UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

HOW K-12 SCHOOL DISTRICT OFFICIALS MADE DECISIONS DURING 2011 NATIONAL WEATHER SERVICE TORNADO WARNINGS

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

Degree of

MASTER OF ARTS

By

STEPHANIE HOEKSTRA
Norman, Oklahoma
2012

HOW K-12 SCHOOL DISTRICT OFFICIALS MADE DECISIONS DURING 2011 NATIONAL WEATHER SERVICE TORNADO WARNINGS

A THESIS APPROVED FOR THE
DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL SUSTAINABILITY

BY

Dr. Scott Greene, Chair

Dr. Eve Gruntfest

Dr. Laurel Smith

THE

DEDICATION

OF THIS THESIS

IS SPLIT

SEVEN WAYS:

TO MY FAMILY,

TO THE LADIES OF APT 6,

TO MY CC GIRLS,

TO KBRAD,

TO SHELLY,

TO LIFE,

AND TO THE 2011 TORNADO VICTIMS,

WHO WERE ROBBED

THE CHANCE OF

LIVING

THEIRS.

Acknowledgements

I would like to acknowledge Dave Stensrud and the Warn-on-Forecast team for supporting this work, as well as Social Science Woven Into Meteorology, the Cooperative Institute for Mesoscale Meteorological Studies, and the Department of Geography and Environmental Sustainability at the University of Oklahoma for allowing me to pursue my passion of interdisciplinary research. I would also like to thank my advisor, Dr. Eve Gruntfest, for all of her guidance and passion throughout this process, along with the rest of my committee, Dr. Scott Greene and Dr. Laurel Smith for their support. I am also grateful to numerous colleagues and professors who were undoubtedly always there for me when I needed them, including Dr. Heather Lazrus, Dr. Harold Brooks, Jennifer Spinney, Kim Klockow, and Dr. Randy Peppler. I acknowledge James Correia, Travis Smith, and Gregory Stumpf for their advice and suggestions for my methodology. Additionally, I owe a special thanks to my colleague and friend, Amy Nichols, with whom I shared countless moments of joy, revelations, and companionship and for whom I will always have respect. Lastly, I would like to thank all of my participants who were willing to share their thoughts with me despite their busy schedules. Their enthusiasm is what kept me going.

Table of Contents

List of Tables

List of Figures

Abstract

School district officials are responsible for the safety of large populations of students and staff. Yet, few have meteorological training to accurately interpret severe weather information to make the best decisions during tornado warnings, and little research has focused on further understanding the context in which these groups make weather sensitive decisions. Including the needs and perspectives of groups such as school district officials into weather product development is necessary in order to create the most valuable and useful products in the future. Eleven participants with various titles from six school districts in central and eastern U.S. were interviewed in the spring and summer of 2011. Semi-structured interviews were used to address four main questions: 1) what is the K-12 public school official's timeline of decision making and action implementation before, during, and after tornado warnings? 2) what sources of weather information do key decision makers in K-12 public schools access and why? 3) what are the non-weather factors that influence how decisions are made?, and 4) what types of weather information might improve operations for K-12 public schools, and how might longer lead times change the decision making process? Interviews were coded according to predetermined themes and analyzed.

Preparations for tornado warnings, such as conducting drills, educating the students, and crafting severe weather plans, occurred during the majority of the year when there was no severe weather. Additionally, much of the action taken, most notably communicating with staff, students, and parents, occurs throughout several phases beginning hours before the severe weather was approaching to when the tornado warning has passed. "Lead time" in the minds of these decision makers thus began

several hours before the tornado warning was issued, emphasizing the need to step away from the traditional mindset that a tornado warning lead time is only minutes before a tornado occurs. These decision makers used sources similar to what the general public is known to use, including NOAA websites, the television, and NOAA radios. Regardless of the severity of the weather, the majority of participants carried out their severe weather plans and sheltered students immediately after a tornado warning was issued for their district. Non-weather factors influenced how they perceived the warning and how students were brought into shelter, but they did not affect their decision of whether or not to shelter; taking shelter was an automatic response after a warning was issued. These participants prefer more spatial information with clear indication of whether or not the storm is likely to impact their district directly. Overall, participants found that extended tornado warning times would provide more time to go over plans and communicate with others, and recognized that this would require a modification of current warning plans and response. Several questioned whether a two-hour lead time would still bring the same sense of urgency as current warnings. This study shows that new meteorological advancements should respond to expressed needs of stakeholders.

CHAPTER 1: INTRODUCTION AND BACKGROUND

Introduction

One reason natural disasters, such as tornadoes, are particularly damaging is because of the lack of collective partnerships and communication between stakeholders and the science community. Tornadoes are naturally occurring phenomena that humans cannot control. Meteorologists and weather forecasters can benefit from a better understanding of weather-societal interactions, so they can issue effective weather forecasts that the various publics find useful for severe weather decision making. Social science research on learning the various ways that weather sensitive decision makers use weather forecasts is underway, yet little progress has been made on weather-sensitive decision making in institutions, and research related to societal impacts across the entire severe weather communication spectrum is needed. This study focuses on one component of the wide spectrum of weather information users: Kindergarden-12th grade public school district officials in the US.

School decision makers are responsible for the safety of their students and staff. How do they use weather information when making important decisions during severe weather? Answering this question will provide useful information to forecasting software developers who need to effectively communicate what is known about tornado threats. Developing forecasting products without the interaction with the people who will use them is ineffective. My research is part of a new line of inquiry that starts with what people do with forecasts instead of what forecasts do to people. Only by paying attention to what information people seek and use can new improved tools truly be "improved".

This study consists of four related research questions:

1. What is the K-12 public school official's timeline of decision making and action implementation before, during, and after tornado warnings?
2. What sources of weather information do key decision makers in K-12 public schools access and why?
3. What are the non-weather factors that influence how decisions are made?
4. What types of weather information might improve operations for K-12 public schools, and how might longer lead times change the decision making process?

National Weather Service Warnings

The National Weather Service (NWS)[1] is one of six federal agencies that make up the National Oceanic and Atmospheric Administration (NOAA). Its mission is to provide "weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy" (NWS 2012). It is made up of numerous entities including the Storm Prediction Center, and local Weather Forecast Offices (WFOs) that provides taxpayer funded information and weather products to a variety of groups, including the public, companies, agencies, universities, cities, international partners, and many others.

The NWS Storm Prediction Center (SPC) and the NWS Forecast Offices provide tornado information via outlooks, watches, and warnings (Golden and Adams 2000). The SPC notifies of potential tornado days at a regional scale several days in advance of severe convective weather. This severe weather information is called an

[1] See Appendix A for a full list of acronyms

outlook. Watches indicate that current conditions have the potential to form tornadoes, and are typically issued with four to six hours of lead time (Stumpf et al. 2008).

As of 2012, NWS tornado warnings are issued by a “warning-on-detection” method. This means that a tornado/funnel cloud has either been seen by a spotter or indicated on radar (Stensrud et al. 2009). Before 2007, WFOs issued warnings by county. Since 2007, they have converted to issuing storm-based warnings, which are based off of the individual storm instead of the county (Sutter and Erickson 2010). Using this method, approximately 70% less area and 600,000 fewer people are warned each year (U.S. Department of Commerce 2007; Waters 2004). This shift in policy was an example of the NWS transitioning to a new method of warning without taking into consideration the input of stakeholders. League et al. (2012) interviewed emergency managers in Oklahoma and Texas and found that although they had the capability to warn smaller areas using the storm based warning system, many did not.

Warn-on-Forecast and Social Science Woven Into Meteorology

This study is funded by the Warn-on-Forecast (WoF) project as part of NOAA’s National Severe Storms Laboratory (NSSL). WoF is developing a method of early tornado prediction with the mission of extending the tornado lead-time from minutes to potentially one to two hours by using convection-resolving, Doppler, and numerical models (Stensrud et al. 2009). NOAA anticipates that it will be operational by the year 2020 (Stensrud et al. 2009). WoF will be a more dependable method of providing enhanced forecasts and predictions of severe weather to the general public, organizations, and stakeholders than the Warn-on-Detection model that is now being used. WoF will look farther in advance by using numerical models to forecast future severe weather events, thus providing an extended warning lead time.

My research is the social science component of WoF that brings stakeholder perspectives into the WoF process. The bulk of the WoF research centers on the development of the technology and software that will extend lead times primarily for tornadoes. My work is among the first effort to consider the social implications of longer lead-times. This research will highlight the importance of recognizing the full spectrum of warning time to include the outlook, watch, and warning time frames, beyond only the short NWS tornado warning lead time.

This research study is one of several studies by Social Science Woven Into Meteorology (SSWIM) researchers in the National Weather Center in Norman, Oklahoma. SSWIM promotes collaborative research and partnerships between the social sciences and physical sciences of meteorology to enhance societal relevance of weather forecasts and highlight how stakeholders make weather-sensitive decisions.

U.S. Schools

On any weekday during the academic year, about 20-25% of the United States population is in a public school (Hull 2010). More specifically, as of 2007, there were over four million school staff members and nearly 50 million students enrolled in US public schools (Snyder et al. 2010). In certain regions of the US, tornado vulnerability is a significant issue. Students represent a non-autonomous population who lack decision-making rights when it comes to their safety. Students rely on the expertise of their authority figures, who are usually teachers, principals, or other administrative staff, to make appropriate weather safety decisions for them. These people often have no severe weather training. Additionally, most schools do not have formally designated emergency personnel. Because of the vulnerability of students, faculty, and staff in schools, the impacts of a tornado in a school setting can be deadly.

Schools are only open a certain number of hours on weekdays, and are mostly closed during the summers, during breaks, and on particular holidays. According to the US Department of Education (2012), schools in the US average 180 days of instruction per year, at both the elementary and secondary levels. They vary in geographical and population size, demographics, and architectural layout. For this thesis, taking “shelter” includes a wide variety of places depending on the size and structure of each school. Each school has pre-designated “shelters” where students and staff go when tornado warnings are issued. These places are usually in classrooms, hallways, or the gym. No judgment is made as to how safe the “shelters” are.

Summary of Thesis

This thesis consists of eight chapters: the first chapter introduces the topic and research questions and provides some background of NWS warnings, WoF, and SSWIM. The second chapter presents a literature review and description of several models and theories relevant to the results found in this study. The third chapter summarizes the study's methodology. The fourth chapter is the results and discussion. This chapter relies heavily on story telling and quotes to reveal this group of stakeholders’ perspectives using their own words. The fifth chapter provides conclusions. The sixth chapter gives a list of potential future research that can build on the findings from this study. The final chapter provides a list of recommendations to

WoF researchers emphasizing the need to work closely with stakeholders and to include their needs in the future development of severe weather warnings.

CHAPTER 3: LITERATURE REVIEW

This chapter details four sets of literature relevant to hazards, behavior and response, and emergency management. It pulls largely from geographers' natural hazards traditions. The sections included are: 1) warning systems model and weather warning partnership, 2) public response and behavior theories, 3) lead time, and 4) other research on how school administrators make weather sensitive decisions.

Warning Systems Model and Weather Warning Partnership

An effective tornado warning requires more than detection. Collaboration among several organizations is needed. Mileti et al. (1990) proposed an integrated warning system (IWS) for hazards, comprised of detection, management, and response subsystems. The detection subsystem is responsible for monitoring the environment, detecting the hazard, and linking the detection and management subsystems. The management subsystem acts as the liaison between the detection and response subsystems and is comprised largely of emergency managers who are given the roles of information interpretation and public dissemination. The response subsystem consists of the ways that the publics and other weather-sensitive decision makers learn about, believe, personalize and take action in response to the hazard, including both individual interpretations of the information obtained and unofficial warnings sent among the public themselves (Mileti et al. 1990).

The weather warning partnership is an adaptation of the IWS model by Mileti et al. (1990), geared specifically towards severe weather warnings. Doswell et al. (1998) and Golden and Adams (2000) discuss the concept of an integrated warning system that integrates warning detection and dissemination among the NWS (detection subsystem), news media and private sector meteorologists, emergency management officials and storm spotters (management subsystem), and the general public (response subsystem). This model, focused on severe weather, consists of forecasting and detecting severe weather, disseminating vital information, and understanding public response. An IWS stresses the concept that weather warnings are only effective when the entire system functions collectively, with each component putting in sufficient effort to prepare for a severe weather event *before* it happens, as well as communicating effectively *during* a weather warning (Doswell et al. 1998).

Each component of the IWS has different responsibilities. The NWS is responsible for the initial forecasting of weather and the relay of this information to the other collaborators of the IWS (Doswell et al. 1988). Their mission is to protect life and property. The media, emergency managers, and private sector meteorologists are then responsible for providing the weather information to the various publics. The media, particularly the television, is the leading source of weather information (Hayden et al. 2007). Additionally, local emergency managers are a vital source of weather information for stakeholders and the publics (Baumgart et al. 2008; League et al. 2010; Dawson 1993). They are responsible for communicating warning information through an emergency alert system, activating sirens, if there a siren system exists, and advising schools and hospitals of appropriate actions to take (League et al. 2010). Emergency managers work closely with the NWS and rely heavily on the NWS information.

However, there are several concerns about this model. It assumes a one-size-fits-all approach meaning that each component responds the same way for each severe weather event. This is not the case. For example, emergency managers often act independently of the NWS. League et al. (2012) found that 36% of Oklahoma emergency managers and 39% of Texas emergency managers do not always warn the public when the NWS issues a tornado warning that includes some portion of their jurisdiction. Meanwhile, 79% of Oklahoma emergency managers and 60% of Texas emergency managers have or would warn the public about a tornado threat when the NWS has not yet issued a warning for their area of jurisdiction. Thus, the management subsystem does not always rely on the detection subsystem for information.

Additionally, the warning process is not just a stimulus response since not everyone immediately takes action when the NWS issues a warning. Some people may choose not to take action at all. The public component of the warning systems model is far more complex than how it is portrayed by this model. The following sections will explore several theories and models that further describe the cognitive processes of hazard response.

Public Response and Behavior Theories

Public Response to Warnings Model

Public awareness and response is a vital component of the IWS. Mileti and Sorenson developed a public response to warnings model that shows how people follow a similar process when confronted with a hazardous situation that lead to varying decisions made and actions taken. The first stage is "hearing the warning" (Mileti et al. 1990). There is a growing number of social science research studies that consider public *daily* weather information use. However the samples in these studies were small and therefore not necessarily generalizable (Lazo et al. 2009; Harris Poll 2007; Bussum 1999; Sink 1995; Saviers et al. 1997; Krenz et al. 1993; and Legates et al. 1999). These studies may be considered baseline studies for more comprehensive research efforts. The remaining phases of public response are understanding, believing, personalizing, deciding and responding, and confirming the hazard (Mileti et al. 1990). Several factors influence how an individual proceeds through this decision process, including their risk perception and awareness of the hazard, their socioeconomic and education levels, and their cultural and environmental surroundings (Aguirre 2000).

A significant criticism of Mileti and Sorenson's model is that it depicts the flow of information uni-directionally, not allowing for the response subsystem, the public component of the IWS, to interact with or respond to the detection and management subsystems. In the Internet-connected universe the publics are no longer submissive. Rather, they actively seek information about the hazard, which the Mileti and Sorenson model fails to recognize (Rodriguez et al. 2007). Additionally, people often rely on unofficial information that they receive from environmental cues and non-weather sources and may not always rely on the NWS to obtain weather information.

Meteorologists must understand how the general public uses weather information during severe weather warnings to make decisions so they can provide the types of weather information and products that fit what people need. People do not respond to warnings in exactly the same way. Rather, individuals interpret the same information very differently, making it difficult for weather experts and emergency managers to gauge or predict public behaviors (Mileti et al. 1990; Sorenson 1991). This model fails to include how an individual makes protective action decisions, which might be not to take any action at all.

Protective Action Decision Model

The Protective Action Decision Model (PADM) recognizes the shortcomings of the Mileti and Sorenson model (Lindell et al. 2004). This multistage model assembles several key decision theories that depict how individuals respond to environmental cues and social messages, such as warnings. The PADM produces a behavioral response by incorporating eight questions that individuals are inclined to ask themselves during a warning (Table 1). It includes crucial pre-decisional processes such as the awareness and interpretation of environmental cues and social messages, as well as perceptions of threat and protective action (Lindell et al. 2004). Table 1 illustrates how the Mileti et al. (1990) public response to warnings model correlates with the PADM. Mileti et al.'s six different public responses to warnings are paired with the appropriate PADM activity. Stage 0 is an adaptation to depict how the *hear* and *understand* stages of the Mileti et al. model parallel the PADM's pre-decisional processes. The PADM model more realistically encapsulates actual human behavior by effectively incorporating societal and cultural influences, behavioral choice, and hazard response (Lindell et al. 2004). It highlights the protective action steps people take when confronted with a hazardous situation.

Table 1: PADM Warning Stages and Actions (Adapted from Lindell and Perry 2004). The right column depicts the correlating public responses to warnings stated by Mileti and Sorenson (1990). The X's depict no available comparisons between models.

Protective Action Decision Model (Lindell and Perry 2004)				Public Response to Warnings Model (Mileti and Sorenson 1990)
Stage	Activity	Question	Outcome	
0	Pre-decisional stages			Hear and Understand
1	Risk Identification	Is there a real threat that I need to pay attention to?	Threat belief	Believe
2	Risk Assessment	Do I need to take protective action?	Protective motivation	Personalize
3	Protective action search	What is the best method of protection?	Decision set (alternative actions)	X
4	Protective action assessment and selection	What can be done to achieve protection?	Adaptive plan	X
5	Protective action implementation	Does protective action need to be taken now?	Threat response	Respond
6	Information needs assessment	What (additional) information do I need to answer my question?	Identified information need	Confirm
7	Communication action assessment and selection	Where and how can I obtain this information?	Information search plan	
8	Communication action	Do I need the information	Decision	

The PADM model has recently been revised from its 2004 version (Lindell et al. 2011). It has been changed to more explicitly identify the three central perceptions that lay the groundwork for making decisions and responding to short or long-term threats. They include threat perceptions, protective action perceptions, and stakeholder perceptions.

Utility Models and Bounded Rationality Theory

Behavioral decision-making theories describe how people choose to take protective actions. However, there is more to the process than simply the PADM model and certain theories provide the framework under which protective action behaviors are carried out. According to Expected Utility Theory, decision-makers assess all possible outcomes and choose what actions to take with the aim of maximizing their net benefits (Burton et al. 1993). This principle is entirely objective and applies only to marginal situations, into which severe weather warnings do not fall (Kunreuther et al. 1978). Consequently, the Subjective Expected Utility Theory was developed that, although it still emphasizes maximizing net benefits, it also allows the decision-maker to *subjectively* choose the value of probable outcomes (Tobin et al. 1997). This theory provides a subjective platform upon which each individual can make decisions based on their own personal circumstances.

The Subjective Expected Utility Theory, however, has its shortcomings. First, this theory assumes that the individual is provided with all the information on a particular hazard. Realistically, people are not always aware of all the associated risks. Second, this theory is rational only in static situations, and does not apply to extreme hazards, including tornado warnings (Slovic et al. 1974). Simon (1957) acknowledged these limitations and recognized that "the degree to which decision making is rational seems to be bounded by cognitive limitations" (Lindell and Perry 2004 33). This Bounded Rationality Theory explains how people make decisions when bounded by the law, societal norms, and cultural circumstances. Decision-makers bounded by factors such as these might act irrationally from an economic perspective, but feel as though their actions are most appropriate according to their personal boundaries and limitations.

Cognitive and Conditional Factors

Geographers Tobin and Montz (1997) provide another explanation for why certain people make what are perceived as irrational decisions. They categorize an individual’s response to hazards as being influenced by both cognitive and situational factors (Figure 1). Cognitive factors include personality characteristics and personal experience that alter an individual’s perspective of nature and risk. Situational factors are more externally driven, such as age, gender, location, and income, which “complicate an individual’s range of choices” (Tobin and Montz 1997 135). An example is someone who stays in the San Francisco Bay area even though they are aware of the risk of a big earthquake occurring sometime in the future. To them, the benefits of the location outweigh the risk of the hazard, and the investments in their property and housing are so substantial that leaving seems impractical.

Behavior and response are strongly influenced by the perception of the environment, or cognitive factors, as well as controlled by situational factors. Yet, this “interplay of environment and perception is constantly changing as more information is received and processed, further complicating… attempts to uncover decision-making processes.” (Tobin and Montz 1997 141) Over the duration of severe weather watches and warnings, stakeholders, including school administrators and emergency managers, continuously change how they perceive an event as more information is received and processed. This process may even begin long before a watch is issued. Time is a determining factor in how the interplay of the environment and an individual’s perception influences their decisions.

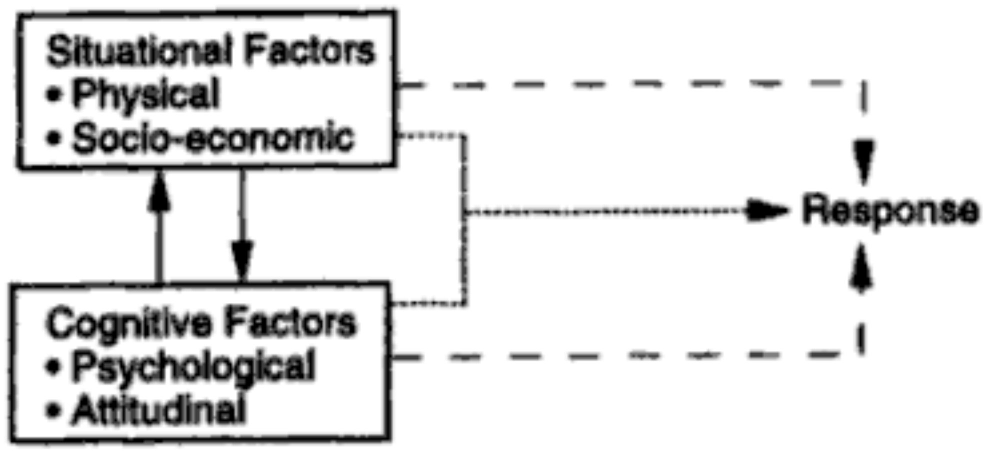

Figure 1: Representation of the interplay between perception and response (from Tobin and Montz 1997). The bullets represent specific cognitive and situational factors that affect response.

Situation Awareness

Situation awareness can be 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” (Endsley 1995, pp. 36). This relatively new concept, coming from human factors research, became a focus of study beginning in the 1980’s as Endsley noticed that decisions were becoming more multifaceted. He constructed a model that situates the three levels of situation awareness, which are perception of current situation, comprehension of current situation, and projection of future status, within the larger context of decision making (Figure 2). Situation awareness, along with other factors including the goals and expectations of the decision maker, experience, memory, and system design and capabilities, influence what decisions are made and actions implemented (Endsley 1995). Individuals have varying levels of awareness of the situation in which they are placed. These different perceptions of the space around them will influence how they respond to a situation.

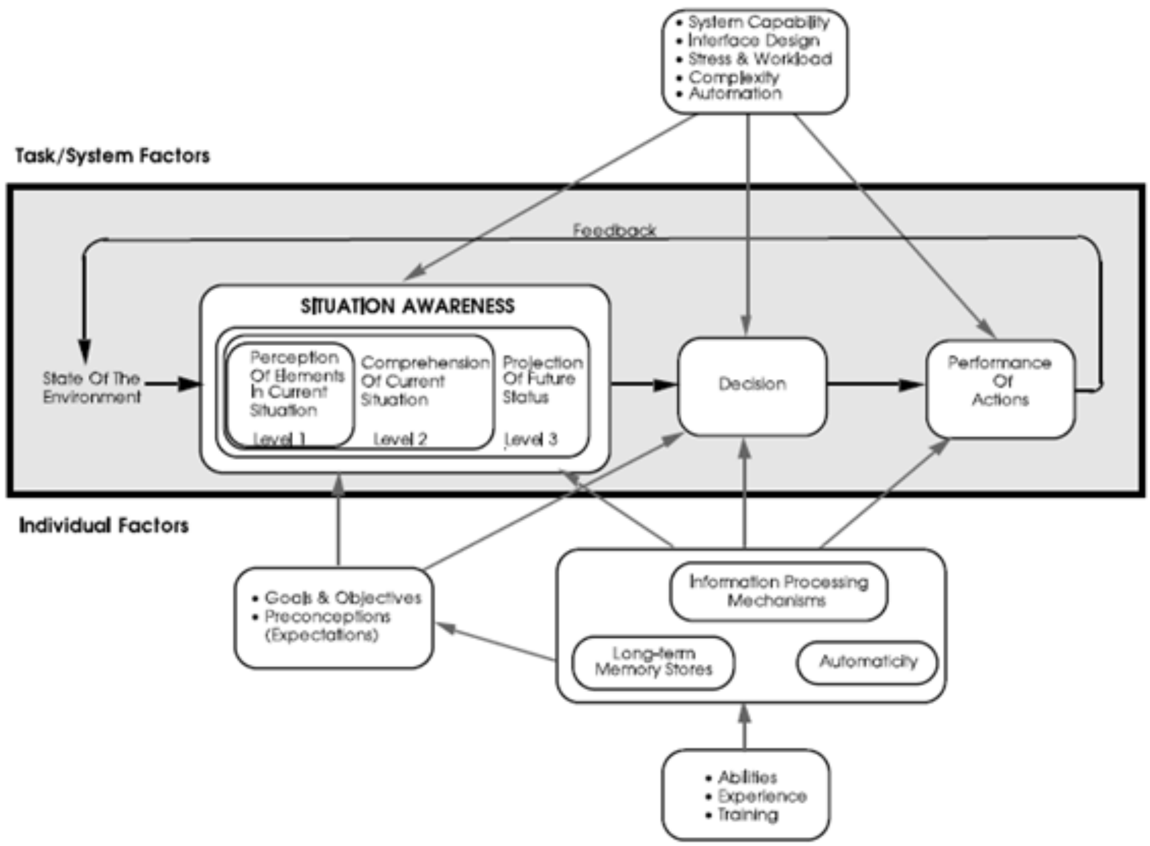

Figure 2: Model of situation awareness in decision making (Endsley 1995).

Lead Time

Extending tornado warning lead time, or the time between the National Weather Services warning and the occurrence of a tornado, is a long-term goal of WoF (Stensrud et al. 2009). One purpose of my thesis is to communicate school administrators' thoughts and perceptions of an extended lead time to the new forecasting product developers and WoF scientists. The definition of lead time, for this thesis, goes beyond evaluating the effectiveness of longer lead times and pinpointing the ideal National Weather Service tornado warning lead time. Lead time for stakeholders may include the time far before a warning is issued. It provides time necessary to begin preparations and make decisions prior to the hazard.

The majority of time and hazards research deems warnings as distinct phases with a concrete start and finish time. Pingel et al. (2005), Carsell et al. (2004), and Schumacher et al. (2010) consider lead time as being three distinct phases: data collection and evaluation, notification and decision making, and action/mitigation time. Schumacher et al. (2010) modified Pingel et al. (2005) and Carsell et al.'s (2004) models of lead time for floods by creating a similar version for tornadoes (Figure 3). This model demonstrates that the amount of time used to collect data and decide what actions to take determines what amount of time is remaining for actual action to take place. Neal in 1994 and 1997 theorized that the four phases of disaster (mitigation, preparedness, response, and recovery) are not separate and distinct categories, but rather overlapping phases that blend together *through* time.

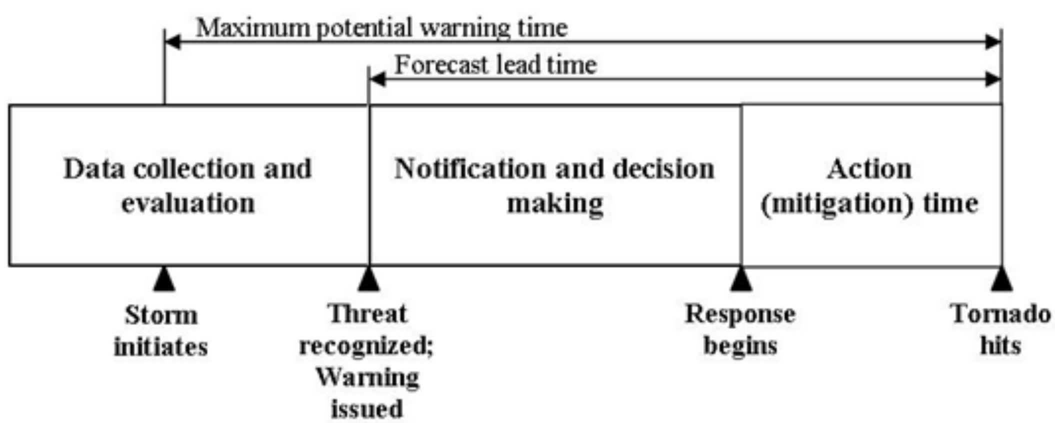

Figure 3: Model of lead time for tornadoes (modified by Schumacher et al. (2010) from Pingel et al. (2005) and Carsell et al. (2004)).

A few studies show that having a longer lead-time in a National Weather Service warning may not be appreciated by the public. Hoekstra et al. 2011 found that the ideal tornado lead-time was 34 minutes for the National Weather Center visitors. Similarly, administrators of schools and nursing homes preferred tornado-warning lead-times of no more than 30 minutes (Ewald et al. 2002). Few studies consider extended lead times, and the few that do consider it do not take into account the external implications that play a part in how longer warnings will impact society. This study will consider new understandings of the notion of lead-time.

Other Research on how School Administrators Make Weather Sensitive Decisions

School decision-makers are bounded by factors out of their control. During tornado warnings, schools within the NWS warned area have many possible actions to consider including, but not limited to, evacuating students or sheltering them in place. Schools receive information from the NWS and other sources and they disseminate that information to their populations and surrounding districts. Schools often receive calls from their local emergency managers when severe weather is expected (League et al. 2010). The emergency managers provide information to initiate school emergency plans. Plans include closing the school, evacuating students, or transporting students to predetermined shelters. Is this the *only* source schools use? How are schools bounded by cognitive and situational limitations? What information do school officials *want*?

There are only a limited number of studies evaluating the decision-making processes and information use within a school setting. Most studies focus on winter weather, earthquakes, or other technological and human-induced disasters. These studies focus more on school closures and delays rather than on the decision making process of deciding whether or not to shelter students in place in a tornado situation.

The WxEM group in North Carolina is working with NWS Office of Science and Technology to develop and evaluate technologies with the goal of improving the weather decision support to emergency managers during events such as hurricanes, tornadoes, blizzards, and floods. Their major questions include the following:

What are the critical decisions being made and by whom?

What knowledge does the decision maker need?

Where does this knowledge come from? and

What influences the confidence of the decision maker?

This group recently completed another study that focused on the inclement weather decision process for schools in North Carolina during winter weather. The methodology for their 2010-011 research, involved three rounds of interviews with multiple participants from nine counties in central and western North Carolina and a statewide web based survey (Montz et al. 2012).

The results of their study included the following 8 findings:

1) Transportation directors were most likely to gather the weather information and communicate it to others, though these employees often struggled to find and understand the weather information.

2) The main weather sources used by the school decision makers were the television and their local NWS, with whom many communicated.

3) Decision makers contacted their school staffs long before the event (up to days), preparing them of the potential impacts.

4) There were differences according to school size, with smaller schools more likely to use more than six sources of weather information, more likely to pass information on, less likely to contact their NWS, and less likely to use media to pass information on.

5) There are complex interactions between weather information and decision making, especially that location, resource availability, and experience all have a direct affect on what decisions are made.

6) Decision makers made a series of decisions based on 2-way communication with other staff and gathered many different types of information from multiple sources, using their *own* understanding of the forecast to make conclusions about road conditions.

7) School decision makers stated the need for an animated onset map to get a better idea of what time the storm is expected to approach their location, as well as a simplified area forecast with clear information.

8) The authors stressed that "one size does not fit all", and every decision maker, many of whom are not weather savvy, will react differently according to their own interpretations of the data (Montz et al. 2012).

Call and Coleman (2012, forthcoming) researched the factors that go into deciding whether or not to close schools for inclement weather, and how this decision process varies geographically. Their study questions centered on how school administrators obtain and interpret weather data, how non-meteorological criteria influence the closing/delaying decision, and what weather conditions result in the most school closures and delays. They found that the decision making process was similar regardless of the type of weather event and geographic location. Directors of transportation were found to play an integral part of the decision making process, becoming weather knowledgeable from experience *not* training. Non-weather factors contributed minimally to closing decisions since the directors of transportation used student and staff safety as their leading rationale for closing. Although his study focused on winter weather and closures, the authors believe these results can be applied to other weather events in other geographic areas (Call and Coleman 2012, forthcoming).

A study conducted by Kano and Bourque (2008) aimed to assess what distinguishes schools that are better prepared for emergencies and disasters from schools that are less prepared. By surveying 157 schools in California between 2005 and 2006, the authors pinpointed several correlates of emergency preparedness. They found that having funds directed to preparedness activities, as well as a faculty member who is specifically designated to handle preparedness responsibilities led to greater overall preparedness. The authors were surprised to find that size, distance from urban centers, available resources, and prior experience was not correlated with preparedness level. Although their study focused primarily on earthquakes, technological hazards, and human-induced hazards, it highlights several significant points regarding emergency preparedness that may be applicable to severe weather hazards as well (Kano and Bourque 2008).

A study conducted by Burling and Hyle (1997) took a systematic approach and sampled the district plans of 36 school districts across the nation. They found that larger schools were found to have less detailed disaster plans, while smaller more rural schools had more detailed plans. Also, districts in areas with more unpredictable hazards such as earthquakes, were found to have more detailed plans than those in areas where hazards are more predictable (e.g. hurricanes). Along with sampling district plans, the authors also interviewed several district administrators to pinpoint any relationship between past experiences and changes in school policies. They found that some administrators readily integrated their experiences into their lessons while others did not change their policies at all (Burling and Hyle 1997).

A multidisciplinary study that looked at schools along with other local decision making organizations during an unusual tornado occurrence on May 22, 2008 highlighted the importance of societal factors in decision-maker perceptions and behavior (Schumacher et al. 2010). This was the first study that applied Mileti and Sorenson's public response model to decision-maker behavior, instead of solely to the public. The authors conducted interviews with local decision-makers, concluding that decision makers interpreted warnings differently. Also, having previous knowledge with severe weather influenced how they perceived the warning. Their study also called attention to the many complexities that exist in the severe weather communication process, emphasizing that lead-time is only one factor in the warning communication process and future research needs to consider more than just lead-time influences (Schumacher et al. 2010).

As forecasts and technologies continue to improve, the warning paradigm will shift to longer lead-times (Stensrud et al. 2009). Before this transition occurs, it is vital to understand *current* warning response to improve the effectiveness of future systems. Researching school administrators' decisions, one subset of the warning communication spectrum, and their response to NWS tornado warnings, is a step toward gathering this information. Although researching schools and weather warnings cannot answer all the questions pertaining to weather-sensitive decision-making, it can bring forecaster attention to one subset of stakeholder perspectives. Research calls for a more thorough consideration of contextual factors that influence decision-making in school districts. Human decisions and behavior are based on weather conditions, forecasts, *and* many other factors. My study focuses on the effects of some of the external forces that may influence decision behavior within school settings as well as provide preliminary thoughts on extended tornado warning lead times from this stakeholder perspective.

CHAPTER 4: METHODOLOGY

My study consists of six in-depth case studies of US public school districts that were placed under at least one National Weather Service tornado warning during the spring 2011 severe storm season.

Sampling Methodology

The most essential source I used is the Iowa Environmental Mesonet (IEM), which collects and stores environmental data from a variety of networks, and includes daily summary images of storm-based warnings and archived NWS watches and warnings. The archived text information provided by the IEM allowed me to create a database with the date, the issuance and expiration times of the warning, and the NWS forecasting office location that issued the warning(s). The IEM also provides storm reports that featured a list of damages, injuries, and fatalities and radar images. It also provided a history of the warning including the duration and change of time/location, intensity of the storm, and recommended precautionary actions the particular warning or warnings.

The severe weather home page on the IEM website (http://mesonet.agron.iastate.edu/current/severe.phtml) provides daily summary images of storm based warnings. Using this tool, I selected the date and sorted by weather forecasting office to receive a summary of all NWS storm based warnings issued on the day of choosing (including severe thunderstorm and tornado warnings). I made note of all the forecasting offices that issued warnings for that day. I then used the archived warning data (http://mesonet.agron.iastate.edu/request/gis/watchwarn.phtml) to examine the NWS warnings for a time period of my choosing.

Once I had all of the warning polygons, I was able to pinpoint which school districts were under each warning by overlaying the archived warning polygons from the IEM with Google Earth Place data (public school districts) (Figure 4 and Figure 5). This overlay technique provides spatial verification that a school district is located within a tornado-warning polygon. Additional information from the affected school district was obtained in order to ensure that the placement of the district was accurate; cross-referencing is necessary since it is not uncommon for the warning data to be displayed in a different datum (or reference point) than the school district data layer. The warning polygons used were storm-based warning polygons.

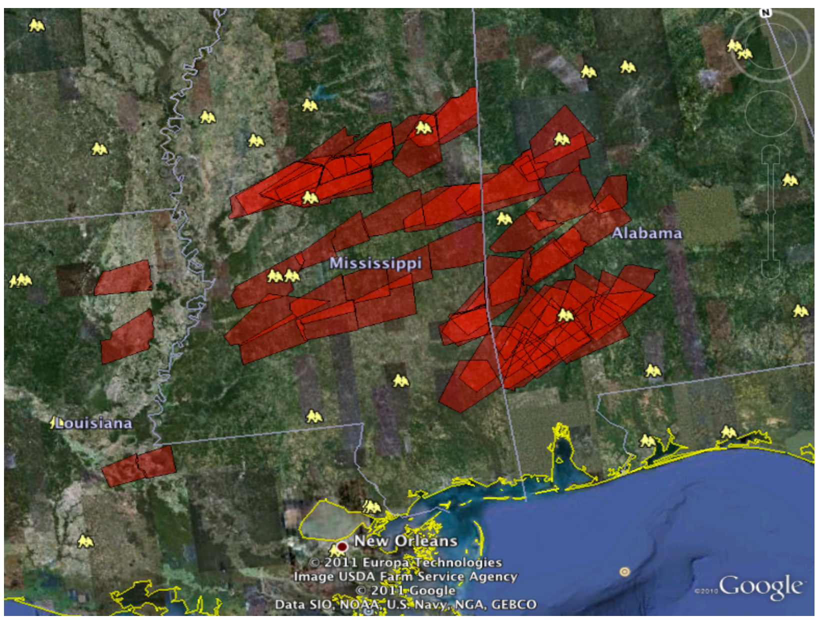

Figure 4: An overlay of NWS warning polygons with school data from Google Earth. These particular warnings were issued on April 15, 2011. The yellow icons represent schools.

Figure 5: A zoomed-in view of a warning polygon encompassing a school district in Arkansas on April 24, 2011. Zooming in allows for the school district icons to appear.

Data Collection

My samples were chosen from the warning data for April and May 2011. I compiled a database of schools under warning(s) starting on the 25th of April. Because almost all warning polygons encompassed at least one school, I needed to find a way to limit which schools I included in my database to create a reasonable sample. I narrowed my case study selection to districts where the superintendent's contact information was conveniently located via their district website. I contacted the superintendent from that district within a week after the event. In total, I contacted 80 administrators and interviewed 11. The case studies were districts under NWS warning(s) on either April 28th or May 25th, 2011 (see Figures 6 and 7 for a zoomed out view of all tornado warnings issued on those days). The duration of these warnings were from 15 to 50 minutes. These sample days were soon after the large tornado outbreak in the southeast on April 27th and the Joplin tornado on May 22nd.

Figure 6: Tornado warnings issued by the NWS on April 28th, 2011.

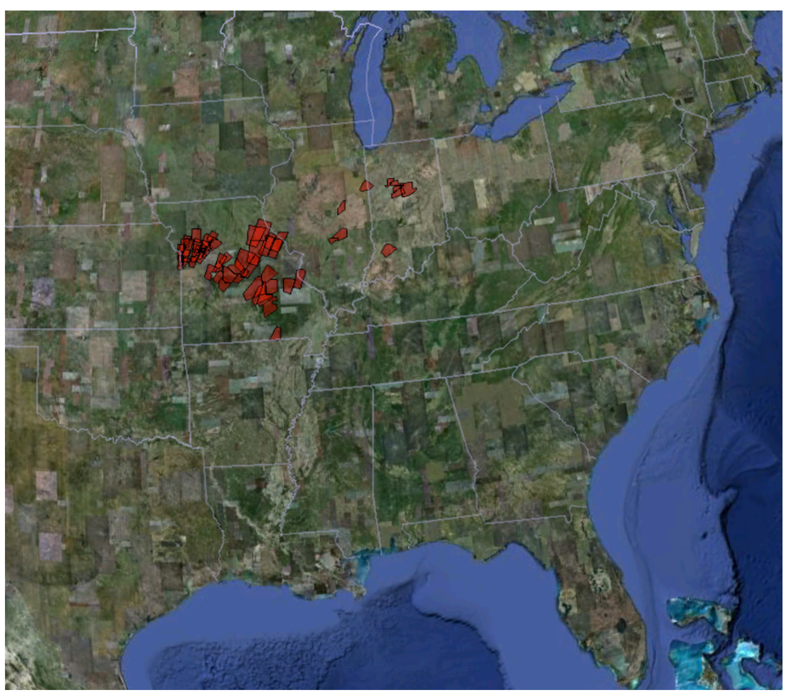

Figure 7: Tornado warnings issued by the NWS on May 25th, 2011.

I set up interview times with the superintendents who responded and were willing to participate. A few of the superintendents referred me to someone else in the district to interview. Those people are included in the total number of those I contacted. Interviewing post-event allowed me to gain insight as to the actual behavior of the decision makers rather than their idealized behavior (Hammer et al. 2002). I interviewed between one and three people with varying positions from six school districts, with a total of 11 participants (Table 2).

Table 2: Participant positions from each school district.

School District	Position
A	Superintendent
B	Superintendent
	Director of Safety and Security
C	Superintendent
D	Director of Transportation Services
	Communications and Public Relations Officer
	Principal
E	Assistant Superintendent
F	Superintendent
	Technology Director
	Principal

Social Science Methodologies

I used snowball sampling to gather more data from a wider spectrum of people involved in the process. I asked my initial participants to refer me to anyone they considered to be vital decision-makers during the warning event. Snowball sampling is a preferred method for exploratory and qualitative studies aimed at obtaining information on sensitive topics from difficult to reach participants.

I used semi-structured interviews. This technique is especially useful when interviewing several people who have different job titles, such as in a school setting

(Longhurst 2010). Semi-structured interviews initiate collaboration between the researcher and the participant, allowing the participant to guide the interview and feel free to express their own views and perspectives. Semi-structured interviews are a reliable data collection method, allowing for comparisons between participants (Longhurst 2010). The semi-structured interview in this study included questions on demographic information, sources of weather information, warning response and decision-making, and weather product preferences. I conducted only phone interviews. The interviews lasted on average of just under one hour. Appendix B provides the interview script.

Sampling Criteria and Limitations

The schools selected to take part in this study were public schools in the central and eastern regions of the US. I preferred interviewing more than one person from each district to better understand the decisions made within the district. However, for three of the six districts included in my study, I interviewed only the superintendent because he/she said reported that he/she is the sole decision makers during the particular warning period. I only sampled districts that were under NWS warnings since that is the archived data source that I acquired.

An additional selection parameter is that the schools being researched must have been under a tornado warning, but not physically impacted by a tornado. Lastly, and arguably the most important selection parameter, warnings had to occur during school hours, which I considered as 1130 through 2000 UTC time Monday through Friday. This is equivalent to approximately 7:30 am through 4:00 pm, in the Eastern Time zone.

Adjustments to this time range were made according to the time zone in which the warning was issued.

Data Analysis

I used qualitative method techniques to analyze the interview responses. I first uploaded the sound files into a computer program called *TAMS analyzer,* which facilitated the transcribing process. Each transcription took between four and five hours. The TAMS program, which stands for Text Analysis Markup System, is an open source Macintosh qualitative research tool that was designed for use in ethnographic research. I explored the data for common themes and patterns. I came up with an initial set of codes and then added and removed codes as I saw fit as I coded each interview transcription. I used my research questions as a basis for choosing my initial set of codes.

CHAPTER 5: RESULTS & DISCUSSION

This chapter reports on the results of the interviews. It is divided into five parts: 1) the timeline of decisions made and actions taken, 2) sources used, 3) non-weather factor influences on decision making, 4) weather information preferences, and 5) thoughts on current and extended lead times. The first section on the timeline conveys the participants' stories as separate cases, to provide an understanding of the individualistic nature of each situation and a context for why particular decisions were made. This section ends with a cumulative assessment of all the participants' decisions and actions. The remaining sections will be described aggregately, as many of the cases used sources for similar reasons, were influenced by related non-weather factors, and shared similar weather information preferences. These sections, in aggregate form, more clearly and strongly illustrate the complexities school district decision makers are faced with during tornado warnings.

Timeline of Decisions and Actions

The decisions made and actions taken are unique to the individual. The following are brief descriptions of what each participant did before, during, and after the warning(s). Descriptions of each warning and district will be kept to a minimum. I will provide approximate student populations and only vaguely discuss their location to ensure the confidentiality of my participants.

School District A

This school district encompasses nearly 100 square miles in Missouri and has a student population of approximately 3,500 students. This district was under NWS warning polygons four times over about a two-hour period around lunchtime, and each school in this district was under more than one tornado warning during this time. I interviewed the superintendent.

Superintendent

He had been the superintendent of school District A for three years. He, along with colleagues, was monitoring the weather south of the district prior to the warning issuance. He emailed his staff two or three times several hours before the warning was issued to alert them of potential hazardous weather and suggest beginning to take preparatory actions. The NOAA Weather Radio in his office alerted him of the warning. He then sent a text message to the building administrators notifying them of the warning. He asked the building administrators to reply back to him with an “all clear” once the warnings expired. He mentioned that the local sirens went off shortly after the NOAA weather began relaying the weather information. Students began taking shelter. During the warning, he was in communication with designated faculty, including weather spotters and the chief of fire and rescue for the county, who were monitoring the weather. After the severe weather day, he and his staff discussed what went well and what procedures need improvement.

School District B

This school district encompasses approximately 85 square miles in Missouri and has a student population of approximately 11,000 students. This district experienced five warnings spanning about two hours around lunchtime, and each school in this district was under at least one tornado warning, with the majority experiencing more than two warnings during this time. I interviewed the superintendent and director of safety and security.

Superintendent

He had been the superintendent of school District B for three years. He mentioned that the director of safety and security and law enforcement officers monitored the weather days ahead of expected severe weather. He received an email from the director of safety and security that is also sent out to other directors and principals, informing him that severe weather was possible mid-morning. Students in outdoor classrooms were brought inside. He, along with the directors and principals, received an email from the director of safety and security that a warning has been issued just before lunch. The sirens then went off. He was out of his office visiting schools when he received the email and his secretary's phone call. He decided to go to the largest elementary school to observe procedures. At the elementary school, he did not take the lead. He stood back and watched the proceedings take place because he felt his role was too "erratic."

> "I never want to put myself in a position where I'm absolutely needed or critical to a process because I'm unpredictable as far as my presence, so I just mostly stood by and observed. And that's mainly what I did…a system needs to run without a superintendents' interaction…because they will be in and out and unavailable, and so things need to happen whether or not I'm there."
>
> - Superintendent from District B

He completely "let [the Director of Safety and Security] run the show when it's severe weather," and was more interested in observing proceedings at their largest elementary school to see how fast the students can be sheltered.

He said that the principals at each school announced over the intercom that everyone needed to follow severe weather procedures and begin to take shelter. Students and faculty took shelter, and remained in predetermined sheltered areas for the duration of all the warnings. The secretary was in the basement monitoring the weather on her computer, via NOAA websites. The superintendent and his secretary received ten emails during the first warning from the director of safety and security. He mentioned that parents were calling while everyone was in shelter. Post-warning, he debriefed with faculty and discussed the possibility of having an automated message to send out to parents to update them on the situation.

Director of Safety and Security

He was been the director of safety and security in District B for seven years. Earlier in the year, he recommended that the district put a computer in the basement of the central office so weather monitoring could continue while being in a sheltered area. He is responsible for monitoring the weather, and thus knew days ahead of time that severe weather was approaching. That morning, he was the official at a motor vehicle accident on the highway. When the watch was issued, he called and emailed the superintendent's office immediately. He suggested that the superintendent send out emails to everyone that severe weather is coming and to prepare to take action. The police dispatcher received the warning from the NWS through a Teletype; this information was forwarded to him via email on his phone. He then emailed the superintendent about the first tornado warning. This action led to people in the schools taking shelter in their pre-designated tornado shelters. He then sent out another message advising students and staff to stay in their safe places for the duration of all the warnings, which totaled more than one hour. When all the NWS warnings expired for the entire county, students were allowed back into their classrooms. He mentioned that he plans to have a post warning debriefing with faculty to talk about some communication issues they had with phones.

School District C

This school district is in a rural county in Virginia encompassing approximately 290 square miles and has a population of approximately 2500 students. This district experienced one NWS warning mid-morning, that affected some, but not all, of the schools in the district. I interviewed the superintendent.

Superintendent

She had been the superintendent of District C for four years. She, along with her staff of the principals and secretaries, paid attention to severe weather starting several hours before the issuance of the warning. That morning, she was visiting the main high school to listen to student presentations. Using her smart phone, she sent out an email to staff to begin preparations and to ensure that NOAA radios were working properly. She heard the principal of the high school that she was visiting brief students on the severe weather plan in case a warning was issued. She then went to the office of this high school to ensure that the secretary and assistant principals were monitoring the weather. She was alerted of the warning via phone and email from the director of secondary education. The warning was then announced over the intercom at individual schools as well as via outdoor bells. As students were moving to shelters, she was on the phone with the other schools ensuring that they were also going to pre-determined shelters. When the warning expired, students were brought back to their classrooms. She mentioned a desire to have a post-warning debriefing to discuss what went well and what changes need to be made to procedures and communication. Because of this district's small size, this superintendent mentioned that she is the only person responsible during these situations and that "things like this are just kind of all vested in me." She considered herself the school district's emergency manager since they lack the funds to employee others with this role.

School District D

This district is in a rural area of Maryland encompassing approximately 45 square miles and has a population of slightly less than 30,000 students. This district experienced five warnings spanning nearly two hours in the morning. Some schools in this district were under no warnings, while others experienced all five warnings during this time. I interviewed the transportation services department director, the communication and public relations officer, and a principal.

Director of Transportation Services

He had been the director of transportation services of school District D for one year. He monitored the weather 24 hours beforehand. He was at home when he was alerted of the first warning in the early morning via the television. He immediately contacted staff in the central office by phone. He then began notifying bus contractors by phone since the first warning was issued when busses were still on the road picking up and dropping off students at schools. He said that it was impossible to contact individual busses and so he made the decision to keep the busses on the roads picking up students as planned. He then drove to school and monitored Doppler radar and NWS websites with the staff. Individual schools were notified of the warning via the AlertNow system from the central office and were told to follow severe weather procedures. Students and staff then began taking shelter. He mentioned a desire to have a post-warning debriefing to discuss necessary changes to procedures and to resolve any communication issues. This participant, whose role and responsibilities include monitoring the weather, utilized more complex weather sources to gather information, such as Doppler radar than other participants.

Communication and Public Relations Officer

She has held this role for 25 years. She met with other staff in the beginning of the year to plan and assign responsibilities for severe weather events. She stressed that she works on the communication side and plays only a small part in interpreting the weather information. She relies on the transportation department and law enforcement for that. On this day, however, she did feel the need to monitor the weather since it was all over the news. She mainly watched the television and looked at NOAA websites for weather information. She was in constant communication with the transportation department director, who called her to inform her that a warning was issued early that morning. She verified the warning with the superintendent. She then briefed her assistant, who went on to speak with the district's website designer and local television station to put announcements out to inform parents of the situation. They also used the AlertNow phone system to notify all principals and parents.

The warning information was relayed to students and teachers via the intercom or phone system depending on the school. Students and staff then took shelter and stayed in shelter for the entirety of all the warnings. She mentioned wanting to have a post-warning debriefing to discuss what worked and what needs improvement. In particular, she mentioned that the communication aspects of procedures needed to be reevaluated:

> "We're going to meet as a group and see what we could've done better. There were some principals that we called on the cell phone that said that they didn't get the message, so we're looking at why they didn't get the message, we're looking at okay let's suppose the principal doesn't answer the phone, we need to have something in place to get the message to someone else in this school as well. So we're looking at our communication procedures to see how we can tighten them up and make them more effective."
>
> - Communications and Public Relations Officer in District D

She was in communication throughout the entirety of the warnings with numerous staff, including the superintendent, assistant superintendent, the transportation director, and the directors of the elementary, middle, and high schools. Because of its larger size, this district employs more staff with designated emergency roles.

<u>Principal</u>

He had been the principal of one of the schools in District D for about five years. He mentioned that he did not hear anything about approaching bad weather on the news, and thus he was not monitoring it that morning. On his drive to work, he heard on the radio that they were under a watch. He was in his office for about 20 minutes before he got a phone call from his director in the central office that a warning was issued. His secretary then ran into his office and told him they were under a warning. He emailed the secretaries and teachers telling them of the warning and used the PA system to announce the warning to the school. Staff received emails on their phones. Because it was so early, staff was still walking into the buildings. Arriving teachers were notified of the warning via a few secretaries who stood at the entrances.

With the help of other staff, he retrieved all students from the busses and moved them into the gym. Several teachers stayed in the lobby outside of the gym to facilitate the process. Once the first warning was lifted, students were brought back into their classrooms from their sheltered areas. Once the second warning was issued, he, along with the recommendations from the director and the director's secretary, decided to keep students in their first class period for the duration of the remaining warnings. Post-warning, he debriefed with the teachers and staff to consider changing the severe weather drill to a "hurricane/tornado drill" that is to be held at least once a year.

School District E

This district is located in a rural/suburban country in Pennsylvania, and has a population of over 3,000 students. This district experienced three warnings spanning more than an hour mid morning. Each school in the district was under at least one warning during this time. I interviewed the assistant superintendent.

Assistant Superintendent

He had been the assistant superintendent of District E for about five years. His district conducts severe weather exercises every spring. He was monitoring the weather hours earlier. He follows the NIMS protocol and several of his administrators are NIMS certified. When the warning was issued, he told his secretary to begin calling individual schools. The secretary called three schools while he called the remaining two, to split the load and increase efficiency. People in schools with access to the Internet were monitoring the weather at their individual schools. His district posted their procedures on their school website to let parents know what they were doing in real time.

Throughout the event, he listened frequently to one of the local television broadcasters who was the husband of one of the teachers at his district. He said, "we're… very fortunate that one of our teachers, actually her husband happens to be on of the head meteorologists and the local news station. So it's kind of an inside track so to speak." He trusts this relationship and thus, when this meteorologist specifically called out their district on television as being in the path of the storm, which spurred many phone calls from concerned parents, he decided to take his advice and keep students in shelter for the duration of all the warnings.

> "that particular day was interesting because one of the alerts that they called off… the local meteorologist said… while the warnings are off I have concern… So rather than moving kids back in and out of the hallways we elected just to stay in that situation and sure enough, within a matter of minutes, the next warning was issued… if we just went with what the weather radio was saying we would have made an additional move in and out of classrooms in a matter of 5 minutes…"
>
> - Assistant Superintendent in District E

He advised the students and faculty in each school to remain in a shelter until they got a call from the central office with updated information, and to expect the process to be long. Teachers and principals reported that staying in shelter for the duration of all the warnings instead of going back and forth between shelters and classrooms was helpful. Post-warning, he mentioned a desire to debrief mainly on communication issues that arose during procedures.

School District F

This district is located in a rural area in Pennsylvania encompassing approximately 110 square miles and has a large population of over 40,000 students. This district experienced three warnings spanning more than an hour in mid morning. Some schools in this district were under no warnings, while others experienced all three warnings during this time. I interviewed the superintendent, the technology director, and a principal.

Superintendent

He had been the superintendent of District F for about two years. His district reviews the severe weather procedures in the beginning of the year in each building. Every March, they conduct severe weather drills in collaboration with the county. At the time the first warning was issued, he was in a meeting with all staff and administrators of the district. Several of the attendees began getting text messages and alerts on their phones that a warning had been issued. He verified the warning via NOAA websites. He told the principals of the schools that were most likely to be impacted to activate their severe weather plan and call their secretaries. He was aware of the most impacted areas because he was looking at the warning polygons. He told everyone else to call their secretaries and activate their emergency weather procedures, but not to take shelter yet. The secretaries of each school contacted the teachers via intercoms. He sent each of the principals to their respective schools, which, in hindsight, he chuckled about since it required driving during a tornado warning.

Secretaries stood at the doors of schools directing students and parents inside. The students in schools under the warning, and near warned areas, took shelter. He understood that shelters with fewer windows are ideal. However, due to the pressures of building "green," he had recently added more windows to increase natural light. Additionally, he was uncertain as to where his teachers should shelter students *as the warning unfolded*.

> "We initially brought them in the gym and then we realized, well the gym is two stories and at the top there are windows that circle the area, that's not a good thing, so we moved them back into the buildings. But all of our buildings have windows at the end of the hallways, we have a two-story lobby with glass from bottom to top, so there are areas that the principals would've been able as a

> result of a little more lead time, to say okay where do we want to house students?..."
>
> - Superintendent in District F

After the warning expired, students were brought back into their classrooms. This process repeated for the second warning. For the third warning, fewer schools took shelter since this warning only affected a small number of schools in the county. He still called *all* the schools alerting them of the warning. He mentioned that the local broadcast meteorologist singled out his district in his broadcast. He made the decision to keep AM kindergarteners at the school but he cancelled the PM kindergarten session. Throughout the warnings, he was sending out AlertNow messages to inform parents of the situation. After the warnings expired, he expressed a desire to create more specific instructions of what actions to take in future situations.

<u>Technology Director</u>

He had been the technology director of District F for approximately 13 years. He mentioned that this district conducts severe weather drills and reviews the severe weather plan before storm season each year. He was attending the staff meeting with the superintendent when the warning was issued. Once people began getting texts and alerts, he pulled up the NOAA website, saw that his county was under a warning, and relayed this information to the superintendent, who then made the decision to begin activating the severe weather plans. For the second warning, the superintendent and assistant superintendent called principals alerting them of continued severe weather. For the third warning, operations shifted. The superintendent was no longer available and so he, along with the elementary coordinator, was left to guide the people in one of the buildings that they thought were potentially in the path of the storm himself. In this district, the students went in and out of sheltered areas as the warnings came and went. He is currently working with staff to figure out why some of the NOAA radios were not functioning properly. He mentioned that the superintendent is now working with the leadership team to better disperse responsibilities among the district and clarify the chain of command.

Principal

He had been the principal of one of the schools in District F for about two years. The superintendent monitored the weather beforehand via NOAA websites. He was also in the administrative meeting along with the previous two participants from this district when the warning was issued. The superintendent told him to report back to his school and follow the severe weather plan. On his way back to his building, he contacted the school resource officer and told him to begin moving students to sheltered areas. When he arrived at his school, he made an announcement over the intercom and emailed teachers to alert them of the situation. He then sent out an automated call to parents to let them know that afternoon kindergarten was cancelled for that day. Elementary students rushed off of busses to sheltered areas. He went to one part of the school while his assistant principals covered the remaining areas to ensure that procedures were going smoothly. When the first warning expired, he sent his students back to their classrooms. He was notified of the second warning via the NOAA radio and websites, and sent students back to the sheltered areas. This is similar to what occurred during the third warning. Post- warning, he was considering discussing alternative shelter areas with his staff.

General Timeline of Participant Action and Sources Used

These brief descriptions provide the individual stories of the interview participants. Each case is unique as each decision maker made different decisions, yet there are similarities. A timeline representing the general behavior of the participants along with the weather sources used is found in Figure 8. Not all decision makers followed this timeline. The timeline represents a generalization of what was mentioned by my participants. This illustration offers a reference that concisely and collectively connects the timeline of decisions made by the participants.

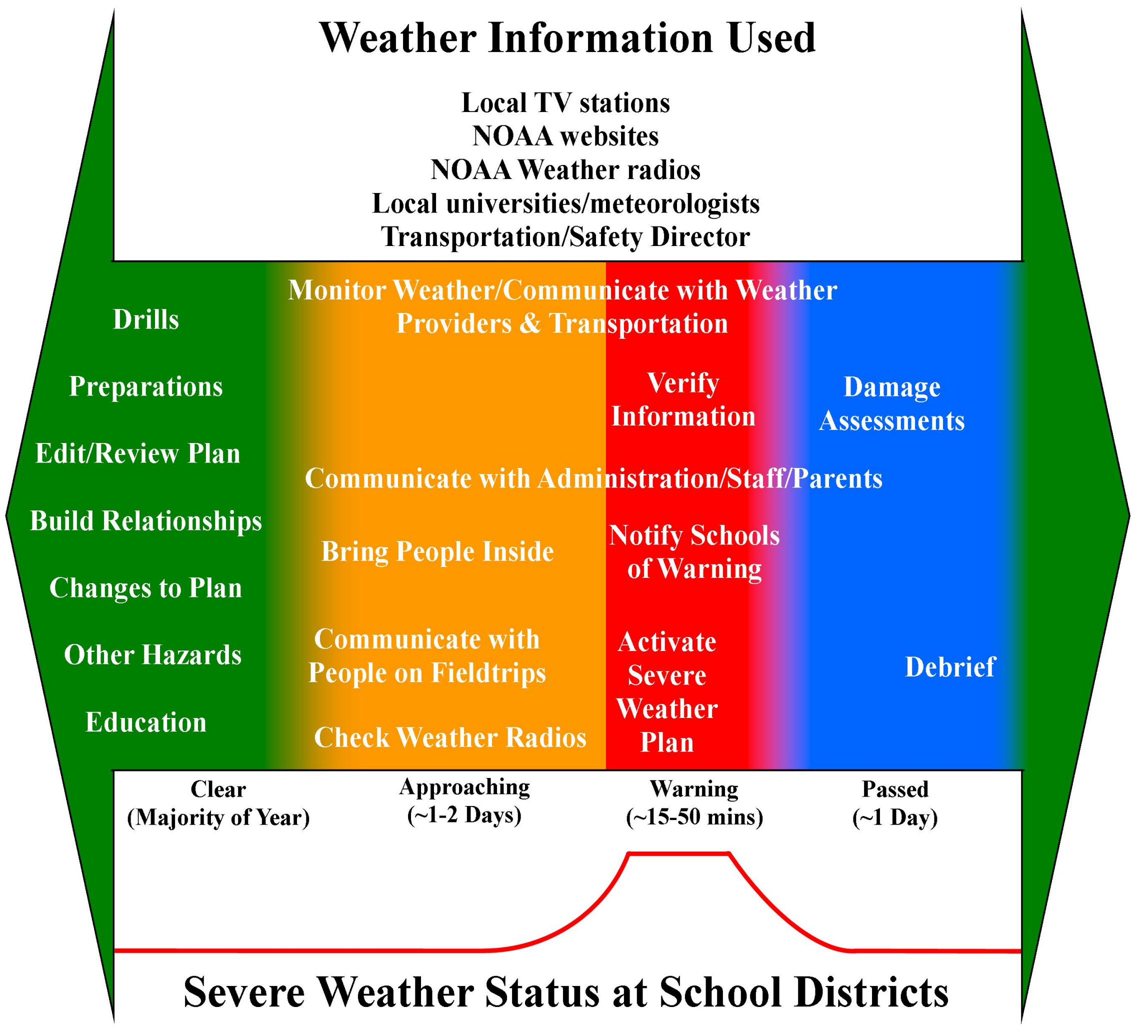

Figure 8: Hypothesized timeline of school district officials' response during tornado warnings.

The left side of the timeline shows the behavior of the officials when there was no severe weather. All of my participants mentioned that they perform severe weather drills at least once a year, with the majority performing drills more than once a year. Participants referred to them by a variety of names including, “tornado drills,” “severe weather drills,” and “tornado/hurricane drills.” Also during the majority of the year when there is no severe weather, school district officials held administrative meetings to discuss and edit existing severe weather plans. The superintendent normally led these meetings. Staff took advantage of this planning time to build relationships with their local police departments, neighboring districts, and district staff, especially with the transportation and safety directors. Like emergency managers, school district officials build relationships when weather is benign, so they can rely on those sources when faced with severe weather. This timeline shows that officials prepare in many steps during the majority of the year before the onset of any severe weather.

When severe weather was approaching, officials began much of the communication with administration, staff, parents, students, and transportation directors that continued throughout the entirety of the event. Cell phones, land lines, text messaging, intercoms (PA system), emails (both to computers and cell phones), and two-way radios were the sources most often mentioned for communication. Participants also mentioned that at least one staff member was monitoring the weather from a few days before the warning was issued until after it had expired. Typically, those employees with designated emergency preparedness roles, such as technology and safety directors, took on the responsibility of weather monitoring.

Several hours before the arrival of a severe weather system, designated staff brought in students and faculty who were outside via outdoor sirens, cell phones, or word of mouth, and were in constant communication with those on field trips via cell phones and text messaging. Parents were often notified via school district website updates, or from alerts sent to them through services such as AlertNow. Several participants mentioned that they communicated with each school to ensure that their weather radios were functioning properly. Weather information sources when severe weather was approaching consisted mainly of local TV stations, NOAA websites, NOAA weather radios, and transportation and safety directors.

Participants learned that a warning was issued from a variety of sources, many of which are the same that they used to monitor the approaching weather. The most prominent sources include hearing their local broadcast meteorologist say it on television, hearing it from their NOAA weather radio, seeing the warning online on a NOAA website, or getting a call from technology/safety directors or local meteorologists. Further specifics and discussion on the sources used will be included in the next section. Once they became aware that a warning was in place, different people took a variety of actions. Several participants verified that there actually was a National Weather Service warning in place by accessing more than one source. Once he/she was certain that the district was inside a warning polygon, he/she began communicating this information to the individual schools in their district. Typically the superintendents and their secretaries took on this role. They advised the building director and/or principals of each building to activate their severe weather plan, which consisted primarily of sheltering students in pre-designated areas. Almost all were aware of what sort of structure serves as a safe shelter. They recognized that large rooms with windows are not very safe. However, some participants were still not sure where to shelter students at the time of the warning even though predetermined shelters were decided upon as part of their severe weather plans.

Within each district, there is a chain of responsibility among administrators and staff that dictates who makes the important decisions during the warning. This specific topic was only explicitly addressed in five of the 11 interviews, though similar observations are implied in the remaining interviews. Figure 9 illustrates the chain of responsibility that was generally found in the sample districts. All the possible contacts that were mentioned by the participants are included; each district thus does not have all of the reported personnel in the figure. Generally, the superintendent has the highest status, unless he/she is out of the office. In that case, the assistant superintendent takes over as lead decision maker. From there, depending on the district, communication/transportation/safety directors, directors of elementary, middle, and high schools, leadership/crisis teams/human resources, and principals are the second in command. Within each school, the assistant principals and their designee follow after the principal.

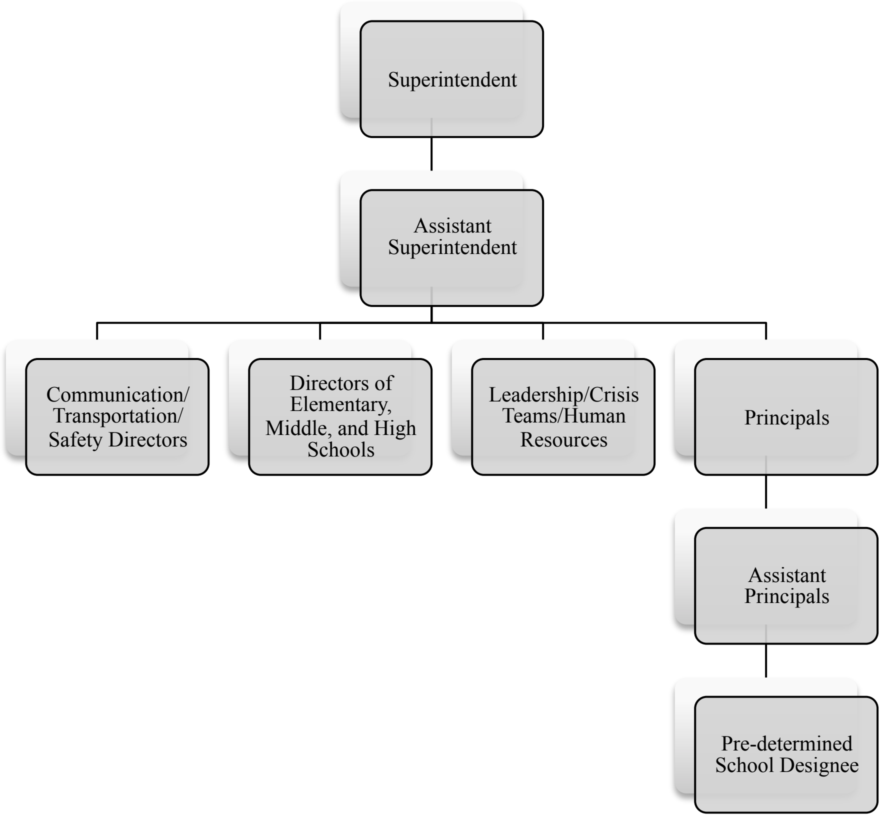

Figure 9: Chain of responsibility within the sampled districts.

The majority of district superintendents worked with at least one other person, whether that was a transportation director, secondary education directors, or leadership team members, when making these severe weather decisions. In a few cases, someone other than the superintendent, such as the transportation director, made the vital decision of whether or not and when to shelter students in place. Thus, the chain of responsibility varies widely among districts, and weather tool developers need to take these significant differences into consideration when designing new weather products as every user has varying needs and responsibilities.

Five out of the six districts were under more than one warning during hours of operation. These districts faced between three and five warnings. Of the five districts that were under more than one warning, three of them stayed in their designated shelters for the entirety of all the warnings, District F had their students go back and forth between shelters and classrooms, and the data was not collected for the remaining district, District A.

After the warning(s) expired, damage assessments were performed and staff and administrators debriefed to evaluate what went well and wrong during the proceedings. A few participants mentioned that the communication aspect needed to be reevaluated post warning. After discussing the event, participants mentioned that any necessary changes to their plans and procedures would be made.

Relation to Other Research

There are two main take home points from this timeline. First, as seen in Figure 8, communication with staff, faculty, administrators, and parents spanned several severe weather states, and played a vital component in the entire severe weather process. This observation is similar to what Neal (1997) observed: the different phases of lead time and warning response are more intertwined than distinct. This contrasts with work by Schumacher (2010) on tornadoes and Pingel et al. (2005) and Carsell et al. (2004) on floods, who found that the differing states of weather act as distinct phases for various actions. Second, the timeline also shows that a great deal of effort is put into preparing for severe weather before it approaches during the majority of the year. Similar observations were made by Spinney and Gruntfest (2012) and Nichols (2012) for emergency managers and university officials, respectively.

This general timeline acts as a supplement to the individual descriptions of actions taken by each decision maker. It is a compilation of the behavior of my participants throughout the severe weather process. As portrayed in the timeline of each case, the individual decision making process varies from case to case, and often deviates from this timeline.

Rationale for Sources Used: Trust and Familiarity

The descriptions of the individual cases include the sources the participants used (portrayed in Figure 8). What has not yet been discussed is the rationale behind why these users used the sources they did. Several reasons include trust, credibility, accuracy, and convenience.

Several of the participants mentioned using local meteorology programs, including universities, as a main source of severe weather information because they trusted them as credible sources. All of the participants except one expressed a large degree of trust in the NWS. Several of them still used alternative sources, such as transportation directors or safety and communication directors, because they felt like they had a closer bond with them than with the NWS. A key component of whether school district officials trusted their sources was that the relationship was on a more personal, than professional, level.

This need for a personal relationship to build trust is evident regarding television broadcasters. Several of my participants mentioned having a great deal of trust in their local broadcasters who were familiar with their local area. Besides trusting their local broadcasters, another reason why school officials used the television as a main source of weather information is because the television relays information in a simple manner. Most of my participants were not weather savvy and not trained in meteorology or weather spotting. Therefore, they appreciated when the television broadcasters would tweak the information to become more "public friendly." A few participants mentioned that the NOAA websites and radar were too difficult for them to fully understand without prior knowledge of how the weather works (one was not even sure what websites he used).

> "I think it [NOAA's site] makes a lot more sense for meteorologists, for me personally it is probably hard to decipher and figure out exactly you know what they have posted on their regular radar. But again our local news station has a rather attractive Doppler radar that they have set up that I personally find a little bit easier to interpret."
>
> - Technology Director from District F

Another reason why the television was an effective resource tool was that it provides more localized spatial information than the weather radio or the NOAA websites. The superintendent from District C emphasized that she appreciates when the broadcaster starts big and then gets smaller, specifically pinpointing their location in relation to the storm. A participant from District F said that their local station "is within a mile of our district border and they have weather people I trust." The desire for more detailed spatial information will be discussed in a later section on weather information preferences.

NOAA weather radios were used by all of the participants, yet there was a vast difference of opinion regarding the radio's benefits. Most participants did not have any complaints about the radios, while others blatantly expressed their dislike for them. For some, weather radios were the first indication that there was a tornado warning. For others, it was merely a source of verification. For example, the technology director from District F stated, "to be very candid, I would much rather… like to know that the weather radio is there as a backup because if a tornado has just taken down cell service well that's not going to help us very much for text service…" Other participants mentioned the radio's benefits when it was turned on and working. One principal mentioned that their radios were not functioning properly at the time of the warnings. Two participants hated weather radios: one superintendent from District F does not like electronic voices and would much rather read the text instead of listen to it, and the other, a superintendent from District C, does not like how vague the radios are when providing spatial location. She mentions, while laughing, "…I don't know if it's the radio or… if it's the weather service but every time there's a 'This is the National Weather Service from Wakefield, VA and I'm going where the hell is Wakefield?"

I made two observations about how the sources used differed according to job title, location, and experience with severe weather. Only two participants mentioned looking at radar, one of which being a superintendent from District A, which is an area that is frequently hit by tornadoes. He understood weather, including how to interpret radar, better than the other participants in less tornado-prone areas, signifying the important of past experience and location on information sources and perception. This participant also mentioned looking out the window as an essential source of weather information.

Larger districts tended to employ people in additional positions, such as a director of transportation services and director of safety and security, who played major roles in information gathering and dissemination. These roles that are more explicitly designated with weather preparedness responsibilities used alternative sources such as NWS scanners, police radios, and teletypes sent from the police department. The director of transportation services from District D referred to broadcasters as *"not an official source,"* prefers using the NWS, and serves on an emergency management committee. The superintendents, principals, and others who felt less knowledgeable of severe weather communicated as often as they could with transportation directors and others who were more weather savvy. This is a disadvantage for smaller districts with limited funding to hire additional staff with designated emergency responsibilities.

The reasons for why officials chose the sources they did are individualistic. Each weather information user thought about the event in a different way. Rationalizing why certain sources were chosen depends on a variety of factors, including district size, district location, officials prior experience, and storm intensity, to name a few. It is crucial that weather tool developers recognize this disparity in user needs and responsibilities, and begin to think about how to tailor future warning products in a way that can best support sensitive weather decision-making.

Hypothesized Model of Decision Making

Meteorologists and others often say that certain public responses to tornado warnings are *irrational*. According to the theory of bounded rationality, irrational decisions do not exist. No one *intentionally* makes a bad choice. In their minds, their decision is completely logical. Their decisions are the result of a complex decision making process that integrates many factors that affect them personally and these factors vary from individual to individual. People rationalize the decisions they make and actions they take by assessing the situation at hand. Many non-weather related factors influence how an individual responds during a hazardous weather event. This holds true for school district decision makers based on my research.

While interviewing school district officials, I noticed that a host of factors, usually not related to weather, influenced the decisions they made. It was never a simple yes/no on whether to shelter students. Each decision maker faced challenges that affected how he or she carried out their procedures. Because non-weather factors played such a vital part in understanding how school officials made decisions, I created a model that illustrates the hypothesized process for action implementation under the influence of these external factors (Figure 10). This is an iterative model occurring across the entirety of the severe weather event. It represents how a single decision is made and action implemented by a single decision maker. The processes are repeated multiple times throughout the severe weather event as the situation evolves, new decisions are made, and other actions are taken. Multiple people could be going through this hypothesized model simultaneously, such as the superintendent, a principal, and a teacher, for example.

The components of each box vary between districts and are depend on the specific situation at the time of the severe weather event. Each box is discussed separately and the discussion includes examples of stories and quotes directly from my participants. I will then explain the relationship among all the boxes that ultimately lead to an action being taken through use of several additional examples. The remaining chapters will be "quote heavy" and participant views will be described collectively since many of them experienced similar non-weather factors and described related feelings when confronted with these challenges. There are five categories of external factors that influence what decisions are made (the middle box): plans/procedures, weather information, situational awareness, knowledge/experience, and responsibilities/capabilities.

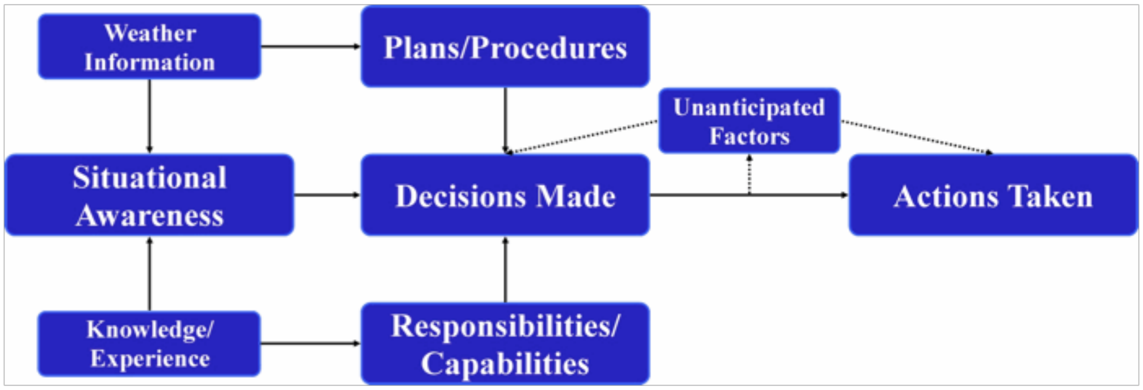

Figure 10: Modeled hypothesis of the non-weather related factors influencing school district official decision making and action implementation during tornado warnings (Nichols and Hoekstra 2012).

The backbone of every decision is what is written in the district's plan. Every district participant prepared some sort of document that listed the procedures for severe weather safety and sheltering. These documents were prepared in advance of the storm and were discussed among the staff at district meetings. The level of detail varied among districts and the plans rarely included "what if's" and ways for dealing with unanticipated challenges. Decisions were based on prewritten plans, but changed as other factors were introduced. One technology director believed (though was unsure) that their procedures were only designed for when students are in buildings, with no plans addressing what to do if a warning is issued during evening activities or periods of transition, times when students are most vulnerable. Regardless of external factors, if a warning was issued, the majority of participants followed their severe weather plan and sheltered students.

The top left box refers to weather information. Questions that the decision makers might ask themselves regarding this category are: Does it affect my campus(es)? When will the storm arrive? How intense will it be? The answers to these questions affect what plans are activated. For example, if the storm is forecasted to affect districts north of the district, then the severe weather plan of deciding to shelter students may not be followed (although the storm is still carefully monitored). In this case, however, most districts chose to make students and staff in every school take shelter regardless of where the warning was in the district and what the weather was like. One principal did not have a television in his office because he thought that it did not look good for public relations reasons. The lack of television limited his sources of weather information.

Weather information also feeds into situational awareness. A decision maker considers factors including the time of day, the location of students and staff, and if any students or staff are exposed to danger during the time the warning is in effect. All participants mentioned the time of day and location of students as being added challenges to an already high-stress situation. A prominent issue mentioned by all of my participants was the connection between warnings issued in the early morning when students were on school busses or at bus stops. Participants in all the districts who experienced warnings during this crucial transition period mentioned this as their biggest concern, while those who did not experience morning warnings mentioned it as being a potential issue in the future.

> "The biggest problem for us is when it hits, and if it hits right in the middle, like 7 in the morning, 7:30, when busses had already left and students are at bus stops, that's when we have our problem. It's not as much of a problem if all of our students are in school. If bad weather's going to hit during dismissal time or during arrival time in the morning, that's the biggest problem for us."
>
> - Communication and Public Relations Officer from District D

> "they haven't been in the morning like this. That's what made this unique… And that's what created more of a situation that we weren't prepared for in terms of kids being at bus stops and busses being out in the street and just the timing of it, you know had this occurred you know an hour earlier, we could've put the breaks on all our bus routes, but our busses were already underway, kids were already at bus stops at 7:15, so that was a unique problem that we have never encountered before here."

- Transportation Services Department Director from District D

> "…it's almost a catch-22. You can tell the bus drivers well stop picking up children and go to some place safe, but you have elementary kids who are out at bus stops so you have no way to alert families that you're no longer picking up in that quick of a time period. Or you can continue on your run and picking up kids but you're driving your busses in the area of a tornado warning."'

- Superintendent from District F

Several others used expressions such as, "not ideal," "unique situation," "presented problems," "biggest concern," "challenge," "weren't prepared for," "what I worry the most about," "alarmed," and "worst possible time for any school system," when describing the difficulty of warnings being issued in the early mornings when busses are running or during lunch times.

Three participants directly asked me what they should do about busses on the road during a warning in the future, asking questions such as, "Well, what can you do?", "What should we do?", and "What do we do…?" This is a concern on which many participants, if not all, would "love to have some expert guidance." Most "don't know if there is any solution…" and when asked what they do about kids waiting at bus stops, one superintendent simply replied, "… I don't know the answer to that." Another participant from District D somberly said, "…we were just keeping our fingers crossed," after deciding to continue picking up students on busses during the warning, highlighting the reality that they truly were not aware of the best practices regarding bus safety during tornado warnings.

However, even knowing the right course of action might not be enough in rural districts, such as in District C where a superintendent said, "…high profile vehicles sitting in a parking lot, God, that's not safe… we are rural and so there are places where if a bus driver had to shelter their kids somewhere, there wouldn't be anywhere." Clearly, the time the warning is issued raises concern among school district officials since it determines where students and staff are located, which can be anywhere from on busses to on a fieldtrip. It is at these locations, when students are not in the classrooms, that make them the most vulnerable. During the decision making process, the level of awareness that the decision maker has of their situation influences what decisions they make and actions they implement.

The bottom left box of Figure 10 refers to the decision makers' knowledge and experience. Factors included are knowledge of weather, knowledge of special events on or off campuses, an understanding of the district location and its possible limitations, decision maker previous experience, and how recent events affect how decision makers perceive the warning(s). Their level of knowledge of the campus and where students are located modifies how situationally aware they are.

Nearly all the participants were not highly knowledgeable of weather or trained in meteorology. Although many of them have degrees of higher education, they have not had much, if any, meteorological education. I found that this was a major determinant in how confident they were in interpreting weather data. They felt responsible to make important decisions, however, they were uncertain as to how to do that successfully based off of information with which they did not feel comfortable interpreting. Most "were trying to make the best decision that [they] could based on not being severe weather experts" leaving some to "fumbl[e] [their] way through it."

A technology director from District F mentioned the added complications of an actual event to those of a drill, since they are left to assess the intensity of the weather situation themselves instead of being fed information by the person leading the drill:

> " When we practice… they tell us here's what's happening. They say 'you're under a tornado warning, or this is happening, begin your procedures'… no one was telling us exactly what to do [during the actual event]. We were sort of at the mercy of trying to interpret the warnings to the best of our knowledge…"
>
> - Technology Director from District F

This is an excellent example showing that the actual act of sheltering students is not the difficult part for school district officials. The complications arise in having to interpret the meteorological data and status of the storm. Thus, although the participants are given huge responsibilities of ensuring the safety of their students, they are given relatively no guidance on how to actually determine if action needs to be taken in the first place.

Several behavior studies have shown that having experienced a disaster in the past makes people more likely to prepare for disasters in the future (Heller et al. 2005; Mulilis et al. 2003; Norris et al. 1999; Sattler et al. 2000; Siegel et al. 2003). The participants in Missouri, a state more often hit by tornadoes than the other states in my study, were more prepared for tornado threats, especially when it came to the frequency of district-wide tornado drills performed. When asked if previous experience with tornado warnings was helpful, a superintendent from District A replied with, "every situation you learn more about what would be an appropriate procedure to follow…"

Participants who had less experience with tornadoes tended to feel more stressed and anxious about the situation: "the fact that a warning was issued for our town was alarming," and it "caught us off guard," since "that doesn't happen here." A Pennsylvania principal from District F felt similarly:

> "…I'm guessing in Oklahoma where they're very common, maybe it sort of lessens the impact because they are so typical. I think the fact that they are rare for us definitely adds and err of 'wow we can take this very seriously.' So not to say I wouldn't take it seriously if I heard them all the time, but yeah I think it probably psychologically sounds more threatening if it's not something that you encounter everyday."
>
> - Principal from District F

I could tell whether the person I was interviewing was from a tornado-prone area or from an area where tornadoes are more rare. Participants in Missouri, for example, spoke of tornadoes as a common occurrence, a part of life, while those in Pennsylvania were overly shocked and found the warning experience to be overwhelming and chaotic. Previous experience, even if it is just growing up in severe weather areas, played a part in how the decision makers I interviewed perceived and thought about the tornado warnings.

Similar to previous experience changing the mindset of participants, recent events played a major role in how they felt about the situation. I interviewed on two severe weather days, both occurring soon after large tornado outbreaks. The following expressions came up several times throughout the interviews pertaining to how the recent tornado events affected the officials interviewed: "heightened awareness," "concerned," "on edge big time," "extra care," and "affects your thinking." A director of safety and security from District B expanded further by saying, "so yeah after that Joplin tornado, I'm definitely even more aware, concerned, than even when I was before. I think that's true of our whole district." Other comments included:

> "It caused everybody to take it more seriously. I noticed an aura of additional concern and seriousness in the demeanor. Now we always try and make sure everyone's taking it serious anyway, and they do, but this was just a level above that. It really was, I noticed that very very clearly. Not really fear, but concern. And wanting to do everything according to the rules, both teachers and kids. I mean everybody was very focused."
>
> - Superintendent from District B

> "I hate to say it assisted in more of the awareness. They [the students] obviously were aware of the storms and the damage that was occurring and how quickly it can occur…that assisted in the immediacy and knowing the severity and seriousness of what could potentially happen…I think having seen the devastation I think it was taking it much more serious[ly]…I think as we always should learn from other situations… and our own as well and it actually assisted us [in] being prepared for that and having a heightened awareness if you will."
>
> - Assistant Superintendent from District E

On the other hand, the technology director from District F, stated that he believed the likelihood of a similar event to occur of that magnitude again was not likely: "…and I think maybe the statistical side too, maybe my logical techy brain probably figured wow that was a real major outlier, you know that's not gonna happen again or something…" Although there are mixed opinions, the majority of participants believed that recent deadly tornado events made them take the situation more seriously.

District locational factors influenced decision making. One superintendent from District C highlighted the significance of living in a rural area and the associated limitations. She said, "we have no internet in the west end of the county… The power goes out here a lot… and so if you have high winds or rain, and your power goes out, you have no idea what's coming. And that is always a concern here." People in the rural area surrounding this district do not own televisions and there are no sirens. When I asked her how people then become aware of a tornado warning, she simply replied, "they don't." She mentioned that having a longer lead time could aid in making parents and others aware that there is a warning via a phone call from the district office, since "that might be the only warning that they get." Location is thus a huge determinant affecting the sources used and decisions made during severe weather. Those in more rural areas are often faced with limitations and forced to work with less information.

Responsibilities/capabilities are additional factors that influence warning perceptions and behavior. This category includes questions such as: What are my job requirements? What am I responsible for? Am I at full or diminished capability? What is my reputation? Am I being perceived by parents and other employees the way that I should be? Knowledge of the school, situational awareness of everyone it encompasses, as well as previous experience helps determine responsibilities and measures the capability of officials to successfully perform their jobs. Having experienced a tornado warning in the past, for example, might ease the official's mind in knowing that they were capable of working through a similar situation in the past.

These five categories: plans/procedures, weather information, situational awareness, knowledge/experience, and responsibilities/capabilities all influence the decision that is ultimately made. However, unanticipated factors may arise that either automatically alter the action that is implemented, or force a new decision to be made. Some examples of unanticipated factors include staff that are not where they are supposed to be, staff that are unfamiliar with plans (i.e. where to shelter students), and technological failures. A superintendent from District B said, "If you lose your landline and your cell phone, that gets very difficult…," especially if this were to occur at the beginning of the warning when communication between all employees is at its peak. The director of safety and security from District B actually did lose cell phone coverage: “Usually I try to call my secretary via cell phone. But that day it worked fine until oh probably 20 minutes into it the phone system had some issues so I couldn’t get through with cell phones. I had to use the computer in my car.” An unanticipated factor such as a technological issue forced a new decision to be made, such as finding alternative methods of communicating.

Another example of an unanticipated factor that occurred after the decision was made to shelter students is a principal who misinterpreted a message sent from the central office. The central office suggested that her specific school was in the path of the storm and that she should take immediate shelter. However, she misunderstood him and continued believing that her school was safe. Due to this unanticipated misunderstanding, this principal did not shelter students. This district planned to debrief about communication issues such as this one during a district meeting that would be held in the weeks after the event. This unanticipated factor led directly to an action, or lack thereof, to be taken, which was not sheltering students, even though it was not the most appropriate action to be taken in this case.

A rather entertaining unanticipated factor occurred to an assistant superintendent from District E:

> "One that I had to laugh about though was in the middle of the first or second warning when I was still trying to contact all the buildings, I had a news reporter call, *and* wanted to speak to the person making those calls if they had time to call *and* hadn't even contacted all the buildings yet..."
>
> - Assistant Superintendent from District E

On the phone, he sounded surprised by the idea of someone thinking it was appropriate to call a school *during* the warning. I am impressed by the reporter’s dedication, but concerned for his manners; he lacked any situational awareness.

The following examples tie the entire hypothesized decision making model together, illustrating the relationship between specific decisions made and contributing external factors using real-life stories:

Example 1:

> "…even though the gym now we have learned engineering-wise is not the elite place to go, the other reason I did that [shelter students in the gym] first thing in the morning and may do it in the future is my teachers aren't on duty yet, contractually, so that first thing in the morning we only had about 10 adults to supervise about 1,000 kids. We needed them in one location because that could create more problems than the possible damage from a tornado if the kids are just running loose all over the place."

- Principal from District D

Even though this principal had the knowledge and experience that gyms are not the safest location to shelter students in, he made the decision to shelter them there anyways since he was situationally aware that he had limited staff and diminished capabilities due to it being in the early morning. In this case, he acted against normal procedures because he thought unsupervised students in more appropriate shelters throughout the campus were more vulnerable than supervised students in a less safe shelter.

Example 2:

> "So typically for our plan…it'd be the superintendent or his designee… [the person responsible for activating the plan]…[The superintendent] was nearby but I believe he was wrapped up in another meeting or dealing with another situation. I couldn't even tell you, I don't believe that he was even within ear shot at that point. Looking back at it now… that morning was extremely chaotic for us…the third warning in particular was troublesome… And it was all sort of nebulous because… we felt… the verbiage of the warning was made difficult for us to make some decisions. You know with that third warning, with him not being right there [the superintendent], [the secretary] and I tried to at least guide… one of the buildings that we felt was based on the warning was potentially in the path of the storm… we felt that at that point it's probably best for them to consider pulling the trigger on that [advising them to take shelter]."

- Technology Director from District F

This participant recognizes that in their plan, the superintendent has the role of lead decision maker. However, in this scenario, this director and the secretary were faced with an unanticipated factor when the superintendent became unavailable to make the decision of whether or not to shelter students. He knew that he then had to take on the role of decision maker, yet his lack of weather knowledge made it difficult to interpret the weather information he was receiving about the third warning. He knew he needed to act fast, though, and so by being situationally aware of the location of the students and knowledgeable of his campus in relation to the approaching storm, he was able to make the decision, with the help of his secretary, to advise the building they perceived as being in the highest risk to begin taking shelter (action implemented).

Example 3:

> "Because it was dark, I could tell there was a little storm system, but it wasn't even raining when I left the house. So on the radio I heard coming in that we had a watch. Okay, no big deal. We don't have to put our plan into affect but it means to be on high alert. So I was here maybe 20 minutes when the phone first rang from central office that said they just issued a tornado warning. Okay, so then we got all of our students as they got off the busses, which was the most dangerous thing they did… we put them into the gym because obviously there's no glass, the gym is in the middle of our building. So we did that, the tornado warning was lifted, sent them to class, it went back into affect and then we were in communication with my director and the director's secretary and it was like alright phase 1… of the plan is absolutely in affect."

- Principal from District D

This principal had enough knowledge and experience with tornadoes in the past to be familiar with how a "stormy" sky appears. He states that his plan will only be put into effect when a warning is issued, and no procedures are followed during the watch. The central office was responsible for relaying that a warning has been issued to each individual school. From this weather information, they made the decision to take students off of busses and shelter them in the gym (action). He had situational awareness that busses were not a safe location, while the gym was a safe shelter since it was free of windows.

Figure 10 was designed to show how situationally aware the decision maker was to his or her surroundings played a huge part in determining how he/she responded. The components of this model match those included in the situational awareness model that Endlsey created in 1995 (Endsley 1995; Figure 2). Every event is different as external pressures arise that may unexpectedly change what decision is made. It is therefore important to have a plan that can be modified at a moment's notice to account for these changes. Perry and Lindell (2003) and Tierney (1993) state "that preparedness is a continual process, while preparedness plans are a snapshot in time. They show that plans must be living documents that take into account changes in resources and vulnerability." One participant said, "you can't have a plan that addresses every contingency," implying that changes to the plan have to be made as issues arise; "it has to be sort of that days call based on the time that all this occurs."

Weather Information Preferences

The final section of the interview asked participants about the types of weather information that would help them in their operations and decision making. I asked them to rank four different categories of weather information dissemination types from most to least preferred. The types included probabilistic information, more detailed spatial specificity, a time frame for storm arrival and departure, and a longer lead time. As the participant ranked the categories, they discussed their reasoning behind their final ranking. Asking them to rank their preferences forced them to talk about the advantages and disadvantages of each in comparison with the other types. I found it very useful in pinpointing what they thought was helpful, not helpful, and why. This section is also described collectively, as many of the participants shared similar rationales of weather information preferences.

The two categories that the participants most desired were more spatial specificity and a time frame for storm arrival and departure. Although most mentioned that a longer lead time is helpful, they tended to rank it lower than having more spatial information and a specified time frame. More on participant thoughts on current and extended lead times will be discussed in the next chapter.

Above all else, participants wanted to know if the storm was going to affect their campuses. To school district decision makers, safety of their students is their number one priority, and knowing whether or not their campus will be impacted is the number one preference for these officials in order to determine impacts and give advanced notice to their populations. The technology director from District F said, "…knowing where it will be, even if it doesn't materialize, is probably the single most important." A principal from District D said that he would "absolutely" rather know more specifically where the warning is than have a longer lead time.

Because school districts are so spread out throughout the district and since school officials tend to lack weather training, it becomes difficult for them to know which schools will be affected. Several expressed the need for "more clearly defined boundaries," to allow them to more easily determine which schools in the district are at highest risk. Beyond just being affected, district officials found it nebulous as to which areas were even being warned. A superintendent from District F asked a hypothetical question to his local forecasting office, "What do you mean by [street name]? What do you mean?..." Similarly, the director of safety and security from District B was confused about the wording of what areas were warned:

> " …the National Weather Service issued a tornado warning for… the southern part of our county and not the northern part…now comes the question, are we considered northern, are we considered southern, where are we at?... we've got schools kinda in the middle of the county. So I think… they should define a tornado warning from… [city name] south or from [city name] north, you know use some kind of city."
>
> - Director of Safety and Security from District B

These are just a few of the examples of the participants regarding their confusion to determining which areas were under warnings.

As mentioned above, school district officials sometimes rely on external sources other than NOAA websites and radios to gather information about the storm. Often, these external sources are individuals, either trained meteorologists or weather-interested people, with whom they have created a personal relationship. The assistant superintendent from District E said that his local broadcast meteorologist specifically singled out certain elementary schools that were likely to be hit by the storm. This allowed him to give a heads-up to those students and prevent worry:

> "…[the broadcaster] was actually mentioning our elementary schools that they were hitting…it didn't change the process but so many times when you feel so vulnerable in that situation, knowing that okay heavy rains are coming, so that you could let kids know, especially at the elementary level you know you're gonna start hearing pounding on the roof, heavy rain is coming and you know that's going to happen, as opposed to it just happening and then them getting upset and trying to explain."
>
> - Assistant Superintendent from District E

These personal relationships were useful to school officials by providing localized intensity information that they could not have otherwise obtained from websites and radios.

Even if the warned area was known, several of the participants were not sure if they should activate their severe weather plans for the entire district if only one area of the district/county was under a warning. For example:

> "So one of the questions that I ask, that I ask you, is there a zone from which we should activate, do we activate it in [city name] even though we have schools that are 20 minutes south? Do you activate it for your whole district? Do you activate it for the region? 5-mile radius?"
>
> - Superintendent from District F

Others were simply unsure as what to do:

> "...to get a high level of precision on where those storms are is sometimes really tricky, *and* it does raise the question, well, does the entire district, especially with such a large school district like ours, do we put maybe the northern end of the district into sort of an emergency procedure mode when only the southern end of the district is being impacted?... it became very clear very quickly that this is entirely gray... we don't have an answer for that yet, we're struggling through that."
>
> -Technology Director from District F

Without knowing the "right" answer, some played it safe and made the entire district take shelter, while others singled out certain schools and kept the remaining schools on high alert. School district officials need guidance from their weather forecasting offices when deciding which schools need to take shelter.

Most participants mentioned the importance of having a time frame of storm arrival and departure in addition to more spatial specificity. They want to know *when* their *specific* schools will be impacted. The director of safety and security from District B thought that knowing the time frame would allow the staff to know when to be especially attentive. Similarly, a superintendent from the same school district said that it would help his principals know when to be on highest alert, and when to start lunch:

> "It would help me communicate with the principals exactly when they need to be on the highest alert and whether or not they should start lunch. If we know that we know it's going to hit right at lunch time, maybe they delay lunch. Or maybe they speed up lunch. If that's accurate, maybe we make some adjustments to those time periods in the school where kids are less supervised."
>
> - Superintendent from District B

The majority of participants agreed that spatial specificity and time-specific information go hand in hand, and that both are preferred during severe weather scenarios.

The type of weather information that was least preferred was probabilistic information, which is interesting since WoF is based off of probabilities. Many participants found that probabilities did not provide that much information about the storm, since people "hear that [probabilities] so often for everything…" The superintendent from District B said, "that's not very helpful to me, because I don't care if there is a 10% chance." Participants much rather preferred deterministic information, meaning they wanted to know whether or not the storm will come. For example, the superintendent from District F candidly stated, "…either tell me it's gonna come or not. It's nice to know we have a higher percentage but I'm going to put everyone on alert that there's a 60%, but I really need to know whether I need to evacuate students in other spaces."

With that said, a benefit of probabilities is that it calls attention to potential storm activity in the near future. The director of transportation services from District D said, "I mean I think probability is something that you might get in advance, much more than an hour in advance, or maybe a day in advance or something. And it's important to give us an alert that that situation could occur." Similarly, the assistant superintendent from District E agreed that it gives an alert, however, adds that trusting a certain percentage is tricky and there are added complexities that may lead to more problems:

> "That I would see as just a heightened awareness. That would have been beneficial had the preceding days, events, not occurred, so it didn't catch us by surprise. But saying there is 60%, that's kind of like here when we hear 60% chance of snow, or even when we hear 100% chance of snow, and then call school delays the night before and have nothing the next morning and take all the heat for canceling school."
>
> - Assistant Superintendent from District E

Participants in this study overall felt that probabilities were of lesser value to spatial and temporal information.

Some other weather preferences mentioned by specific participants include a desire for text alerts and verification that storm spotters have seen a tornado. Also, visuals, such as a localized map of the area with the storm path, would be helpful. As mentioned earlier, broadcasters that mentioned a specific school is helpful in making the school officials take notice. Lastly, for those under several warnings, they would prefer one long warning rather than several warnings with five minutes in between; transporting students back and forth between shelters and classrooms is time consuming, and becomes chaotic with such a short time period between warnings.

Thoughts of Current and Extended Lead Times

When participants were asked what they thought of the current average tornado warning lead time of about 13 minutes, most said that it 'gives [them] plenty," or "ample time" to take shelter. Most felt comfortable to put their plan into effect in that time period, noting, "everything can happen between that period of time…" Some did mention that 13 minutes is adequate for sheltering students who are in classrooms, but that a 13-minute warning during transition periods would be more difficult. However, most participants also did mention, “the more time the better.”

This sentiment quickly changed once I introduced the idea of WoF and its associated extended lead times. Initial feelings were those of amazement, confusion, and doubt. The technology director from District F shouted, “Really? One to two hours? Seriously?” Another participant was hesitant, as he “would have to see how accurate this technology is…,” and others deemed it “impossible.” Once I briefly explained the new system and its future possibilities, and as they began to give this new reality more thought, their initial response of more lead time as being beneficial changed to include some negative implications that would accompany longer warning times.

“…Sometimes, too much information can almost be problematic.” This was a common response among participants. They brought up several negative points associated with longer lead times. These are responses based on hypothetical questions, and may not prove to be true in an actual case of a longer tornado warning lead time. First, many would anticipate a substantial increase in the number of parents coming to pick up their children, and in the number of parent phone calls to offices. Assisting individuals via the telephone is respected among the staff, but my participants did not view attending to hundreds of parents in a small time span as realistic.

Second, some participants were concerned that students taking shelter for that long a period would result in loss of class/instructional time:

> “It may be a little bit of a distraction to the learning environment if everybody knows that we’re on high alert ahead of time. You want those kids to be focused on their school work, unless we know something’s going to happen or at least there’s a likelihood of it. So it might be a little bit of an issue to keep kids on task.”
>
> \- Superintendent from District B

Similarly, a few officials thought that it would be difficult to keep students, especially the younger students, busy for that length of time. The superintendent from District A mentioned,"…taking cover for two hours is really not feasible," while the technology director from District F said he "would not want to have small children in sort of like a protective position for an hour…"

Third, several participants expressed concern that increased lead time would lead to less accuracy in the warned area and an increase in false alarms. A few mentioned that false alarms tend to make people pay less attention to the warnings. The superintendent from District A said, "I recognize that there is a balancing act because greater lead time will also probably lend itself to inaccuracy, and too many false warnings we know result in people not paying attention to all of the warnings, the legitimacy of warnings." Another participant also shared his concern with false alarms, saying, "and that would be my fear if we did it too much earlier is you may get some non-complacents, or people that are not listening, not taking it serious."

Fourth, many of these officials thought that such an extended warning lead time reduced the urgency of the situation, and "wouldn't be as much of a crisis mode as it would be you know just an emergency." Several school officials admitted that they would not take action until well into the warning. In fact, the director of safety and security from District B said if "...they're issuing a warning an hour in advance, we got 20 to 30 minutes before we need to really take this serious. Where now, as soon as a warning is issued, they know it's imminent... we need to take it serious." The superintendent from District C shared similar feelings when she said, "...if we had an hour warning, we wouldn't immediately go into position at the beginning of that hour.

Yeah we would probably start moving to position maybe a half an hour or twenty minutes... [We would] review the plans [for the first half an hour]."

This is no different than officials taking immediate action with the *current* 20-minute lead times; nothing has changed except for having extra time before taking shelter. An assistant superintendent questioned whether or not he should take shelter right away or wait and monitor the sky. Additionally, most believed that extending the amount of warning time would not actually change the actions they would take during the warning. The director of safety and security from District B alluded to an extended warning being similar to a watch, giving them a heads up that severe weather is approaching. Other than acting as a "pre-warning," this director feels that an hour lead time serves little purpose.

Although participants voiced several concerns regarding longer lead times, they also mentioned significant benefits. The superintendent from District C said, "the more time we can get, the more confidence I have that we can get everybody where they need to be." Another major benefit is having more time to make decisions. A technology director states that they need the time for the decision making component of the warning process, not for the actual physical act of sheltering students:

> "I think the decision making part *and* communication pieces are where we need the time. Actually implementing the plan, our buildings are quick, I mean, they're very quick. I think it's the decision *and* the decision making process getting as much lead as possible *and* then time to disseminate those decisions is where it would be beneficial."
>
> - Technology Director from District F

He later adds that it “... would give us time to digest, to begin to look at questions, to begin to say, ‘okay do we have all the facts right now?’ It would give us a lot of decision making power... It would give us the ability to better respond.”

The majority of participants also mentioned that longer lead time would give them more time to review plans with staff and faculty to ensure that everyone was fully prepared and knew what to do. A principal from District D said, "it would give us more time to… have everybody pull out their plan and review it, and be completely clear on what to do, and know where the risk spots are..." Ideally, this should be taken care of long before the warning is even issued during plan preparation as a part of faculty meetings. More time would also allow for the superintendents, or those in charge, to more thoroughly relay information to other employees and schools and provide more specific instructions:

> "If we had an hour to two hour lead time, I could have discussed it with the assistant superintendent, the elementary coordinator, *and* we could've been much *more* focused in issuing *more* clear directions to buildings. We found out when it was issued, so we were almost in a reactive mode rather than a proactive mode."
>
> \- Superintendent from District F

> "I don't think it would've changed what we did, but it would give us *more* time to communicate *and* to do it *more* effectively, *and* to be able to provide *more* explanation to people what was going on. It would've been nice, it would give us *more* time to quickly meet as the staff *and* decide what we were going to do. We didn't have a lot of planning time, we were kind of reacting. So, if we had a little bit *more* time, we would've been able to coordinate our efforts I think a little bit better."
>
> \- Communication and Public Relations Officer from District D

Many participants felt that they were forced to react to the warning information without fully assessing the situation; more time would thus provide the time to proactively decide what is best with more confidence.

Another benefit of longer lead times is having extra time to consider delaying or canceling school, afternoon activities, assemblies, and/or sporting events; to “re-factor [the] entire afternoon schedule.”

> "...the longer lead time helps us know whether or not we should send kids home at the end of the day, or... it would be very helpful during sporting events, field trips, things that are outside of the school building, making a decision whether or not to have those events. That's when kids are most vulnerable, when they're not in the building..."
>
> - Superintendent from District B

> “Well given that the first warning was issued at 7:15, if we had notification two hours earlier at 5:15, we would have an opportunity to delay or close schools for that day. The more advanced notice we have the more ability we have to react and do what’s in our estimation the safest thing for kids, which is what we’re all about.”
>
> - Director of Transportation Services from District D

More thought could be placed on weighing the pros and cons of delaying, canceling, or canceling school or events. Current lead times do not provide sufficient time to plan for later in the day.

The participants shared their thoughts on increased lead time, providing several reasons for why it may, or may not, be valuable. Above all else, all the participants recognized that the implementation of WoF will force them to modify existing plans and change their current system. There is much uncertainty among this group of decision makers as to what an increased lead time will entail. The assistant superintendent from District E cautiously stated, “yeah that would drastically change what we do... We'd really have to think through that one, and it would certainly change the way we prepare for this. ” Several participants expressed the need for guidance from meteorologists on how to successfully shape their current plans to adjust to increased time:

> "… we'd certainly have to think through that *and* look to the weather folks *and* the emergency management response people on what the recommendation would be for districts if we had that lead time, how to effectively use that lead time."
>
> - Assistant Superintendent from District E

Relation to Other Research

Several other studies found similar results regarding how longer lead times would impact certain populations. Call and Coleman conducted a winter weather study of school officials and found that closing school due to weather disrupted learning and decreased test scores due to less instructional time (Call and Coleman 2012, *forthcoming*). Additionally, Nichols (2012) and League et al. (2012), who conducted studies of university emergency managers and state emergency managers, respectively, found that too much lead time makes the situation “lose the emergency status.” The results from these studies can help shift the mindset of weather tool developers from thinking of tornado warning lead times as only a 13-minute window to a weather information continuum that spans several hours.

CHAPTER 6: CONCLUSIONS

This thesis showed how K-12 school district decision makers made weather sensitive decisions during several Spring 2011 tornado warnings. There were numerous similarities in how they prepared for the severe weather and preparations were taken long before the warning was issued. The majority of the participants were aware of the approaching severe weather. Non-weather factors, such as time of day and location of students, influenced how they perceived the event, but it rarely changed what they actually did. If a warning was issued, participants followed their severe weather plan and sheltered students and staff. Unlike the Mileti response model, responses in this case were stimulus-driven and environmental cues that mattered in several other studies did not influence the decision of whether or not to shelter students.

Participants expressed an interest in having more localized information to know which schools within the district will be impacted. Thoughts on extended tornado warning lead times were mixed: some thought too much time would make the situation seem less imminent and dangerous, while others felt that extended lead time would also allow more time review plans and communicate with others in the district. Knowing the potential effects of extended lead time and influence of external factors on decision making for school district decision makers provide evidence of how these specific school officials use weather information to make decisions during tornado warnings in the context of their specific complexities and circumstances. User needs vary and a "one size fits all" approach will be ineffective.

This project is part of a new body of research that is trying to change the equation from a top down research-to-operations process to a more grass roots, operations-to-research process. Figure 11 is a graphic that was developed by SSWIM researchers that shows the collaboration between different stakeholders. All groups should work together throughout the process in iterative ways. Meteorologists and software developers should not create new technologies solely because the science and technology allows the advancements. Instead, new advancements should *respond* to expressed needs of the publics, for whom the products are initially intended.

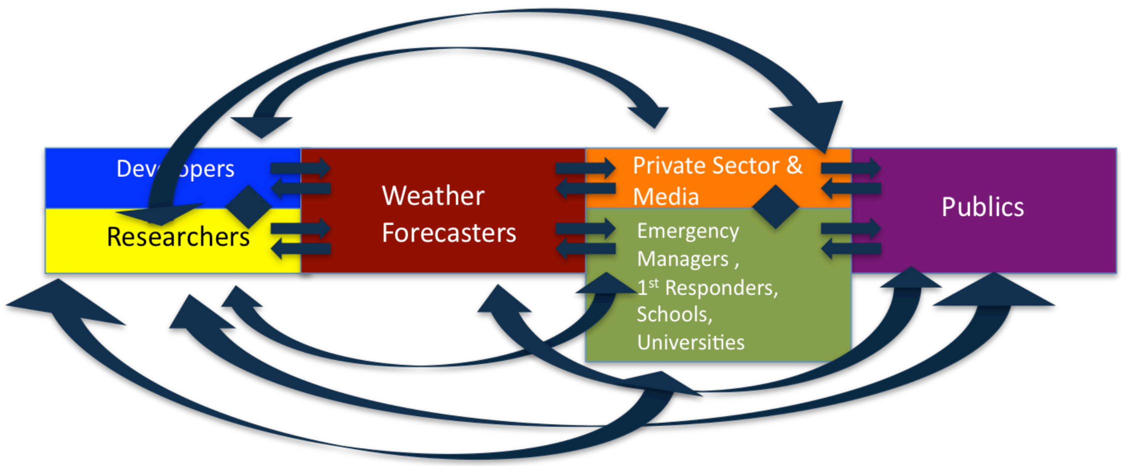

Figure 11: SSWIM-developed graphic of stakeholder collaboration and communication.

CHAPTER 7: RECOMMENDATIONS FOR FUTURE RESEARCH

There are several topics that future researchers conducting studies on K-12 school district decision maker behavior could consider. They include:

1) Including a "pre-survey" that participants filled out in order to find out ho*w much* they knew about their local geography and NWS products *before* the interview. Such a survey would also have given me a more thorough idea of their past experience in their job and with tornadoes.
2) Focusing on school officials in one region. This would allow more direct comparisons of how experience influenced actions could have been made.
3) Expanding the project to go beyond just tornadoes to include how school officials use weather information to support their decisions for all types of hazardous weather events.
4) Focusing on one school district and all types of weather. This would allow the researcher to see how consistent the participants are in their actions through a variety of conditions and sets of warnings. A future study on school district officials should include a metric for considering if/how false alarms affect decisions and actions.
5) Using sample warning days that are not right after a recent tornado outbreak.
6) Interviewing more participants. The results from this study serve as hypotheses that future researchers can test for comparison.
7) Using Google Earth, it was clear that in some cases not all the schools within the district were under a tornado warning (see Figure 12 for an example). Participants in this study were not sure if they should make all the schools

take shelter even if certain ones were not under a warning. Future research should ask the question: Would improved warning specificity make it easier for them to make only the schools under the warning take shelter?

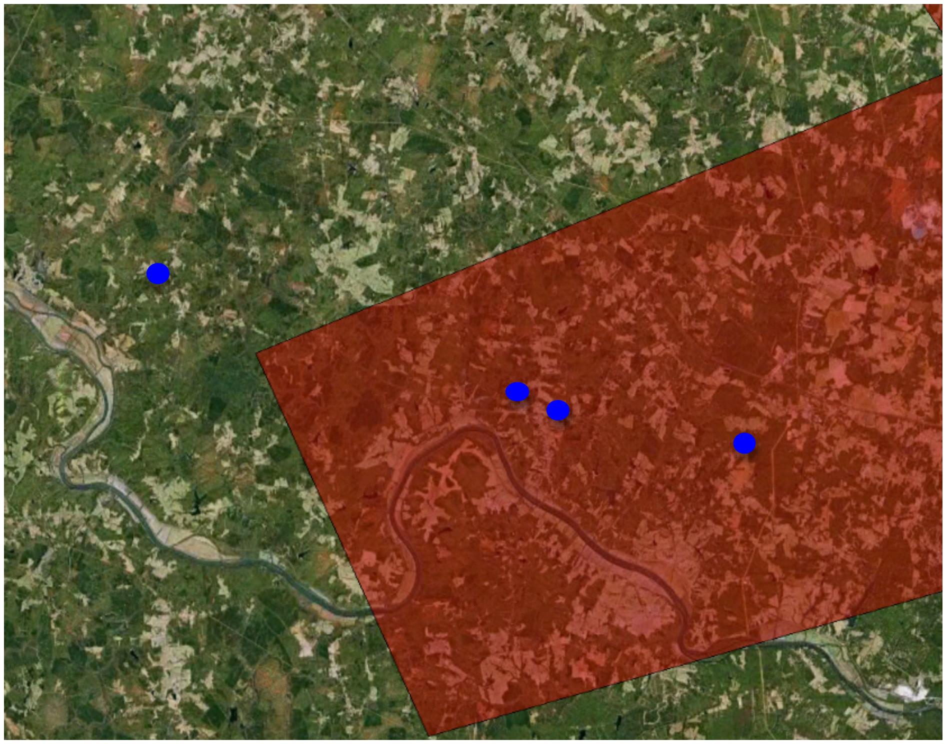

Figure 12: District C under a tornado warning on April 28th, 2011. The blue dots indicate the *approximate* locations of schools in this district. Note that one school was not under the tornado warning. This participant made students in all schools take shelter, regardless of whether or not they were under a warning.

8) Exploring the degree to which the different types of "shelters" used by the participants reduced their student and staff vulnerability.

9) Observing the participants in person when the districts were under warnings. This would add depth that is not possible through the telephone post event interviews. For example, for the participants who thought the situation was chaotic, being on site would have allowed me to witness how that mindset translated to real-life behaviors.

10) Obtaining more detailed spatial and temporal information of the situation would have been ideal, once again emphasizing the benefits of being on site. A gap in the study is that I did not know what the weather was like during these warnings since it played little part in the decision making of the participants. Future research should include an anatomy of a close-up view of a storm, the warning, and a district to further explore all the components.

Here is a list of other more general suggestions for future researchers doing projects that focus on decision making of certain groups during severe weather:

1) What people say they would do and what they actually do usually are different. An advantage of this study is that I asked administrators what they *did*, and not what they said they *would do*. This is part of a new trend in social science of moving away from perceptions research to studying actual behaviors and the motivations behind them.
2) Using qualitative interviews. I obtained rich detailed information from my participants and I recommend that future studies also rely on qualitative interviews. Using quotes provided the perspective of the participants using their own words.
3) Taking a step back to consider big picture topics: how do the public and different stakeholders perceive a warning? How do people define a warning? Future research should assess what a warning *means* to people. What do people actually do during a tornado warning and before a tornado warning is issued? This study shows that a warning is closely associated with imminence and immediacy. What do you call the information that

scientifically may be available by 2020 that indicates that a tornado may happen 2 hours from now? According to my participants it would not be a warning using the 2012 definition. The following quote showcases that the superintendent from District C clearly did not think of an hour “warning” *as a*n actual warning: " Now if we had an hour, and *knew we were going to have a warning,* we would be able to make sure that everybody was off the road if anyone was on the road... it wouldn't be as much of a crisis mode as it would be you know just an emergency." This superintendent implied that the greater than one hour lead time would provide would not be her warning. Rather, she expects the warning to come later when the situation becomes more imminent, which is when a warning should be given. Another participant, the director of safety and security from District B, also alluded to the disconnect between warnings and lead time: “I don’t think a warning needs to be issued until it’s imminent.”

4) Reevaluating the meaning of lead time. Lead time is defined differently according to the user group and is not the same as the NWS definition. Taking protective action is not confined to the space of the lead time as defined by the NWS, but decision *making, preparatio*ns to take action, and some actual actions, are taken before the warning is issued. The warning tends to act as a trigger to begin the sheltering process. Much preparation is taken well in advance of the warning, which in the minds of school administrators constitutes tornado warning lead time. Research should investigate what people are doing with the time that they have now, looking beyond just the warning and re-conceptualize the idea of lead time to take into account all the actions that are taking place to prepare for the event across the entire spectrum of time. This study shows that some stakeholders do see time along a continuum where the warning is only one short component.

CHAPTER 8: RECOMMENDATIONS FOR THE WARN ON FORECAST PROJECT SCIENTISTS AND ENGINEERS

Now is the time to bring in the perspective of stakeholders while WoF is in the early stages of development. It is important to find the ways that WoF can accommodate these findings to make its research most useful to weather sensitive decision makers. WoF should be developed in a useful and meaningful way and not just focused on technological advancements. WoF must ensure that social science remains an integral component as WoF progresses. The integration of the customer's perspectives and opinions is integral to creating systems with the most potential to save lives and property and meet the original mission of the NWS. The development of WoF products that extend lead time for storm warnings is underway. One goal of my thesis is to show WoF how certain stakeholders understand warnings in order to inform the WoF research process.

The following are recommendations to WoF:

1) Future research should clarify how WoF fits into the current continuum of weather information along temporal and spatial scales. How will it fit in with current outlooks and watches?
2) WoF developers need to continue to work closely with varying stakeholders to understand their weather information needs. They need to listen to stakeholders. These collaborations need to be at the forefront of WoF research.
3) New terminology is required. As I briefly discussed in the future research section, we are unsure as to how stakeholders and the public perceive the term warning. Preliminary observations are that a "warning" is closely affiliated with

imminence and immediate danger. A two-hour lead time may not register the same feelings of dread and concern as the current 15 minute lead times. I therefore suggest that a new name be created as WoF evolves and develops. A possible interpretation of the product might be more similar to an enhanced watch than a warning.

References

Aguirre, B.E., 2000: Social science and severe weather warnings. *Storms*, R. Pielke Jr. and R. Pielke Sr., Eds., Routledge, 98-108.

Baumgart, L.A., E.J. Bass, B. Philips, and K. Kloesel, 2008: Emergency management decision making during severe weather. *Weather and Forecasting*, **23**, 1268-1279.

Burling, W. K., and A.E. Hyle, 1997: Disaster preparedness planning: Policy and leadership issues. *Disaster Prevention and Management*, **6**(4), 234–244.

Burton, I., R.W. Kates, and G.F. White, 1993: *The environment as hazard.* New York, NY: The Guilford Press.

Bussum, L.V., 1999: A composite look at weather surveys: Using several weather surveys to get an estimate of public opinion. *Western Region Technical Attachment*, No. 99-20.

Call, D.A., and J.S.M. Coleman, 2012: The decision process behind inclement-weather school closings: A case-study in Maryland. *Forthcoming.*

Carsell, K.M., N.D. Pingel, and D.T. Ford, 2004: Quantifying the benefit of a flood warning system. *Natural Hazards Review,* **5**(3), 131-140.

Combs, B., and P. Slovic. 1979: Causes of death: biased newspaper coverage and biased judgments. *Journalism Quarterly*, **56**, 837-843.

Dawson, G., 1993: A comparison of research and practice: A practitioner's view. *International Journal of Mass Emergencies and Disasters*, **11**(1), 55-62.

Doswell, C.A., A.R. Moller, and H.E. Brooks, 1998: Storm spotting and public awareness since the first tornado forecasts of 1948. *Weather and Forecasting,* **14,** 544-557.

Endsley, M.R., 1995: Toward a theory of situation awareness in dynamic systems. *Human Factors*, **37**(1), 32-64.

Ewald, R., and G. L. Guyer, 2002: The ideal lead time for *tornado* warnings- A look from the customer's perspective. *Proc. 21st Conf. Severe Local Storms*, San Antonio TX, American Meteorological Society.

Golden, J. H., and C. R. Adams, 2000: Tornado problem: Forecast, warning, and response. *Natural Hazards Review*, **1**(2), 107-118.

Hammer, B., and T.W. Schmidlin, 2002: Response to warnings during the 3 May 1999 Oklahoma City tornado: Reasons and relative injury rates. *Weather and Forecasting*, **17**(3), 577-581.

Harris Poll, 2007: February 28, 2010. The Harris Poll #118. Local television news is the place for weather forecasts for a plurality of Americas. Retrieved from www.harrisinteractive.com/harris_poll/index.asp?PID=839.

Hayden, M.H., S. Drobot, S. Radil, C. Benight, E.C. Gruntfest, and L.R. Barnes, 2007: Information sources for flash flood warnings in Denver, CO and Austin, TX. *Environmental Hazards*, **7**, 211-219.

Heller, K., D.B. Alexander, M. Gatz, B.G. Knight, and T. Rose, 2005: Social and personal factors as predictors of earthquake preparation: The role of support provision, network discussion, negative affect, age, and education. *Journal of Applied Social Psychology*, **35**(2), 399–422.

Hoekstra, S., K. Klockow, R. Butterworth, J. Brotzge, H. Brooks, and S. Erickson, 2011: A preliminary look at the social perspective of warn-on-forecast: Ideal tornado warning lead-time and the general public's perceptions of weather risks. *Weather, Climate, and Society,* **3**(2), 128-140.

Hull, B., 2010: Changing realities in school preparedness using the all hazards approach. *Proc. International Association of Emergency Managers Annual Conference*. San Antonio, TX.

Lazo, J.K., R.E. Morss, and J.L. Demuth, 2009: 300 billion served: sources, perceptions, uses, and values of weather forecasts. *Bulletin of the American Meteorological Society*, **90**(6), 785-798.

Kahneman, D., and A. Tversky, 1979: Prospect theory: an analysis of decision under risk. *Econometrica*, **47**(2), 263-291.

Kano, M., and L.B. Bourque, 2008: Correlates of school disaster preparedness: Main effects of funding and coordinator role. *Natural Hazards Review*, **9**(1), 49-59.

Krenz, S. H. and J. S. Evans, 1993: Weather terms used in National Weather Service forecasts – Does the public understand these terms? A user's survey. Central Region Highlights. DOC, NOAA, NWS Central Region Headquarters, Kansas City, MO.

Kunreuther, H., R. Ginsberg, L. Miller, P. Sagi, P. Slovic, B. Borkan, and N. Katz, 1978: *Disaster insurance protection: Public policy lessons.* John Wiley.

League, C.E., D. Walter, B. Phillips, E.J. Bass, K. Kloesel, E. Gruntfest, and A. Gessner, 2010: Emergency manager decision-making and tornado warning communication. *Meteorological Applications*, **17**, 163-172.

League, C.E., Phillips, B., Bass, E.J., and Diaz, W., 2012: Tornado warning communication and emergency manager decision-making. *Proc. 92nd American Meteorological Society Annual Meeting,* New Orleans, LA.

Legates, D.R. and M.D. Biddle, 1999: Warning response and risk behavior in the oak grove- Birmingham, Alabama, tornado of 08 April 1998. Quick Response #116. *Natural Hazards Research Applications and Information Center*. Boulder, Colorado.

Lindell, M.K. and R.W. Perry, 2004: *Communicating environmental risk in multiethnic communities.* Sage Publications, Thousand Oaks, California, 246 pp.

Lindell, M.K., and R.W. Perry, 2011: The Protective Action Decision Model: Theoretical modifications and additional evidence. *Risk Analysis*, doi: 10.1111/j.1539-6924.2011.01647.x.

Longhurst, R., 2010: Geography and the Social Science Tradition. *Key Methods in Geography*. N.J. Clifford, S. French, and G. Valentine, Eds., London: Sage Publications, 103-115.

Mileti, D.S., and J.H. Sorenson, 1990: Communication of emergency public warnings: A social science perspective and state-of-the-art assessment. *Oakridge National Laboratory,* U.S. Department of Energy.

Montz, B.E., J.L. Losego, C. Smith, K. Galluppi, and K. Mulder, 2011: Schools and Winter Weather: Communication Needs and Networks in North Carolina. *Proc. Weather Warnings and Communication Conference*, Oklahoma City, OK.

Mulilis, J.P., T.S. Duval, and R. Rogers, 2003: The effect of a swarm of local tornados on tornado preparedness: A quasi-comparable cohort investigation. *Journal of Applied Social Psychology*, **33(**8**)**, 1716–1725.

National Weather Service, cited 2008: Why storm-based warnings. Retrieved from www.weather.gov/sbwarnings. Accessed 11 November 2011.

National Weather Service, National Oceanic and Atmospheric Administration, 2012. United States Department of Commerce. Retrieved from http://www.weather.gov/.

Neal, D.M., 1997: Reconsidering the phases of disaster. *International Journal of Mass Emergencies and Disasters*, *15*(2), 239-264.

Nichols, A.C., and S. Hoekstra, 2012: How space and time influence the decision making of K-12 school and university officials during tornado warnings. *Proc. Annual Meeting of the Association of American Geographers*, New York, NY.

Nichols, A.C., 2012: How university administrators made decisions during National Weather Service Tornado Warnings in the Spring of 2011. Thesis, Department of Geography and Environmental Sustainability, University of Oklahoma, 102 pgs.

Norris, F.H., T. Smith, and K. Kaniasty, 1999: Revisiting the experience-behavior hypothesis: The effects of Hurricane Hugo on hazard preparedness and other self-protective acts. *Basic and Applied Social Psychology*, **21(**1), 37–47.

Pingel, N., C. Jones, and D. Ford, 2005: Estimating forecast lead time. *Natural Hazards Review,* **6**(2), 60-66.

Rodríguez, H., W. Diaz, J.M. Santos, and B.E. Aguirre, 2007: Communicating risk and uncertainty: Science, technology, and disasters at the crossroads. *Handbook of Disaster Research,* H. Rodríguez, E. L. Quarantelli, and R. R. Dynes, Eds., Springer, 476-488.

Sattler, D.N., C.F. Kaiser, and J.B. Hittner, 2000: Disaster preparedness: Relationships among prior experience, personal characteristics, and distress. *Journal of Applied Social Psychology*, **30(**7), 1396–1420.

Saviers, A.M. and L.J. Van Bussum, 1997: Juneau public questionnaire: Results, analyses and conclusions. NOAA Technical Memorandum, NWS AR–44.

Schultz, D.M., E.C. Gruntfest, M.H. Hayden, C.C Benight, S. Drobot, and L.R. Barnes, 2010: Decision making by Austin, Texas, residents in hypothetical tornado scenarios. *American Meteorological Society,* **2,** 249-254.

Schumacher, R.S., D.T. Lindsey, A.B. Schumacher, J. Braun, S.D. Miller, and J.L. Demuth, 2010: Multidisciplinary analysis of an unusual tornado: meteorology, climatology, and the communication and interpretation of warnings. *Weather and Forecasting*, **25**, 1412-1429.

Siegel, J.M., K.I. Shoaf, A.A. Afifi, and L.B. Bourque, 2003: Surviving two disasters: Does reaction to the first predict response to the second? *Environmental Behavior,* **35(**5), 637–654.

Sink, S.A., 1995: Determining the public's understanding of precipitation forecasts; Results of a survey. *National Weather Digest*, **19**(3), 9-15.

Simmons, K.M. and D. Sutter, 2007: Tornado warnings, lead times, and tornado casualties: An empirical investigation. *Weather and Forecasting*, **23**, 246-258.

Simon, H., 1957: *Administrative behavior.* Macmillan. 259 pp.

Slovic, P., 1987: Perception of Risk. *Science*, **236**, 280-285.

Slovic, P., B. Fischhoff, and S. Lichtenstein, 1979: Rating the risks. *Environment*, **21**(3), 14-20.

Slovic, P., H. Kunreuther, and G. White, 1974: Decision processes, rationality and adjustments to natural hazards. *Natural Hazards*, G.F. White, Ed., Oxford University Press, 80-86.

Snyder, T.D., and S.A. Dillow, 2010: Digest of Education Statistics 2009 (NCES 2010-013). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Sofaer, S., 1999: Qualitative methods: what are they and why use them? *Health Services Research,* **34**(5), 1001-1118.

Sorensen, J.H., 1991: When shall we leave? Factors affecting the timing of evacuation departures. *International Journal of Mass Emergencies and Disasters,* **9**(2), 153 165.

Spinney, J., and E. Gruntfest, 2012: *What makes our partners tick? Using ethnography to inform the Global System Division's development of the Integrated Hazards Information Services (IHIS)* Report prepared for NOAA Integrated Hazards Information Systems Project.

Stensrud, D.J., M. Xue, L.J. Wicker, K.E. Kelleher, M.P. Foster, J.T. Schaefer, and J.P. Tuell, 2009: Convective scale WoF system: A visions for 2020. *Bulletin of the American Meteorological Society,* **90**(10), 1487-1499.

Sutter, D., and S. Erickson, 2010: The time cost of tornado warnings and the savings with storm-based warnings. *Weather, Climate and Society*, **2**(2), 103–112.

Stumpf, G.J., T.M. Smith, K.L. Manross, and D.L. Andra Jr., 2008: The Experimental Warning Program 2008 Spring Experiment at the NOAA Hazardous Weather Testbed. *Proc. 24th Conference on Severe Local Storms,* Savannah, GA, American Meteorological Society. 8A.1.

Tobin, G.A., and B.E. Montz, 1997: *Natural Hazards: Explanation and integration.* The Guilford Press, 388 pp.

Tversky, A., and D. Kahneman, 1981: The framing of decisions and the psychology of choice. *Science*, **211**, 453-458.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration National Weather Service, 2007: *Storm based warnings team report.* Silver Spring, Maryland. Retrieved from http://www.weather.gov/sbwarnings/docs/Polygon_Report_Final.pdf. Accessed 2 February 2012.

U.S. Department of Education, 2012: Retrieved from www.ed.gov. Accessed 1 April 2012.

Waters, K.R., 2004: Polygon weather warnings- a new approach for the national weather service. *National Weather Service.* P14.1.

Appendix A: Acronyms

Name	Acronym
Integrated Warning System	IWS
Iowa Environmental Mesonet	IEM
National Incident Management System	NIMS
National Oceanic and Atmospheric Administration	NOAA
National Severe Storms Laboratory	NSSL
National Weather Service	NWS
Protective Action Decision Model	PADM
Social Science Woven Into Meteorology	SSWIM
Storm Prediction Center	SPC
Weather Forecast Office	WFO
Warn-on-Forecast	WoF

Appendix B: Interview Script

Interview Debrief

Hello! My name is Stephanie Hoekstra. Thank you so much for agreeing to participate in this study. I really appreciate it.

As I explained to you in the email, the purpose of this study is to learn more about how schools (K-12) use weather information to make decisions during severe weather warnings, as well as to understand what information you would like as a school decision-maker. I am asking for your involvement in particular because you had some part in the decision making process during this past tornado warning on XX Month. I anticipate this interview lasting about one hour.

Great, we can now start the interview. *[Start recording and conduct interview]*.

Interview Questions

Planning

1. What position do you hold at your school?
    a. How long have you held this position?
2. Does your school conduct tornado drills?
    a. If yes, how often?
3. Does your school have a severe weather plan? *If yes, can I have a copy of it?*
    a. Does your school have a separate *tornado* plan?
    b. Who is responsible for activating the plan?
        i. Is there a back-up person to activate the plan?
    c. What is your role in the tornado plan? What responsibilities do you have?
4. Who is in charge of monitoring the weather at your school?
    a. Who, if anyone, usually pays attention to severe weather that may happen days ahead of time?
    b. Who keeps an eye on developing situations on the severe weather day?
    c. How long have they been doing this job?
    d. Have they undergone severe weather spotter training?

Onset of Tornado Warning – Situational Awareness

Think about the event on XX Month, 2011…

5. How did you learn that there was a tornado warning for this area?
6. What sources did you use to get that weather information – how and who? (National Weather Service, TV, NOAA weather radio, Emergency Manager, phone call, etc.)
    a. *[If uses the National Weather Service]* What level of trust do you have in the NWS to provide you with useful and accurate information?

   b. *[If uses a specific person within the NWS]* When did you start using the assistance of a NWS employee for obtaining weather information and making decisions? Did he/she approach you or did you ask the NWS for the extra assistance? Do you find him/her helpful? Do you pay for this service?
   c. *[If uses an emergency manager]* Since when have you used an emergency manager to help you obtain information and make decisions? Do you trust what the EM says? Do you find him/her helpful?
   d. *[If Other]* Who?
7. Approximately what time did you learn of the warning?
8. Where were you and what were you doing at that time?
9. On the day of the warning, were there any circumstances that hindered your ability to get the weather information you needed related to the eventual tornado warning?
   a. What was the situation? For example, were you outside/in a staff meeting/in the cafeteria/in class?
   b. Did this influence what actions you took?
   c. Did it delay the implementation of any action plans?
10. After learning that the school was under a warning, what thoughts went through your head? What were your priorities?

Actions Taken During Duration of Warning

11. Once you knew your school was under a tornado warning, what did you do? Walk me through the minute-to-minute steps that you took. *Do you mind if I create a timeline when you describe what you did?*

12. Who made the decisions during the warning? Is it just one person or did multiple people make the decision?

   a. *[If one person]* How long has this person been making the decisions? Is this job listed in their job description?

   b. *[If more than one person]* What is the chain of responsibility within the school and school district?

13. How did this information get relayed to all faculty/staff/students*?*

14. What is your relationship with the students' parents during a tornado warning?

   a. Did you notice a difference in the number of phone calls/ parents driving to school? If so, what did/do you do to manage that?

15. Were there any extracurricular or sport activities going on at the time of the warning?
   a. How did you notify those who were outside that there was a warning?
   b. What is the protocol during such a situation?
   c. Did you follow the protocol during this past warning?

History with Tornado Warnings

16. Have you had previous experience with tornadoes or tornadoes warnings? If so, what were they?

Preferences/Lessons Learned

17. Did the weather information you received help you to execute your school's plan for what to do in this past tornado warning? If yes, how so?
18. Was there any information you obtained that was particularly useful? If so, what and why?
19. Do you feel that the information you received about the tornado was clear?
    a. Was there information that could have been communicated more clearly? How so?
20. Was there anything about the information that you received that made you feel particularly alarmed?
21. What are your thoughts on the current tornado lead-time (or warning time) of about 13 minutes? Do you feel like that is adequate time for taking appropriate action?

[Currently, a possible new method of predicting tornadoes is being researched. With this new method, tornadoes may have an extended lead-time, or warning time, of between one and two hours. One objective of my study is to assess how a longer lead-time would impact schools.]

22. Would a longer lead-time change what you did during this past warning? If so, what would you have done differently? How would the time line we created earlier change?
    a. *[If yes]* Do you feel like you would use the extra time efficiently, or would it be more of a hindrance?
23. If given, say, a one-hour warning, would you anticipate any of the following?
    a. Keeping students busy for that length of time being an issue?
    b. Loss of class time being a concern?
    c. More parent phone calls (automated phone outs)?
    d. More parents coming to school to take their students home?
        a. Could you imagine orchestrating mass pick-ups of students?
24. I will now provide you with several examples of specific weather information. On a scale from 1 to 5, how would you rank the following options as being beneficial, according to your personal preferences (with 1 being least beneficial and 5 being most beneficial)?
    i. Probabilistic information
        Example: You hear that there is a 60% chance a tornado could come through the area where your school is located.
    ii. Spatial information
        Example: You are provided with a map of the anticipated storm path.
    iii. A defined time frame for storm arrival
        Example: You are provided with a specific time when the storm will start and end in your area.

iv. A longer lead-time

Example: You now know one hour ahead of time that tornadoes may be imminent in the area where your school is located.

25. In an ideal situation, what weather information would you want?

Looking Ahead

26. As a result of this tornado warning, is there anything that you are planning to change or would like to change in the future about your school's plan during a future tornado warning?
    a. If yes, do you feel like there will be any barriers to implementing these changes?
27. Is there anyone that you think played a role in this past warning that you would suggest I interview?
28. Do you have any further comments about your experience that you would like to share?

[Stop recorder]. That concludes the interview. Thank you so much again for participating! If you have any more questions about anything, please don't hesitate to get in contact with me.

Appendix C: Institutional Review Board (IRB) Acceptance Letter

The University of Oklahoma®

OFFICE OF HUMAN RESEARCH PARTICIPANT PROTECTION - IRB

IRB Number: **13412**
Approval Date: **April 12, 2011**

April 12, 2011

Stephanie Hoekstra
Geography
120 David L. boren Blvd Ste. 2100
Norman, OK 73072

RE: Weather Information Use, Preferences, and Decision Making of K-12 Public Schools during Tornado Warnings

Dear Ms. Hoekstra:

On behalf of the Institutional Review Board (IRB), I have reviewed and granted expedited approval of the above-referenced research study. This study meets the criteria for expedited approval category 6, 7. It is my judgment as Chairperson of the IRB that the rights and welfare of individuals who may be asked to participate in this study will be respected; that the proposed research, including the process of obtaining informed consent, will be conducted in a manner consistent with the requirements of 45 CFR 46 as amended; and that the research involves no more than minimal risk to participants.

This letter documents approval to conduct the research as described:

Consent form - Subject Dated: March 24, 2011
Other Dated: March 24, 2011 Proposal
Other Dated: March 24, 2011 Recruitment email to candidates
Other Dated: March 24, 2011 Recruitment email to Admin/Principals
Survey Instrument Dated: March 24, 2011 Interview questions/debrief
Protocol Dated: March 24, 2011
IRB Application Dated: March 24, 2011

As principal investigator of this protocol, it is your responsibility to make sure that this study is conducted as approved. Any modifications to the protocol or consent form, initiated by you or by the sponsor, will require prior approval, which you may request by completing a protocol modification form. All study records, including copies of signed consent forms, must be retained for three (3) years after termination of the study.

The approval granted expires on April 11, 2012. Should you wish to maintain this protocol in an active status beyond that date, you will need to provide the IRB with an IRB Application for Continuing Review (Progress Report) summarizing study results to date. The IRB will request an IRB Application for Continuing Review from you approximately two months before the anniversary date of your current approval.

If you have questions about these procedures, or need any additional assistance from the IRB, please call the IRB office at (405) 325-8110 or send an email to irb@ou.edu.

Cordially,

Donald Baker, Ph.D.
Vice Chair, Institutional Review Board

1816 West Lindsey, Suite 150 Norman, Oklahoma 73069 PHONE: (405) 325-8110

Ltr_Prot_Fappv_Exp