning response and weather information needs to help the developers of PHI products and the WoF project.

Universities and Hazards

Research suggests that universities are not prepared for different types of crises (June, 2007), and they may only be prepared for the types of events they have already experienced (Mitroff et al., 2006). Disasters at a university can result in loss of enrollment, funding, reputation, and credibility (Kiefer et al., 2006; Mitroff et al., 2006), as well as impacts that reach much further into the surrounding community or the nation (Yamaiel, 2006). As of 2007, there were 4352 accredited universities with approximately 18.2 million students and 3.2 million faculty and staff in the United States (Snyder & Dillow, 2010). These institutions need to keep their populations and operations safe from extreme weather events.

The Higher Education Act of 2008 (Public Law 110-315) is a set of rules for universities if they are considered Title IV institutions, or an institution that can provide federal student aid. The act requires the notification of students and staff in the event of a threat to the community's health or safety. These communication systems come in multiple forms, including Short Message Service (SMS) text messaging via cellular phones, mass email, and siren systems, among others (Schneider, 2010). The goal of this research is to understand 1) the ways university officials are made aware of severe weather information, 2) the decisions they made to active these communication systems, and 3) the contexts in which these decisions are made.

Summary of Thesis

My thesis consists of eight chapters. Chapter 2 covers a literature review on warning response models and decision making under uncertainty, probabilistic weather information and forecast uncertainty, tornado warning lead-times, emergency management weather information use, and university emergency management. Chapter 3 discusses the methodology used to conduct the research. Chapter 5 consists of the results and discussion about the four main research questions. Chapter 6 summarizes recommendations to the weather enterprise based on these results. Chapter 7 makes recommendations for future research on universities and hazards, lead time, and a list of recommendations for modifications to the methodology and lessons learned during the research. Chapter 8 provides a summary of major findings and conclusions.

Chapter 2: Literature Review

This thesis draws from six sets of literature including theoretical frameworks used in hazards geography and specific approaches relevant to applied geography about emergency management: 1) warning response models, 2) decision models and theories, 3) probabilistic weather forecasts and uncertainty, 4) tornado warning lead times, 5) emergency management weather information use, and 6) university emergency management.

Warning Response Models

Warning response has been studied in multiple disciplines including geography, sociology, and psychology (Mileti & Sorenson, 1990; Lindell & Perry, 2004; Lindell & Perry, 2011; Donner, 2007). From these studies, models have been developed and refined to predict individual behavior during warnings. These models include the Mileti and Sorenson (1990) model of warning response and the Protective Action Decision Model (Lindell & Perry, 2004; Lindell & Perry, 2011).

Mileti and Sorenson Warning Systems Model and Model of Warning Response

Mileti and Sorenson (1990) propose that warnings are released through three subsystems: the detection subsystem, the management subsystem, and the response subsystem. Hazards are predicted, detected, and monitored by the detection subsystem. The detection subsystem provides information to the management subsystem. The management subsystem chooses who, where, when, and how to warn the public. The management subsystem disseminates the warnings to the public. The response subsystem follows a sequence of six stages: 1) hearing the warning; 2) understanding the warning; 3) believing the warning; 4) personalizing the warning; 5) confirming the warning; and 6) deciding to respond. Schumacher et al.'s (2010) study of a tornado in northern Colorado found that university officials impacted by that storm followed these six stages of warning response.

The Mileti and Sorenson (1990) model of warning response has proven empirically sound (Donner, 2007), but technological advances, increased news coverage, and the private weather industry have increased the amount of available information (Rodriguez et al., 2007; Sorenson & Sorenson, 2007). With the introduction of these new technologies the official channels are no longer the only place to receive weather information. This means the systems on which these models were built are no longer top-down (Dow & Cutter, 1998; Hayden el at., 2007) and that some users increasingly seek out information rather than passively receiving information from the management subsystem (Rodriguez et al., 2007).

Hayden et al. (2007), Lazo et al. (2009), and Van Bussum (1999) have explored the multiple sources of weather information people access in their daily lives. Emergency managers have been shown to use multiple sources of information that they access for particular types of information depending on the progression of the storm (Baumgart et al., 2008; League et al., 2010). Hayden et al. (2007) argue that providing information to all users requires warnings to be provided in multiple ways, making the systems more responsive to real world situations. The Mileti and Sorenson (1990) model also does not account for the processes that lead an individual to make decisions to take protective action, including the decision to take no action.

The Protective Action Decision Model

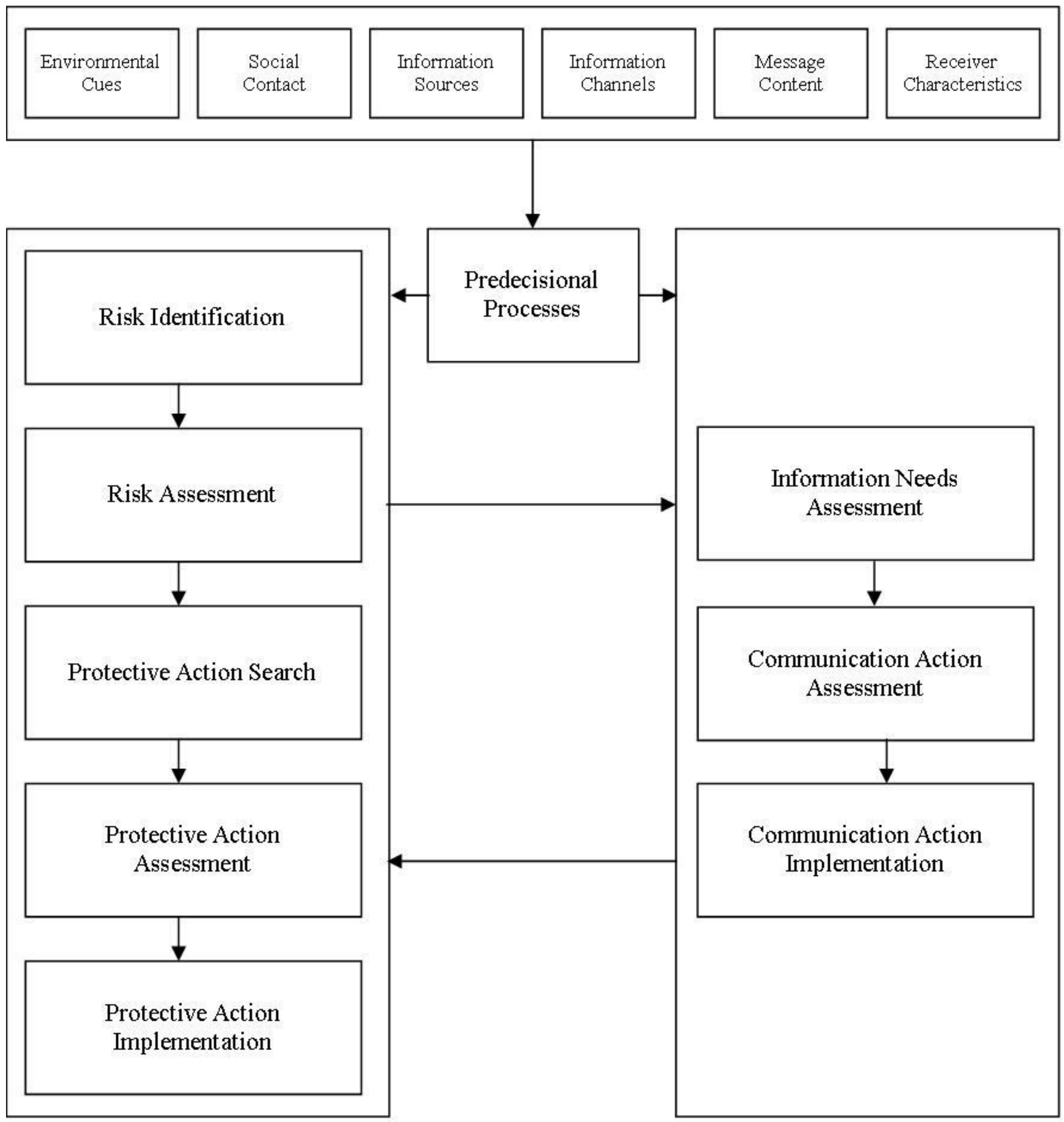

Figure 3: The Protective Action Decision Model (Lindell & Perry, 2004).

The Protective Action Decision Model (PADM; Lindell & Perry, 2004) follows a sequence of nine stages of decision making that includes the processes of information seeking and deciding to take protective action (Figure 3). The nine stages include predecisional processes, risk identification, risk assessment, protective action search, protective action assessment, protective action implementation, information needs assessment, communication action assessment, and communication action implementation. After the predecisional process of hearing and understanding the warning, an individual's decision to respond begins with risk identification (Lindell & Perry, 2004). The individual then goes through a process of risk assessment that can be influenced by the proximity, certainty, severity, and immediacy of the hazard (Lindell & Perry, 2004). The next stage is the protective action search. Individuals identify possible actions to take from memory, communication with other people, or by seeking information (Lindell & Perry, 2004). Once a set of actions is determined, an individual goes through a process of protective action assessment (Lindell & Perry, 2004). Possible actions are compared based on their efficacy, safety, time requirements, perceived implementation barriers, and perceived costs. During the protective action implementation stage, an individual determines whether the most suitable protective options need to be taken immediately (Lindell & Perry, 2004).

During these stages of response an individual seeks out information (Lindell & Perry, 2004). When an individual lacks sufficient information regarding the hazard or protective actions to take, s/he determines the information needed to reduce uncertainty through information needs assessment (Lindell & Perry, 2004). The individual determines where to get the information through communication action assessment (Lindell & Perry, 2004). Sources of information will vary depending on the stage of the protective action decision and the channels of communication that are available. Once individuals have a communication plan, they go through the final stage, communication action implementation to determine if they need the information then and find the information (Lindell & Perry, 2004). This final stage can return to the previous two stages if information or channels are insufficient to meet their needs.

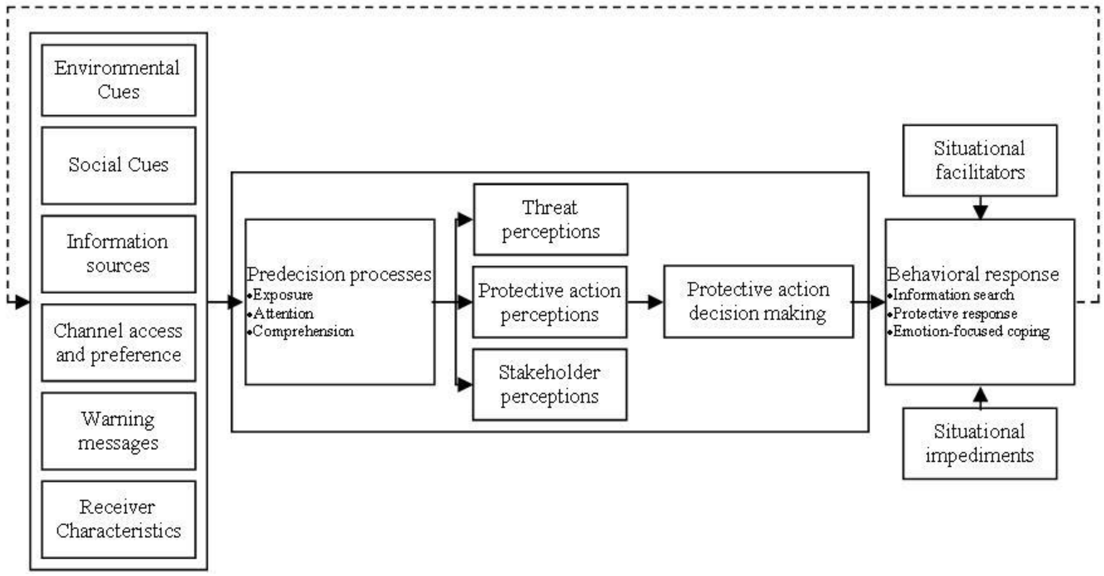

Figure 4: The updated Protective Action Decision Model (Lindell & Perry, 2011).

Based on further research findings, Lindell and Perry modified the original PADM model in 2011 (Figure 4) (Lindell & Perry, 2011). The influences on predecisional processes have largely remained the same, but the model itself looks substantially different from the original. New additions to the model include the concept of perceptions of the threat, protective actions, and stakeholders. Stakeholder perceptions means the way a person perceives another person or institution and the decisions they are making. For example, if a person perceives a stakeholder as trustworthy and sees them taking protective action, this may influence their own protective action decisions. This leads to the protective action decision making phase followed by the implementation of that action, which may be hindered or helped by situational impediments or situational facilitators. The model reiterates across itself as different behavioral responses are taken. The original PADM model (Figure 3) is still embedded within the theory but is less apparent in the new version of the model (Figure 4).

Decision Making Models

Utility Models and "Bounded Rationality"

Conventional economic theory suggests that people make purely rational decisions based on maximizing the utility of situations (Burton et al., 1993). According to expected utility theory, individuals will make the decision that ensures the least loss of utility (Burton et al., 1993). In an alternative theory, the subjective expected utility model, individuals subjectively view outcomes and costs are assessed based on personal perceptions. Individuals will act to minimize losses of utility from a subjective point of view (Burton et al., 1993).

Kahneman and Tversky (1979) suggested that utility theories failed to empirically model real world decision making so they developed prospect theory. Prospect theory proposes that, assuming people possess and understand all the pertinent information, they will not always act in a ‘rational’ way to maximize utility. They found that people favor certain outcomes, for example a guaranteed win of $450, as opposed to uncertain outcomes, such as a 50% chance of winning $1000. They also found that people will tend towards risk taking when the possible gain is substantially higher than the certain loss, and will tend towards risk aversion when the possible loss is substantially higher than the certain loss. Prospect theory is used to explain why people buy lottery tickets where the cost of the ticket is low but the payout is high and also why people buy insurance when the threat is high risk but low probability.

Expected utility models and prospect theory suggest that individuals understand all the facts, actions, and consequences of a decision. This is not always the case. Individuals work within a limited set of information and options (Burton et al., 1993; Tobin & Montz, 1997). Even if all the facts could be present, individuals are not capable of processing all possible sets of information. They may also be working toward alternative sets of goals than purely economic outcomes. Individuals are thus using "bounded rationality," working within their bounds of information, options, potential outcomes, and social, cultural, or individual perceptions of what is important (Burton et al., 1993; Tobin & Montz, 1997). Bounded rationality was originally coined by Simon (1956) and focuses on the concept of "satisficing," having certain need requirements and stopping a search for alternatives when that need is met without optimizing the decision.

Response to hazards is not entirely dependent on communication of information and rational processes of decision making. People may make decisions that seem completely irrational, but are based in a set of cognitive or situational factors that play a part in the actions taken (Figure 5); (Tobin & Montz, 1997). Cognitive factors are internal attitudinal and psychological aspects of an individual that shape their perceptions of nature and risk. Conditional factors are real or perceived external socioeconomic and physical aspects. Cognitive and conditional factors interact and influence one another in generating a response. For example, mitigation efforts, such as retention ponds or drainage basins, may result in the perception that floods are no longer a hazard, and change attitudes towards floods. For emergency managers, a change in attitude about flooding due to mitigation has been shown to be a reason for decreased monitoring of rainfall in favor of monitoring weather capable of producing tornados (Donner, 2008).

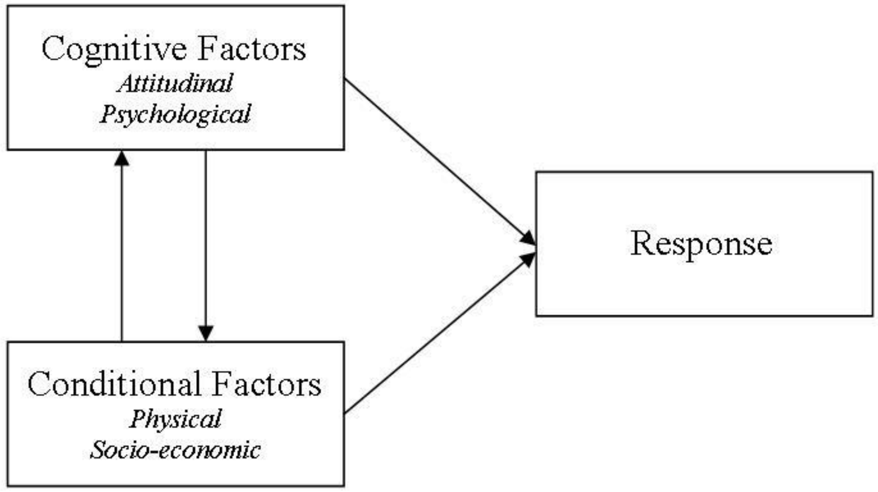

Figure 5: Cognitive and conditional factors role in response to hazards (adapted from Tobin & Montz, 1997). Influences on these factors shown in italics.

Situation Awareness

An alternative to economic and psychological decision making models and rationality comes from human factors researchers. Situation awareness (SA) became a focus of study in military operations during World War I and gained prominence in the 1980's as systems in which decisions are made were becoming more complex (Endsley 2000). SA studies have largely focused on piloting, air traffic control, and plant operations but have started to gain prominence in other fields as well.

An accepted definition of SA comes from Endsley (1995, pp. 36). SA is defined as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." Following Endsley (1995), SA is composed of three levels. Level 1 SA is the perception of environmental cues, Level 2 SA is the integration of those cues to comprehend the environmental situation, and Level 3 SA is interpreting and forecasting what will change in the near future. Endsley (1995) developed a decision making and action implementation model (Figure 6). He theorized that SA is a single, yet important, component of decision making and action implementation, though these two processes are influenced by other factors including the goals of the decision maker, their level of experience and training, their choice of information processing mechanism such as a mental model or schema, and the system being used to gain situational awareness including its design and capabilities (Endsley 1995, Endsley 2000).

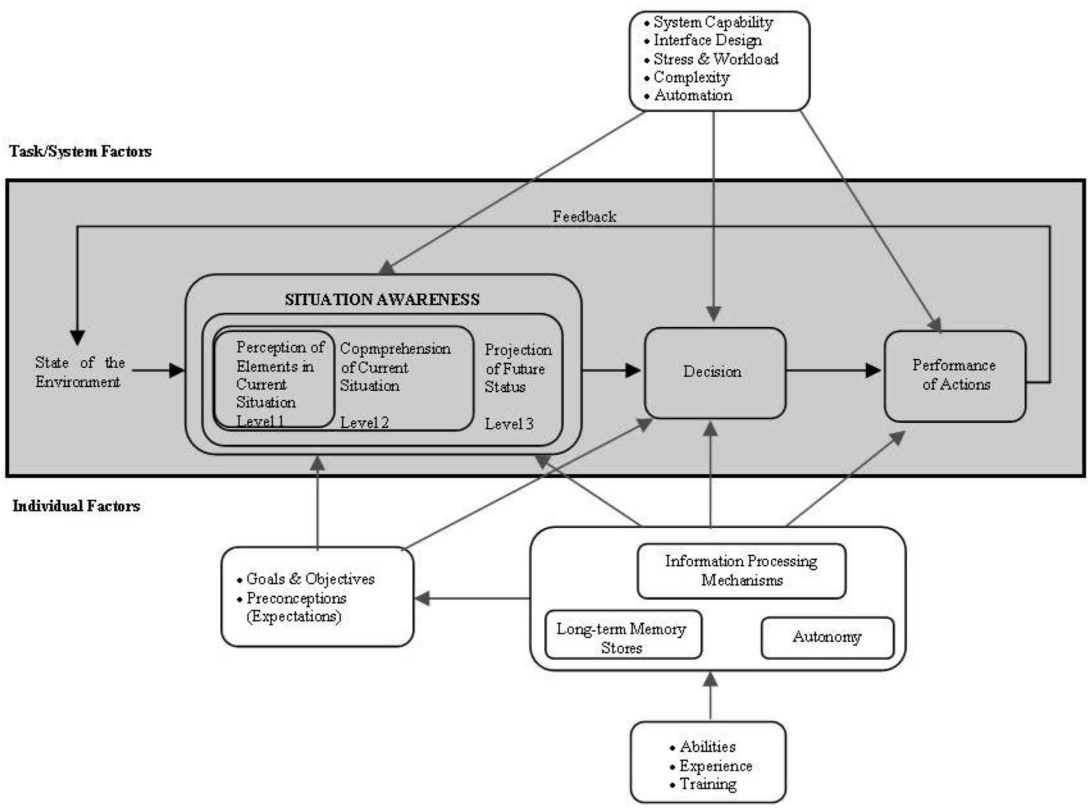

Figure 6: Decision making model including situation awareness (Endsley, 1995).

Probability and Uncertainty in Weather Forecasts and Warnings

Forecasts are inherently uncertain and the NWS wants to communicate this information effectively (NRC, 2006). The agency is working on new ways to communicate uncertainty in its public forecasts. While studies have shown that the exact definition of forecasted events, such of probability of precipitation, is commonly misunderstood (Gigerenzer et al., 2005; Murphy et al., 1980), probabilistic information is understood (Murphy et al. 1980) and is a preferred method of receiving forecast information (Baker, 1995; Morss et al., 2008; Nadav-Greenberg & Joslyn, 2009). Other studies have found that probabilistic forecasts are best communicated through the use of frequencies, such as 1 in 200 (NRC, 2006). Probabilistic forecasts have also been shown to improve decision making compared to deterministic forecasts (Nadav-Greenberg & Joslyn, 2009; Roulston et al., 2006). Studies about probabilistic forecast tend to use experimental designs that remove people from the contexts of their daily lives and do not represent the complexities of reality.

In a review of existing literature, the Committee on Estimating and Communicating Uncertainty in Weather and Climate Forecasts of the National Research Council (2006) concluded that there is a great deal of complexity in decision making under uncertainty. Because of this, no information product is "one size fits all" and products should be developed based on different stakeholder needs and wants. University decision makers represent one set of stakeholders. This study will not examine the ways in which these decision makers use uncertainty to make decisions or the preferred methods of communicating this uncertainty, but it will look at the way increased lead-time with probabilistic information may alter and change decisions and the contexts in which they are made.

Lead Time

Lead time is the amount of time between the issuance of a warning by the NWS and the time the event occurs (Schumacher et al., 2010). Lead time is intended to provide the time necessary to initiate preparedness plans and take action prior to a hazard (Carsell et al., 2004). Carsell et al. (2004) created a model timeline for a flood warning system including detection of the event, analysis of the data, notification of emergency response personnel, decision making, and response. This model was modified by Pingel et al. (2005) to represent the lead time in a flood warning system that was further modified by Schumacher et al. (2010) for tornado warnings (Figure 7).

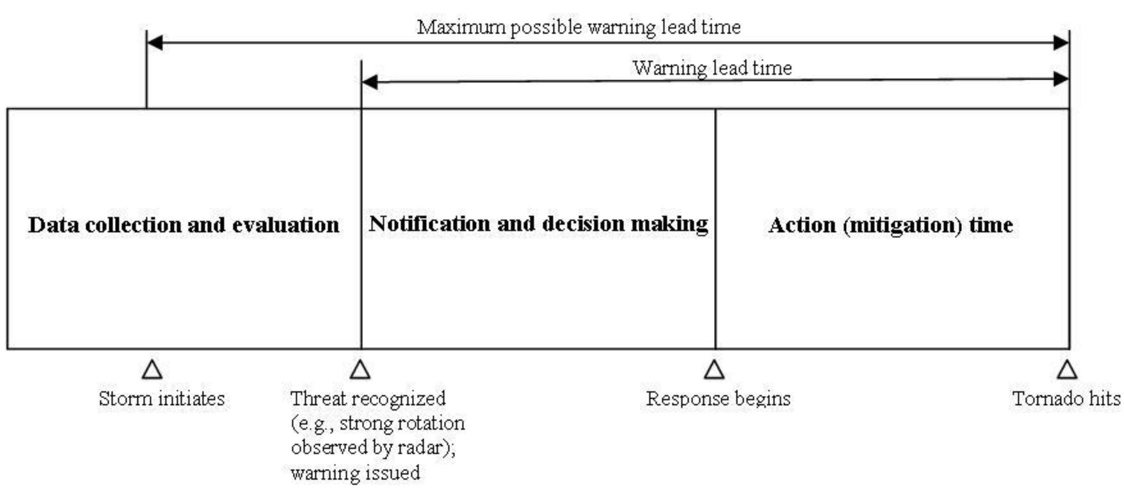

Figure 7: Model of lead time for tornados (Schumacher et al., 2010).

Figure 7 shows a general model of data collection and evaluation, notification and decision making, and action. The time spent in any one of these stages impacts the time spent in the next. The longer it takes to make decisions regarding protective action the less time available for action to be taken (Carsell et al., 2004; Schumacher et al., 2010).

A goal of the NWS is to increase tornado warning lead time to up to two hours. Current lead times have increased to an average of 13 minutes (Stensrud et al., 2009). Studies have varied in defining ideal lead times from 15 minutes to 34.3 minutes (Ewald & Guyer, 2002; Hoekstra et al., 2011, League et al., 2012). Simmons and Sutter (2008) have statistically shown that there is no decrease in fatalities for lead times longer than 15 minutes.

The WoF project and PHI systems will possibly increase lead times by up to one to two hours by 2020, and these longer lead times will be accompanied by probabilistic information (Kuhlman et al., 2008; Stensrud et al., 2009). While the work done thus far has examined preferences and fatalities using current lead times, the new tornado warning systems in development could alter the contexts in which people make decisions and respond. Little work thus far has taken into account the shift in warning response and decision making that may occur as a result of significantly longer tornado lead times coupled with PHI, particularly within complicated operations like university emergency management.

University Emergency Management

Hazardous weather information use and decision making by university officials are only beginning to be the foci of research (Schumacher et al., 2010). While previous research efforts have focused on the preparedness, planning, and recovery phases of university emergency management (Collins et al., 2008; Curtis et al., 2006; Farber, 1982; Friesen & Bell, 2006; Hartzog, 1981; Human et al., 2006; Johnson, 2007; Kiefer et al., 2006; Osburn, 2008; Wilson, 1992) relatively little work has focused on actual response to hazardous weather situations (Schumacher et al., 2010; Sherman-Morris, 2010; Zdziarski, 2001). This thesis builds on existing studies and provides new understanding of the contexts in which public university officials make notification decisions during tornado warnings.

Public universities are communities with their own particular sets of complexities in emergency management decision making (U.S. Department of Education, 2010). Universities can resemble small towns that are embedded into larger communities because of their extensive geographical area, public services such as utilities plants and law enforcement, small businesses on the campus, and residential housing. Some universities manage satellite operations and research facilities that can be geographically distant from the main campus. University borders are largely uncontrolled, and people and resources are constantly moving across these borders. University populations are legally autonomous and the individuals are capable of making their own decisions. Amid these complexities, universities are legally responsible to disseminate warnings to the campus population when there is a threat (Public Law 110-315). Given this responsibility, their roles in current warning systems theories and their processes of decision making during tornado warnings are unclear.

Summary

While research has been done to create models of warning response and decision making, few studies (Schumacher et al., 2010) have examined the response of university officials to tornado warnings. Understanding the processes in which university officials make decisions, and the way their sources of information and different contexts and concerns in emergency management affect those decisions, can inform the development of new tornado warning products that meet university communities' expressed needs.

Chapter 3: Methodology

This study looked at five public universities that were placed under National Weather Service tornado warnings during the 2011 spring storm season but were not impacted by a tornado. The original proposal for the research called for three case studies based on the assumption that multiple people would be involved in the decision making process during tornado warnings. However, because some universities had one main decision maker and some decision makers from participating universities did not respond to invitations for interviews, the number of case studies was expanded to five. This alteration in the plan provided more data for comparison between different universities.

Because universities engage in so many different types of activity and have a large number of departments responsible for different functions, the interviews focused on one element of response. The interviews sought detailed descriptions and explanations of decision making from multiple perspectives of university staff and partners involved in the redissemination of warning information through ENS, including the communication of information as the severe weather approached, during the tornado warning, and after the tornado warning had expired.

Sampling Methodology

Public university case studies were chosen during the spring severe storm season in April and May of 2011. The potential for severe weather was monitored via products released by the NWS through the use of the GovDelivery service, an email service that provides governmental updates from multiple agencies. These services provide email updates of NWS products, including outlooks and watches. SPC Day 1, 2, 3 and 4-8 convective outlooks provide advanced notification of possible severe weather up to eight days in advance. SPC Tornado/Severe Thunderstorm Watches send a notification when a watch is released by the NWS.

The issuance of warnings by the NWS was monitored through the use of the Iowa Environmental Mesonet, an archive of NWS warnings. Warning files were uploaded into Google Earth^{TM} and the location of universities was displayed by typing the term "university" into the search tool within Google Earth^{TM} (see Figure 8). This data was cross-referenced with the university's website and campus maps to avoid inaccuracies. When a university or college was located within the warning polygon, it was sampled for contact regarding participation in the research.

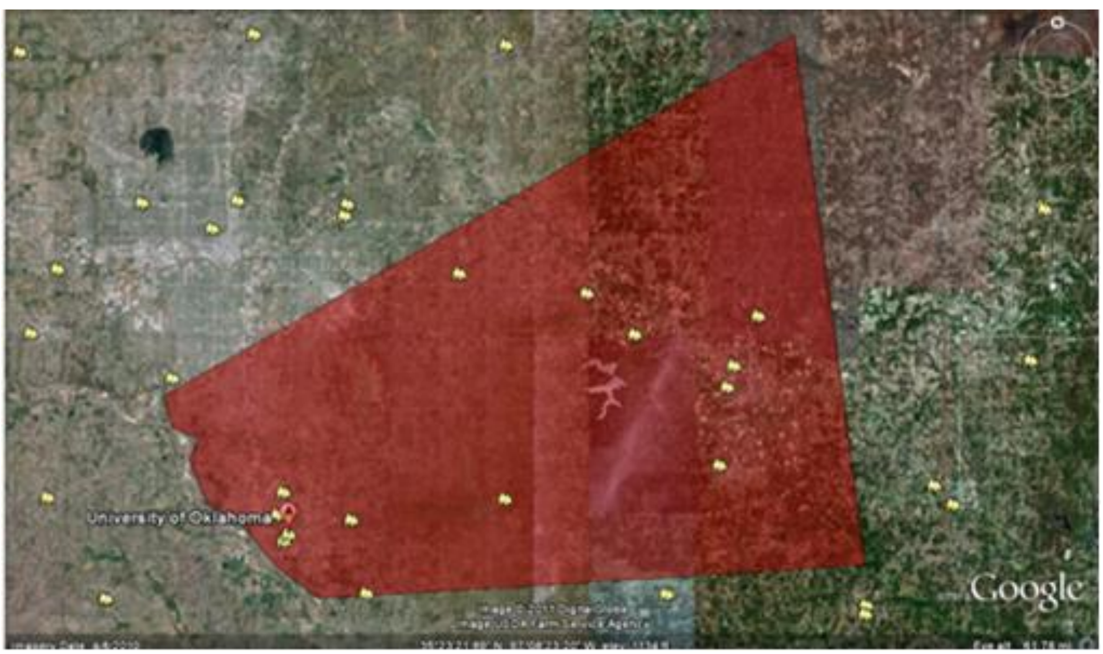

Figure 8: Example of an archived tornado warning polygon.

Because during the Spring of 2011 hundreds of warnings were being issued the initial sampling methodology was changed. As an alternative, a master list of universities fitting the sampling criteria and located in states affected by NWS tornado warnings during the sampling period was created and plotted in Google Earth™ using data from collegeboard.org, the SAT college search website. This information was cross-referenced with the university's website before being contacted to ensure the university matched the sampling criteria.

The sampling criteria called for public universities with a campus population over 5000 students and Title IV designation that were placed under tornado warnings but not impacted by a tornado. Hartzog (1981) stated that the public status of universities is a unifying factor in planning for emergencies and a campus population over 5000 is large enough to constitute a need for emergency planning. Campus population was determined through the analysis of university self reported student population numbers and collegeboard.org (College Board, 2012). Title IV institutions are legally required to provide emergency notification to students at the time of a threat on campus, and were thus chosen as they are those most likely to provide emergency notification during tornado warnings (Public Law 110-315). The Title IV status of institutions was determined through a search of the Federal School Codes supplied by the Federal Application for Student Financial Aid program (Federal school codes, n.d.). Universities that were placed under warnings but not impacted by a tornado kept the sample consistent. While multiple universities were placed under a tornado warning, very few are directly impacted by tornadoes because of the differences between the spatial scale of warnings and the actual size of a tornado. It was considered unlikely that multiple universities would be directly struck by a tornado, and comparisons between universities that sustained tornado damage and those that did not could alter the results. This sample criteria was also requested by the University of Oklahoma's Institutional Review Board so that university administrators would not be impaired in performing their jobs by this research.

These sampling methods gave insight into actual behavior during a tornado warning, and interviews took place as soon as possible after the event. The research questions asked participants to remember times, locations, sources of information, and decisions during a tornado warning affecting their institution's campus. This approach aimed to ensure the most complete recollection of memory possible while maintaining ethical and legal guidelines.

Initial interviews were conducted with emergency managers at the institutions either over the telephone or in person. Because of the differences among universities, the title and department of the emergency manager varied between institutions, including the University Police Department, Department of Environmental Health and Safety, or Department of Emergency Management. For the purposes of simplification those decision makers with emergency management responsibilities will be called the emergency manager or EM from this point forward. The institution's EM was determined on a case-by-case basis through internet searches or contact with the department responsible for ENS. When this information was not available on the university website, the university was not contacted.

After determining who the university EM was, participants were asked to identify other key decision makers in the emergency notification process for each university, both on and off campus. These decision makers were then contacted to request participation in the study. Additional decision makers varied by institution and included housing services, public safety administration, public relations, and the NWS. This method was used because of the particular and varied structures of universities. This ensured that sampling methods for participants were appropriate for the individual institution. Two of the five universities included interviews with additional participants beyond the emergency manager. The breakdown of participants is in Table 1, and the breakdown of participants by university is in Table 2.

Table 1: Participants by general job description.

Participant Type	Number
Emergency Managers	5
Housing Services Administrators	2
Public Safety Administrator	1
Media Relations Spokesperson	1
Public Sector Meteorologist	1
Total	10

Table 2: Participant numbers and type from universities.

University	Participants
Γ University	1 Emergency Manager 2 Housing Service Administrators 1Public Sector Meteorologist
Ω University	1 Emergency Manager 1 Public Safety Administrator 1 Media Relations Spokesperson
Ψ University	1 Emergency Manager
Π University	1 Emergency Manager
Σ University	1 Emergency Manager

Data Collection

Data collection took place through the use of digitally recorded semi-structured interviews with participants. Semi-structured interviews provide a series of questions and topics for discussion, but also allow unexpected information and themes to be explored on a case-by-case basis (Longhurst, 2010). This data collection process allowed for the participants to provide their perspectives on information sources and warning response but also allowed for the collection of data considered important by the researcher based on her/his analysis of the literature on emergency management, warning response, and the dissemination of warnings (Longhurst, 2010). Schumacher et al. (2010) used semi-structured interviews with decision makers for their study of the 22 May 2008 tornado in Colorado. This research design builds off their approach to studying tornado warning decision making by university administrators.

Interviews with participants were broken into four parts during one or two interviewing sessions that took place over the telephone or in person. Participants were asked for information about the institution including their role at the institution, weather monitoring at the institution, and emergency notification systems. The next three parts of the interview included questions about decision making, communication, and sources of information before, during, and after the tornado warning with regards to the redissemination of warnings. The participants were asked about factors beyond weather information that influenced decision making. The last portion of the interview asked the decision makers what other information would be helpful in making decisions before, during, and after tornado warnings. This portion of the interview included scenario based questions regarding the effect of a longer and shorter lead-time (2 hours, 15 minutes) coupled with probabilities (30%, 70%) of impact. These questions were phrased in such a way as to investigate perspectives on the complex and abstract concepts of products that are currently being developed using terminology similar to probability of precipitation forecasts with which users are familiar. The times of two hours and fifteen minutes were chosen to represent the maximum proposed lead times of the WoF project and a lead time close to the current average lead time. Thirty and seventy percent were chosen as hypothetical probabilities at the mid range between zero and fifty percent and fifty and 100 percent. Appendix 2 provides a list of the scripted interview questions.

Data Analysis

Data analysis was conducted using Nvivo9 qualitative analysis software. After transcription of the recorded interviews, two sets of codes were created. The first set consisted of time period including pre-warning, warning, and post-warning. The second set consisted of thematic codes based on similar concepts that arose in multiple interviews. Predetermined thematic codes were initially defined based on the research questions and then expanded to include additional concepts that arose during analysis (Weiss, 1994). Numerous thematic codes were used, the most commonly mentioned being communication, weather of the event, time, space, emergency notification systems, and weather in general. The codes were then made more specific based on similar themes within the broad codes. For example, weather of the event included the coded subset of weather information sources. Organization of data in this way made it possible to see when in the course of events different issues, such as the spatial location of people or storms, sources of weather information, or communication with people on and off campus, were considered, decisions were made, and actions taken by cross referencing time periods and the codes. This information was then used to create a generalized timeline of events when a majority of institutions mentioned actions taking place during the phases of the event.

Nvivo 9 software also provides the ability to see all the codes used for a fragment of text, showing the connections between different themes. For example, the fragment of transcript "The only exception would have been when the first severe thunderstorm warning came out we're like 'It's [the middle of the night], bars are closed, nobody's walking, are asleep in their beds. Maybe I won't use the sirens.'" was coded for time of day, location of people, emergency notification systems, situational dependency, decision making, and source of weather information, indicating that all these codes were connected for this piece of the transcript. This information was used to develop a hypothesis model of factors influencing decision making by university emergency management and administrators.

Limitations of Methodology

The results of this study are a first step in learning how university emergency managers and other decision makers respond to tornado warnings. The study has three main limitations:

1) The sample of university decision makers is small due to time constraints and the sample size limits the study's generalizability. The results can be used to develop preliminary hypotheses for further testing by future studies and initial recommendations to meteorological software developers and forecasters.
2) The study was also limited by the availability of information on university websites about departments or individuals responsible for emergency

management and the activation of ENS at institutions. This problem made the sample non-random and dependent on the information available on the internet.

3) The tornado season began shortly after the questions were written and approved so there was not enough time to conduct a pre-test with university decision makers. While the questions were extensively reviewed by trained interviewers, testing the questions with members of the stakeholder group would have provided feedback on unintentional omissions and insights about questions that could have been written more clearly. Every attempt was made during the interviews to clarify questions if the participant was confused by their wording, but additional pre-testing of the questions would reduce this confusion.

Confidentiality

To maintain confidentiality, names of people, universities, and places, including city, county, and state, are not included in the discussion. People are identified by their job description or title, such as a university emergency manager, and universities are distinguished by a unique capital Greek letter (see Table 2). Dates and times are also not included, but discussed in general terms, such as the middle of the night or between semesters, to provide enough contextual detail without compromising the confidentiality of the participants.

Summary of Major Points and Relation to Previous Research

The study interviewed ten decision makers from five public universities using semi-structured interviews. Participants were identified using tornado warning polygons and university place data in Google Earth™. This research builds on earlier research conducted by Schumacher et al. (2010) about university administrator's decision making during tornado warnings. It uses a similar data collection methodology to Schumacher et al. (2010), but expands on the research to include multiple universities placed under tornado warnings during the spring of 2011 that were not impacted by a tornado.

Chapter 4: Results and Discussion

The results of this study are divided into the four main research questions. This chapter will provide the results and discuss the findings for each research question and connect the results to previous research. The chapter is divided into five main parts: 1) a general timeline of decision making and actions for university administrators, 2) non-weather factors that influenced decision making, 3) sources of weather information, 4) weather information preferences, and 5) lead time.

General Timeline

One goal of this research was to understand how and when university decision makers, particularly emergency managers, made decisions about the activation of emergency notification systems (ENS) on their campus. To answer this question a general timeline of events was produced from the analysis of the case studies showing some of the major similarities among the different universities sampled (Figure 9). The timeline is based on actions taken with regard to university emergency management and public safety. It does not take into consideration those participants acting outside of the emergency management role or engaging in other university activities. Recognize that not every university engages in the actions shown on the timeline. The timeline is based on multiple mentions by different universities, but no single university fits the timeline perfectly.

The timeline is divided into four main phases based on the state of the weather at the university. These phases include non-severe, severe weather approaching, warning, and severe weather passed. The use of these phases is for heuristic purposes, but the phases are not completely discrete. Phases for emergency management are a common heuristic which typically include mitigation, preparedness, response, and recovery. Neal (1997) makes the argument that these phases are not mutually exclusive and can overlap. The same argument is made here using the phases developed for the generalized timeline. The four phases used in the timeline contain overlap, with each phase affecting the next, and the point of phase change is not always clearly distinguishable. The only exception to some extent is the warning phase. The timeline is not to scale. Participants had difficulty remembering exact times, so all times are approximations.

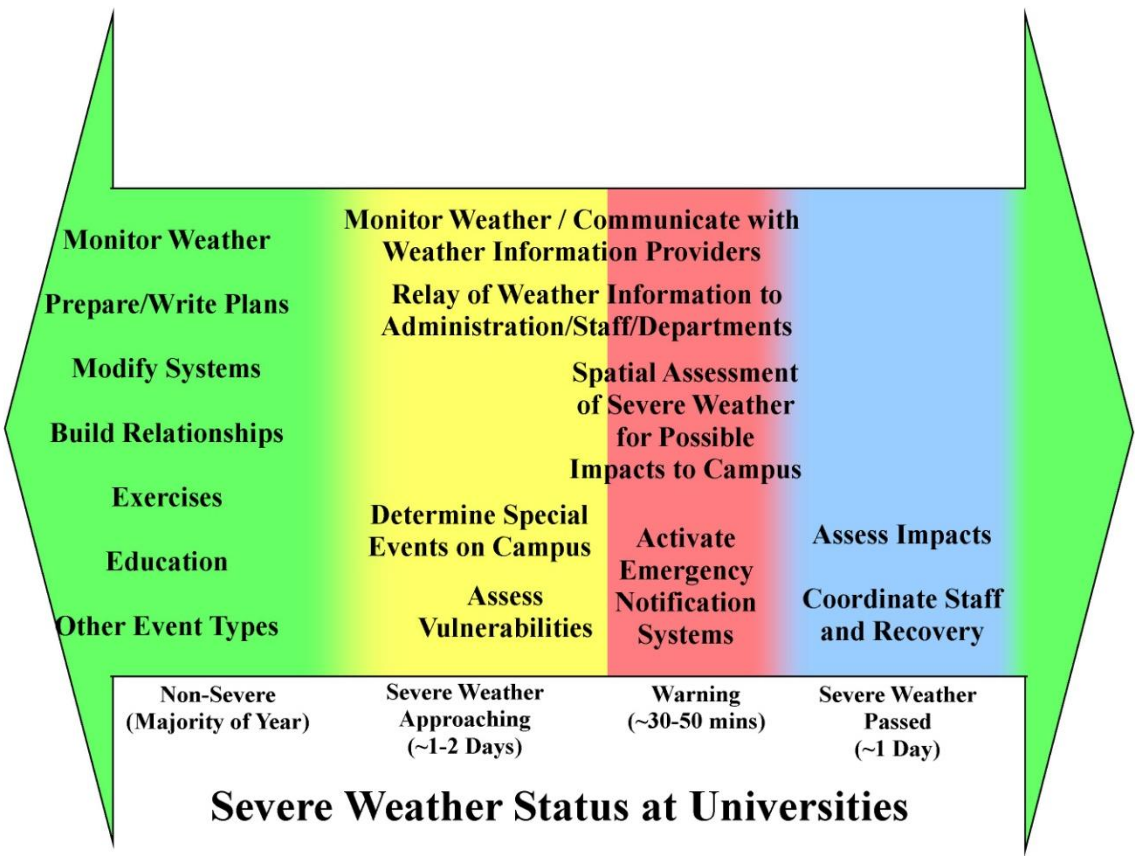

Figure 9: General timeline for severe weather at universities from the university emergency management perspective.

Status of Weather at University: Non-Severe

The first phase classifies the normal functioning of university emergency management when severe thunderstorm and tornado warnings are not in effect. This encompasses the EM's role in the university during the majority of the year. Despite the lack of severe convective weather this phase plays an important role in the response to hazardous weather events.

During this phase, the EM is monitoring the weather either actively or passively depending on the individual. They are checking the forecasts produced by the NWS or other private weather information providers, or have acquired ways of becoming alerted to weather of concern, such as emails from weather information providers. For example, the EM from Γ University was monitoring the weather forecasts on the day of the interview because there was a planned athletic event taking place that weekend and the EM needed to be aware of any potential weather threats for that event. The EM stated, "Now, for example, this weekend is our spring football game. It's considered a home game, so I'm already looking at the forecasts, I've already been emailing key people the forecast." Weather monitoring is not the exclusive responsibility of the university EM and does not consume all of their time, but it does play an important role in maintaining the safety of the campus as it can affect a number of activities that the university engages in, such as outdoor social, ceremonial, or athletic events.

The EM is also engaging in preparedness activities by writing plans and conducting exercises to ensure the university is ready should an emergency situation occur. Along with this is the development and changing of emergency notification systems (ENS) to deliver messages to the campus in times of emergency. A majority of the participants mentioned that plans or ENS had recently or were being changed or expanded when the warning in question occurred or at the time of the interview. These changes included the complete modification of a response plan, transfer of ENS providers, changes to the methods of activation, or the addition of ENS capabilities such as social media or installing more public address systems in university buildings. The EM from Γ University stated, "…we are constantly investing into improving and making things faster."

Plans and procedures are written in advance of any severe weather event to provide guidelines to emergency management and law enforcement. This also provides advanced authorization of ENS messages, both vocal and text based, so that permission is not required when a tornado warning is issued for the campus if the university EM or other personnel are responsible for the activation. The messages are passed through a chain of command to ensure that the message is approved for university use. This creates canned messages so that when a tornado warning is issued there is a statement ready for dissemination that is part of the official response plan for the university. The EM from Γ University said,

> "…the policy is pre-approved… we've already gone through the discussions and negotiations, the language was all approved and now the policy's in effect, so there's no second guessing. It's just when it happens you do it. You don't have to say 'mother may I?'"

Similarly, the EM from Π University stated,

> "Basically my position would [create the content of messages] and then have it vetted through our… Public Information Officer, as well as the Associate Vice Chancellor for Environmental Health and Campus Safety, for approval. Those are for… pre-scripted messages which we try to have ready for things such as tornadoes."

When systems are controlled by an organization outside of the university there is no control over the message content or when it is created.

Relationships are crucial to effective response in the event of a hazardous situation. Within the university community EMs have to know who to contact with information, as well as where and what information needs to be acquired. All of the EMs contacted mentioned having a pre-determined group they contact in the case of an approaching emergency, both to update these groups and gain necessary situational information such as planned events. The relationships may be as basic as having a list of pertinent email addresses or as complex as having dedicated staff members from various departments or buildings to act as emergency response personnel.

Relationships are also built with people outside of the university community such as with the NWS, local meteorologists, and/or other EMs. The relationships were mentioned during the course of the interviews and were recognized as an important part of the tornado warning response. It is hypothesized that these relationships are created during the non-severe phase so that people know and trust one another when they need to work together during severe weather since the relationships were already established during the 2011 tornado warnings.

Staff and student education about hazardous weather and emergency procedures is also an important aspect. Three of the five EMs mentioned running drills or exercises with their staff to ensure everyone was familiar with the plan. Periodic messages about the severe weather plan may sometimes be sent to students or staff to remind them of procedures. Two university EMs mentioned that they tried to educate students about severe weather. The EM from Σ University held an optional severe weather class for out-of-state students to educate the population about tornadoes and tornado safety. The EM from Γ University mentioned education initiatives geared towards residential populations to generate a "culture of preparedness" on the campus.

Other types of events were not specifically asked about but the interviewees made some mentions of other hazardous event types. These included hurricanes, floods, winter weather, traffic accidents, and muggings, and the active shooter event was mentioned as a hypothetical low probability, high risk event of concern. EMs must also deal with athletic games and ceremonies that increase the number of people on campus. The EM from Γ University stated that a particular difficulty with these athletic events is that many attendees are not part of the regular campus population and are not registered for the email and text messaging warning services. Severe weather is only a small part of the context in which the university EM conducts their job.

Status of Weather at University: Severe Weather Approaching

Every EM interviewed was aware that there was the possibility of severe weather that day or night at their university hours or days before the tornado warning was issued. As mentioned before, monitoring the weather is a part of the typical job responsibilities of EMs. Because of their job responsibilities, they were all made aware of the potential of severe weather before the tornado warning. The amount of time ranged from several hours to four days. Once they are aware that there might be a tornado based on outlooks or watches from the NWS and SPC, EMs maintain awareness of the approaching convective storms through the use of radar, NWS updates, or other private weather information providers. The EM from Π University said, “And I was monitoring the radar through a number of different sources to try to get some information, early information if there was any rotation or severe rotation within the thunderstorm system that might indicate the potential for a tornado to form.” And the EM from Ω University said, “If there’s a potential, I’ll always watch the weather…” The EM from Γ University was the only one who did not monitor the weather continuously because the tornado warning occurred in the middle of the night. He stated,

> “I was watching the [NWS] chat all day long seeing how it was going through [State to the West] and all that stuff. But, and really, I’m not gonna stay up all night staring at it so basically I double checked I had my laptop ready to go, I had my weather radio on, and… got a few hours of sleep.”

All EMs interviewed mentioned contacting members of their administration or other departments across campus to communicate the possibility of severe weather affecting the campus. The most common departments mentioned were those that dealt with high numbers of students outside of the classroom setting, such as housing, student recreation, student life, or athletics. The EM from Ω University explained,

> “The reason I called housing, I called the [recreation] center, these are the three highest areas, of populated areas, on campus for after hours. In other words, there’s a lot of people in our recreation center, a lot of people in the student center, and a lot of people in housing…. so what I wanted to do was make sure, even though we practice, it’s been a while since we practiced, and make sure they review their policies and procedures with taking shelter in place and those type of things.”

Police departments were another frequently mentioned communication point because police dispatchers were often responsible for some segment of the ENS for the campus, and the EMs were ensuring that they had the systems ready in case of the issuance of a tornado warning. For example, the EM from Π University said, “… I contacted our [university] police, let them know that there was a possibility for severe weather. And so they had individuals who were ready to… send the message if we needed to send it." The number of additional university personnel contacted varied by university, ranging from hundreds to a few select members who acted as additional dissemination points across the campus. This communication came in the form of emails, radio transmissions, phone calls, and direct communication depending on the structure of the university's plans and protocols. The relationships formed during the non-severe phase are hypothesized to be the basis of this communication structure.

Depending on the anticipated arrival time of the severe weather the university EM also contacted certain departments on campus to determine if there were events on campus. These departments included athletics, student affairs, and others. The EM from Π University said,

> "…we did check with our groups like athletics to see if they had any events going on. We checked with student affairs to see if they had any events going on, and we checked with our medical school to see if they had any events going on…"

This communication allowed the university EM to determine possible vulnerable situations that may be occurring upon the onset of severe weather. A Γ University and Ψ University, this type of campus assessment was not made or not mentioned by participants because of the time of year or hour of expected arrival for the severe weather. If the campus was going to be largely empty because it was between semesters or the severe weather would arrive overnight there was no mention of gathering this type of information.

As the severe weather grew closer the EMs interviewed were continuing to monitor the weather. They were assessing the spatial proximity of the severe weather to their campus through the use of radar. In some cases they were looking at the impacts of the severe weather to neighboring counties. The EM from Ω University mentioned he "…communicate[d] with the [Local Emergency Planning Committee] in [City Name], [State], which is just southwest of us, and usually those bad storms are coming out of the southwest. And they usually call me if it's something directly affecting them." In this way university EMs can anticipate what weather is approaching.

Status of Severe Weather: Warning

The warning phase is the only phase with a clear delineation between the earlier phases. The issuance of a NWS tornado warning typically triggers the implementation of particular plans and protocols. This delineation, however, is not completely defined because there is some spatial processing of the warning occurring. For two EMs this spatial processing meant determining if the tornado warning polygon intersected the campus. For example, the EM from Γ University utilized text messaging services and NWS Chat to determine if the warning was applicable to their campus. He stated,

> "So if it hits [County Name] I get one kind of text message. Then the iNWS system, the interactive NWS, will send me another one if it's touching my polygon. So if I get one and not the other, I'm usually pretty sure, and if anything I'll call or get on the NWS chat and verify,' just making sure that does not include campus.' 'That's correct [EM].' And they answer that. But if I get the iNWS page that means it intersects my campus, or intersects my polygon."

The EM from Π University used various services to learn about the warning and then checked the radar to see if the city was in the warning polygon. He explained,

> "I learned I was under a warning when I got an email from our utility provider which we are on their alert list. And as soon as I read that, my weather radio went off. And as soon as I turned that off the [other weather service] alarm went off. And I turned that one off and went to the radar and looked for a polygon box to see if we were in that warning area. Which I like the polygons much better than I like the county wide warnings."

For three of the five universities, the EM was in communication with their local emergency management offices for guidance on what the city EM would be doing with the tornado warning information and monitoring the radar and warning texts to determine spatial proximity. The EM from Ψ University noted that, while the tornado warning had been issued, the storms were further to the north than the campus and held off on sounding the ENS until the storms grew closer. In this case the warning was not the trigger, but the spatial proximity based on radar data acted to guide the EM's decision making.

The activation of ENS differed between the universities that were interviewed. Two of the universities in my sample had full control over their own ENS while three used ENS services that were fully or partially activated by an organization outside of the university command structure. For those EMs who had control over the ENS at the university their decisions were determined by the plans and procedures of the university and other factors in regard to authorization to activate, which systems to activate, and when that activation took place. For those with an external organization controlling the activation, the participating EMs approached ENS activation in different ways. For Ω University the text messaging system activated automatically when a warning was issued for the county, and the EM made the decision to activate other systems in place as the storm grew closer. For two other universities the activation of ENS was done in coordination with the local emergency operations center because the sirens or other systems were controlled by that organization or could be heard on campus.

Universities varied in the types of ENS they used. There were fifteen different ENS types mentioned in the interviews:

1. SMS Text Messaging,
2. Mass Email,
3. Siren,
4. Public Address,
5. NOAA Weather Radio,
6. Private Radio Frequency;
7. Social Media (Facebook, MySpace, Twitter),
8. Telephone,
9. Emergency Blue Light,
10. Computer Pop-up,
11. Mobile Application,
12. Website,
13. Plasma Screen Televisions,
14. Television Scroll, and
15. Interpersonal Communication.

There are a wide variety of methods in place to reach the campus community. No single university uses all of these types, but this list comprises a sampling of some of the systems in place used by universities to reach students, faculty, and staff in the event of a tornado warning.

Weather monitoring by the university EM continued throughout the warning. As weather updates were sent out some university EMs would continue to pass that information along to members of the campus community. In some cases passing on this information to others served as confirmation because the person being communicated with was receiving the same information through their own weather monitoring. The EMs in these cases were confirming that the information was coming through and all the necessary actions were being taken.

In two cases additional information was communicated through the ENS regarding the weather. At Γ University the EM was posting additional updates about the storms to the ENS. One update indicated that there were two storm cells arriving in close succession and the tornado warning was for the second cell. The other update provided the location of a spotted funnel cloud in the city but not near the campus. In the case of Ω University a public safety administrator was overriding the automatic ENS to post information about damage on the campus. The extent to which the additional activation of ENS was specific to the situation is unknown. As mentioned in the methodology, no university interviewed was physically struck by a tornado so the amount of additional communication via ENS may be greater in the event of physical damage or closer spatial proximity of a tornado.

Status of Severe Weather: Severe Weather Passed

The issuance of an all clear differed between universities and between ENS used. Two universities did not issue an all clear to the campus using the ENS. Three used some ENS methods to communicate the all clear to the campus population. Of those that did communicate the all clear, none used all of their ENS methods. Γ University posted to the university website but did not use other methods. Π University used verbal and text based ENS but did not use the siren to avoid confusion. Ω

University issued the all clear through the methods the university controlled but not through methods controlled by the local emergency management office.

Most university EMs used the expiration or cancellation time as the indicator that the tornado threat had passed but the spatial assessment of severe weather continued after the tornado warning was expired. The EM at Π University did not issue the all clear until approximately ten minutes after expiration. The reason for this was because another storm was approaching and the EM wanted that storm to pass before issuing the all clear. Other university EMs mentioned ensuring that the coming weather was no longer potentially tornadic.

After the threat of weather had passed and the tornado warning expired three university EMs stated that this was the end of the event. Two university EMs mentioned damage assessment and the subsequent repairs required due to wind damage after the warning was over. Additionally, a public safety administrator at Ω University mentioned making decisions about staffing to ensure there was sufficient staff to handle the storm damage as well as the typical functioning of the university police. It is unknown if damage assessments were not mentioned by other university EMs because there was no damage, the assessment responsibility lies with another department, or there was no damage assessment.

Difference in Timeline with Housing Department

As mentioned previously, the general timeline is for university EMs, and also encompasses some decisions made by a public safety administrator. The two housing administrators from Γ University had some significant differences with regard to their timeline of actions. The timeline was significantly contracted in the case of the two housing administrators because they were not aware of the possibility of severe weather in advance of the warning. Both were awakened by members of their staff calling them to inform them that weather radios were going off. This began a protocol of implementing a phone tree to alert the different residence halls to have the staff knock on doors and have students move into the hallways away from windows while the administrators were communicating with one another, their staff, and the university police to receive updates on the storms. In the days following the event the plans for the residence halls were changed to encourage students to sign up for the text messaging alert system and to promote a sense of student personal responsibility rather than relying on staff to walk down the halls and knock on students' dorm room doors.

Non-Weather Factors that Effect Decision Making

Weather and information about the weather are not the only variables considered in decision making. People live and work in contexts and larger situations where a number of factors besides weather play roles in decisions and outcomes, and these situations evolve and change across space and time. The second goal of this research was to understand how these non-weather factors influence decision making. The main non-weather factors included plans and procedures, knowledge and experience, responsibility, situational awareness, and unanticipated factors. A model (Figure 10) was developed by Stephanie Hoekstra (2012) and myself to display the interactions among various factors that influence decision making and action implementation for university EMs. The model is dynamic in function, iterating across time as the various factors change, new decisions are made, and new actions are taken.

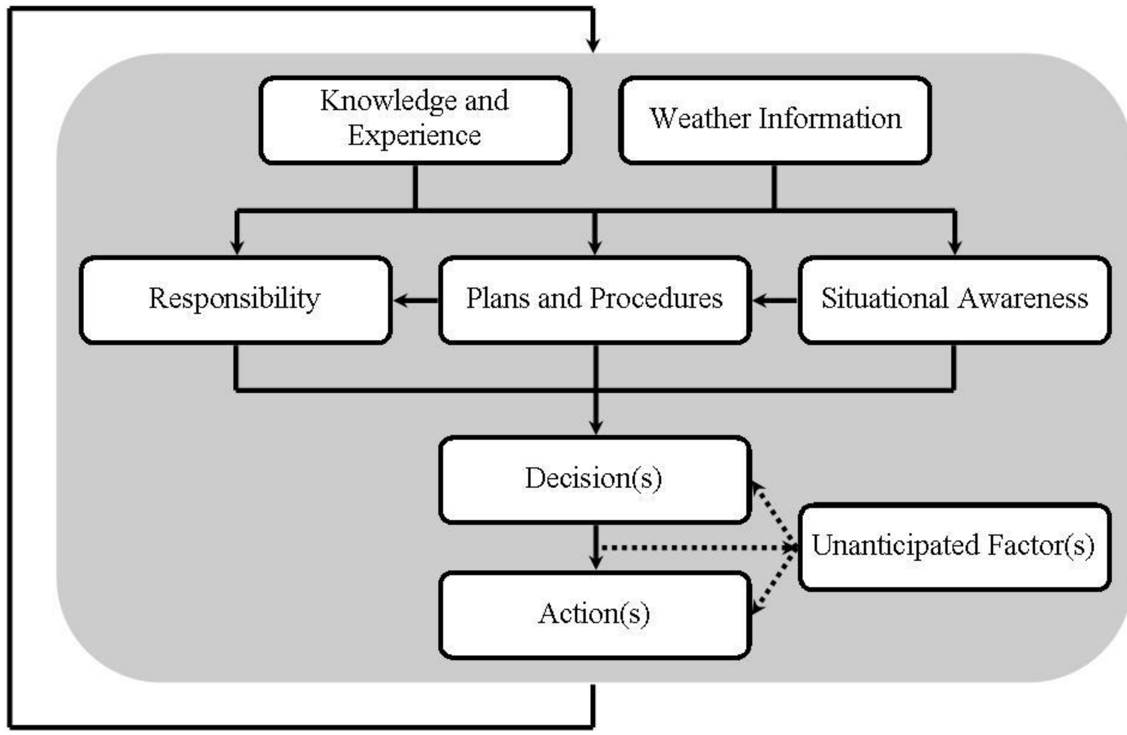

Figure 10: Hypothesis model of non-weather factors influencing university official decision making. Dotted line indicates that unanticipated factors do not always impact decision making.

The plans and procedures of the institution for tornado warnings act as the backbone of decision making. Universities have set plans in place in case of emergency, and those policies dictate the way emerging and existing situations are handled and what types of actions are to occur under the given circumstances. As a general guideline, emergency management plans are intended to be detailed enough to provide guidance but fluid enough that the emergency response can be tailored to the individual situation, as each event is unique (Perry & Lindell, 2003). As such, the policies in place by the university allow for flexibility and modification based on the situation.

Plans and procedures designate a chain of responsibility, indicating which department or individual is responsible for certain actions. This chain of responsibility was not consistent across universities, but in general the EM was responsible for monitoring the weather, coordinating with other departments or external entities, such as local EMs, and deciding when to activate ENS. The plans and procedures have also dictated what the university staff is responsible for in the event of severe weather. The universities spokesperson from Ω University stated, "We decided a long time ago that, you know, better be safe than sorry." The EM from Σ University felt a sense of responsibility to protect the international students on campus by sending additional information to that community. This sense of responsibility to relay information and protect the community was a common factor in decision making.

Plans and procedures can be modified temporarily by knowledge and experience. Three out of five EMs used knowledge about their campus to alter plans in particular situations. This knowledge about the campus came in two forms. One was based on the general local knowledge of the EM, such as Ψ University, where the university did not use the SMS text messaging system to disseminate the tornado warning because it was between semesters and many students were not on campus. The other version was based on specific knowledge of unique occurrences on the campus. Due to a special event at Ω university, the EM decided to allocate additional personnel to that location in case of an evacuation.

This knowledge directly relates to the situational awareness of decision makers. University campuses have large fluctuations in population depending on the time of year and the time of day. Between semesters the student population is significantly less than it is during a semester. At night there are fewer students on campus than there are during the day. Athletic events bring in large crowds that would otherwise not be on the campus. The EM from Γ University stated, "… I think a lot of it depends on what time the threat is expected to hit and who we expect to be on campus. So we decrease our risk in an overnight hit because we've only got 10,000 people on campus as opposed to 80,000 people during a football game." The knowledge of the campus, both general and specific, increases the situational awareness of the EM. This allows them to modify their decisions depending on the specific situation for the event.

A decision being made does not guarantee that this is the final action implemented as envisioned in the original conception of that decision. Unexpected factors, such as system malfunctions, changing conditions, communication lapses, or the actions of other individuals integral to action implementation, can interfere with the successful translation of the decision into action. These problems result in either an alternative decision being made or an action being taken despite the unexpected factor or circumstance. The EM from Π University experienced an unexpected factor when the police officer familiar with activating the ENS for the campus was not in position when the tornado warning was issued. The EM had to guide a different police officer with less experience through the activation process.

Unexpected factors can also arise because of the dynamic nature of severe weather. Situations are in a constant state of change over time and space, and these changes result in new decisions and new actions being taken. A power outage at the police precinct at Ω University resulted in the decision by a public safety administrator to drive their police vehicle around campus. This, in turn, resulted in an update being sent to the university campus through the SMS text messaging and mass email system about fallen trees and damage the administrator could see from the vehicle. Weather situations are not static, and as information and situations change and unexpected factors arise, decisions and actions change with them, resulting in an iterative process of awareness, decision, and action.

Examples from Case Studies

Three examples are used to further illustrate the way non-weather factors influence decisions made about severe weather.

<u>Example 1: Time of Day- Γ University Emergency Manager</u>

> "…if it's a broadband delivery method like sirens, or text, or emails, we're using all of those. We're not choosing to not use one. The only exception would have been when the first severe thunderstorm warning came out we're like 'It's [the middle of the night], bars are closed, nobody's walking, are asleep in their beds. Maybe I won't use the sirens.' But then, you know, a couple minutes later it was a tornado warning and there's no hold barred on tornado warnings."

For the above example the NWS issued a severe thunderstorm warning in the middle of the night and the EM chose not to use the sirens, though sirens are typically sounded for severe thunderstorms. With the issuance of the tornado warning shortly after the severe thunderstorm warning, the decision was changed to sound the sirens. This example shows how the plans for severe thunderstorm warnings were modified by the EM's awareness that people were inside. This awareness was informed by the EM's knowledge of the town's curfew for the bars and the typical location of the student resident population at that time of night, as well as the EM's knowledge that being indoors was the safest location for people during a severe thunderstorm warning. This knowledge of the link between time of day, spatial location of students, and the reduced threat they faced informed the decision to activate all the various ENS methods except the sirens. But when the tornado warning was issued a short time later, those decisions were quickly modified because of the increased threat to the population. The process of decision making was altered when the weather information changed. This resulted in a new decision and action of sounding the sirens and issuing the tornado warning across the other ENS methods. The EM also reported that

> "If the severe thunderstorm warning came an hour and a half earlier when the bars are letting out I know that I may have hundreds or a thousand people who are walking back from a bar to a residence hall. They're more at risk at that time than any other time so that may have prompted a little more aggressive warning."

The time of day and the location of students thus had an impact on the decisions made by the EM, and different decisions would have been made even if the weather information had been the same.

Example 2: Event on Campus - Ω University Emergency Manager

> "…one of the things that was going on involved the Chancellor at a speaking engagement at our library. And the influence of the weather conditions prompted us to have a couple of [emergency response] team members available with the ENS system to give timely notification of a severe weather impact to our area."

In this example the EM was aware of a special event on campus and was able to allocate additional resources to the location of that event in the case of an emergency. Because of advanced notice that severe weather was possible at the campus and the knowledge that there was a special event occurring in the library, the EM made the decision to place additional emergency response volunteers at the library because that location of the campus was at risk due to increased population density. This ensured that the people in the library would receive adequate information and have the capacity to evacuate and reach a safer location in the event of a tornado at the campus. The knowledge of the event and the weather information informed the EM's situational awareness that in turn influenced decisions and actions about resource allocation. The EM also stated "…it's our job to make sure that we are ahead of the game when it comes to protecting them with these types of… weather related activities." The decision was impacted by the sense of responsibility the EM felt regarding the protection of the campus.

<u>Example 3: System Error- Π University Emergency Manager</u>

> "We did incur a problem with us getting an error message back from the software program, or the provider that sends messages over the VOIP phones and the indoor and outdoor speakers. I attempted to contact our IT folks, the help line, their lines were all busy. I tried to contact the IT operations. Did not get an answer. So I contacted another IT person who is well versed in the system. But it turned out that even with the error message the system activated as normal and everything went out appropriately."

At Ω University the decision was made to activate the ENS systems when the tornado warning was issued as stated in their plans and procedures for tornado warnings. However, when attempting to activate the ENS an erroneous computer error message was received and the EM spent time trying to fix the problem despite the system working. The unanticipated factor of an error message modified the decision of the EM and the new course of action was communication with information technology specialists to fix the technological problem. Yet, despite the computer error message, the action of setting off the ENS took place as originally planned. In this case the unanticipated factor resulted in both an action, the systems going off despite the error, and a change in the EMs decisions and actions, contacting information technology staff to fix the error.

Sources of Weather Information

The third research question for this thesis was what sources of weather information do university officials currently use to make decisions before, during, and after tornado warnings. A comprehensive list of all the sources mentioned during the interviews with university officials is found in Table 3. Table 3 is divided into four subsections: public, private, personal, and other. The sources found in the public section are those sources that come from NOAA or state agencies that are not for profit. Private weather sources include both purchased weather information software and broadcast meteorological products that, while free to access, are for profit services. Personal weather sources are those that are based on relationships between university emergency management and others involved in hazardous weather forecasting or response. The other category includes internal sources, such as the ENS system, or those sources that are neither public nor private primary sources.

Table 3 is further demarcated with superscript numbers: 1 indicates that the source was mentioned at least once as a source of weather information prior to the issuance of the NWS warning.; 2 indicates that the source was used to be alerted that a warning was in effect for the area or to obtain additional information while the warning was in effect; 3 indicates that the source was used to determine the expiration or cancellation of the warning and to monitor the weather after the warning was over.

Table 3: Sources of weather information mentioned by participants.

Public	Private
NWS Web Packet[1]	TV News[1,2]
NWS Webinar[1]	Weather.com[1,2]
SPC Website[1,2]	Local TV Text Message[2]
Convective Outlooks[1]	Weather Channel[3]
Hazardous Weather Outlooks[1]	TV Radar (Local, Non-Local)[1,2]
Mesoscale Discussions[1]	GR Level 3[2]
Watch Information[1]	GR2 Analyst[1]
Watch Probabilities[1]	Weather Tap[1,2]
Radar[1,2,3]	Other Radar Sources (unspecified)[2]
NWS Chat[1,2,3]	
NWS Email[1,2,3]	
NWS Text Message[1,2,3]	
NOAA Weather Radio[1,2,3]	
Interactive NWS (iNWS)[2]	
Law Enforcement Administration Data System[1,2,3]	
NWS Warnings (Severe Thunderstorm, Tornado)[2,3]	
Severe Weather Statement[2,3]	
EMs Weather Information Network[1]	
Other Public/State Weather Services*[1,2]	
Personal	**Other**
Local Meteorologist[1]	Environmental Cues[1,2]
Neighboring EM[1]	Campus Text Message[2]
Local EM[1,2,3]	Campus Email[2]
Campus Police[1,2,3]	Power Company Email[2]
Staff Communication[2]	
Local EOC Radio[2,3]	
Storm Spotters via Local EM[2]	

This table is divided into four sections including those sources from the public sector, private sector, personal relationships, and those outside these three segments. [1] indicates that the source was mentioned being used before the warning was issued. [2] indicates that the source was mentioned being used when the tornado warning was issued or during the tornado warning. [3] indicates that the source was used after the tornado warning was cancelled or expired.

Table 3 is a cumulative accounting of all the sources mentioned by all users during the interviews. Some were used by a majority of users, particularly public and private radar services that were used by all the EMs interviewed, NOAA Weather Radio used by four EMs and two housing administrators, NWS tornado warnings that were used by eight participants, and NWS briefings, either through a webinar or through a packet, that were used by four of the EMs. Others were only mentioned by one or two users, such as the various private weather services, the Law Enforcement Administration Data System (LEADS), or environmental cues, among others. The variety in the number and type of sources mentioned and the lack of a common set among users indicates that these users gather information that they deem necessary for the performance of their job responsibilities and the individualized nature of weather information. No single weather information source meets all the needs of every individual and each individual has determined their own set of weather information on which they rely.

Common Sources of Information

One source mentioned by all university EMs was radar services. These were mentioned as coming from both private and public sources. This is of particular importance when considering the spatial concerns that university EMs expressed. Radar provided the EMs with an understanding of where the severe weather was located in relation to their campus or city and provided additional information as well. For example, the university EM from Γ University noted that there were two lines of storms indicated on the radar and that the tornado warning was for the second line. The EM issued an additional message via the ENS that the second line was the tornadic storm so that the campus population would not think that the storm was over after the first line passed and cease taking cover. He stated,

> "Staring at the radar I realized that two separate cells would hit the campus and I didn't want people to get confused that once the first passed that the event was over. So I posted a situation update that said, 'There's two lines of storms. The warning applies to the second line.'"

In another case the university EM from Π University held off on issuing an all clear because a second line of storms was entering the area. He explained, "When the initial tornado warning expired… I was continuing to monitor the weather radar, there was another cell moving into the area, and I decided to wait to send an all clear until after that cell had moved out." Based on the frequency of radar being mentioned as a source of information and comments about what the university EMs were looking for in weather information, it is hypothesized that spatial information is of great importance to university EMs. Due to the relatively small size of universities compared with other jurisdictional boundaries such as a city or county, this reliance on spatial information makes sense when considering that the university EM's major responsibility is the safety of their campus population and property.

NOAA Weather Radios were another common source mentioned by the participants. NWRs are important as both a source for the university EM as well as for notification across the campus. Four of the five university EMs mentioned that many NWRs were located across the campus in multiple buildings and facilities. As such, NWRs acted as a type of ENS for some campuses that is not controlled by the university. NWRs were also commonly mentioned as a notification method for the university EM themselves. The EM from Γ University used the NWR because they were asleep when the severe weather came into their location and needed to be awakened when the tornado watch was issued. Three other EMs mentioned the NWR going off in their location when the tornado warning was issued. NWR was never the only information source used to be notified about the tornado warning for the EMs, but it was a common component of the various sources used. On the other hand, NWR played an important role for the administrators of the housing department at Γ University. For both administrators their first indication that a warning had been issued and that the weather was severe was through phone calls from staff located at the housing desks. These desks were equipped with NWR. The NWR was not a direct source of information but it acted as the main notification source for the housing administrators at Γ University indirectly through the spread of information via personal communication with staff.

The communication with staff at the housing department at Γ University was not the only instance where communication with others acted as an important source of information, both directly and indirectly. Three of the five university EMs interviewed were in communication with their local emergency operations centers (EOCs) and were using that communication as a source of weather information. Local EOCs also have the additional resource of storm spotters that no university EM interviewed said they had, and two EMs mentioned that they were getting information about spotter reports from their local EOC. The EM from Γ University heavily relied on NWS Chat, a NOAA developed chat room for forecasters, media, and emergency managers to communicate, as a source of information, communicating with the NWS when the severe weather was forecasted a couple days in advance and monitoring the communications during the day of the severe weather and during the tornado watch and warning. Two other EMs mentioned having access to NWS Chat, but one stated that they were too busy to make use of it. Other sources of information that came from direct communication included speaking with emergency management from neighboring counties, emails from a local television meteorologist, and emails from the NWS.

Reasons for Use

The participants indicated that most of the sources mentioned during the interview were their typical source of information regarding severe weather. When asked why the particular sources of information were used, words such as trusted, reliable, accurate, and pertinent were used to describe the information. This indicates that a relationship with the information source is important, even if that relationship is not personal in nature.

Another aspect mentioned in regard to sources of information was the existence of redundancy. The university EMs indicated that they were receiving the same information from multiple sources, so if one did not work then the others would take their place. For example, the EM from Γ University stated,

> "So, it's like, a lot of redundancy. So even if the weather radio didn't go off or I didn't hear it, even if I slept through my cell phone, I would have gotten a call from dispatch saying, 'Weather radio just went off' or 'We're getting alerts on the law enforcement system.'"

Similarly, the EM from Π University said,

> "I learned that it's good to have multiple sources. If the web had gone down, the weather radio would have worked. If the web and the weather radio had gone down, my cell phone would have picked up the text message. So multiple

sources are good. And it was a good thing they have that time, cause each one confirmed the one prior."

Weather Information Preferences and Lead Time

In order to develop meteorological products that meet the needs of university decision makers, the final question for this thesis asked what weather information sources would improve operations, with a particular focus on lead time. When asked what weather information would help the do their jobs three of the university EMs stated that the information they had was adequate and did not specify any other information they would need to improve their job performance. They believed that they received timely information and the tornado warning response went well for their university. For five other university decision makers, two main themes were specified when they were asked what weather information would improve their job performance: specificity and direct lines of communication with the NWS.

Increased specificity was requested by three decision makers. The three decision makers requested more information about tornadoes that are on the ground or could develop. Increased spatial information was also requested by two decision makers. The public safety administrator from Ω University said,

> "I guess, when these storms are coming sometimes we don't know how much in the path of the brunt of the storm we are. Are we sort of on the outskirts of it? Is the main portion of the storm gonna be ten miles south of us, five miles south of us, north of us? You know, that kind of specificity would be useful."

The EM from Π University added temporal specificity to the request for spatial specificity stating,

> "To have more detailed and exact information, preferably on a radar screen of the indication of a possible tornado or a confirmed tornado and the direction of travel would be a big help. Speed would be a big help. Those are the things

> that, you know, would help us, you know, focus on where these hazards might be heading and give use a little bit more time to send out an alert."

As mentioned previously, spatial and temporal information play a major role in the decision making of university officials. The university EMs monitor radar from various sources to gauge the location of the storm and some use the storm based warning polygons to personalize the threat to the campus. Events on campus or knowledge of the particular campus schedule guides some decisions to use particular ENS or allocate resources. An increase in spatial and temporal information is hypothesized to improve the capabilities of university decision makers in determining the potential threats to campus. Knowing the location and path of the storm, expected time of arrival, and the intensity of that storm could help them decide what actions are necessary to keep the campus population informed and safe.

The other weather information preference cited by three EMs was a direct link to the local NWS WFO. The EM from Γ University, who has a well developed relationship with the local WFO, particularly emphasized that relationship as being an important aspect of their severe weather response. He stated,

> "…the relationship between us and the National Weather Service is impeccable.... You don't necessarily have that same level of partnership and that same level of service at other offices…. So I really, always, every opportunity that I get stress that relationship and the cooperation I have with everybody in [the WFO] cause that's a huge factor in a lot of the things that we do. And, you know, if there was a way to institutionalize that and make it mandatory across the country so everybody has that same level of support, that'd be critical."

This EM also used NWS Chat as a major source of weather information before, during, and after the tornado warning and repeatedly stated that it was a useful tool for monitoring the weather, contacting the NWS, and receiving information quickly. Similarly, the EM from Σ University stated that the NWS should continue to provide briefings to the emergency management community and stressed the importance of having direct links to the local WFO through NWS Chat and radio communication. The EM from Ω University did not have that same level of support, and when asked about what weather information would improve their job performance he requested,

> "… for me to have better information, it would be better to have a direct feed to me from the National Weather Service instead of going through the alert (text message from NWS) system because, you know, there's obviously, probably a little bit of a delay when the National Weather Service puts something out, correct? And then there's a delay when the [notification] system actually activates and puts something out. And we don't know exactly what the time factor is from when the National Weather Service pushes that button to send all that information out to the alert systems.… how much time has lapsed?… So timely notification, timely information, and being able to have that stuff at your fingertips, in other words storm spotters at my fingertips, like the emergency manager has at the city of [City Name]. That would make it easier for me to be able to put something out quicker or hold off on disseminating information."

Lead Time- Definition

The definition of lead time varied between participants. One of the housing administrators from Γ University expected that their staff had until the time specified as the warning expiration, approximately 45 minutes, to get students into the hallways, displaying a misunderstanding that the expiration time of the warning was the expected time of arrival. The housing administrators that participated expressed less use of weather information, and this particular housing administrator lacked a critical understanding of the warning information. With the change in policy for the housing department at Γ University, this misunderstanding should no longer affect the decisions made by the department with an increasing reliance on the personal responsibility of student residents for the their own safety, but the interpretation of warning information could be a concern.

The EM from Ψ University defined lead time to include the advanced notice provided throughout the day. The other EMs worked within the NWS definition of lead time, but they all knew in advance that severe weather was approaching and considered this “advanced notice” or “a heads up.”

Lead Time- Stated Preference

The next question was whether an increased lead time for tornadoes would improve the job performance of the university decision makers. Answers to this question varied. Two decision makers felt there was plenty of lead time to take the actions necessary to effectively notify the campus, four requested some additional lead time, indicating a preference between 15 minutes to an hour, two stated that they want as much time as possible, but recognize the limits to the science of meteorology, and one requested more lead time but did not give a specific amount. Because of the extreme variation between decision makers, no conclusions can be made as to what constitutes an ideal lead time for these public university decision makers.

The EMs from Γ, Ω, and Σ Universities stated that increases in lead time could be beneficial when there are complex situations that are demanding their attention. For example, during athletic games when the stadiums are crowded an increased lead time would give the emergency responders the ability to evacuate the crowd. The same would apply to other large venue events that universities host such as graduation. These were in response to smaller increments in lead time prior to the introduction of the concept of PHI in the interviews. This was further expanded upon by two participants in the later questions regarding PHI.

When ENS are technically complicated, as was the case for Π University, an increased lead time would give the opportunity to complete technical support and get the information out faster. The activation of ENS at Π University took approximately twenty minutes. Under current lead time averages, the message probably would not have been delivered prior to impact if a tornado did strike the campus.

Four university EMs and emergency response personnel who were interviewed also mentioned that there were problems with using SMS text messaging services to deliver emergency notifications. Once a message is sent out, it is delivered through the various cell phone providers that are not under the control of the university staff. The density of information being delivered and the speed of the cell phone provider dictate how quickly the message will be delivered, and that can delay receipt of the information. Increased lead time may provide the additional time necessary for more of that information to be delivered before a tornado impacts the campus area, though with the current delivery issues related to SMS text messages an increase of up to two hours will not resolve all of the delivery issues. These issues related to the time it takes to deliver SMS text messages were dealt with through redundant systems at four of the five universities that participated, and the other university did not use the SMS text messaging system for tornado warnings because of these delays.

Probabilistic Lead Time

At the end of the interviews the participants were presented with scenario questions. There were two main questions asking if the scenarios would change their decisions and if they responded that it would there were some additional questions requesting an explanation of what they could do with this information and how it would change their decisions. In each question the participant was presented with the scenario of a time (2 hours or 15 minutes) and a percentage (30% or 70%). They were asked if knowing that in the stated amount of time there was the stated percent chance that their institution would be struck by a tornado would alter the decisions that they made for their recent tornado warning experience. These questions aimed to get an initial gauge of the usefulness of the WoF system.

A 30% Chance in Two Hours

The responses to the question of a 30% chance of a tornado in the campus area in two hours received a mixed set of responses, but there were some similar themes that arose in the responses from the different participants. Two EMs were skeptical that meteorologists would be able to make these kinds of forecasts. Until they saw the science behind this increased lead time they would question the validity of the predictions. The EM from Γ University was particularly skeptical about the ability of meteorological sciences to make these types of predictions. "Right now I definitely wouldn't believe it. I know the science and the technology's not there." The EM went on to say, "… I say this now today but once it's a proven science or technology I may buy into it." For this particular EM, the basis of all decisions is what the NWS has available, so if the NWS begins to use probabilistic warnings then that is what will be communicated to the campus community.

Other decision makers stated that changes in how the NWS delivers warnings would require changes in their university plans and procedures. A university spokesperson who is a member of the university's emergency communication subcommittee from Ω University stated, "So we'd probably have to look at the way we communicate with the campus community in terms of the language that would be used…" A housing administrator from Γ University echoed this idea that a change in the way the NWS issues warnings would require a modification to the plans and procedures set in place, and that those discussions would have to be guided by how the university chose to communicate that type of information through the ENS.

Another common response was that probabilistic tornado information would provide time to review or create plans and communicate with the campus community. Five of the ten participants stated that these longer lead times would give an opportunity for preparation and communication with the campus community. The EM from Γ University explained, "I may tell, you know, I'll send an email to the emergency management team 'Hey, 30% chance of a tornado striking us in the next two hours.' I would relay that information and people would get a heightened sense of alert." Similarly, the EM from Π University stated,

> "Well if we had that kind of information, we could probably communicate it via email to various, I guess, interested parties …We could even… possibly send out something to the entire campus so that they'd be ready and… review what procedures they should take should a warning… a critical warning be issued. So… advanced warning that way could be helpful as far as getting people's attention and getting them ready to take action."

This type of communication already occurs with the advanced notice provided by outlooks. The degree to which PHI would modify current procedures is unclear.

The other form of communication and planning that this type of information would provide would be to make plans for special events. A public safety administrator and the EM from Ω University both focused on this, as they had both had experience with severe weather during a major event on a previous occasion. They both emphasized that the probabilistic information would not be enough to cancel an event, but they could be better prepared for severe weather affecting the event. The public safety administrator explained,

> "For example, if graduations are planned and I've got people in town and I can't change the direction of this event very easily, then the more notice you get the better because you can make some significant decisions with regards to where do we move this?... Cancelling it is probably out of the question, where do we move this event to that might potentially be safer? Or do we delay the start of the event, for instance?"

The EM similarly stated,

> "You know, if you had a higher probability that the tornado would hit then you may have a different outlook about how you want to handle this (a special event). Now, not necessarily to stop it but to handle this. Cause if we know, maybe we can start it earlier. You know, depends on what it is. Maybe we can start it earlier than what we anticipated cause of the weather conditions. There's several variables that we can use and that would be one of them."

They focused on the increased planning opportunity that PHI two hours in advance would provide, and that this would make it less complicated to deal with an event if the proper plans were in place well in advance. However, the public safety administrator also recognized that the capability to plan for or modify events because of severe weather comes with additional challenges because any changes to planned events would have to be communicated to the attendees, and that could be problematic.

The other confusion that arose among some of the participants regarding this type of PHI is whether or not it would be considered a warning. The EM from Π University focused on the idea of an imminent sense of danger stating, "The percentage would be nice 2 ½ hours out but… we would still wait until we had a reasonable sense that danger was present." This was further expressed by the use of the term "a critical warning" mentioned previously. The university spokesperson from Ω University also focused on this by stating, "I don't know if that'd be considered a warning at that point. It's not imminent danger." The EM from Γ University indicated that longer lead times lead to a diminished sense of danger, and the university currently issues another message through ENS closer to the expected time of arrival when lead times are long. If a warning is considered imminent, then two hours of lead time may not be defined as a warning but rather as "advanced notice." This may also be influenced by the probability, as some university decision makers stated that a 30% chance was too low to take action, but would instead increase awareness that a tornado was possible but not necessarily imminent. In this case, some stated that they would be watching the changes in the probabilistic information to see how the likelihood of a tornado would change over time before taking action.

A 70% Chance in 15 Minutes

The questions focusing on a 70% chance of a tornado in the campus area in fifteen minutes had more similar responses between participants than the question of a 30% chance in two hours. Four participants stated that this information would not change the actions they took or the decisions they made, but that 70% was a high enough probability to increase their sense of risk to the campus and that they would be more aggressive and decisive in disseminating that information to the campus population. The EM from Ψ University who did not use SMS text messaging and email because it was between semesters stated that these ENS would probably be used if this type of information was received. The public safety administrator from Ω University stated,

> "I am putting into effect much more decisive recommendations, much more urgency that people need to stay put or seek shelter. I mean, yeah, it changes everything as far as the speed and the degree at which you provide recommendations to my administration and to the affected population."

The general consensus was that the decisions and actions would remain largely the same, but the higher the probability and the less time available would decrease the amount of discussion and increase the level of urgency in activating the ENS.

Summary of Major Points and Relation to Earlier Research Findings

The universities' plans and procedures acted as the backbone for all decision making. These plans set out responsibilities for the different actors involved in warning the university campus, but the exact plans were modified on occasion. The most common factors that modified the plans were situational, where time of day/year, location of people, the threat perception of the EM, or unanticipated factors influenced the decisions they made. Context matters and a different set of non-weather contexts results in different decisions.

Figure 10 bears similarities to the SA model developed by Endsley (1995). In both models, SA is not the only factor affecting decisions being made. Plans and procedures and knowledge and experience can relate to mental models and schemas since both give a foundation based on experience and expectations of what decisions are to be made. Weather information, as well as ENS, can be related back to system design since their complexity and design can influence the other factors involved. The more capable the EM is of understanding and working with weather information, the more useful the information is in making decisions and taking appropriate action. By decreasing the complexity of the information through training or developing open relationships where information is provided in a simplified manner and questions can be asked, the system's capabilities are enhanced to improve situation awareness, decision making, and performance. The key difference between Figure 10 and Endsley's (1995) SA model is the inclusion of responsibility. In some ways responsibility in Figure 10 relates to the goals and objectives in Endsley's (1995) model in that the responsibility of the university to protect students is a goal or objective for university EMs and other administrators and the responsibilities designated to individuals by plans and procedures set the goals and objectives of those individuals. But the sense of responsibility EMs expressed to their campus is not accounted for in Endsley's (1995) model.

Each EM had a different set of information sources they relied on, based on their own unique needs. These information sources were chosen prior to the indication of severe weather, and were their typical sources, indicating that it is likely that these public university EMs do not actively seek out new sources of information during severe weather but instead rely on sources with which they have already developed a trusted relationship. This does not match the process of information seeking in the original PADM model (Lindell & Perry, 2004).

The most common sources were those that provided spatial information, such as radar, and personal relationships and communication with weather information providers or emergency response personnel outside of the university, indicating the importance of these two types of information. The use of radar acts to personalize the tornado warning, a step in the Mileti and Sorenson (1990) warning response model, by indicating if the severe weather is in close proximity to the campus. Confirmation is another step in the Mileti and Sorenson (1990) warning response model, and redundant sources of information were a common way that this confirmation of the threat was made by the EMs interviewed.

Increases in spatial and timing information and the development of relationships with weather information providers are hypothesized to be the most important weather information needs of university EMs. Some increase in lead time may also be beneficial, but the exact amount of additional lead time needed depends on the individual and the context. The change to the WoF system of increased tornado warning lead time based on PHI may be useful to university decision makers under certain contexts, but may not be viewed as a tornado warning based on the current warn on detection paradigm and would require changes to the current plans and procedures of universities. The less lead time available and the higher the chance of a tornado occurring in the area increases the decisiveness and aggressiveness of redisseminating that information to the campus while longer lead times and lower probabilities could be used for major events on campus but are less needed during the university's normal activities.

Lead time within this particular group may be defined differently than lead time described by Schumacher et al. (2010). The general timeline shows that a number of important actions for tornado warning response occurred when there was no severe weather approaching, all university emergency managers were aware that severe weather was approaching well in advance of the storm's arrival, and multiple decisions were made and types of communication were carried out as severe weather approached, but these decisions and actions are not accounted for in the model developed by Schumacher et al. (2010). None of the universities with participants for this study were impacted by a tornado, but based on the sequence of events described and the use of information beyond the tornado warning, a modified version of the model by Schumacher et al. (2010) is hypothesized (Figure 11). In this model, the phases of data collection and evaluation, notification and decision making, and actions and mitigation are not discrete, but continuous. They also extend beyond the NWS definition of lead time to include the advanced notice provided by forecasts, outlooks, and watches. Further research would have to be conducted with universities that are impacted by tornadoes to test this hypothesis.

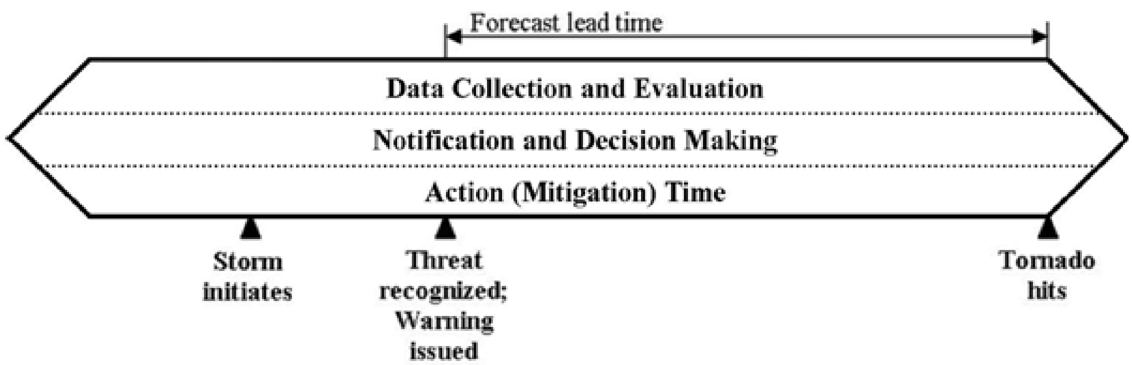

Figure 11: Lead time hypothesis model for university emergency managers (adapted from Schumacher et al., 2010).

Chapter 5: Recommendations to the Weather Enterprise

The findings from this research can be relevant for the NWS and weather product developers who have been mentioned throughout my thesis. This chapter summarizes these recommendations based on my research, and suggests hypotheses for future research resulting from my research.

Those universities that had strong relationships with their local NWS WFO or other meteorologists put a strong emphasis on the importance of that relationship. NWS Chat was considered highly valuable to the EM from Γ University, and the webinars and packets produced by the NWS were considered useful tools by four of the EMs interviewed. The first recommendation is that NWS WFOs, particularly Warning Coordination Meteorologists, should develop relationships with the universities and colleges located within their CWA and identify the key personnel who require additional support regarding weather information, particularly those on the campuses responsible for disseminating warning information. This level of support should be available across the NWS based on user needs. A first step is to provide university emergency response personnel access to the NWS forecasters through NWS Chat and other communication technologies if they want access to those tools so universities and colleges can request information or clarification in the event of severe weather and have access to information before or as it is publicly disseminated to provide additional time to make decisions and activate ENS.

This research shows that university EMs and law enforcement are aware of the possibility of severe weather hours or days in advance of the tornado warning. These users are making decisions and taking actions to prepare their campus departments and populations throughout this entire time. This advanced notice may be part of the "lead time" for the tornado warning for these users that is not considered in the official NWS definition of tornado warning lead time. Additionally, preparedness activities such as writing plans, developing or changing ENS, and building relationships is an important part of university tornado warning response that takes place when there is no severe weather or approaching severe weather.

The results of my research shows that PHI with low probabilities across longer time frames could provide some additional guidance and help decision makers formulate plans for special events, such as athletics or ceremonies. However there is evidence that these decision makers would wait until the danger is more imminent and the probabilities are higher for complete notification of their campuses or the cancellation of events. The warn on detection paradigm that exists in 2012 is based on imminent danger and deterministic information, and this research shows that imminence and proximity are the definition of a tornado warning in existence at this time. Low probability forecasts over long time frames did not meet the criteria of a warning for two of the participants of this study, and was skeptically viewed by two other participants.

The development of new meteorological products should be done based on the needs of weather sensitive decision makers, such as university officials, rather than based on technologically driven capabilities. It should also take into consideration the current actions taken by users and the definitions and terms they employ. My research found that the proposed WoF paradigm utilizing PHI based on long time frames and low probabilities does not work with the current actions taken by universities or the definitions of a warning or lead time that they use. If implemented, WoF and PHI may 1) not be seen as a warning but rather as an addition to the advanced notice decision makers receive at the current time, 2) be met with a lack of trust in the information until the system is proven to be accurate, or 3) require changes to plans and procedures already in place at universities for NWS tornado warnings.

Meteorological product development focused on 1) increased decision support and communication with users and 2) increased spatial and temporal specificity of radar for monitoring severe weather would be useful for university officials based on their stated needs. These improvements would provide university decision makers with the information they need to make decisions about warning the campus, and provide them with the time required to activate their ENS and protect vulnerable populations on campus, particularly those at special events.

Chapter 6: Recommendations for Future Research

Based on this study and its results, some questions for future research and ways to expand on it emerge. This chapter provides 1) questions for future research related to universities and hazard response and on the concept of lead time and 2) recommended modifications to the methodology used in my research based on lessons learned.

Research on University Hazard Response

This research postulated a number of hypotheses including a general timeline of university emergency management response, hypotheses about non-weather factors that influence decision making, and hypotheses about preferred weather information and thoughts on extending lead time. Because of my small sample size, the results are not generalizable. Future research will need to expand on my research to test the validity of the preliminary hypotheses posed in my thesis and generate more hypotheses based on expanded research. The best way of doing this would be through more in depth interviews, large scale surveys, focus groups, and ethnographic participatory methods to gain a full insight into the processes behind decision making for university tornado warning response. Additionally, my research focused on public universities with over 5000 students and future research will need to include private universities and colleges, smaller universities, and community colleges to understand the similarities and differences between the different types of institutions of higher education and the applicability of the hypotheses posed by my research to different institution types.

My research also focused on one segment in the chain of information. Future research should focus on the entire chain of communication including weather information providers, local emergency management, university emergency management, various departments on university campuses, and the university population to understand the entire sequence of university tornado warning response. Research of this type may have to focus on case studies initially to form some general hypotheses and then expand the research to larger sample populations. There has been a limited amount of research conducted on university tornado warning response including my research, research by Schumacher et al. (2010), and Sherman-Morris (2010). In general, many questions remain unanswered about the tornado warning response at universities and further research should be conducted to better understand the entire system.

My research focused on only one NWS hazard: the tornado. Expansion of research on university hazard response should also include other types of hazards faced by universities including floods, hurricanes, winter storms, severe thunderstorms, and earthquakes, as well as technological and terrorist hazards such as chemical spills, active shooters, and bomb threats. This is just a small sample of the types of hazards that universities face. Further research could expand on this list of hazard types and be conducted to understand the similarities and differences between the different hazard responses and how the weather enterprise and other public services can better meet the needs of universities in responding to these different hazard types.

Special events and large venues also pose various complications to university hazard response. During the course of my research, one university EM requested that a study be conducted to look at large venue hazard response in particular. This research could consider best practices of universities and other large venue decision makers to help universities and other large venue decision makers develop the best plans for these types of response. This is not limited to athletics, but also includes major events such as graduations or large conferences that could pose difficulties to university decision makers.

As was discussed in Chapter 4, some universities had relationships with their local emergency management officials to coordinate response. The spatial arrangements of these universities were of particular interest because the three that had these relationships were located in the central United States, within what is known as “tornado alley.” The two universities located in the eastern United States did not have these relationships with their local emergency management officials. A question for future research is whether or not there is a spatial pattern behind these types of external relationships. All three universities were coordinating with emergency management officials because there were city sirens located either on or near campus that were controlled by the city. Future research on the spatial patterns of tornado sirens and the existence of relationships between local EOCs and university EMs could determine if there is a relationship between local siren systems and university EM relationships with their city or county counterparts. Additionally, research on the relationships between university EMs and their local EOCs would provide information on the role of universities within their local city or county jurisdictions during tornado warnings. Universities have a distinct position because of the variety of roles they play as independent institutions resembling small cities that are located within a larger city. This research considered decisions made by university officials about the university campus, but the decision makers at these institutions may have a larger role as a member of their local community on community response to tornado warnings.

The last recommendation is to conduct additional research on the effectiveness and drawbacks of university ENS. Universities are engaging with a diverse array of technologies to communicate warnings to their populations. While some are not appropriate for the weather enterprise, such as public address systems in buildings, there are things to be learned from university warning systems. These systems are already in place and being used by different university campuses across the country. Collaboration between the weather enterprise and university EMs could benefit product development to meet stakeholder needs and could also inform the weather enterprise and other emergency response agencies about new technologies being used to disseminate information, and provide an opportunity to test their effectiveness.

Related to this is research on the effectiveness of the StormReady University designation of the NWS. StormReady communities have to meet specific requirements including establishing an EOC, having redundant systems for receiving and disseminating warning information, having a local weather monitoring station, developing plans for severe weather, and emphasizing local education (Franklin, 2012). Universities are eligible to be designated as StormReady and 108 universities have achieved StormReady recognition. No research has assessed the effectiveness of the StormReady program. Research on university ENS could be part of research on StormReady universities with a more comprehensive approach to university preparedness.

Research on Lead Time

My research has shown that public university EM decision making extends beyond the time when warnings are in effect. Their decision making is not restricted to the period of the warning. Lead time for university decision makers may not be defined according to the model depicted in Schumacher et al. (2010) but may be expanded to the period of "advanced notice" given by outlooks, forecasts, and watches. Similar results were found by Spinney and Gruntfest (2012) for emergency managers and Hoekstra (2012) for school district administrators. Future research on lead time, particularly for stakeholders with responsibilities for large groups, should look beyond the period of the warning and consider the decisions made and actions taken during this period of advanced notice. The restricted definition of lead time as the period between when the warning is issued and when a tornado hits may not be the actual "lead time" within which these decision makers are working. More research is required to understand the time used for decision making across the entire spectrum of weather information, from outlooks to warnings. Lead time is used as a metric of success within the NWS, but it may be a false construct that needs redefinition based on stakeholder use of weather information.

Two Recommendations for Improving the Research Methodology

The Google Earth™ place data is inaccurate for some institutions and each university had to be cross referenced with campus maps to ensure accuracy. The first recommendation is the creation of a GIS database of university and college polygon shapefiles for the United States. The database should include the student population for the university and the institution type, such as public university, private university, or community college, to allow for queries to meet specific sampling requirements.

My research relied upon interviews conducted both in person and over the phone. I found that the in person interviews provided increased depth of information. The second recommendation is to conduct interviews in person. In person interviews would also allow for a more ethnographic approach because participants would be able to show the researcher their facilities, their sources of information, and their interactions with those sources to provide examples of how the source of information functions and what features are considered important or useful.

Chapter 7: Summary and Conclusion

The development of improved numerical models and weather forecasts may result in new ways that tornado warnings are issued, such as PHI and WoF that include increased spatial, temporal, and intensity information, increased tornado warning lead times as defined by the NWS, and probabilistic information. The goals of my research were to gain a preliminary understanding of how university decision makers use current weather information to make decisions, the other factors that influence these decisions, and the way PHI and WoF might modify the decisions being made. The overall purpose of my research was to provide this information to weather forecast product developers so that the input of university stakeholders would be accounted for in the development of PHI and WoF.

The results of my study were that NWS tornado warnings are not the only factor involved in decision making by university officials. University EMs use weather information that is available hours or days before the issuance of a tornado warning to begin making decisions, communicating with departments on campuses, and gathering information about planned events on campus that are considered more vulnerable in the event of severe weather. NWS tornado warnings and spatial information, such as radar and tornado warning polygons, act as a trigger to activate ENS, but the activities taking place prior to the tornado warning issuance play an important role in preparing for this activation.

Additional factors, such as university procedures, designation of responsibility, situation awareness, and the dynamic nature of situations, influence university EM decision making as well. Plans provide a pre-approved model of what decisions to make and who makes those decisions. Situation awareness and dynamic changes to these situations force decision makers to modify these models to meet the needs of the particular situations taking place at the university on any given day and to make new decisions as the situation evolves over time. Time and the location of people were found to be the major determinant of these particular situations. Time acts as a predictor for the location of people which in turn acts as a predictor of the perceived level of threat.

Sources of weather information varied between different users. Each user had a distinct set of weather information sources they relied on, and that set of information consisted of their usual sources during severe weather events. Spatial information was one of the most important sources, and every EM relied on various sources of radar information before, during, and after the tornado warning. Direct communication was the other common source of information, but these relationships varied between users to include the local NWS WFO, local meteorologists, and local or neighboring EMs. The lack of commonality between EMs indicates that different users, even within the same stakeholder group, have different needs that they have determined individually. The fact that the sources mentioned were their typical sources and that these sources were described as trusted, reliable, or credible indicates that sources are used because the user has developed a positive relationship with the source of information.

EMs said that communication with the NWS was one of the most common types of information that they rely on to improve their job performance. Those who had a relationship placed strong emphasis on its importance, while some who did not requested more direct communication with the NWS. I recommend that providing university decision makers with access to NWS Chat could be a first step in opening those lines of communication. The other requested information was increased spatial and temporal specificity and improved indication of the location of tornadic activity. No conclusions can be made about increased tornado warning lead time, as defined by the NWS, but evidence from my study shows that changes to the WoF paradigm and the addition of PHI to NWS tornado warnings 1) may not be defined as a tornado warning by users, 2) may be met with skepticism until the science is proven reliable, 3) may require changes to currently existing plans, or 4) could provide additional time to make plans for special events.

A dramatic switch to the proposed lead times of 2 hours under the WoF paradigm compared to current lead times averaging 13 minutes under the warn on detection paradigm leaves a number of questions to be answered. Letson et al. (2007) argue that dramatic shifts in forecasting capabilities, such as increases in tornado warning lead time, may provide new types of response that are unavailable with current capabilities. University decision makers have developed their plans under the current forecast capabilities and as WoF evolves, new options for response may become apparent that are not now known. Hypothetical probabilities and communication types were used in my interviews to try and understand what some of these new options may be. Until the capabilities and limitations of the WoF project are revealed, only hypothetical product types can be explored, and these may differ from the WoF products once they are completed. My research indicates that low probabilities with longer lead times would result in less decisive actions by university decision makers while higher probabilities with shorter lead times would lead to more aggressive dissemination of the warning to the campus.

I hope that the findings of this research will be useful in the following ways. This research provides evidence that one size does not fit all for weather information. First, context plays a large role in decision making, and each event has its own set of circumstances. Small differences in time can result in entirely different decisions being made. Second, each decision maker chooses those sources that they consider most valuable to them and develops strong relationships with them. Changes to weather information products will have to be completed with the importance of these relationships in mind and recognize that new systems will be adopted once they are proven trustworthy. Finally, the ways that the NWS defines their products and metrics may be quite different than the ways they are defined by users. Warnings were considered to indicate imminent danger by some participants, and two hours did not fit that criterion. Also, lead time, as defined by the NWS, may not be the actual "lead time" of users. Advanced notice provided by forecasts, outlooks, watches, their own assessment of the weather, and communication with others is part of the decision making process for university EMs.

The small sample size of this study means that these results are not generalizable to the entire population of university decision makers. The methods were chosen because of the value of qualitative semi-structured interviews in providing data with depth and nuance. The stories provided by these interviews give a snapshot of the response of key university decision makers at five public universities to tornado warnings and also provide glimpses into how tornado warnings and severe weather fit into the larger context of the functioning of the universities from the perspective of these decision makers. This type of information, that the closing time of bars can change an EMs response for example, would be difficult to obtain in large scale surveys. The depth of information and the unique stories about the decision makers' thought processes and factors involved in decision making provide a new perspective on how tornado warnings work at these types of institutions.

Additionally, the sampling criteria for this project of universities placed under tornado warnings but unaffected by a tornado is unique for hazard response studies. The majority of hazards and disasters research considers either large scale disasters or hypothetical situations. The only studies that consider warnings without impact are those assessing the effects of false alarms (Dow & Cutter, 2006). My research, along with a similar study conducted by Hoekstra (2012), broadens the research to include response to the majority of tornado warnings, those that result in no direct impact, and found that there is a response by decision makers in charge of large groups such as university decision makers and school district administrators (Hoekstra, 2012). More collaborative studies between weather sensitive users, social scientists, and meteorological software developers should be conducted to take in the broader set of hazard response that exists in terms of the time considered for response and the range of hazard impacts, and will consider the contexts in which people live their daily lives where weather plays one part.

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Appendix A: List of Acronyms

CIMMS: Cooperative Institute for Mesoscale Meteorological Studies

EM: Emergency Manager

ENS: Emergency Notification System(s)

EOC: Emergency Operations Center

EWP: Experimental Warning Program

GIS: Geographical Information System(s)

HWT: Hazardous Weather Testbed

LEADS: Law Enforcement Administrative Data System

NOAA: National Oceanic and Atmospheric Administration

NWR: NOAA Weather Radio

NWS: National Weather Service

PADM: Protective Action Decision Model

PHI: Probabilistic Hazard Information

SA: Situation Awareness

SMS: Short Message Service

SPC: Storm Prediction Center

WoF: Warn-on-Forecast

WFO: Weather Forecast Office

Appendix B: Interview Script

Hello, my name is Amy Nichols and I am working on a research project for Social Science Woven into Meteorology in collaboration with the National Oceanic and Atmospheric Administration's Hazardous Weather Testbed. I am a graduate student in the Department of Geography and Environmental Sustainability at the University of Oklahoma. This research will be part of a master's thesis requirement and the results will be provided to Hazardous Weather Testbed to be used in the development of new tornado warning tools and products.

You were previously contacted to request your participation in this research and you have signed a consent form agreeing to this interview. If you have any questions regarding this consent form, please ask at any time.

If they agreed to be recorded:

On your consent form you agreed to have this interview recorded. To maintain confidentiality, please use department names or titles instead of names of people in your responses. If you do not wish to have this interview recorded please inform me and I will turn the recorder off. Do you still consent to have this interview recorded?

We are now ready to begin the interview. You may request to end this interview at any time. Any information given will remain confidential. The interview will take approximately one hour to complete. If any questions are unclear, please let me know and I will clarify.

Confirmation of Involvement

1) Were you on duty at the time of the tornado warning on (insert date and time)?

   If no...

a. Were you involved or consulted in making decisions at your institution regarding the emergency notification of students during the tornado warning?

If yes...

i. What time did you become involved in making decisions at your institution during the tornado warning?

If no...

(Go to *Thank You Statement B*.)

2) At any time during the warning, were you aware that the National Weather Service had issued a warning for your area?

If no...

(Go to the *Thank You Statement B*)

Demographic Information

3) What is your role or position at your institution?
4) What are your responsibilities at your institution?
5) How long have you held your position at your institution?
6) What are the main hazardous weather threats your institution faces?
7) Using only their titles, who is responsible for monitoring the weather at your department?

a. Is this person responsible for monitoring the weather for all departments and offices at your institution?

If no...

i. Using only their titles, who else is responsible for monitoring the weather at your institution?

8) Does you institution usually activate emergency notification systems during hazardous weather warnings?

9) Only supplying their title, who authorizes activation of the emergency notification systems?

10) Only supplying their title, who activates the emergency notification systems?

If they are the responsible party...

a. What types of emergency notification systems (for example sirens, text messages, email, PA systems, etc.) does your institution usually operate during tornado warnings?

b. How long does activation of those emergency notifications take?

c. If known, how long does it take for those emergency notifications to reach their intended audience?

d. If known, how many people/much of campus do those emergency notification systems reach?

e. Which, if any, of those emergency notification systems are text or verbally based?

If text or verbally based emergency notification systems are used...

i. Only supplying their title, who creates the content of the message?

If the participant is the responsible party...

1. Are previously written message templates used for text or verbal emergency notification systems?

f. What types of emergency notification systems does your institution operate that are not used during a tornado warning?

   i. Why are these emergency notification systems not activated during a tornado warning?

   ii. What barriers are there to using these systems during a tornado warning? For example, technological problems, does not reach campus fast enough, does not notify enough people?

Recent Warning Experience

Prior to Warning

11) Prior to the tornado warning, were you aware of the possibility of hazardous weather at your institution?

If yes...

a. When did you become aware of the possibility of hazardous weather at your institution?

b. How did you learn that there was the possibility of hazardous weather at your institution?

c. What actions did you take to prepare for the possibility of hazardous weather at your institution?

d. Who did you communicate with about the possibility of hazardous weather at your institution?

   i. When did you communicate with them?

ii. Why did you communicate with them?

e. Were campus notification systems used to notify the campus of the possibility of hazardous weather?

If yes…

i. Which systems were used?

ii. Why were these systems used?

iii. When were they activated?

iv. Who activated them?

v. What information was distributed?

vi. Are notification systems typically used to notify the campus of the possibility of hazardous weather?

If no…

vii. Are notification systems typically used to notify the campus of the possibility of hazardous weather?

f. What sources of weather information did you use to make these decisions about the possibility of hazardous weather at your institution?

i. When did you access these sources of weather information?

ii. Why did you use these sources of weather information?

iii. What did you learn from these sources of weather information?

g. What other factors were considered in making these decisions about the possibility of hazardous weather at your institution?

Initial Response

12) Regarding the tornado warning on (insert date and time), how did you learn your institution was under a tornado warning?
    a. Why did you use this source to learn about the tornado warning?
    b. What did you learn from this source of information?
    c. Is this different than your usual source of information regarding tornado warnings?

       If yes...

       i. What is your usual source of information regarding tornado warnings?
       ii. Why was this not your source of information on (insert date and time of warning)?
13) At what time did you learn your institution was under a warning on (insert date and time)?
14) What were you doing when you learned your institution was under the tornado warning?
    a. How did this influence your perceptions of the tornado warning?
    b. How did this influence your decisions about the tornado warning?
15) What was your first action after learning your institution was under the tornado warning?
16) At what time was your first action after learning of the tornado warning?
17) Using only their title, who did you first communicate with after learning of the tornado warning?

a. What method did you use to communicate with them?

b. What information was communicated?

c. Why did you communicate with this person?

Re-dissemination of Information

18) What systems of emergency notification were activated during the tornado warning, if any?

If none...

a. Why were systems of emergency notification not activated for this event?

(Go to *End of Event*)

If yes…

b. Were there problems in disseminating the information?

i. What problems did you encounter in disseminating the information?

ii. How were these problems resolved?

If different from answers to question 11.a...

c. Why were (insert unmentioned emergency notification systems) not used during this tornado warning?

19) When were notification systems activated during the tornado warning?

20) If known, how long did dissemination/activation of the emergency notification systems take?

21) Which textual or verbal emergency notification systems were activated during the tornado warning?

If textual or verbal information was disseminated...

a. What was the content of the message?

b. When was it written?

c. Who wrote the message?

Course of Incident

For this portion of the interview, I am going to ask you walk me through your decision-making process over the course of the tornado warning with regards to the emergency notification of the campus. I will ask about what actions were taken, who you communicated with, sources of information, and additional factors influencing your decisions. I am going to create a timeline of events from this information. Please be as specific as you are comfortable with.

(For each response to question 22 ask questions 23-25)

22) What actions did you take over the course of the tornado warning regarding emergency notification of students?

23) Using only their title, who did you communicate with over the course of the tornado warning regarding emergency notification of the campus?

    a. What method did you use to communicate with them?

    b. What information was communicated?

    c. Why did you communicate with this person?

24) What sources of weather information did you use to make decisions through the course of the tornado warning, if any?

    a. When did you access these sources of weather information?

b. Why did you use these sources of weather information?

c. What did you learn from these sources of weather information?

25) What other factors were considered in making decisions about emergency notification of the campus during the tornado warning? For example, special events on campus or off-campus populations.

a. How did these factors influence the decisions made about emergency notification of the campus?

End of Event

26) What sources did you use to learn that the tornado warning was over?

a. Why did you use these sources?

b. When did you use these sources?

c. What did you learn from these sources?

27) What time did you learn that the tornado warning was over?

28) What actions did you take when you learned that the tornado warning was over?

29) Using only their title, who did you communicate with when you learned the tornado was over?

a. What method did you use to communicate with them?

b. What information was communicated?

c. Why did you communicate with this person?

30) Did you notify the campus that the tornado warning was over?

If yes...

a. What methods were used to notify the campus that the tornado warning was over?

i. Why were these methods used to notify the campus that the tornado warning was over?

Future Needs

31) What information would have improved performance of your job during the tornado warning?

32) Would increased lead-time have changed the decisions you made during the course of the warning?

If yes...

a. What amount of lead-time would have changed the decisions you made?

b. How would increased lead-time change the decisions you made?

If no...

c. Why would increased lead-time not change the decisions you made?

33) If you were provided increased lead-time but a decreased probability that the tornado would occur, would this change the decisions you made? For example, you are informed that there is a 30% chance of a tornado striking your institution two hours from now; would this change the decisions you made?

If yes...

a. How would this change the decisions you made?

b. What actions could you take with this information that you were unable to take during the tornado warning on (insert date and time)?

34) You are informed that there is a 70% chance that a tornado will strike your institution in 15 minutes; would this change the decisions you made?

If yes...

a. How would this change your response?

b. What actions could you take with this information that you were unable to take during the tornado warning on (insert date and time)?

35) Do you have any further comments you wish to include?

36) Would you consent to being contacted for follow-up questions or clarification?

If yes...

a. What is your preferred method to receive a consent form for follow-up questions?

Snowball Sampling

As part of my research methods I am using a technique called snowball sampling. For this technique, participants are requested to provide information regarding possible additional participants for the study. This technique ensures that all relevant decision-makers are contacted regarding your institutions response to the tornado warning. During this interview you indicated that you contacted (list the titles of those mentioned in the interview).

37) Which of these people were involved or consulted in making decisions about emergency notification of the campus during the tornado warning?

38) Are there any additional people you recommend I speak with who were involved or consulted in making decisions about emergency notification of the campus during the tornado warning?

Thank You Statement A

This concludes the interview. If you have any questions or comments regarding this interview please contact me at Amy.C.Nichols-1@ou.edu or (352)328-1190. If you have any questions for my advisor, please contact Dr. Eve Gruntfest at egruntfest@ou.edu. Thank you for your time and cooperation.

Thank You Statement B

Because this research is about hazardous weather warning response by institutions of higher education, this concludes the interview. If you have any questions or comments regarding this interview please contact me at Amy.C.Nichols-1@ou.edu or (352)328-1190. If you have any questions for my advisor, please contact Dr. Eve Gruntfest at egruntfest@ou.edu. Thank you for your time and cooperation.