# GEOGRAPHIC DIFFERENCES IN EMERGENCY MANAGEMENT DECISION-MAKING: A CASE STUDY OF SEVERE WEATHER IN THE MIDWEST

by

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July, 2014

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Tornadoes are one of the most dangerous meteorological hazards on a local scale. While tornadoes can occur virtually anywhere, response—and the processes that lead to it—can vary based on location. It is the task of an emergency manager (EM) to inform the public about the threat of impending weather. However, the completion of that task differs with each EM as various situational and cognitive factors are geographically dependent, such as tornado experience and training. A survey taken by emergency support function personnel within five National Weather Service weather forecast office locations is analyzed in conjunction with historical county tornado data to investigate the influences of various factors present while EMs make decisions. Perceptions of warning effectiveness, warning message priorities, and past tornadic activity are specifically evaluated for the purpose of discovering the communication needs EMs have in various locations. Results show that very few significant differences in response are geographically dependent and that false alarms have little effect on how EMs make subsequent severe weather decisions. The results from this research can provide meteorologists with the knowledge of specific EM decision-making needs, which will enable the EMs' tasks to

be more effective and, in turn, they will be able to better protect the public during severe weather.

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# CHAPTER 1: INTRODUCTION

Tornadoes are one of the most dangerous meteorological hazards due to their rapid formation, unpredictable tracks, and occasionally high intensities. They can be especially damaging when they hit large, populated cities. It is important, therefore, for the people near a tornado's path to not only be informed of the tornado, but to respond appropriately in order to protect themselves and others. This is the task of an emergency manager (EM)—the person who is responsible for the dissemination of the warning information. They are also the ones who are usually responsible for notifying schools, hospitals, and other highly vulnerable institutions as well as activating sirens and other alert systems (League et al. 2010). Due to the importance of these tasks, it is essential to understand EMs and how they interpret warnings and the associated risk.

The purpose of this study is to examine emergency management operations in conjunction with past tornadic activity and current warning practices to investigate if there are differences in how EMs make decisions during severe weather based upon their geographic location. This will provide knowledge of the communication needs of EMs in specific locations. It will also help to uncover the factors that influence EMs while they make decisions. This research will advance our knowledge about emergency management decision making, enabling their tasks to be more effective and, in turn, they may be able to better protect the public during severe weather.

While tornadoes can occur virtually anywhere, response (and the processes that lead to it) can vary based on geographical location. Experience and training, for instance, vary based on location; Oklahoma is a great example of this. Many EMs in Oklahoma have the opportunity to participate in an information and support system called OK-FIRST where they receive tailored weather training and resources to aid in decision making (Morris et al. 2001). While this provides an excellent and invaluable resource for the EMs in Oklahoma, it leaves big gaps in EM resources and risk perception between that region and all other regions. With this idea in mind, determining geographic differences in the characteristics of emergency managers is the focus of this thesis. More specifically, this thesis seeks answers to the following research questions:

1. Does the amount of past tornado activity in an EM's jurisdiction influence the way he/she responds to a tornado warning?
2. Are there differences in the priorities of the information provided in warning messages among EMs of different locations?
3. Are there differences in EMs' perceptions of warning effectiveness across all the surveyed locations?

These questions are addressed by examining a survey taken by EMs in the Midwest. A review of the relevant literature is presented next in Chapter 2, followed by a description of the methods used in Chapter 3. Then, the results are presented in Chapter 4 and discussed in Chapter 5.

# CHAPTER 2: REVIEW OF LITERATURE

With their potential for major destruction, tornadoes present an important topic in hazards research. Therefore, having baseline knowledge of tornadoes, warnings, and response is critical. Before attempting to understand how EMs interpret tornado warnings at various locations, a review of the characteristics of tornadoes is presented. Following that, the general warning response system is described to help understand the processes that take place between the time forecasters issue warnings and the response made by the general public. Research involving tornado warning response with regard to both the general public and emergency managers is then presented. Finally, a brief review of the geographical differences in response is analyzed, providing a foundation for the research conducted in the current study.

## *Tornado Characteristics*

The very nature of a tornado merits the attention of anyone who may be near the path of one. The American Meteorological Society (AMS) defines a tornado as "a violently rotating column of air, in contact with the surface, pendant from a cumuliform cloud, and often (but not always) visible as a funnel cloud" (Glickmen 2000). The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) goes one step further stating, "on a local scale, it is the most destructive of all atmospheric phenomena" (National Weather Service 2009). With such potentially damaging consequences, it is important to have knowledge of basic tornado characteristics.

The flat terrain of the Great Plains and points eastward, in conjunction with the synoptic flow that tends to occur in that area, provide the best dynamics for tornadoes to form (Suckling and Ashley 2006). This does not mean that tornadoes cannot form west of the Rocky Mountains, but the frequency of occurrence there is significantly less. Parts of the United States (U.S.) are well known for the large number of tornadoes they experience (Figure 2.1).

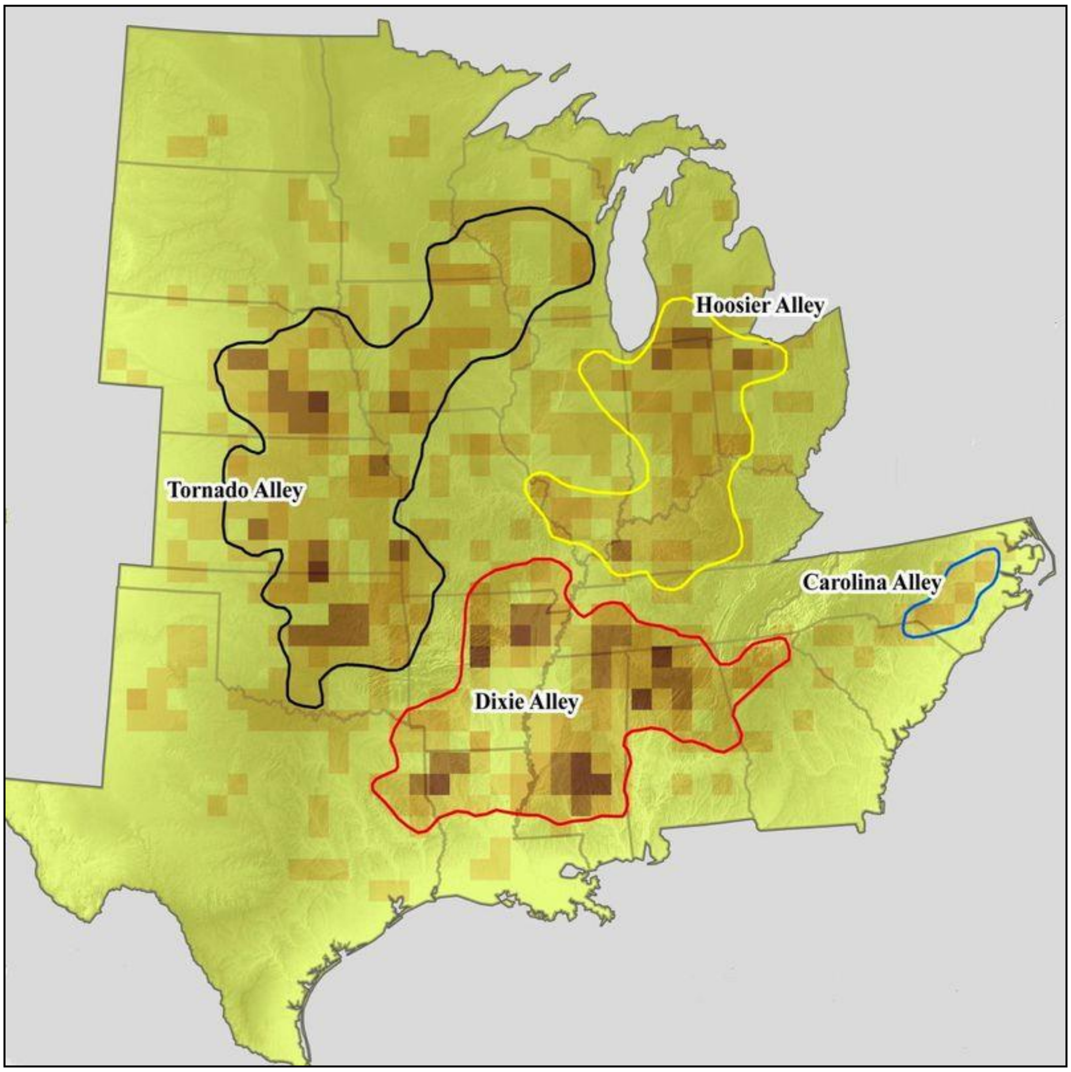

Figure 2.1: Locations of High Tornadic Activity (Cox. 2010).

“Tornado Alley,” which covers the Central Plains, and “Dixie Alley,” which covers the southeastern U.S., are the two most well-known areas for frequent tornadic activity. However, the Midwest region of the U.S. cannot be underestimated either. Together, these three regions comprise the areas of the most tornadic activity (Kelly et al. 1978, Suckling and Ashley 2006). As a result, these are also the areas where EMs need to be most prepared to respond to tornadic risk.

The three regions of high tornado frequency differ on their temporal distributions. Although tornado season throughout the South is predominately in the months of March, April, and May, tornadoes occur in both the fall and winter months within this region with some frequency. Interestingly, the summer months of July, August and September are the months with the least amount of tornadic activity in the South (Suckling and Ashley 2006). This is in contrast to the north central to northeast U.S. states whose months of highest tornadic activity are slightly earlier, April through June, yet whose winter months rarely see any tornadoes. The diurnal distribution of tornadoes is more similar for all regions, showing peak times for the formation of a tornado during the late afternoon hours of the day, specifically 3:00-6:00 p.m. local time (Kelly et al. 1978). However, it needs to be remembered that reports of tornadoes may decline after the sun has set and it becomes harder to see them, which may skew data on diurnal distributions slightly. The time of day that tornadoes occur (whether during daylight hours or darker hours) greatly affects an EM's interpretation of tornadic threats as they often rely on spotter reports to provide ground truth (Baumgart et al. 2008, League et al. 2010, Schumacher et al. 2010).

Severity of tornadoes and the associated damage and death toll vary with each storm. The Enhanced Fujita scale assigns a severity number (EF-0 to EF-5) to each tornado once it has ended and damage has been evaluated. The severity numbers are based on the damage and the winds that can cause that damage (Table 2.1) (Storm Prediction Center (SPC) 2011a, b).

Table 2.1: Operational EF Scale Used by the National Weather Service

| **EF Number** | **3 Second Gust (mph)** |
|---|---|
| 0 | 65-85 |
| 1 | 86-110 |
| 2 | 111-135 |
| 3 | 136-165 |
| 4 | 166-200 |
| 5 | Over 200 |

Kelly et al. (1978) show that weaker tornadoes (in the range of EF-0 to EF-1) occur much more frequently than moderate (EF-2 to EF-3), and the most extreme tornadoes occur even less frequently than those intermediate tornadoes. However, fatalities due to tornadoes increase as the intensity increases. Therefore, there are a few, strong tornadoes that cause the most damage and deaths, providing an inverse relationship between the frequency of fatal occurrence due to tornadoes and tornado severity based on the Enhanced Fujita scale. Tornado path lengths fluctuate as well. A single tornado can be on the ground for seconds covering only a few feet or it could travel hundreds of miles, spanning several counties across multiple states. Despite the difficulty in forecasting the exact location, time, intensity, path length, and the amount of time a tornado will traverse the ground, EMs must act once conditions suggest an impending event, in order to give people at risk time to respond.

### *The Warning Process*

A warning for any type of hazard is a message to the public of an impending threat. It then allows those who may be in danger to make a decision about how they want to respond. This idea may seem simple, but with the number of people involved in both communicating the warning and making decisions about how to respond, the warning process becomes quite complex. During a warning, the government, scientific agencies (public and private), news media, emergency managers, technology, and the public all become linked together in a web of communication operations. For this reason, warning systems have scientific, managerial, technological, and social components, and the various communication operations are what link them all together in the warning process (Mileti and Sorenson 1990, Sorensen 2000).

Warnings during each communication operation are further complicated by a three-step process by which warnings are disseminated and to which response occurs. Mileti and Sorenson

(1990) outline this process. The three subsystems of the warning process include detection, management, and response to an impending threat as shown in the darker blue in Figure 2.2. Detection involves the monitoring of both natural and physical surroundings that may produce an emergency. Once detection of an impending atmospheric risk occurs, the National Weather Service issues a warning. It then becomes the task of the EM to manage public notification of that impending threat; this is the management subsystem. In this subsystem, the EM must evaluate who the hazard puts at risk, where, and at what time. If the risk to the public is high enough, EMs will issue additional warnings. Communication between detection subsection personnel and management subsection personnel is usually common during this step to provide EMs with further details of the threat, should it be needed (Baumgart et al. 2008). After the threat is properly identified and a public warning is issued, it then becomes each individual's responsibility to respond to those warnings. In an ideal situation, everyone would respond to the warning in the ways which the EMs recommend. However, once this third step of the warning process is achieved, the actions of the general public are their own and are based on the various situational and cognitive factors that influence their risk perceptions and responses (Tobin and Montz 1997).

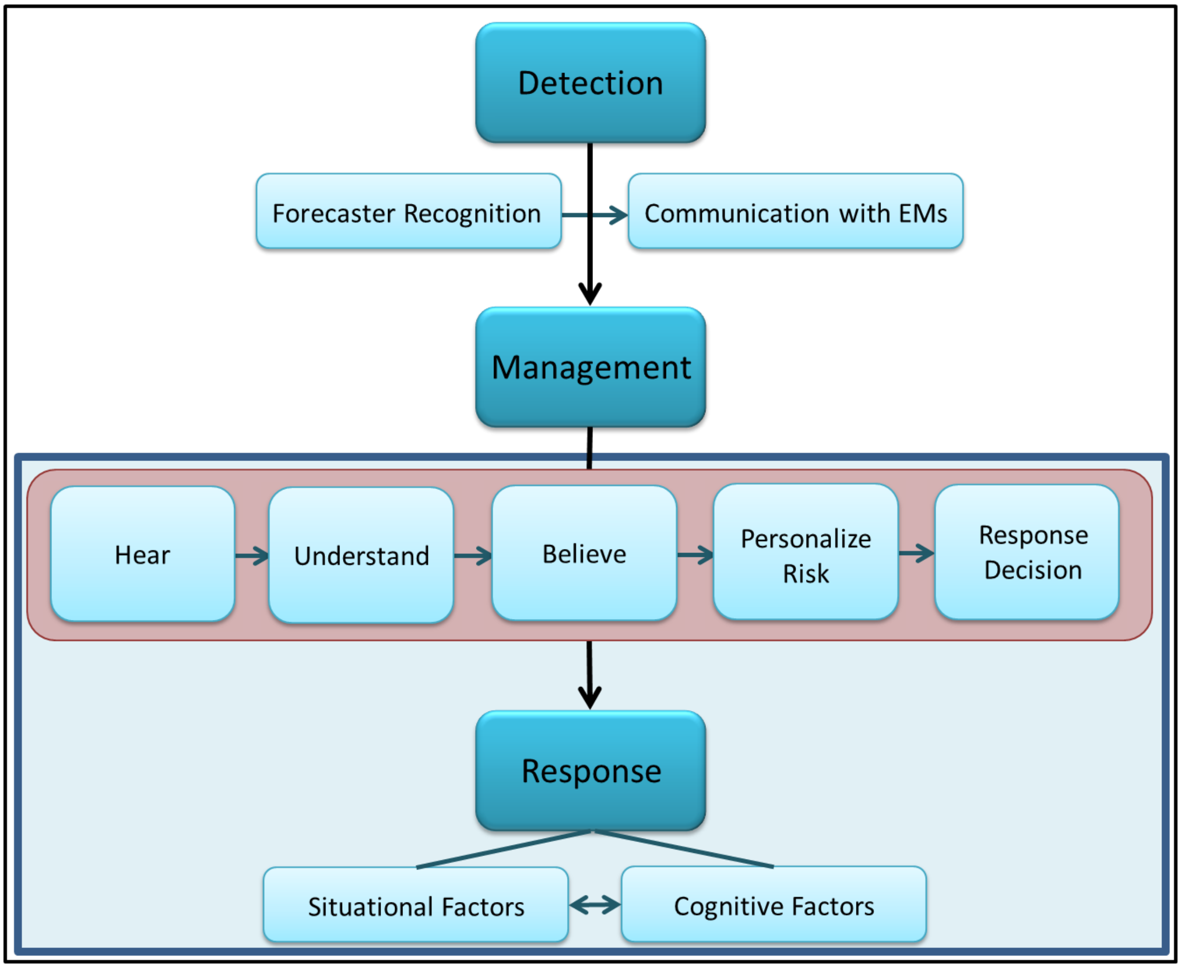

Figure 2.2: Warning System Framework (adapted from Mileti and Sorenson 1990, and Tobin and Montz 1997)

Public response to warnings is itself a sequential system within the warning process outlined above. Five further actions are part of the response subsystem (Mileti and Sorenson 1990). First, an individual must hear that a warning has been issued. Second, they must be able to understand the message of the warning. Third, the message must be believed to be accurate for the individual to continue the response process. Fourth, the individual must personalize the risk within the warning to him or herself. Fifth, they must confirm that the warning is true and make a decision. Once these steps are taken, they respond by taking action. It should be noted that it is not imperative that each one of these steps is taken or that the order in which the steps are followed matters for response measures to be fulfilled. However, whether or not an individual responds to a warning in an appropriate way is entirely his/her own decision. For this reason, it is imperative to understand the ways in which people perceive risk.

### *Risk Perception and Response during Tornadic Events: The Public*

Risk perception of any hazard is a complex process. Gilbert White (1988) presents risk perception as a process that involves three dimensions: a social component, a decision-maker component, and the environment component. In the social component, socioeconomic factors including age, race, and income influence the ways in which response occurs. The decision-maker component includes the ability of the decision maker, which may be an individual or an EM, to analyze and interpret the risk information being presented. Finally, the environment component involves the physical attributes of the threat—magnitude, frequency, location, and duration. It is a combination of these three components from which an individual perceives risk. The social component is explored here.

Past research on tornado risk perception showcases the variety of influences that shape response. One such influence is past experience with tornadoes. The experience of living through one or several tornadoes, and thereby gaining knowledge of relative storm frequency and storm motion, is important for determining response to subsequent tornadoes (Schumacher et al. 2010). Past experience can be either beneficial to appropriate response or hinder proactive response. For instance, if an individual has lived through a strong tornado and suffered only minor losses, he or she may believe that future tornadoes, stronger or weaker, will not have devastating consequences, when in reality even a weaker tornado can cause significant damage (Storm Prediction Center 2011b). On the other hand, if an individual has sustained major losses from a tornado in the past, he or she may respond more proactively for tornadoes in the future in order to minimize damage.

Having shelter in which to take refuge during severe weather also affects response. It has been found that having a basement in the home is positively correlated with protective response to a warning (Balluz et al. 2000). An example of this is the case of residents in Joplin, Missouri. On 22 May 2011, an EF-5 tornado tore through the center of town leaving 162 people dead and countless others injured and homeless. A questionnaire regarding the tornado warning that was issued that day and the compliance to it reveals that having a safe place to go to in severe weather influenced response (Paul and Stimers 2012). Most respondents (nearly 90%) received the tornado warning that day and 77% said that they complied with the warning message. However, only 16% took cover in a basement (the safest place to go during severe weather) due to the fact that 78% of houses in the area lack basements. Clearly, if a basement is lacking, an individual cannot retreat there whether a decision was made to take cover or not. This is not to say that other areas such as interior rooms, bathtubs, and bathrooms were not used, however.

Possibly the most well-known and controversial topic in tornado risk perception and response is the false alarm rate (FAR), the number of warnings unable to be confirmed as having produced a tornado. Barnes et al. (2007) found that approximately 75% of tornado warnings go unverified. It has long been thought that this high rate of tornadoes going unverified leads to complacency in the general public and that they perceive their risk to be lower than it might be otherwise (Anderson-Berry 2003, Drabek 1986, Paul et al. 2003). Findings from a NWS Service Assessment in the aftermath of the Joplin tornado showcase this idea: "familiarity with severe weather and the frequency of siren activation not only reflect normalization of threat and/or desensitization to sirens and warnings, but they also establish that initial siren activation has lost a degree of credibility for many residents" (National Weather Service 2011). It was even found that a one standard deviation increase in the FAR increases expected fatalities from tornadoes by 12-29% (Simmons and Sutter 2009). However, many other studies suggest that this "cry-wolf" effect is not evident. Dow and Cutter (1998) found that false alarm near-misses involved with Hurricanes Bertha and Fran did not affect residents’ perceptions of risk or their plans for future events. In addition, it has been suggested that hazards with short time frames such as tornadoes allow for more tolerance of high FARs than hazards with longer time frames such as hurricanes when evacuations greatly disrupt livelihoods (Barnes et al. 2007).

Another factor that contributes to risk perception and response is communication with others. In the response subsection of the warning process discussed earlier, one of the processes that generally occurs is to personalize the risk. Once individuals hear of a threat, they may contact friends, family, or co-workers to help interpret and confirm what they have already heard and understood (or lack thereof). Hammer and Schmidlin (2002) found that people often confirm tornadic risk via multiple sources, but especially by telephone, meaning that communication during hazardous events is critical for an individual to make decisions about how to respond. In fact, 47.5% of students at a southeastern university ranked communicating with others as the top source of weather information and the employees at the university ranked it as their second-highest source (Sherman-Morris 2010). The same study found that talking with others is the second-most effective influence on whether or not the respondents took shelter (26%), only slightly behind the tornado sirens (27.2%) (Sherman-Morris 2010). This shows that a vital way individuals gain confidence in their decision-making processes and eventually their decisions, is through effective communication.

Socio-demographic characteristics also greatly influence response. A study by de Man and Simpson-Housley (1987) explores socio-demographic response to three situations. When considering the expectation of tornado reoccurrence, gender was the single best predictor. Females tend to perceive tornadoes as more threatening than do males. When considering the expected damage should there be a tornado, level of education was the single best predictor.

Less educated individuals expected more damage should there be a tornado than those with more education. The last situation evaluated was the level of anxiety in those surveyed should there be a tornado expected in their area. Again, gender prevailed as the best predictor, with women having higher anticipated anxiety levels. Other socio-demographic characteristics that influence response include age, race, income level, number of children, and prior experience, among others. The importance of socio-demographic characteristics in understanding response is reflected by the numerous studies that address these variables (Balluz et al. 2000, Baumgart et al. 2008, Blanchard-Boehm and Cook 2004, de Man and Simpson-Housley 1987, Hoesktra et al. 2011, Morss et al. 2008, Nagele and Trainor 2012, Paul and Stimers 2012, and Schmidlin et al. 2009).

### *Risk Perception and Response during Tornadic Events: the Task of an Emergency Manager*

Emergency managers have the important responsibility of insuring that the public is aware of impending emergencies, including severe weather. They serve in the management phase of the warning process, between the first detection of severe weather by forecasters and the responses made by public. They gather information from weather forecasters, interpret that information in terms of the risk to the public, and make decisions about if and how to disseminate the warning to the public. They also communicate with highly vulnerable institutions such as schools, hospitals, and first responders ahead of the event in order to initiate disaster preparations (Baumgart et al. 2008). With such responsibility, it would be beneficial to have baseline knowledge about how EMs go about their tasks.

Emergency management decision-making regarding tornadoes is especially important for three reasons as outlined by Donner (2008). First, the physical attributes of tornadoes merit a prompt response due to their rapid changes and potentially dangerous severities. Second, tornadoes are very short-term events meaning that an EM can abandon other, less-threatening situations, such as a flood, and devote time to management of the tornado while it is occurring. Third, while some less-damaging disasters can be overlooked by a community, violent tornadic events often initiate immediate repercussions should the EM be unprepared and loss is high. For these reasons, as well as the responsibilities mentioned above, the task of an EM is examined next.

One key component of an EM's job during severe weather events is monitoring weather information sources. Clearly, EMs must know that a severe weather threat is possible in order to start their task of relaying the message to the public. Once the potential has been recognized, various weather information sources give the EM a more complete picture of the imminent weather. In fact, most EMs rely on multiple sources of weather information (Baumgart et al 2008, League et al. 2010, Morss and Ralph 2007, Demuth et al. 2012, Schmacher et al. 2010). The most frequently used weather information source is radar—both reflectivity and velocity (Baumgart et al. 2008, League et al. 2010). In fact, an average of four different radars from various agencies is used by EMs. Spotter reports are another vital weather information source. Baumgart et al. (2008) and Schumacher et al. (2010) found that EMs often request guidance from spotters in order to make assessments during the warning process. Other important sources used and requested by EMs include NWS Warning Text, the media, police/fire departments, lightning data, and NOAA weather radio (Baumgart et al. 2008).

The experience and ability to interpret weather risk information is another key component of an emergency manager's job. Interpretation abilities vary based on experience. A novice EM, who is just starting his or her career, will have a different perception of the threat than a veteran EM who has been on the job for decades. Another factor that influences EM's interpretation of risk is how the message is communicated to them in the first place. For example, Schumacher et al. (2010) outline two scenarios. The first involves an EM who has heard of a storm moving north toward their jurisdictional area and is able to respond appropriately. The second scenario features an EM who did not hear about the storms' northward movement. He or she assumed that the storm would move in the southwest to northeast direction that is perceived to be common with tornadoes (Suckling and Ashley 2006) and therefore left their community unprepared. This is a useful example of how experience and the interpretation of risk are interrelated.

A third key element that determines how an emergency manager interprets information is the confidence and trust that they have in forecasters, spotters, and other emergency operations officers. During the entirety of a severe weather event, communication is key (Baumgart et al. 2008) and EMs will often converse with these professionals in order to understand the risk better to aid in the decision making process. For instance, while most EMs have some training in radar interpretation, many still seek the advice of forecasters during decision-making times such as when to activate the sirens (League et al. 2010). EMs will also have contact with spotters, as mentioned above. The more communication and correspondence there is between EMs and forecasters, the greater the level of confidence and trust an EM has in the forecaster's ability to accurately predict severe weather (Morss and Ralph 2007). In addition, Baumgart et al. (2008, pg. 1276) state that "as EMs make initial assessments, they may decide to cycle back and gather additional perceptual cues from various information sources," showing that confidence is built by the use of multiple information sources and communication with forecasters and other EMs.

After the evaluation and communication with professionals, an EM must decide whether or not to communicate the warning to the public. League et al. (2010) found interesting results regarding the dissemination of EM warnings in contrast to NWS warnings. Not all EMs would warn the public about severe weather even if the NWS has issued a warning. In fact, only 60% of those surveyed said they would always warn the public if the NWS has issued a tornado warning. In addition, even if the NWS has not yet issued a tornado warning, 67% of the surveyed EMs responded that they would warn their jurisdiction if they feel it is necessary. With all the ways that EMs are influenced during critical severe weather decision-making times--including the various weather information sources, experiences, confidence and communication with forecasters--the process by which decisions are made is anything but simple.

### *Geographic Differences in Emergency Management*

Another critical aspect of risk interpretation is location and its influences on the way in which response occurs. While tornadoes can occur virtually anywhere, response (and the processes that lead to it) can vary based on geographical location. For instance, the sources of information about severe weather may change based on the resources available to them and the social and physical characteristics of their jurisdictions (Morss and Ralph 2007). An EM whose jurisdiction covers a large, urban area might require additional information about the location of a tornado in order to make sure the highly vulnerable institutions in that area are aware of the threat. In contrast, if additional information about location is received and the EM knows that the area that will be affected is very remote and unpopulated, the response will be different.

Cognitive factors present in space also showcase geographic differences in response to tornadoes. Sims and Baumann (1972) evaluated the coping styles in response to a tornado between a surveyed location in Illinois (a northern state) and Alabama (a southern state). They hoped to discover why so many more deaths occur in the South versus the North by conducting psychological evaluations of the residents at each location using a sentence-completion survey. Overall, results show that Illinoisans are more action-oriented and possess more rationality when reacting to the threat of a tornado than Alabamians. Also, the use of technology is higher in the North as compared to the South; Alabamians believe the encounter is between humans and Nature.

The study by Sims and Baumann (1972) does not come without criticism, however. They only consider how psychological factors lead to response rather than considering psychological factors in conjunction with other situational factors present in space. Tobin and Montz (1997) outline how it is a combination of both these factors that lead to a response. That is not to say that Sims and Baumann did not hypothesize about situational factors such as the diurnal distribution of tornadoes, the severity of tornadoes, the housing stock and the quality of the warning systems at the two locations; however, each of those hypotheses were argued in such a way that those factors did not vary based on location. In this way, Sims and Baumann (1972) implied that there were so many more deaths in the South due only to the differences in psychology of the residents at the two places. However, Boruff et al. (2003) argue that response is in fact dependent upon warning systems, housing structures, and other situational factors, supporting the previous discussions.

This examination shows stark differences in the ways in which response occurs based on geographic location. The study by Sims and Baumann (1972) is a study about the general public, however EMs are also influenced by social constructs of their geographic region. In addition, while this is just one study, it does provide good reasoning to uncover and research further the geographic differences in emergency management decision making—something that merits much more research than currently exists.

# CHAPTER 3: METHODOLOGY

A survey was used in order to address the research questions. This method was chosen because it allows for a much higher number of respondents than a more time-intensive method such as one-on-one interviews. In addition, the survey used is constructed in a multiple-choice format, meaning that answers are discrete and can easily be coded for use in a statistical software program (Appendix B). As the goal of this study is to see if there are geographic differences in emergency management decision-making, it was important to identify any associations between how EMs in one Weather Forecast Office (WFO) answer the survey questions compared to those in other WFOs. The results of the survey and the statistics produced are joined with three "background" variables for each WFO including population/population density, historical tornadic activity and warning activity, and false alarm rate (FAR). Together, these three background variables permit comparison of the WFOs to each other and give some insight into the reasoning behind the resulting differences found.

## *Data Sources*

### *Survey Details*

The survey used in this study was conducted as part of a project, the "Social and Behavioral Influences on Weather-Driven Decisions (SBI)" funded by the National Oceanic and Atmospheric Administration (NOAA) as part of the Weather-Ready Nation initiative. The overall goal of SBI is to develop an understanding of the factors beyond weather information that influence weather-driven EM decision-making and to help translate the most important factors into operations. The goal of this project follows in that the survey fosters understanding of the ways in which EMs and other emergency support function (ESF) personnel are influenced, by both social and behavioral components, and how those influences affect their decision making during severe weather events.

This survey was distributed online to EMs and other ESFs in five NWS WFO locations in Illinois, Indiana, Michigan, and Wisconsin during late 2012 (Figure 3.1). It was initially sent to the five Warning Coordination Meteorologists (WCMs) at each WFO location; they then sent the survey out via email to the EMs and ESFs on their contact lists. The number of respondents totaled 243 people with a varying number of respondents from each WFO (Table 3.1). Four of these respondents were unaware of their primary WFO location, and are therefore left out of the statistical analyses. While the total number of respondents is large considering the relatively small spatial extent of the survey coverage area, the total number of EMs and ESFs in the area is not known. Therefore, the overall response rate is unknown. Regardless, those who have responded provide important insight to emergency management decision-making.

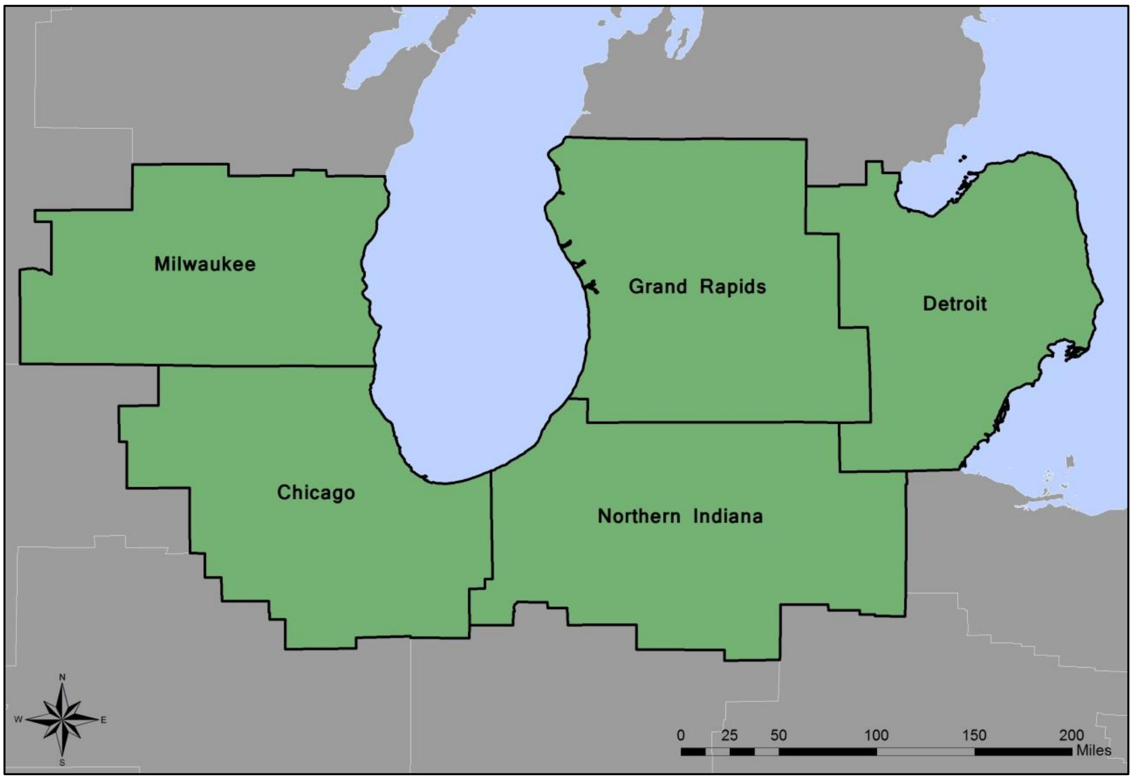

Figure 3.1: Study Area, Including the Five Weather Forecast Offices (WFOs)

Table 3.1: Number of Respondents by WFO Location

| **WFO Location** | **Number of Respondents** | **Percent of Total (%)** |
|---|---|---|
| Chicago | 90 | 37 |
| Detroit | 26 | 10.7 |
| Grand Rapids | 54 | 22.2 |
| Milwaukee | 37 | 15.2 |
| Northern Indiana | 32 | 13.2 |
| I don't know | 4 | 1.6 |
| **Total** | **243** | **100%** |

For the purposes of the current study, the phrase "EMs and ESFs" is shortened to simply "EMs;" however, it should be noted that all fifteen emergency support function annexes, as recognized by the Federal Emergency Management Agency, are included in the term "EMs" (Table 3.2).

Table 3.2: FEMA Emergency Support Function Annexes

| **Emergency Support Function** |
|---|
| Transportation |
| Communications |
| Public Works and Engineering |
| Firefighting |
| Information and Planning |
| Mass Care, Emergency Assistance, Housing, and Human Services |
| Logistics |
| Public Health and Medical Services |
| Search and Rescue |
| Oil and Hazardous Materials |
| Agriculture and Natural Materials |
| Energy |
| Public Safety and Security |
| Long-Term Community Recovery |
| External Affairs |

It is important to include both EMs (those with the actual title of emergency managers) and the other ESF personnel as it has been recognized that decisions during severe weather are made in the context of a web of communication including both EMs and ESFs (Montz et al. 2014).

In addition, other communities are also represented that would not be classified in the aforementioned fifteen. This is because one of the socio-demographic questions on the survey asks them to list their "primary job classification," leaving some interpretations to be done as to which ESF annex they fit. Therefore, Table 3.3 shows the range of job classifications in the current study as identified by the author.

Table 3.3: Job Classifications Identified in the Current Study

| **Job Classification** |
|---|
| Emergency Management |
| Firefighting |
| Law Enforcement |
| Communications |
| Education |
| Preparedness/Planning |
| Transportation |
| Other |

The range of questions in this survey provides the means by which to address the research questions (Appendix B). Although the survey contains 35 questions, not all are used in this study. Questions within the survey ask about the usefulness and effectiveness of current warning practices used by the NWS, what EMs would like to see in future warning messages, risk perception and response characterizations, the priority of critical information elements provided to EMs, socio-demographic questions regarding age and tenure, and the aforementioned location and job classification. Table 3.4 shows the survey questions that were used in this study and which research questions they address.

Table 3.4: Survey Questions Used and the Research Questions Addressed

| Research Question Addressed | Survey Question |
|---|---|
| Does the amount of past tornado activity in an EM's jurisdiction influence the way he/she responds to a tornado warning? | If you hear a tornado warning for your area, what do you think is the likelihood that a tornado will impact your immediate area? |
| | If there was a tornado warning for your area and a tornado did not occur, how do you think it might influence your decision-making the next time a tornado warning is issued for your area? |
| | Based on past tornado occurences in your vicinity, what is your opinion about the number of warnings issued? |
| Are there differences in the priorities of the information provided in warning messages among EMs of different locations? | What is the primary reason you need to receive a weather warning? |
| | What would be the most helpful to your decision-making to have in a warning message? |
| | Does it matter that a tornado is "radar-indicated," as compared to a tornado being "observed?" |
| | Which of these best conveys urgency about a tornado to you? |
| | If you could get more precise information on size or impact of the hazard, which would it be? |
| | How many minutes in the future would you like to see a forecasted tornado track ("pathcast")? |
| | What is the lowest level of forecaster confidence at which you'd like to see a forecasted tornado track ("pathcast") issued? |
| Are there differences in EMs' perceptions of warning effectiveness across all the surveyed locations? | How effective is an NWS warning message in conveying urgency to you? |
| | How useful is this warning to you when making an operational decision? |
| | How often are you in contact with your local NWS office during a severe weather event? |
| | Level of Agreement: I am receiving exactly what I need to know about (timing/location/the storm's history/duration/forecaster's confidence/hazard) from the National Weather Service. |
| | Level of Agreement: Severe thunderstorm watches should be eliminated completely. |
| | Level of Agreement: Severe thunderstorm warnings should be eliminated completely. |
| | Given that EMs need more, earlier, and different information than the public, should there be two different warnings created, one for EMs and one for the public? |

### *Population Data*

One of the main goals of the EM community is to “prepare for, protect against, respond to, recover from and mitigate all hazards [natural or man-made],” (Federal Emergency Management Agency 2013). Those tasks become much harder for the EM when there are many people in a jurisdictional area, meaning vulnerability to hazards such as tornadoes is high.

Therefore, population size and corresponding population density have the potential to influence the way an EM responds in certain decision-making situations. For this reason, data on population was gathered for each WFO location in the analysis.

The survey asks one question regarding location: “What is your primary National Weather Service Office?” Because of this, the only data regarding each respondent’s location is their WFO, not their city, county, or jurisdictional area. Therefore it is important to know the population of each of the five WFOs, even though it is not necessarily representative of each EM surveyed and the spatial extent of the area for which they are responsible. To find data on the population of each WFO, county population data was found since the County Warning Area (CWA) boundaries of each WFO are separated along county lines (U.S. Census Bureau, 2010). Then, all county populations within each WFO were summed to produce the population of the WFO.

Since the spatial extent of each WFO’s CWA can vary, population densities were also derived for each WFO. In order to calculate this, the area (in square miles) for each county was found and summed with all county areas in each WFO. Total population per total square mile produces the population densities per WFO. This is important to know as it better represents the distribution of people in each WFO location.

Urbanization is also considered for its effect on EM decision-making. Since the WFOs are divided into counties, an urbanization classification of either “Metropolitan” or “Non-Metropolitan” is given to each county based on the county’s population. All counties with populations less than 50,000 are considered “non-metropolitan” and those with populations greater than or equal to 50,000 are considered “metropolitan.” This number was used as the threshold for classification, as outlined by the Center for Disease Control and Prevention’s (CDC) National Center for Health Statistics (2012). Then, the percentage of counties within each WFO classified as metropolitan or non-metropolitan was calculated. This data, along with the population densities, allows for further analyses to help understand potential differences in EM decision-making.

### *Tornado Experience and False Alarms*

One of the research questions addresses whether or not the amount of past tornadic activity in an EM's jurisdiction influences the way he/she responds to a tornado warning. In order to answer that question, data on the amount of past tornadic activity was gathered from the NWS's Storm Prediction Center (SPC 2014), which provides detailed information about every reported tornado in the United States from 1950-2013. For the purposes of this study, all tornadoes before 1986 and after 2012 were eliminated (reasoning to follow) as well as any tornado occurring outside of the study area. An online document (Storm Prediction Center 2010) makes it possible for the user to decode the tornado information based on such variables as tornado date, time, state, county FIPS code in which it occurred, F-scale (EF-scale after 2007), latitude and longitude, whether or not a tornado crossed state lines, damages, and fatalities, among other characteristics.

Having this detailed information about each tornado is critical to understanding exactly which counties, and therefore which WFOs, were affected by each tornado along with the time of occurrence, since the tornadoes are considered in conjunction with historical tornado warning information. Warning information is important to understanding the number of tornadic events to which EMs in each WFO have had to respond given that EMs need to respond and make decisions for their jurisdictional area whether or not a tornado actually occurs. Therefore, to account for all tornadoes and tornado warning activity, and to insure that a tornado and a tornado warning for the same event are not counted as two separate events, three pieces of information were found for each WFO:

1. Tornadoes with a verified warning ($T_w$)
2. Tornadoes with no verified warning ($T_{nw}$)
3. Unverified tornado warnings ($W_{nt}$)

Two sources are used to find tornado warning data. The first data set is available from the Iowa Environmental Mesonet (IEM) (2014) through Iowa State University of Science and Technology. The total number of tornado warnings by county can be found here for the entirety of the time frame used in the current study. However, another tornado warning source was used in concurrence: tornado warning data from the NWS's Performance Management Severe Weather Verification interface (2014). Here, archived warnings at both the county level and storm-based level can be found. County-level warnings are available from January 1, 1986 through September 30, 2007 whereas storm-based warnings are available thereafter up until December 31, 2012, the last day considered in this analysis. Since this is the time frame used for tornado warning information, those are the same dates during which tornado activity is gathered as well as tornado warning data from the IEM.

The reason for having two sets of historical tornado warning data is that the data from the IEM includes the total number of warnings affecting a single county for the entire time frame, whereas the Performance Management (PM) interface provides data on whether or not the warnings were verified, not directly by county, however. There are some complications using the PM interface due to the implementation of the storm-based warnings. County-level warnings (warnings that occurred before October 1, 2007) are listed along with whether or not each warning was verified (i.e. a tornado occurred). However, tornado warning information does not match the results of the IEM tornado warning data because the storm-based warnings occurring from October 1, 2007 through December 31, 2012 are not included. Storm-based warnings do not warn whole counties, but rather just parts of different counties that are likely to be impacted by impending weather systems. Therefore, storm-based warnings often include parts of two or more counties within a single warning. Because of this, all three data sources were used in conjunction to determine tornado activity and tornado warning activity by county and therefore by WFO: historical tornado activity coming from the SPC, total historical tornado warning data from the IEM, and verified tornado warning history from the PM interface. The process of insuring that a tornado and tornado warning for the same event are not counted as two separate events is shown in Figure 3.2.

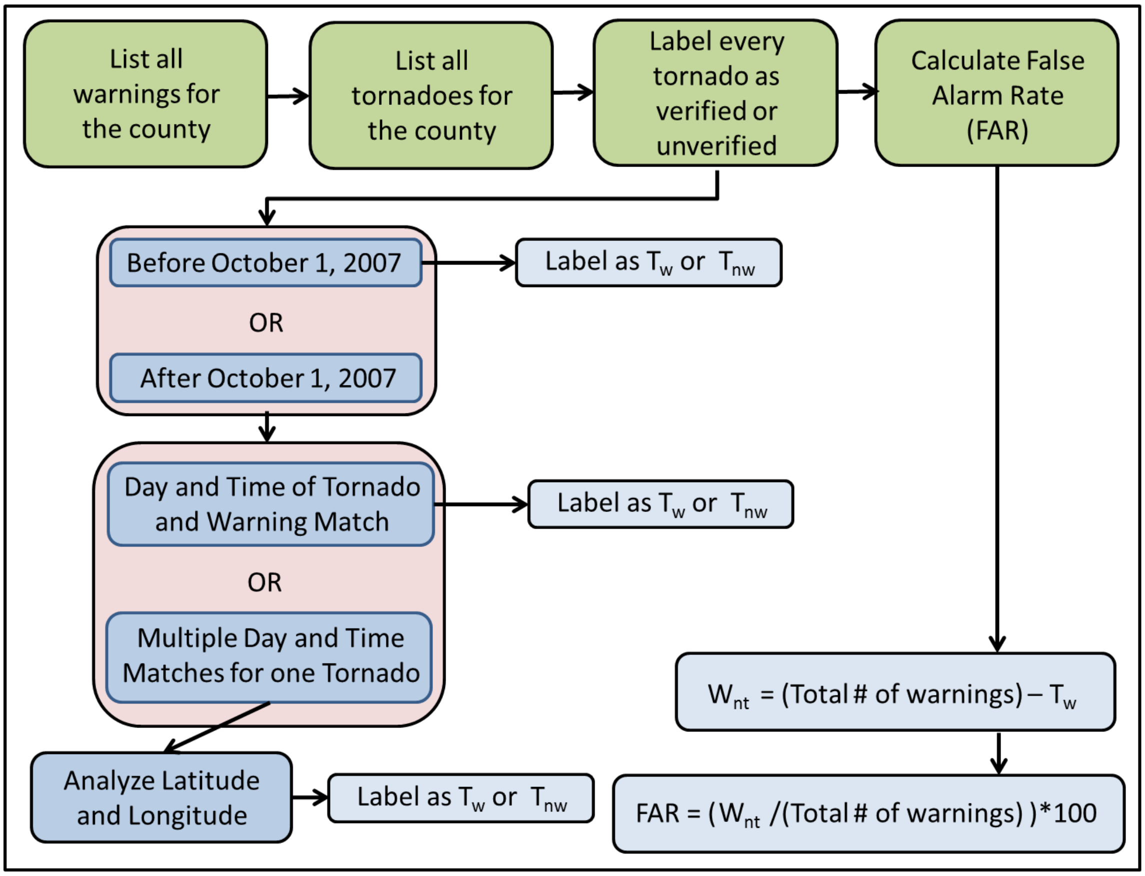

Figure 3.2: Flow Chart of Warning Classification

In this process, county-level tornado warning data from the IEM is considered alongside historical tornado data from the SPC for the same county to determine the total number of both tornadoes and tornado warnings, regardless of the fact that both may be counted for the same event. To resolve this issue and as a way to perform quality control, independent classification of each tornado was completed. Each was labeled either as a tornado having a verified warning ($T_w$) or a tornado with no verified warning ($T_{nw}$). Once completed, the PM data was used as it allows for a count of verified and unverified warnings. When classifying a tornado before October 1, 2007 (before implementation of the storm-based warnings), the classification of verified or unverified was listed on the PM interface. However, once the storm-based warnings are considered, the timing of the tornado and tornado warning were compared to determine the classification. If the time of the tornado and the tornado warning match (i.e. the tornado occurs during the time frame of the warning), then the tornado is classified as $T_w$. Due to the chaotic nature of severe weather, many tornadoes can occur and tornado warnings issued at relatively the same time. When this situation occurred in the current dataset, the latitude and longitude of the tornado and the warnings were then considered. If the locations of each matched, then the tornado was labeled $T_w$. All other warnings that were unverified were then labeled $T_{nw}$.

The last step in Figure 3 shows the calculation of each WFO's False Alarm Rate (FAR). FAR is the statistical measure of reliability of forecasted tornadoes. Studies have shown that FAR can influence response to tornado warnings (Simmons and Sutter 2009) and, thus it is included in this study. Once there is a count of the number of tornadoes with a verified warning ($T_w$), simple subtraction of the total number of warnings minus $T_w$ gives the number of warnings with no verified tornadoes ($W_{nt}$). The ratio of the $W_{nt}$ to the total number of warnings produces the FAR percentage:

$$\text{FAR} = (W_{nt} / (\text{Total \# of Warnings}))*100$$

### *Statistical Analyses*

Several different statistical analyses were used to explore whether or not there are any differences in EM decision-making across locations. The first analysis involved evaluating each WFO against the others to check for differences in responses to the survey questions. The statistics used here are either Chi square or independent sample one-way ANOVA, depending on whether the answers to the survey questions were categorical or continuous. If they were categorical, then Chi square was used; if they were continuous, ANOVA was used.

The second set of analyses addresses the background variables explained above (population densities, tornado and warning experience, and FAR). Here, WFOs are grouped together based upon relatively high and low results of each background variable. For instance, two of the WFOs, Chicago and Detroit, have relatively high metropolitan percentages, so they are grouped together, as are the other three less urbanized WFOs, and the two separate groups were then compared. The same type of grouping was done for population density and FAR as well (Table 3.5). The statistical test used here was the T-test as it examines the difference between the means of two groups.

Table 3.5: Grouping of the WFO Locations for Each Analysis

| **Analysis** | **WFO Groupings** |
|---|---|
| Urbanization | Chicago and Detroit vs. Grand Rapids, Milwaukee, and Northern Indiana |
| Tornado Experience | Detroit and Grand Rapids vs. Chicago, Milwaukee, and Northern Indiana |
| False Alarm Rate | Detroit and Milwaukee vs. Chicago, Grand Rapids, and Northern Indiana |

The analyses would not be complete without considering the potential influence on decision-making from the other sociodemographic variables. These variables include age, tenure, and job classification. Here, again, the statistics used were chi square and ANOVA, depending on whether or not survey answers were categorical or continuous.

Examination of the SBI survey results produces valuable knowledge about EM decision-making. However, it is the combination of false alarm rate, tornado and warning experience, and population along with the survey questions that provides a full, in-depth analysis of the decision-making processes that EMs encounter during severe weather and will fully address the research questions.

# CHAPTER 4: STATISTICAL ANALYSIS OF SURVEY RESULTS

## *Demographic Variables*

While conclusions about geographic differences in EM decision-making are the overall goal of the current study, results involving the sociodemographic variables are presented first. Only four questions on the SBI survey relate to the EMs' backgrounds; however, that data is important in order to understand the context of the EMs specifically surveyed here.

### *Job Classification*

Table 4.1 summarizes the results of the survey question in which the EMs were asked about their primary job classification.

Table 4.1: Job Classification Distribution of the Survey Respondents

| **Job Classification** | **Number of Respondents** | **Respondents (% of total)** |
|---|---|---|
| Emergency Management | 83 | 43.2 |
| Firefighting | 22 | 11.5 |
| Law Enforcement | 17 | 8.8 |
| Communications | 14 | 7.3 |
| Education | 14 | 7.3 |
| Preparedness/Planning | 13 | 6.8 |
| Transportation | 9 | 4.7 |
| Other | 20 | 10.4 |
| **Total** | **192** | **100%** |

The job classification with the highest percentage is emergency managers at 43.2% of the total number of respondents. First responders, firefighting and law enforcement sectors make up the next largest sectors followed by communications, education, preparedness/planning, transportation, and a category titled "Other." This category includes (in this case) respondents who gave themselves the titles of hospital security chief, government employee, instrument technician, meteorologist, and Skywarn Coordinator, to name a few. In order to make the utility of the statistics meaningful, however, some of the eight job classifications are recoded and grouped together. The new groups include Emergency Management (respondents who gave themselves the title of “emergency manager”), Public Safety (firefighting, law enforcement, and communications), Preparedness (preparedness and transportation), and Other (planning, education, and other). Once this regrouping was done, the statistics produced still could not effectively represent response, so the Preparedness job class was combined with the Other job class. The statistics that were produced after the second regrouping better represent the responses of each job classification while still maintaining the separate duties of each. Results showing the differences in responses to the survey questions based upon job classification are shown in Table 4.2.

Table 4.2: Differences in Decision-Making Based upon Job Classification

| **Survey Question** | **Statistic Type** | **Result** | **Degrees of Freedom** | **Significance** |
|---|---|---|---|---|
| Receive_Warning | Chi Square | $\chi2=21.403$ | 4 | 0.000* |
| Effective_Urgency | ANOVA | F=0.521 | 3 | 0.669 |
| Warning_Usefulness | Chi Square | $\chi2=7.762$ | 6 | 0.256 |
| Most_Helpful | Chi Square | $\chi2=1.672$ | 3 | 0.643 |
| Radar_vs_Observed | Chi Square | $\chi2=6.832$ | 3 | 0.077 |
| Likelihood | ANOVA | F=1.308 | 3 | 0.273 |
| Tornado_Not_Occur | ANOVA | F=0.910 | 3 | 0.437 |
| Number_of_Warnings | Chi Square | $\chi2=3.679$ | 3 | 0.298 |
| Contact_with_NWS | ANOVA | F=13.849 | 3 | 0.000* |
| Conveys_Urgency | Chi Square | $\chi2=13.383$ | 6 | 0.037* |
| Timing | ANOVA | F=3.492 | 3 | 0.017* |
| Location | ANOVA | F=0.470 | 3 | 0.703 |
| History | ANOVA | F=0.977 | 3 | 0.405 |
| Duration | ANOVA | F=1.673 | 3 | 0.174 |
| Forecaster_Confidence | ANOVA | F=1.001 | 3 | 0.394 |
| Hazard | ANOVA | F=3.444 | 3 | 0.018* |
| Size_or_Impact | Chi Square | $\chi2=4.414$ | 3 | 0.22 |
| Pathcast | ANOVA | F=0.859 | 3 | 0.463 |
| Lowest_Confidence | ANOVA | F=0.418 | 3 | 0.741 |
| Tstorm_Watches | ANOVA | F=0.760 | 3 | 0.518 |
| Tstorm_Warnings | ANOVA | F=0.633 | 3 | 0.594 |
| Two_Warnings | Chi Square | $\chi2=0.509$ | 3 | 0.917 |

*Significant at the 0.05 level

Most results show that there are no significant differences in decision-making based on job classification with the exception of five survey questions.

The first question asks why each job class needs to receive a warning message. Here, most of the respondents answer that they need to "initiate standard operating safety actions," regardless of their job classification (Figure 4.1). However, the Emergency Management classification shows a slightly more uniform distribution of the survey answers. They often need to alert other agencies of impending weather more than do those in the other job classifications.

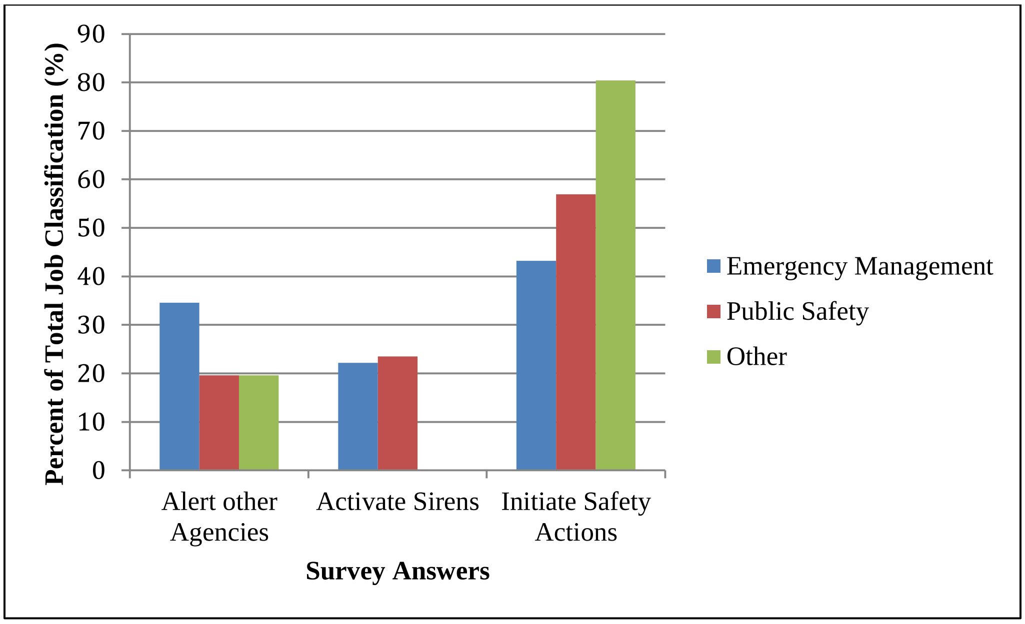

Figure 4.1: Reasons for Receiving a Weather Warning by Job Classification

The second survey question that showed significant differences based upon job classification asked respondents how often they are in contact with their local NWS office during a severe weather event (Figure 4.2).

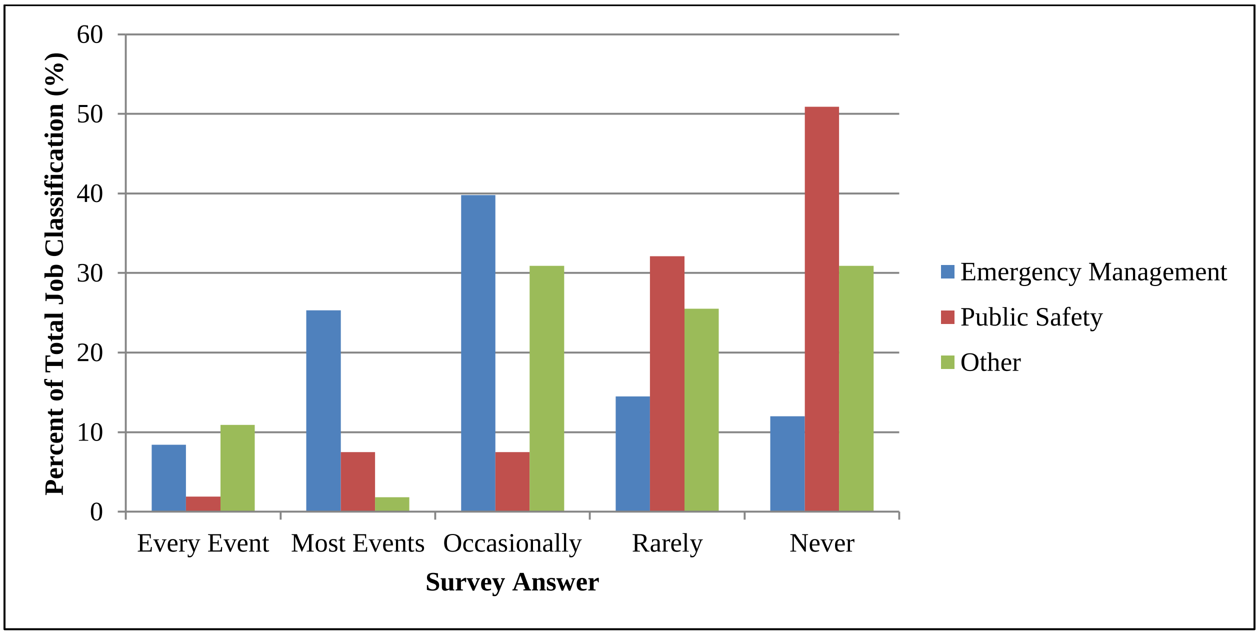

Figure 4.2: Frequency of NWS Contact by Job Classification

Here it can be seen that, overall, the Emergency Managers contact the NWS significantly more than the other two job classifications. In most cases, Emergency Managers contact the NWS either for "most events" or "occasionally" during severe weather, whereas the Public Safety and Other job classifications responded that they "rarely" or "never" contact the NWS in most severe weather situations.

Another significant difference is found when asking about the sources of weather information which best convey urgency about a tornado (Figure 4.3).

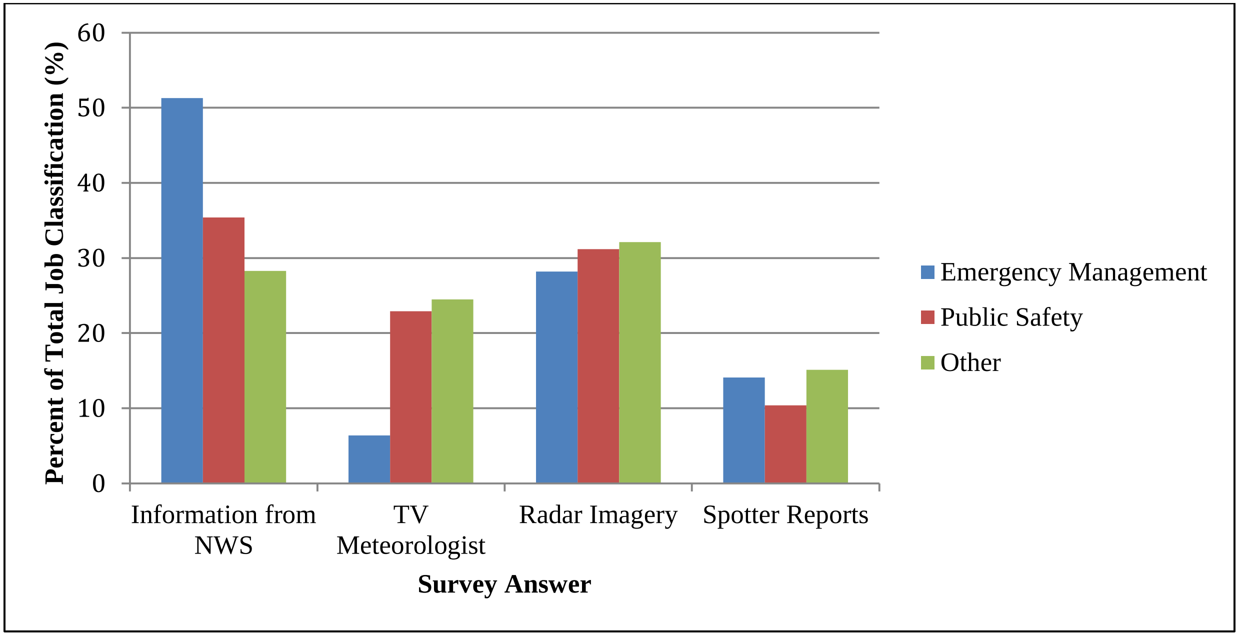

Figure 4.3: Source that Conveys Urgency Best by Job Classification

Again, the group that stands out from the others is the Emergency Management job classification. They rely on sources coming from the NWS, such as warning messages, phone calls, and multimedia briefings, more than do other sources. Specifically, Emergency Managers are able to discern the urgency of impending severe weather much more from the NWS than from the local broadcast meteorologist. That is not to say that the other job classes do not believe the NWS conveys urgency in its warnings, but the proportion of Emergency Managers is higher than the other job classes. It should be noted here that the statistics resulted in 6 degrees of freedom, suggesting a weak relationship, but this still provides a general picture of response based on job classification.

Finally, respondents were asked about their level of agreement with certain parameters within a tornado warning message. For example, "Given that *timing* about a tornado is critical, I am receiving exactly what I need to know about the *timing* of the storm from the NWS." Here, the variable *timing* is one of several variables including location, storm's history, duration of the storm, forecaster's confidence about the storm, and details about the hazard and its size. In this job classification analysis, two of these variables had significant differences in response based upon the EM's job: timing (Figure 4.4) and details about the hazard and its size (Figure 4.5).

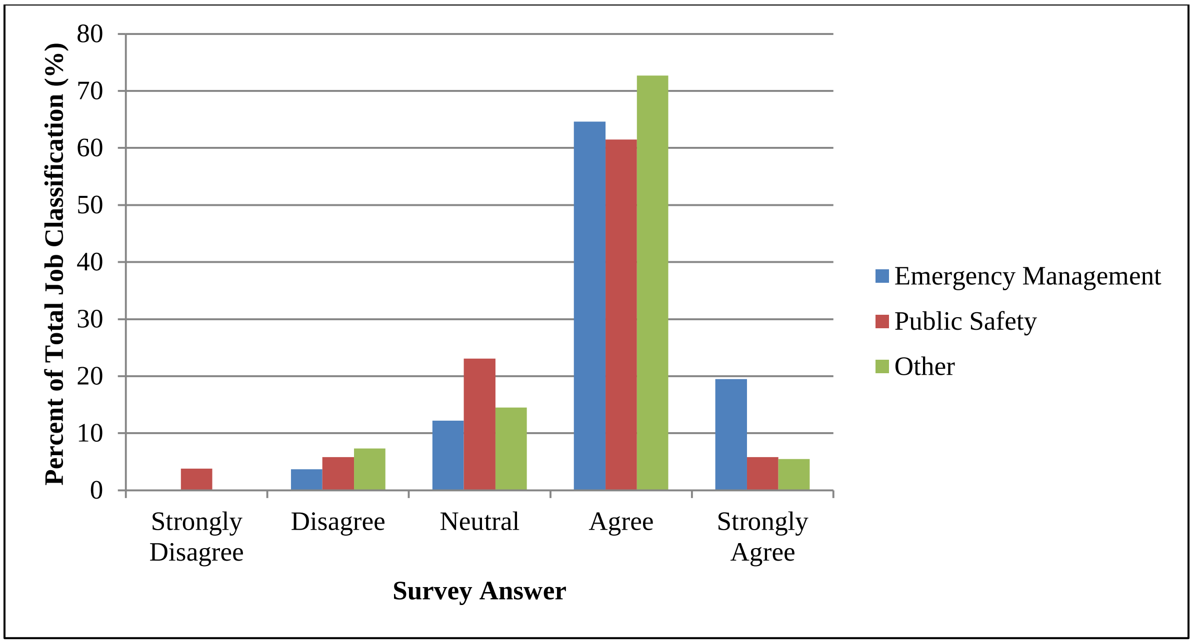

Figure 4.4: Receiving Sufficient Timing Information from the NWS by Job Classification

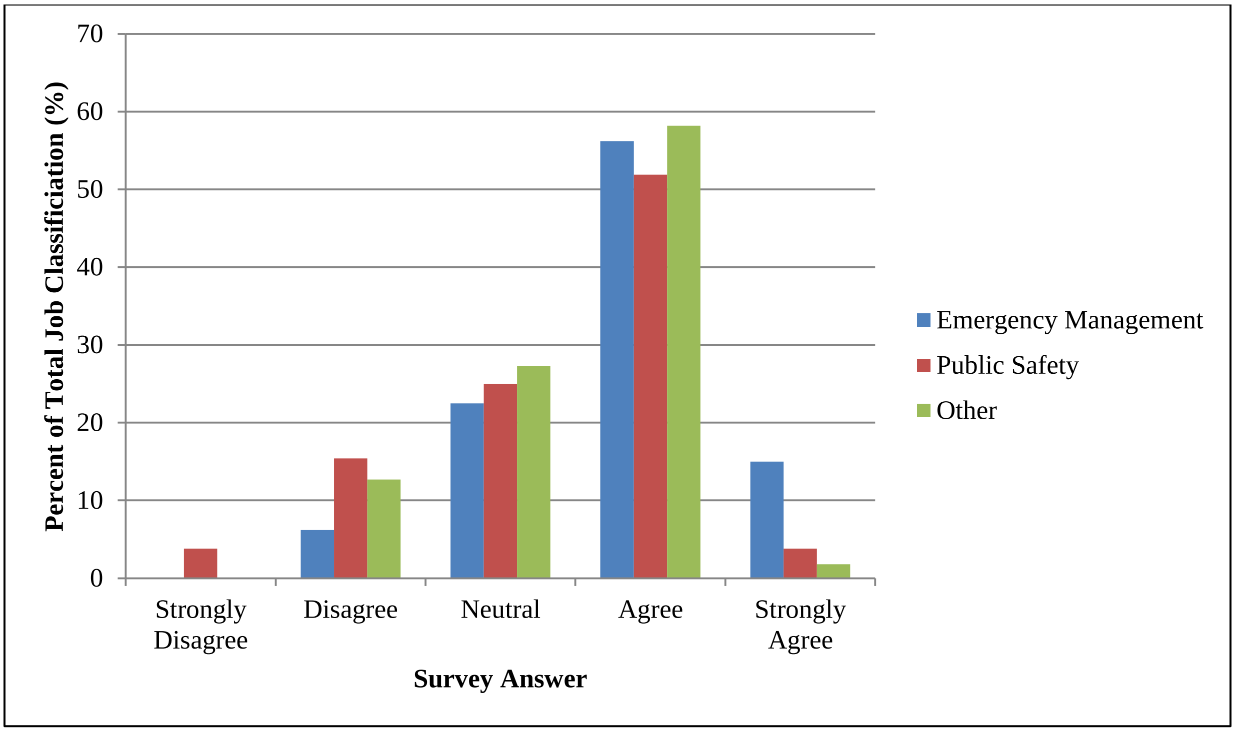

Figure 4.5: Receiving Sufficient Hazard Information from the NWS by Job Classification

Both figures show that differences in response are limited while still being statistically significant. Despite this, the emergency management job classification has more respondents strongly agreeing that they are receiving enough information from the NWS for both of these variables. Further, although it is a lower percentage, Public Safety respondents were the only job class to respond with "strongly disagree" that they were receiving enough information about both timing and hazard details.

*Age*

The second demographic question asks about the respondents' ages. This is important to know as age can influence risk perception as discussed in Chapter 2. Table 4.3 summarizes the age of the respondents into preset age categories.

Table 4.3: Ages of the Survey Respondents

| Age | Number of Respondents | Percent of Respondents (%) |
|---|---|---|
| Under 30 | 10 | 4.1 |
| 30-40 | 39 | 16.0 |
| 41-50 | 84 | 34.6 |
| 51-60 | 81 | 33.3 |
| Older than 60 | 29 | 11.9 |
| **Total** | **243** | **100%** |

Almost all respondents are in the 30-60 age range (89.9%) and only 4.1% are below 30 years of age. Again, regrouping was done in order to produce meaningful statistics. In this case, the "Under 30" category was combined with the "30-40" age group so that the age group with the lowest number of respondents does not make it seem like they responded differently to a higher degree than the other age groups.

In order to check whether or not certain WFO locations have significantly more EMs in certain age groups which would therefore affect results, graphs were created that show the distribution of the age groups (Figure 4.6).

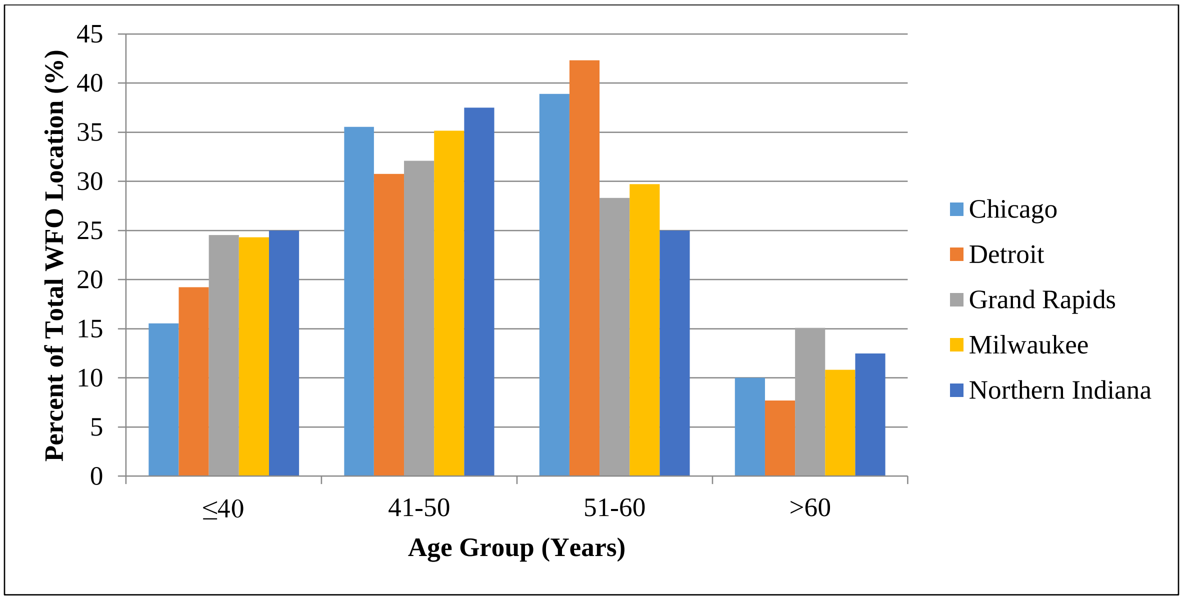

Figure 4.6: Distribution of Age Groups Across the WFO Locations

Here it is shown that the majority of the EMs surveyed are in the 41-50 and 51-60 years age groups. More importantly, however, the distribution of EMs' ages across WFO locations is relatively similar.

Table 4.4 summarizes the results of the differences found in respondents' answers based on their ages. Most of these results show no significant differences in response based on age; however, three questions were statistically significant.

Table 4.4: Differences in Decision-Making Based upon Age

| **Survey Question** | **Statistic Type** | **Result** | **Degrees of Freedom** | **Significance** |
|---|---|---|---|---|
| Receive_Warning | Chi Square | $\chi2=8.812$ | 6 | 0.184 |
| Effective_Urgency | ANOVA | F=0.553 | 4 | 0.697 |
| Warning_Usefulness | Chi Square | $\chi2=0.816$ | 3 | 0.846 |
| Most_Helpful | Chi Square | $\chi2=3.890$ | 3 | 0.274 |
| Radar_vs_Observed | Chi Square | $\chi2=2.175$ | 3 | 0.537 |
| Likelihood | ANOVA | F=0.921 | 4 | 0.452 |
| Tornado_Not_Occur | ANOVA | F=1.157 | 4 | 0.331 |
| Number_of_Warnings | Chi Square | $\chi2=1.681$ | 3 | 0.641 |
| Contact_with_NWS | ANOVA | F=1.310 | 4 | 0.267 |
| Conveys_Urgency | Chi Square | $\chi2=21.048$ | 9 | 0.012* |
| Timing | ANOVA | F=0.320 | 4 | 0.864 |
| Location | ANOVA | F=0.559 | 4 | 0.693 |
| History | ANOVA | F=1.071 | 4 | 0.371 |
| Duration | ANOVA | F=2.070 | 4 | 0.086 |
| Forecaster_Confidence | ANOVA | F=2.900 | 4 | 0.023* |
| Hazard | ANOVA | F=0.441 | 4 | 0.779 |
| Size_or_Impact | Chi Square | $\chi2=1.723$ | 3 | 0.632 |
| Pathcast | ANOVA | F=0.282 | 4 | 0.889 |
| Lowest_Confidence | ANOVA | F=1.435 | 4 | 0.223 |
| Tstorm_Watches | ANOVA | F=1.587 | 4 | 0.178 |
| Tstorm_Warnings | ANOVA | F=0.724 | 4 | 0.576 |
| Two_Warnings | Chi Square | $\chi2=14.255$ | 3 | 0.003* |

*Significant at the 0.05 level

First, differences were found with the survey question that asks about the sources of weather information that best convey urgency (Figure 4.7).

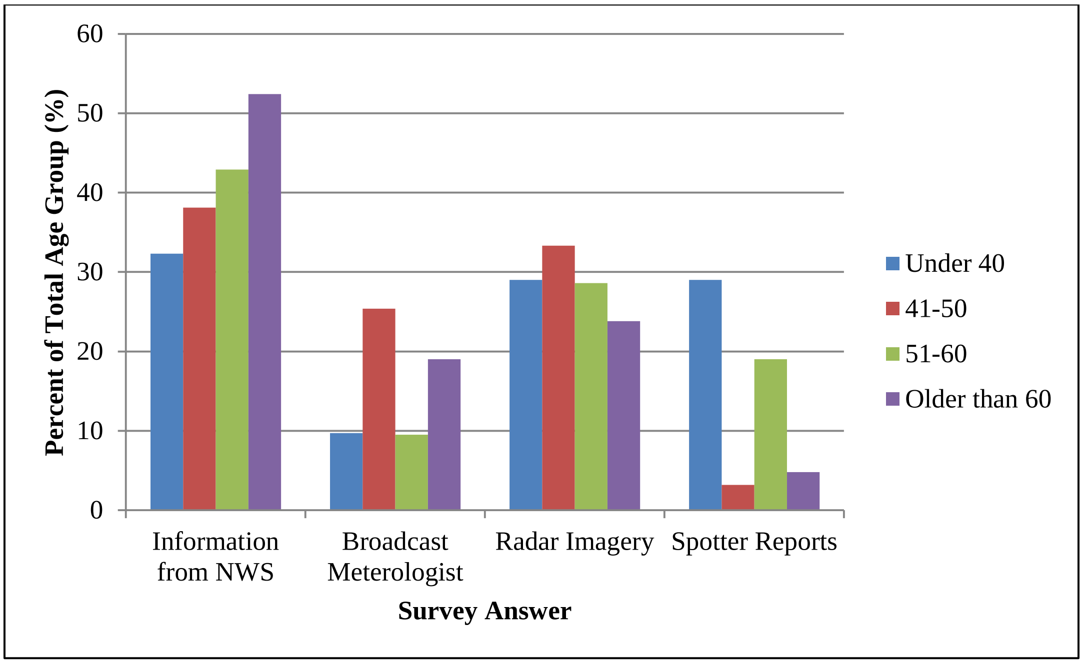

Figure 4.7: Source that Conveys Urgency Best by Age Group

Just as with job classification, information coming from the NWS is again shown to be the best source for conveying urgency for all age groups. However, variations in responses exist with the other survey answers. Interestingly, EMs under 40 years of age have a more uniform distribution of responses as compared to the EMs older than 60 years of age, over half of whom turn to the NWS when looking to determine urgency in a severe weather event as compared to only 4.8% who look for ground confirmation coming from spotter reports. Here again, it is important to point out that the statistics produced 9 degrees of freedom.

Whether or not the EMs are receiving exactly what they need to know about the forecaster’s confidence in the storm is another survey question where significant differences are found (Figure 4.8).

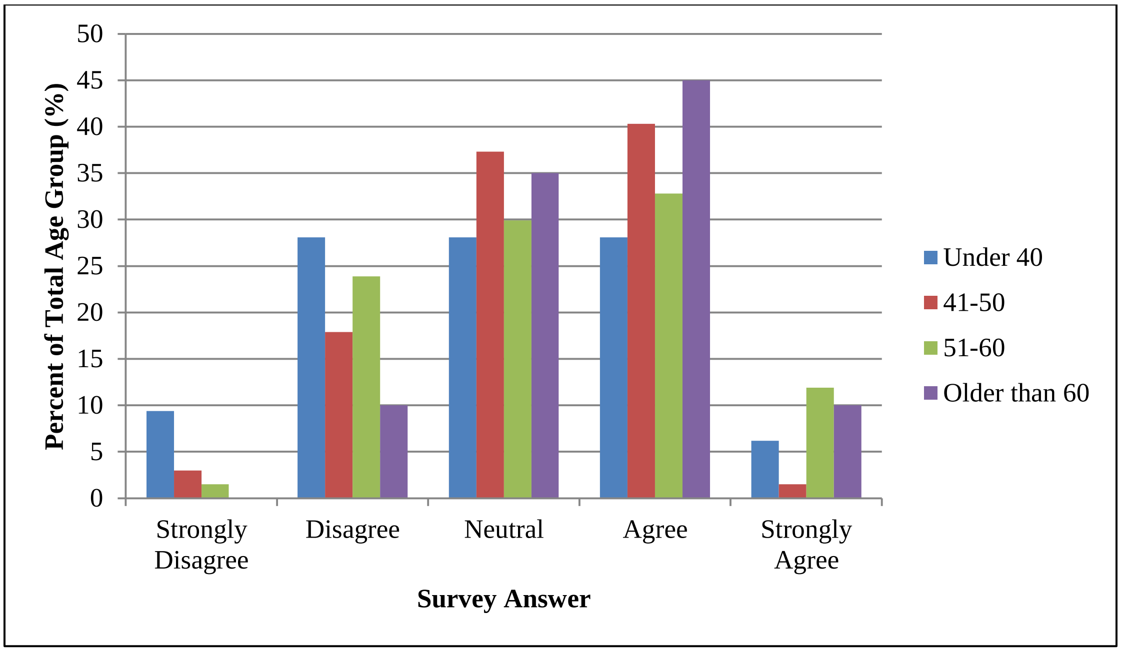

Figure 4.8: Receiving Sufficient Confidence Information from the NWS by Age Group

Although most EMs are neutral or agreeing that they do receive exactly what they need, the extreme answers of "strongly disagree" and "strongly agree" perhaps show why this survey question is statistically significant. There are more EMs under 40 years of age who feel as though they are really not receiving enough information about the forecaster's confidence than the other age groups. Further, the two older EM groups agreed that they are receiving exactly what they need about the forecaster's confidence compared to the younger two age groups. So in general, the older the EM, the more satisfied they are with the message given by the NWS relating to the forecaster's confidence.

Another significant difference comes from the survey question asking whether or not the EMs think that there should be two warnings: one for the EM, and one for the general public (Figure 4.9). Interestingly, the younger EMs seem to prefer two warnings more than those in the older age groups. In fact, 78.1% of the EMs under 40 years of age prefer to have two warnings, whereas only 38.2% of the EMs 51-60 years of age prefer two warnings.

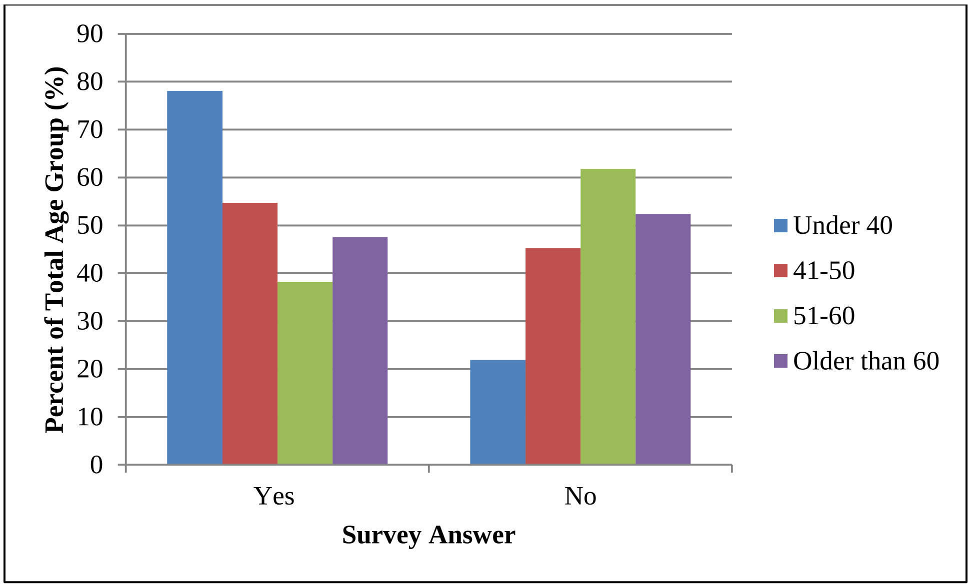

Figure 4.9: Preference for Two Warnings by Age Group

*Tenure*

Next, the survey asks about the length of time the respondents have been in their current position, because experience is also a critical element known to influence EMs, as outlined in Chapter 2. Table 4.5 summarizes the duration of current job experience held by the respondents of this survey. The distribution of the duration of tenure is relatively uniform with the exception of the respondents who have been on the job for less than a year, which is a much lower percentage of the survey population at only 3.7%. For this reason, all EMs with less than or equal to 5 years of experience are grouped together in statistical analyses to produce meaningful results.

Table 4.5: Duration of Tenure in Current Position of Survey Respondents

| **Length of Time** | **Number of Respondents** | **Percent of Respondents (%)** |
|---|---|---|
| Less than a Year | 9 | 3.7 |
| 1-5 Years | 75 | 31.1 |
| 6-10 Years | 62 | 25.7 |
| 11-20 Years | 53 | 22 |
| More than 20 Years | 42 | 17.4 |
| **Total** | **241** | **100%** |

The distribution of the tenure groups across WFO locations is also graphed in order to determine if there are geographic differences in tenure (Figure 4.10). The distribution of tenure groups is relatively uniform across WFO locations. Most EMs have had less than 5 years of experience on the job, regardless of the location. Northern Indiana is an exception with a slight majority of their EMs having 6-10 years of experience on the job. In general, however, the distribution of tenure groups is relatively uniform.

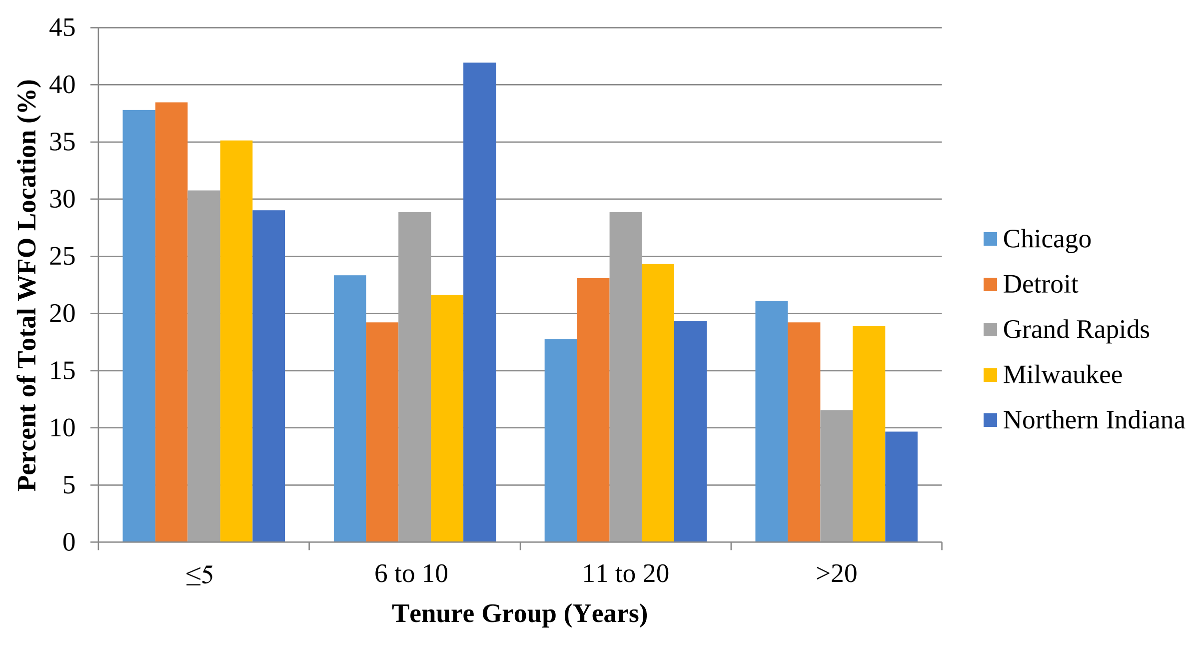

Figure 4.10: Distribution of Tenure Groups Across WFO Locations

The differences in how EMs answer the survey questions based upon their length of time on the job is shown in Table 4.6. Only three of the survey questions had responses with statistically significant differences between EMs of different length of tenure.

Table 4.6: Differences in Decision-Making Based upon Tenure

| Survey Question | Statistic Type | Result | Degrees of Freedom | Significance |
|---|---|---|---|---|
| Receive_Warning | Chi Square | $\chi 2=2.880$ | 9 | 0.969 |
| Effective_Urgency | ANOVA | F=2.182 | 3 | 0.092 |
| Warning_Usefulness | Chi Square | $\chi 2=14.800$ | 6 | 0.022* |
| Most_Helpful | Chi Square | $\chi 2=6.265$ | 3 | 0.099 |
| Radar_vs_Observed | Chi Square | $\chi 2=2.391$ | 3 | 0.498 |
| Likelihood | ANOVA | F=0.484 | 3 | 0.694 |
| Tornado_Not_Occur | ANOVA | F=1.070 | 3 | 0.363 |
| Number_of_Warnings | Chi Square | $\chi 2=3.439$ | 3 | 0.329 |
| Contact_with_NWS | ANOVA | F=1.046 | 3 | 0.374 |
| Conveys_Urgency | Chi Square | $\chi 2=14.696$ | 9 | 0.100 |
| Timing | ANOVA | F=1.020 | 3 | 0.385 |
| Location | ANOVA | F=1.179 | 3 | 0.319 |
| History | ANOVA | F=1.784 | 3 | 0.152 |
| Duration | ANOVA | F=0.313 | 3 | 0.816 |
| Forecaster_Confidence | ANOVA | F=1.809 | 3 | 0.147 |
| Hazard | ANOVA | F=2.748 | 3 | 0.044* |
| Size_or_Impact | Chi Square | $\chi 2=0.437$ | 3 | 0.933 |
| Pathcast | ANOVA | F=0.749 | 3 | 0.524 |
| Lowest_Confidence | ANOVA | F=2.793 | 3 | 0.042* |
| Tstorm_Watches | ANOVA | F=0.772 | 3 | 0.511 |
| Tstorm_Warnings | ANOVA | F=0.114 | 3 | 0.952 |
| Two_Warnings | Chi Square | $\chi 2=5.555$ | 3 | 0.135 |

*Significant at the 0.05 level

The first of these asks how useful a NWS warning message is when making an operational decision (Figure 4.11). Most EMs for any tenure group believe that a NWS warning message tells them “much of what they need to know, but not everything.” While there is not much difference in responses beyond that, it seems that the longer the tenure, the more the EM believes that the warning messages tell them exactly what they need to know.

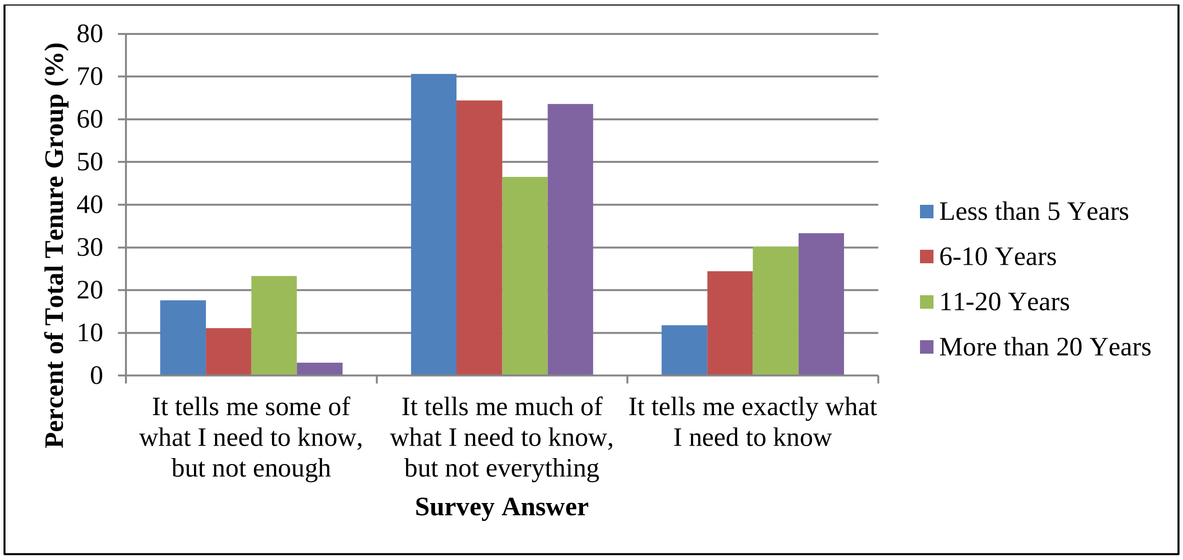

Figure 4.11: Warning Usefulness by Tenure Group

The second survey question that resulted in significant differences in response is with regard to details on the hazard of the storm and its size and if the NWS is giving enough information on these characteristics (Figure 4.12). Differences here are very slight, yet still result in a 0.044 ANOVA significance value. Although very general, it seems as though EMs with longer tenure believe they are receiving exactly what they need from the NWS about the hazard and its size.

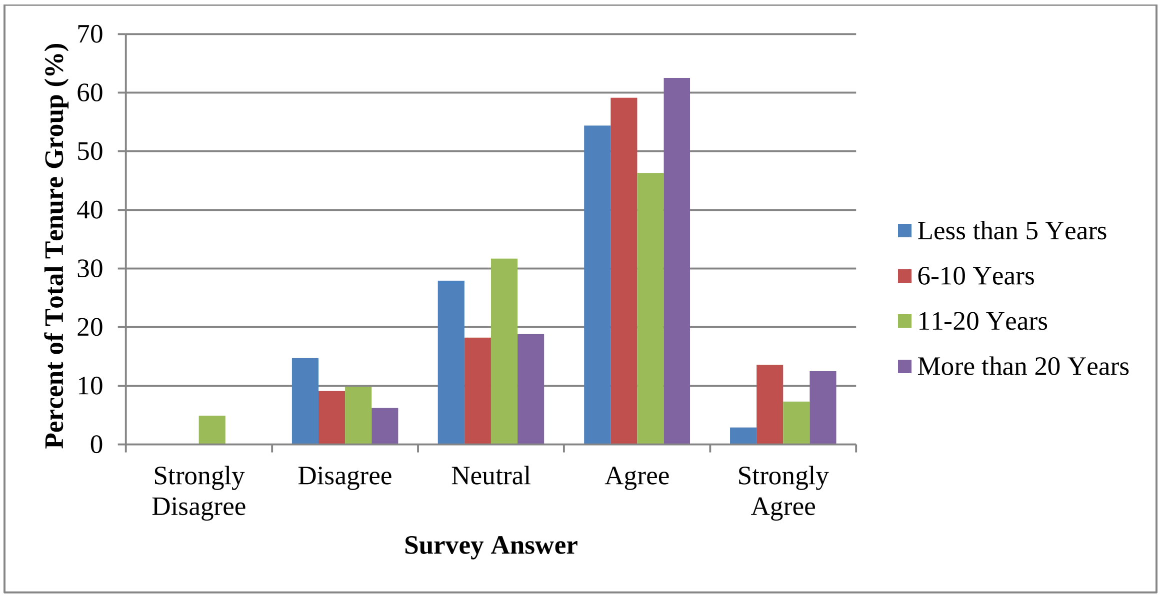

Figure 4.12: Receiving Sufficient Hazard Information from the NWS by Tenure Group

The third survey question with significant differences in response is one regarding the lowest level of forecaster confidence at which the EM would like to see a forecasted tornado track (“pathcast”) issued (Figure 4.13). While it is ideal to have 100% confidence, these EMs know that that is not possible and it is seen here. Interestingly, 33.8% of the EMs with 5 years or less experience wanted 50-60% forecaster confidence, whereas 36.4% of the EMs with more than 20 years of experience responded saying that any level of forecaster confidence is acceptable when issuing a forecasted tornado track. This suggests that EMs with more experience are comfortable with less forecaster confidence.

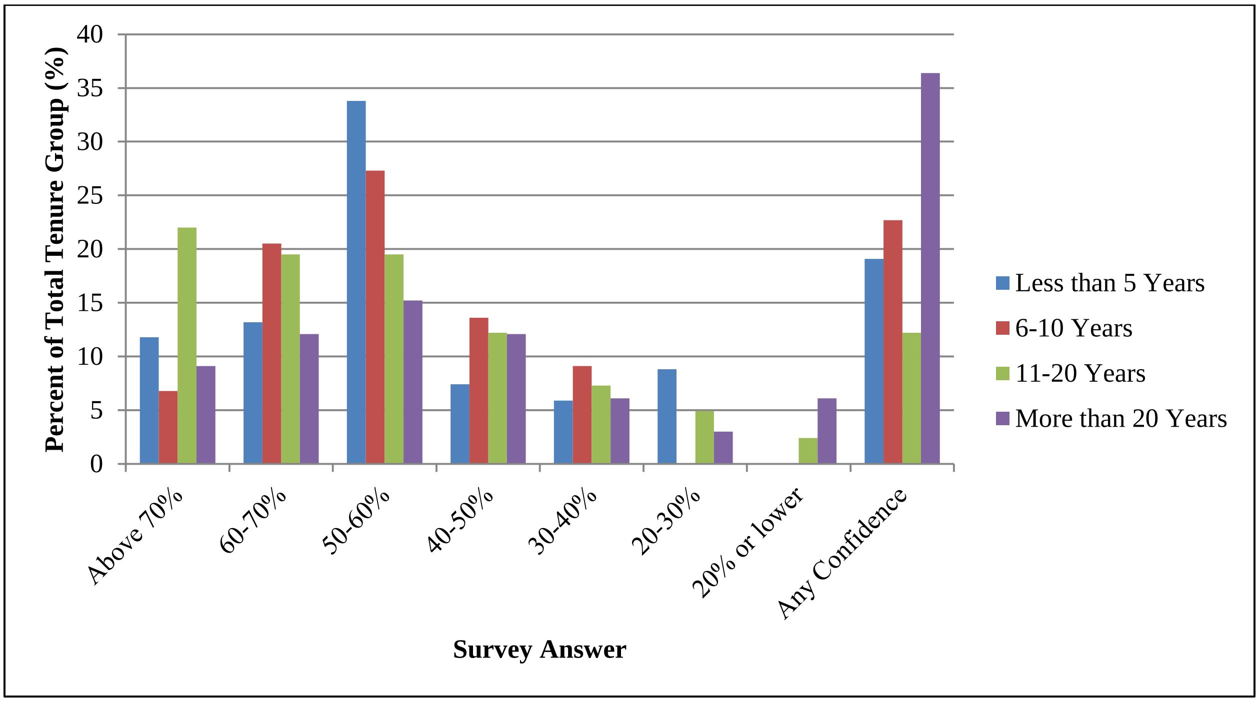

Figure 4.13: Confidence Level for Pathcast by Tenure Group

## *Background Variables*

### *Population*

As was outlined in Chapter 3, population and population densities for each WFO were calculated as they give an indication of potential vulnerability should a tornado form. Table 4.7 summarizes the population densities for each WFO location.

Table 4.7: Population Densities by WFO Location

| WFO Location | Population | Area (sq. mi.) | Population Density |
|---|---|---|---|
| Chicago | 10052614 | 14067.68 | 714.59 |
| Detriot | 5912922 | 11421.03 | 517.72 |
| Grand Rapids | 2748771 | 14054.06 | 195.59 |
| Milwaukee | 3288588 | 11574.27 | 284.13 |
| Northern Indiana | 2343404 | 15844.38 | 147.9 |

The major metropolitan city of Chicago provides the Chicago WFO with a very large population of over 10 million people, while the other WFO locations are significantly less populated, ranging from 2-6 million people. The areas of each WFO are relatively similar, ranging from 11,000 to almost 16,000 sq. mi., meaning that population densities reflect the populations of the WFOs. Chicago and Detroit WFO locations have the two largest population densities (714.59 and 517.72, respectively) while Grand Rapids, Milwaukee, and Northern Indiana have significantly lower population densities, showcasing the more rural characteristics of those locations.

### *Tornado Experience and False Alarm Rate*

Another factor that can influence EM decision-making is prior experience with tornadoes and tornado warnings as discussed in Chapter 2. Figure 4.14 shows the number of historical tornadoes with warnings ($T_w$), tornadoes with no warnings ($T_{nw}$), warnings with no tornadoes ($W_{nt}$), and the total number of warnings per WFO location.

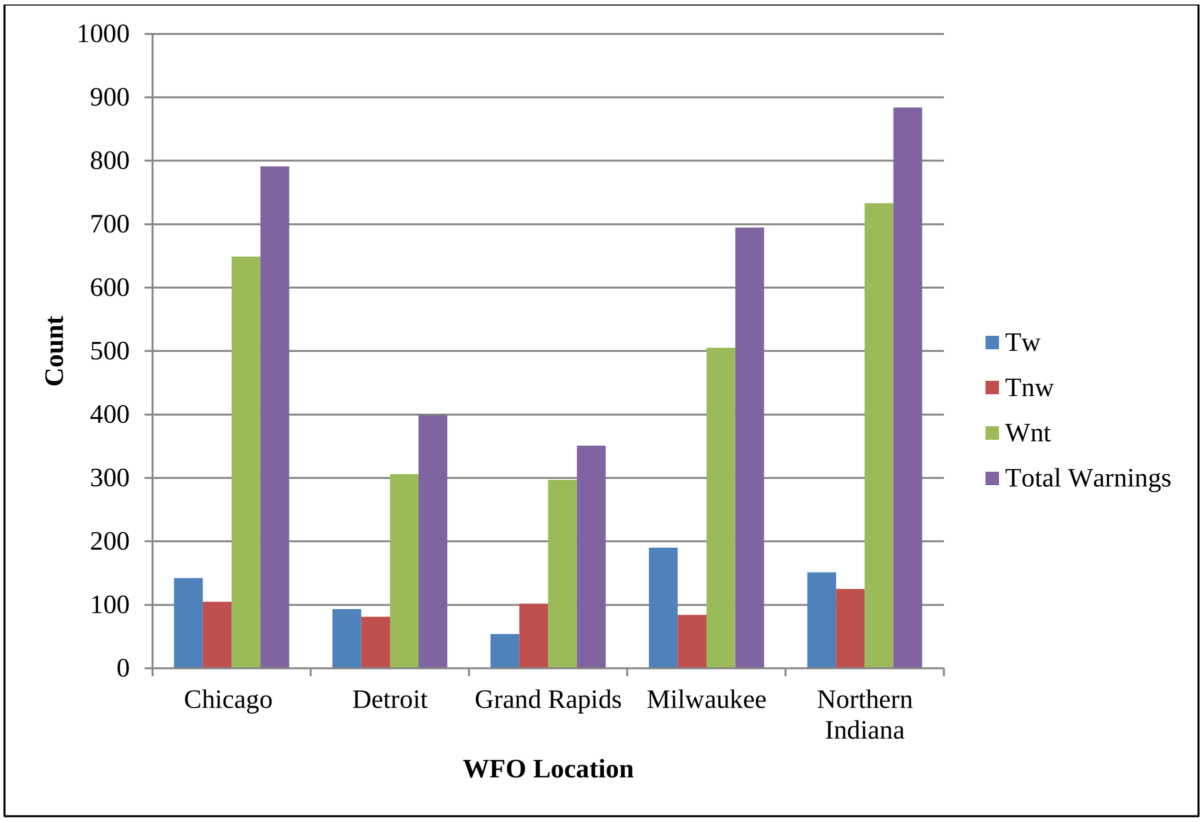

Figure 4.14: Tornado and Warning Experience by WFO Location

The two WFOs in Michigan (Detroit and Grand Rapids) have significantly lower tornadoes and warnings as compared to the other WFO locations. This could be due to the fact that these locations are positioned on the east side of Lake Michigan, which is the leeward side of the atmospheric synoptic flow generally associated with tornadic activity (Suckling and Ashley 2006). The general lack of tornadic activity on the leeward side of Lake Michigan can be seen in Figure 4.15.

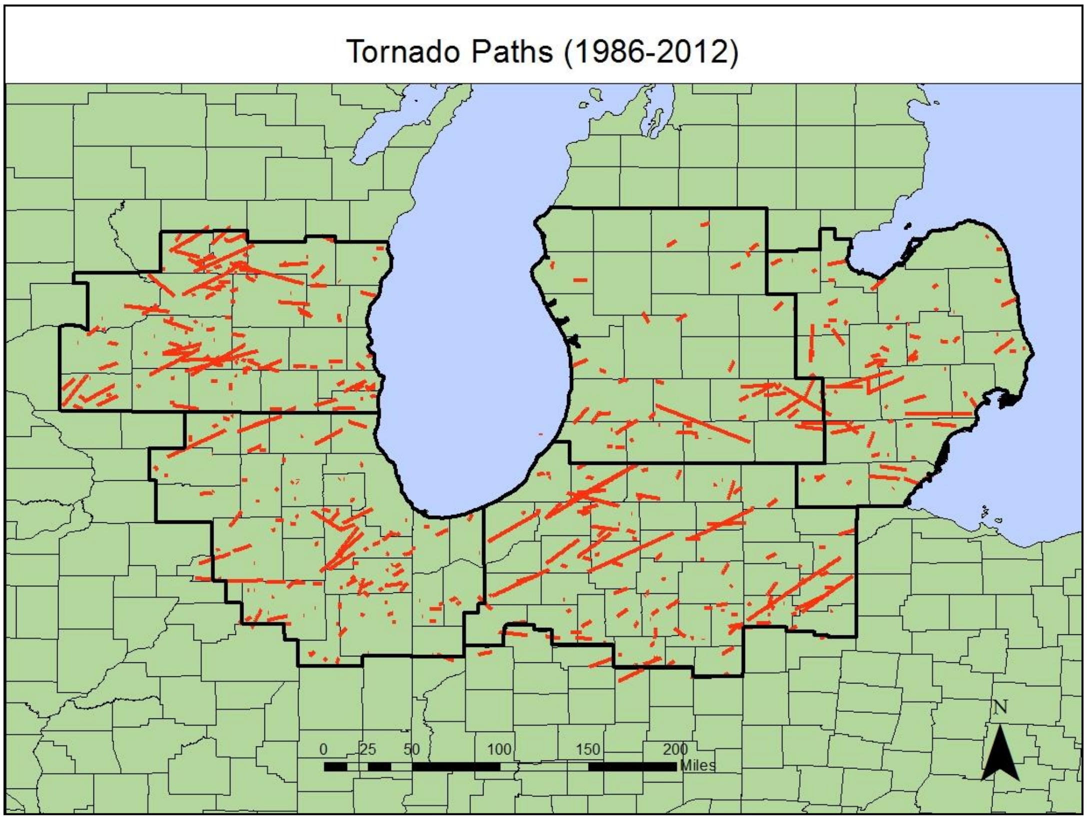

Figure 4.15: Tornado Activity within the Five WFO Locations

Since data on the total number of warnings as well as the number of unverified warnings is known, a simple ratio (outlined in Chapter 3) can produce the false alarm rate (FAR) for each WFO location (Figure 4.16). The scale on Figure 4.16 should be noted, however, as it goes from 68% FAR to 85% FAR; therefore, differences between the WFOs are magnified. Milwaukee is the WFO with the lowest FAR at 74%, while Grand Rapids has the highest at 85%. Interestingly, Milwaukee has relatively high tornado experience (as seen in Figure 4.14) and Grand Rapids has relatively low tornado experience, providing an inverse relationship of FAR and tornado experience between those two WFO locations. However, as mentioned previously, there is only an 11% difference in FAR between the two WFOs with the extreme FAR values, so in general, FAR is relatively uniform throughout the entire study area. This needs to be remembered when examining the FAR analysis results.

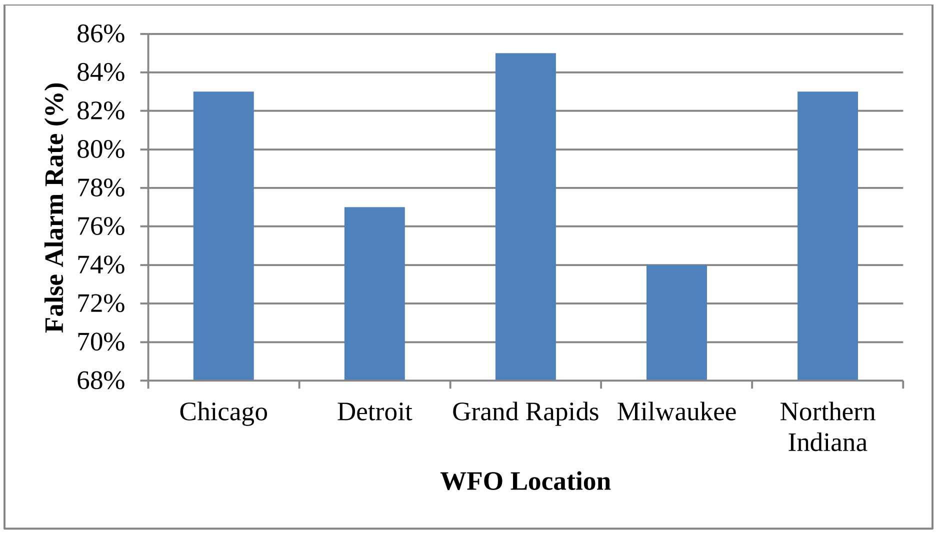

Figure 4.16: False Alarm Rate at Each WFO Location

### *Geographic Differences in Decision-Making*

The main goal of this study is to determine whether or not there are differences in how EMs make decisions based upon their geographic location. Therefore, several different analyses are conducted to test this last variable. The following sections address the three research questions. Further, each research question is analyzed in two different ways as outlined in Chapter 3: first, by evaluating each WFO against the others; and second, by grouping the WFOs based upon the results of the background variables in order to have a metro vs. non-metro analysis, a tornado experience analysis, and a false alarm rate analysis (refer to Table 3.5).

#### *Addressing Research Question 1: The Influence of Past Tornadic Activity*

The first research question explores whether or not the amount of past tornadic activity influences the way EMs make decisions during severe weather. Since data on past tornado activity was found for each WFO location, the three survey questions with regard to past tornadic activity are considered (see Table 3.4). These three questions ask about the likelihood of a tornado impacting the immediate area if a tornado warning is issued for that area, whether or not an unverified warning would influence the EM the next time a tornado warning is issued, and their opinions on the number of warnings issued based on past tornado occurrences. Table 4.8 summarizes the results of these three survey questions when each WFO is evaluated against the others. It can be seen here that regardless of respondent's WFO location, past tornado occurrences do not affect response to the survey questions as none are statistically significant.

Table 4.8: Differences in Decision-Making: Past Tornado Occurrences by WFO

| Survey Question | Statistic Type | Result | Degrees of Freedom | Significance |
|---|---|---|---|---|
| Likelihood | ANOVA | F=0.082 | 4 | 0.988 |
| Tornado_Not_Occur | ANOVA | F=1.033 | 4 | 0.392 |
| Number_of_Warnings | Chi Square | $\chi2$=3.138 | 4 | 0.535 |

Next, the analyses with the background variables are examined. Again, WFOs were grouped together based upon the results of the background variables to produce a metro vs. non-metro analysis, followed by a tornado experience analysis, and ending with a false alarm rate analysis (Table 4.9). Here we can see that a WFO's level of urbanization, past tornado experiences, and FAR do not affect survey responses since none of the analyses produce statistically significant results.

Table 4.9: Differences in Decision-Making: Past Tornado Occurrences and Background Variables

| Analysis | Survey Question | Statistic Type | Result | Significance |
|---|---|---|---|---|
| Urbanization | Likelihood | T-Test | t = -0.238 | 0.812 |
| | Tornado_Not_Occur | T-Test | t = 0.609 | 0.543 |
| | Number_of_Warnings | T-Test | t = -1.195 | 0.233 |
| Tornado Experience | Likelihood | T-Test | t = -0.433 | 0.666 |
| | Tornado_Not_Occur | T-Test | t = -0.354 | 0.724 |
| | Number_of_Warnings | T-Test | t = -0.239 | 0.812 |
| FAR | Likelihood | T-Test | t = -0.507 | 0.612 |
| | Tornado_Not_Occur | T-Test | t = 1.095 | 0.274 |
| | Number_of_Warnings | T-Test | t = 0.399 | 0.691 |

*Addressing Research Question 2: Priorities of Warning Elements*

The second research question explores whether or not there are differences in the priorities of the information provided in warning messages among EMs of different locations. Some of the survey questions used to answer this question ask about the lowest level of forecaster confidence the EM would like to see, what is the most helpful data to have in a warning message, and which elements best convey urgency about a tornado, among others. First, evaluation of each WFO against each other was undertaken (Table 4.10). Of these seven survey questions, only one shows significant differences in survey response.

Table 4.10: Differences in Decision-Making: Priorities and WFO Location

| **Survey Question** | **Statistic Type** | **Result** | **Degrees of Freedom** | **Significance** |
|---|---|---|---|---|
| Receive_Warning | Chi Square | $\chi2=23.957$ | 8 | 0.002* |
| Most_Helpful | Chi Square | $\chi2=2.106$ | 4 | 0.716 |
| Radar_vs_Observed | Chi Square | $\chi2=2.128$ | 4 | 0.712 |
| Conveys_Urgency | Chi Square | $\chi2=20.779$ | 12 | 0.054 |
| Size_or_Impact | Chi Square | $\chi2=3.487$ | 4 | 0.48 |
| Pathcast | ANOVA | F=1.791 | 4 | 0.132 |
| Lowest_Confidence | ANOVA | F=0.484 | 4 | 0.748 |

*Significant at the 0.05 level

This survey question asks for the reason as to why EMs need to receive a weather warning (Figure 4.17). In every WFO location, over 30% of respondents chose “initiate safety actions,” showing the importance of the EM’s task to initiate standard operating practices and deploying resources during severe weather. Beyond that, however, variations in response are present. Chicago and Detroit stand out from the other WFOs as both locations have a more uniform distribution of survey responses, specifically EMs stated they need warnings in order to activate sirens more in these locations than did EMs in the other three WFOs.

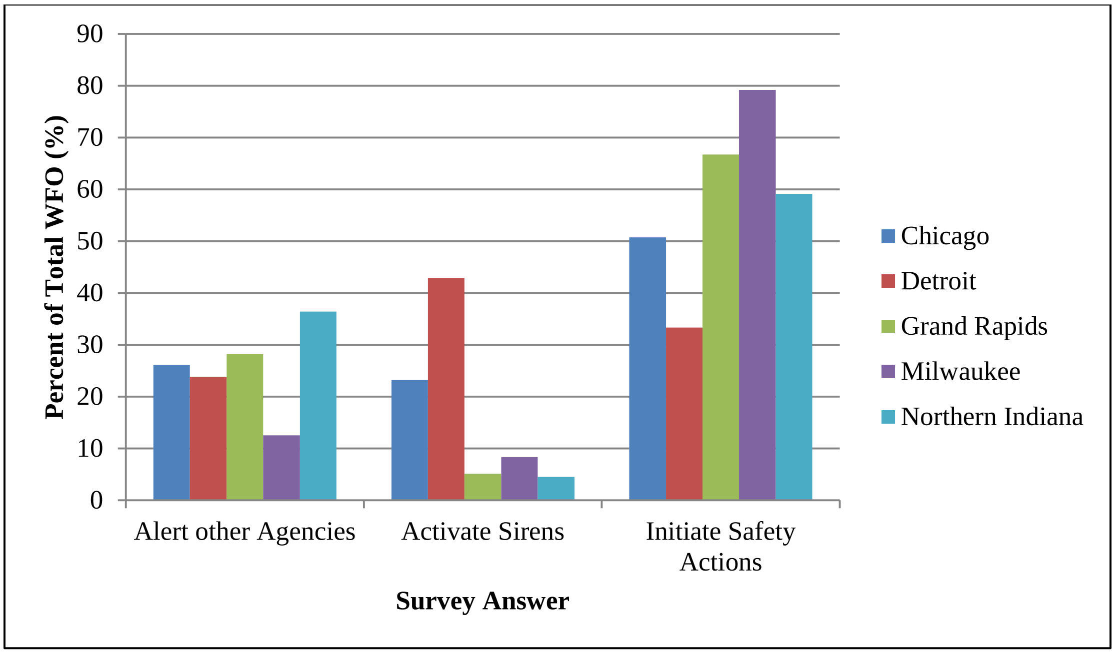

Figure 4.17: Reasons for Receiving a Weather Warning by WFO Location

As far as differences in response based upon grouping WFOs on their background variables, the same results as the first research question are found (Table 4.11). All three of the WFO groupings based upon the background variables show no statistically significant differences in the responses to the survey questions. As might be expected, however, the responses to the “Receive_Warning” question based upon urbanization is close to being significant (at 0.075) due to Chicago and Detroit (the two “metro” WFOs) responding similarly to the survey question as shown previously in Figure 4.17.

Table 4.11: Difference in Decision-Making: Priorities and Background Variables

| Analysis | Survey Question | Statistic Type | Result | Significance |
|---|---|---|---|---|
| Urbanization | Receive_Warning | T-Test | t = -1.789 | 0.075 |
| | Most_Helpful | T-Test | t = 0.453 | 0.651 |
| | Radar_vs_Observed | T-Test | t = 1.627 | 0.105 |
| | Conveys_Urgency | T-Test | t = -0.518 | 0.605 |
| | Size_or_Impact | T-Test | t = 1.703 | 0.090 |
| | Pathcast | T-Test | t = 0.740 | 0.460 |
| | Lowest_Confidence | T-Test | t = -0.745 | 0.457 |
| Tornado Experience | Receive_Warning | T-Test | t = 0.478 | 0.633 |
| | Most_Helpful | T-Test | t = -0.880 | 0.380 |
| | Radar_vs_Observed | T-Test | t = 0.010 | 0.992 |
| | Conveys_Urgency | T-Test | t = 1.590 | 0.113 |
| | Size_or_Impact | T-Test | t = 0.667 | 0.506 |
| | Pathcast | T-Test | t = -1.791 | 0.075 |
| | Lowest_Confidence | T-Test | t = 0.340 | 0.735 |
| FAR | Receive_Warning | T-Test | t = -0.552 | 0.582 |
| | Most_Helpful | T-Test | t = -0.368 | 0.713 |
| | Radar_vs_Observed | T-Test | t = 0.129 | 0.897 |
| | Conveys_Urgency | T-Test | t = 1.513 | 0.132 |
| | Size_or_Impact | T-Test | t = 1.521 | 0.130 |
| | Pathcast | T-Test | t = 1.132 | 0.259 |
| | Lowest_Confidence | T-Test | t = 0.727 | 0.468 |

### *Addressing Research Question 3: Effectiveness of Warning Messages*

The final research question investigates whether or not there are differences in EM's perceptions of warning effectiveness across the surveyed locations. The survey questions used to address this question ask about the usefulness of a warning when making an operational decision, whether or not severe thunderstorm watches and warnings should be eliminated, and whether or not EMs should have their own warning in addition to public warnings, among others. Table 4.12 shows the differences in survey responses based upon WFO location. Again, hardly any significant differences in response are found based upon geographic location. Two exceptions are found however.

Table 4.12: Differences in Decision-Making: Warning Effectiveness and WFO Location

| **Survey Question** | **Statistic Type** | **Result** | **Degrees of Freedom** | **Significance** |
|---|---|---|---|---|
| Effective_Urgency | ANOVA | F=1.257 | 4 | 0.289 |
| Warning_Usefulness | Chi Square | χ2=8.132 | 4 | 0.087 |
| Contact_with_NWS | ANOVA | F=3.520 | 4 | 0.009* |
| Timing | ANOVA | F=1.166 | 4 | 0.328 |
| Location | ANOVA | F=1.395 | 4 | 0.237 |
| History | ANOVA | F=1.216 | 4 | 0.306 |
| Duration | ANOVA | F=2.589 | 4 | 0.038* |
| Forecaster Confidence | ANOVA | F=0.119 | 4 | 0.975 |
| Hazard | ANOVA | F=0.258 | 4 | 0.904 |
| Tstorm_Watches | ANOVA | F=0.525 | 4 | 0.717 |
| Tstorm_Warnings | ANOVA | F=0.495 | 4 | 0.739 |
| Two_Warnings | Chi Square | χ2=3.061 | 4 | 0.548 |

*Significant at the 0.05 level

First, the survey question asking how often EMs are in contact with their local NWS office during a severe weather event is examined (Figure 4.18).

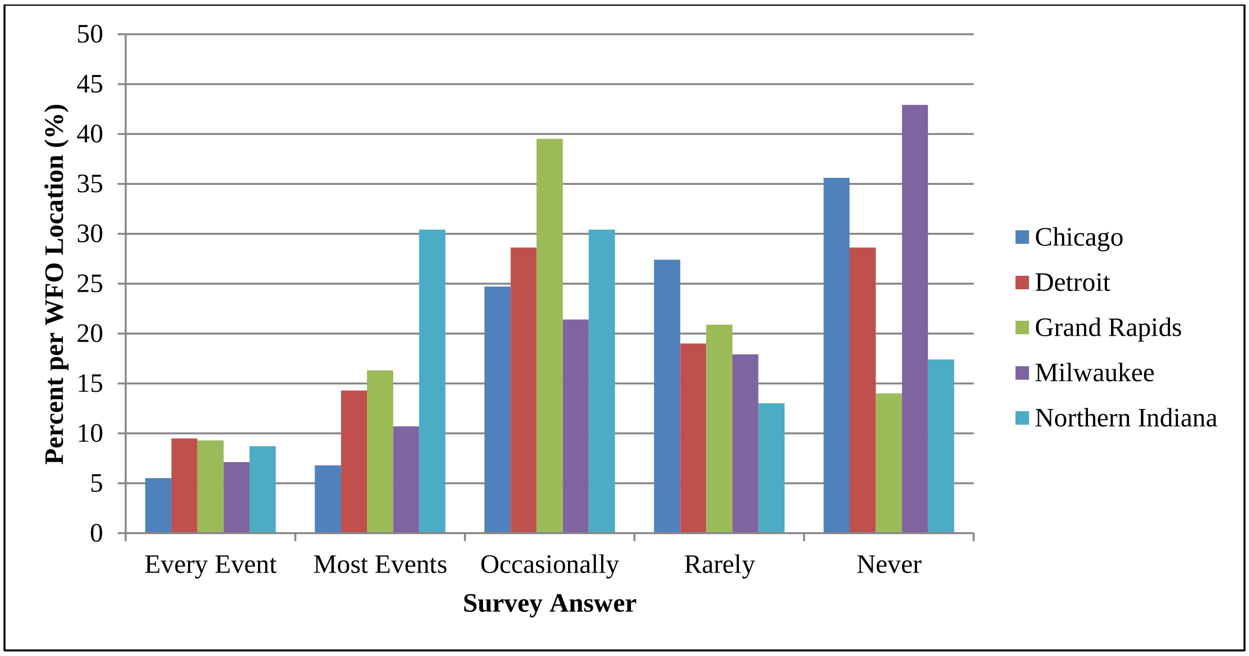

Figure 4.18: Frequency of NWS Contact by WFO Location

Responses from EMs in Grand Rapids and Northern Indiana appear similar in nature. Additionally, responses from Chicago, Detroit, and Milwaukee have a similar pattern. Those in

Grand Rapids and Northern Indiana seem to have more contact with their local NWS office as compared to those in Chicago, Detroit, and Milwaukee. Possible reasoning for this is discussed later.

The other survey question with significant differences in response asks the extent to which the EM is receiving sufficient information from the NWS about a storm's duration (Figure 4.19). The WFO that responded in a much different way from the others is Northern Indiana. There were no EMs from the location who strongly agreed that they were receiving exactly what they needed with regard to storm duration information. Further, 36.4% of Northern Indiana EMs responded that they "disagree" that they were receiving exactly what they needed, more than double any of the other WFO locations.

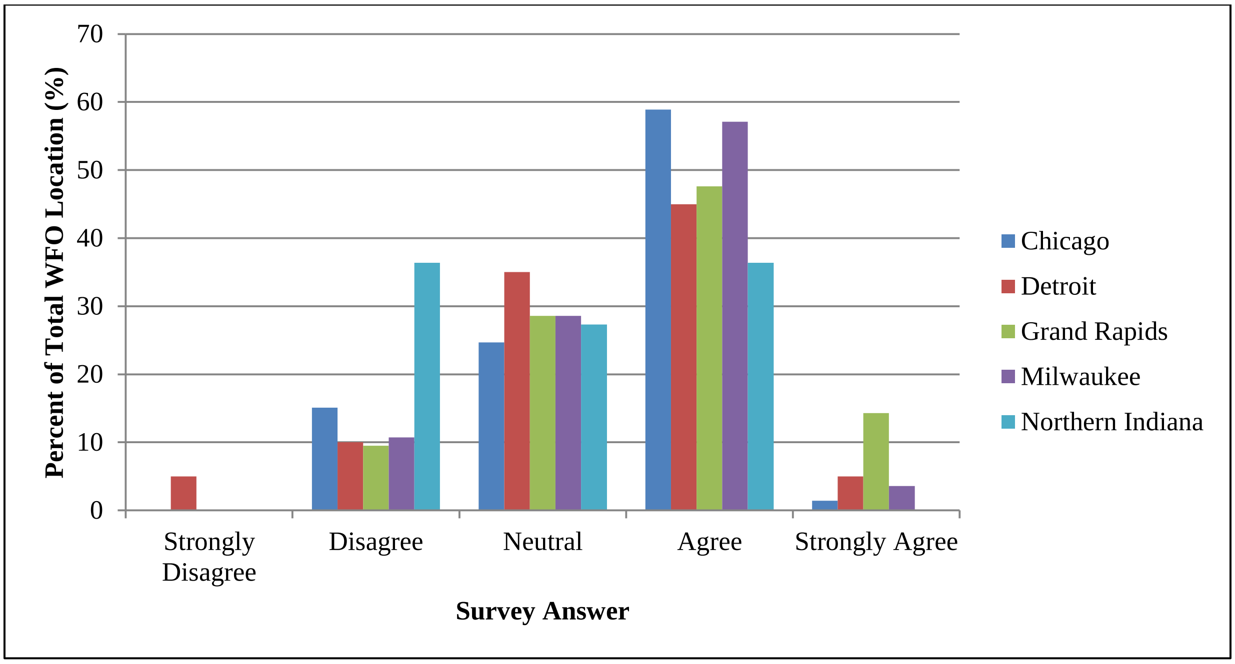

Figure 4.19: Receiving Sufficient Duration Information from the NWS by WFO Location

The results of the differences in responses to warning effectiveness based upon the three background variable are considered next (Table 4.13). Again, results show very few differences between WFO groupings based upon each of the background variables, with the exception of five of the survey questions.

Table 4.13: Differences in Decision-Making: Warning Effectiveness and Background Variables

| Analysis | Survey Question | Statistic Type | Result | Significance |
|---|---|---|---|---|
| Urbanization | Effective_Urgency | T-Test | t = -1.410 | 0.160 |
| | Warning_Usefulness | T-Test | t = -2.717 | 0.007* |
| | Contact_with_NWS | T-Test | t = 2.661 | 0.008* |
| | Timing | T-Test | t = -0.257 | 0.798 |
| | Location | T-Test | t = -1.992 | 0.048* |
| | History | T-Test | t = -0.499 | 0.618 |
| | Duration | T-Test | t = -0.554 | 0.580 |
| | Forecaster Confidence | T-Test | t = -0.870 | 0.385 |
| | Hazard | T-Test | t = -1.212 | 0.227 |
| | Tstorm_Watches | T-Test | t = 0.985 | 0.326 |
| | Tstorm_Warnings | T-Test | t = 0.834 | 0.405 |
| | Two_Warnings | T-Test | t = -0.280 | 0.780 |
| Tornado Experience | Effective_Urgency | T-Test | t = -0.454 | 0.650 |
| | Warning_Usefulness | T-Test | t = -1.029 | 0.305 |
| | Contact_with_NWS | T-Test | t = 2.018 | 0.045* |
| | Timing | T-Test | t = -0.806 | 0.421 |
| | Location | T-Test | t = -0.970 | 0.333 |
| | History | T-Test | t = 1.567 | 0.119 |
| | Duration | T-Test | t = -1.315 | 0.190 |
| | Forecaster Confidence | T-Test | t = -0.939 | 0.349 |
| | Hazard | T-Test | t = -0.514 | 0.608 |
| | Tstorm_Watches | T-Test | t = -0.581 | 0.562 |
| | Tstorm_Warnings | T-Test | t = 1.415 | 0.158 |
| | Two_Warnings | T-Test | t = 0.459 | 0.647 |
| FAR | Effective_Urgency | T-Test | t = 2.142 | 0.033* |
| | Warning_Usefulness | T-Test | t = -0.499 | 0.619 |
| | Contact_with_NWS | T-Test | t = -0.870 | 0.385 |
| | Timing | T-Test | t = -0.537 | 0.592 |
| | Location | T-Test | t = -0.702 | 0.484 |
| | History | T-Test | t = 1.057 | 0.292 |
| | Duration | T-Test | t = 0.104 | 0.917 |
| | Forecaster Confidence | T-Test | t = 0.216 | 0.830 |
| | Hazard | T-Test | t = -0.701 | 0.484 |
| | Tstorm_Watches | T-Test | t = -0.299 | 0.765 |
| | Tstorm_Warnings | T-Test | t = 0.772 | 0.441 |
| | Two_Warnings | T-Test | t = -1.358 | 0.176 |

*Significant at the 0.05 level

Three significant differences are present in the urbanization analysis. First, EMs were asked about how useful a NWS warning message is to them when making an operational decision (Figure 4.20).

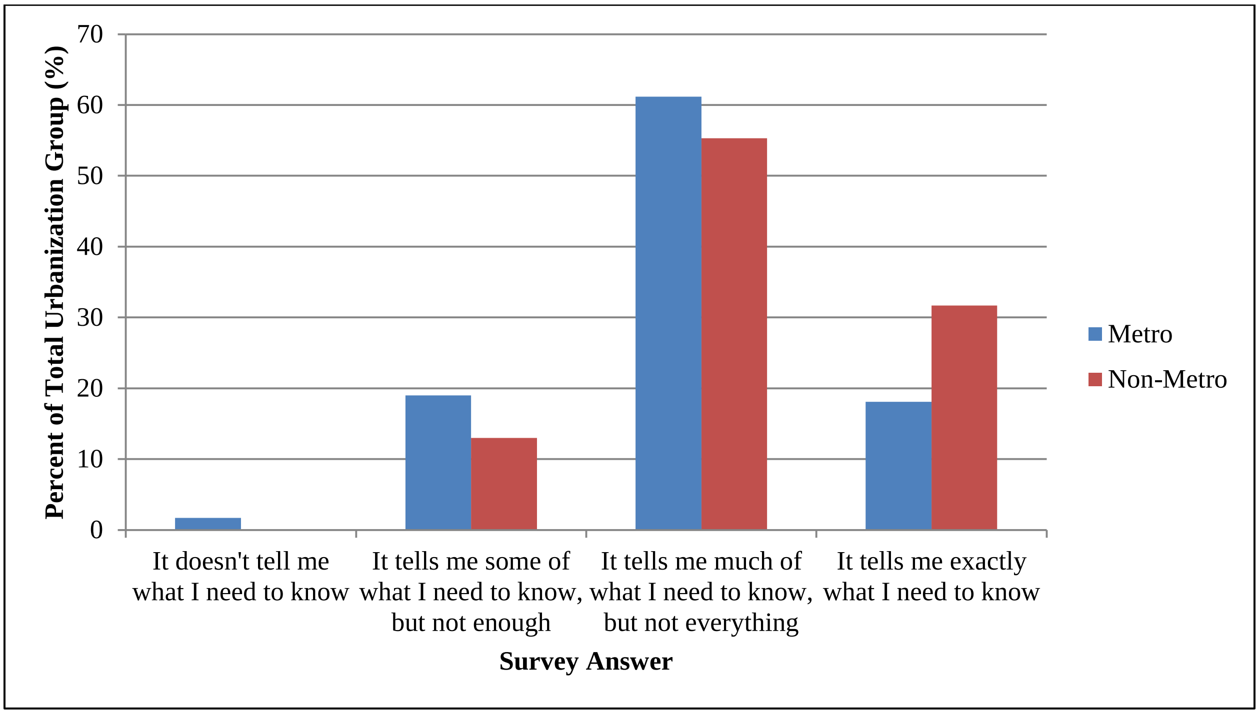

Figure 4.20: Warning Usefulness by Urbanization Group

While most EMs from all WFO locations responded that warnings tell them "much of what they need to know, but not everything," a much larger percentage of the EMs from the non-metro WFOs (Grand Rapids, Milwaukee, and Northern Indiana) believe that warning messages tell exactly what they need to know. Further, there are more metro EMs who responded that warnings either don't tell them what they need or that they tell them some of what they need, but not enough as compared to the non-metro EMs.

The second significant difference from the urbanization analysis is from a survey question that asks how often EMs are in contact with their local NWS office during severe weather events (Figure 4.21). This question shows major differences in respondents' answers. Some 60% of the metro EMs (Chicago and Detroit) responded that they rarely or never contact the NWS as compared to only 40.7% of the EMs from non-metro locations (Grand Rapids, Milwaukee and Northern Indiana). This is what was seen in Figure 4.18. Overall, metro EMs do not contact the NWS as often as non-metro EMs.

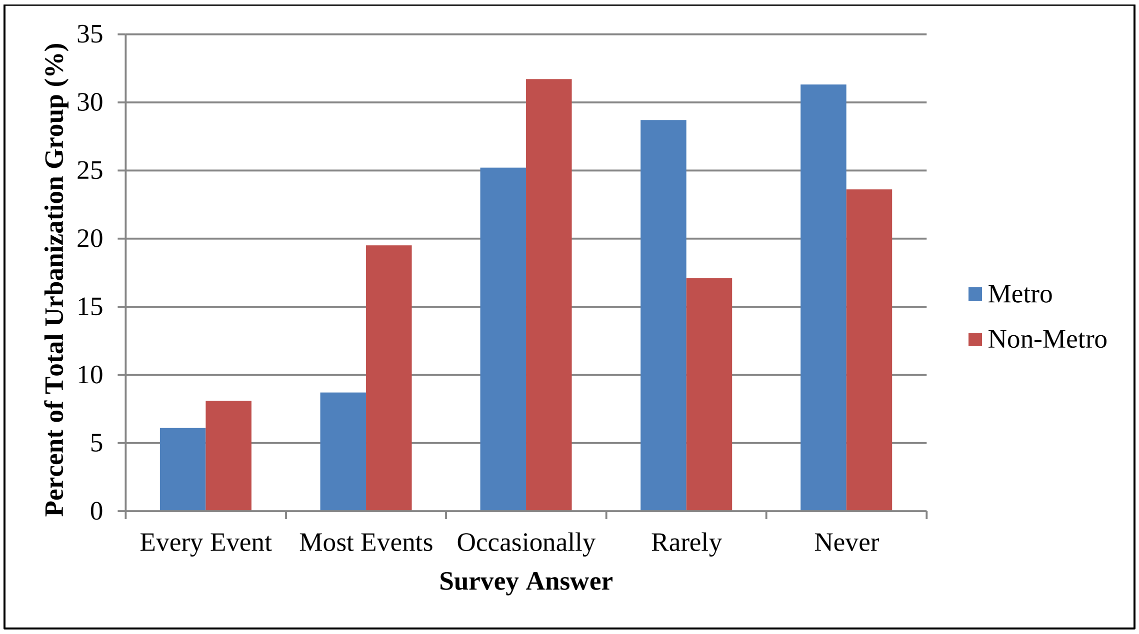

Figure 4.21: Frequency of NWS Contact by Urbanization Group

The third and final urbanization survey question with significant differences in response asked about whether or not EMs are receiving exactly what they need to know from the NWS with regard to the location of a storm (Figure 4.22). While differences are modest, there are slightly more non-metro EMs who responded that they agree or strongly agree with that statement. Overall, non-metro EMs are slightly more satisfied with locational information from the NWS than metro EMs.

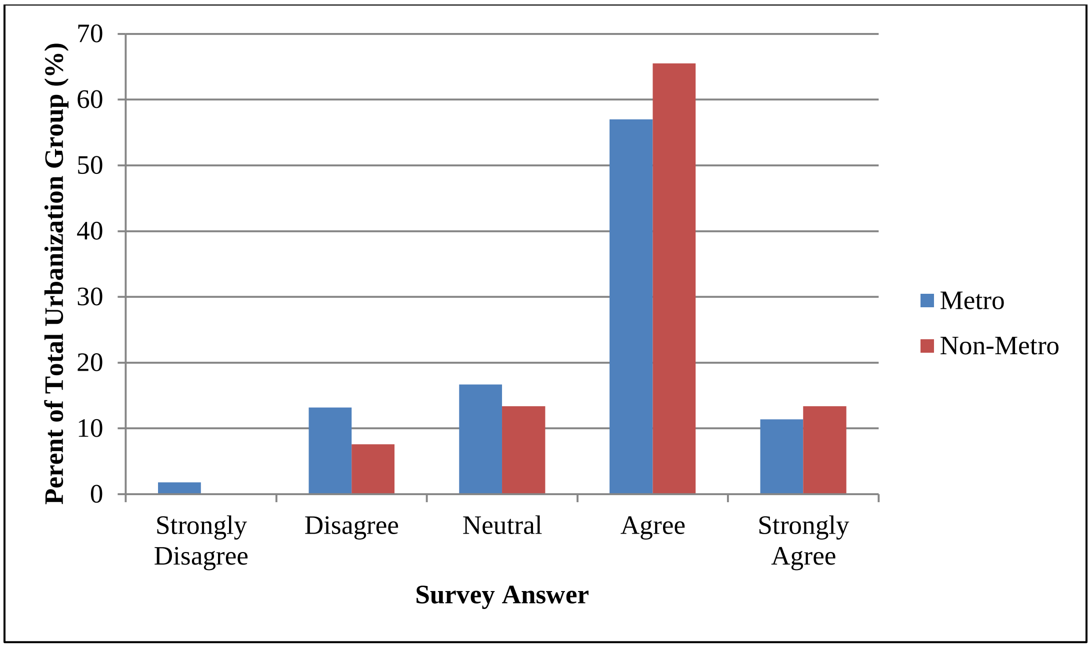

Figure 4.22: Receiving Sufficient Location Information from the NWS by Urbanization Group

The tornado experience analysis produced one survey question that had significant differences in response. That survey question is the same as one of the questions from the urbanization analysis, asking about how often EMs are in contact with their local NWS office.

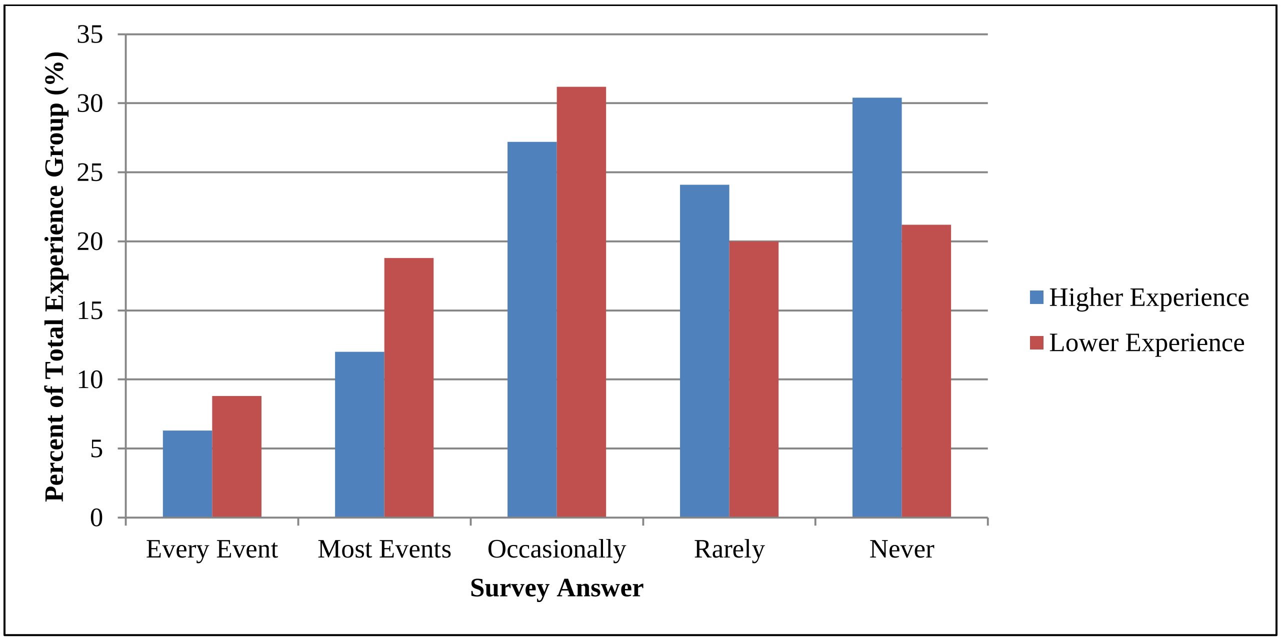

Figure 4.23: Frequency of NWS Contact by Tornado Experience Group

In Figure 4.23 it can be seen that EMs from WFO locations with higher tornado experience contact the NWS slightly less than EMs from WFO locations with less historical tornado experience. Almost 55% of EMs from locations with higher tornado experience responded that they rarely or never contact the NWS and only 18.3% contact the NWS for most or every event. Of the EMs from locations with lower tornado experience, 41.2% rarely or never have contact and 27.6% do for most or all severe weather events.

The final significant difference in response came from the false alarm rate analysis. Here, the question asks EMs how effective a NWS warning message is in conveying urgency (Figure 4.24).

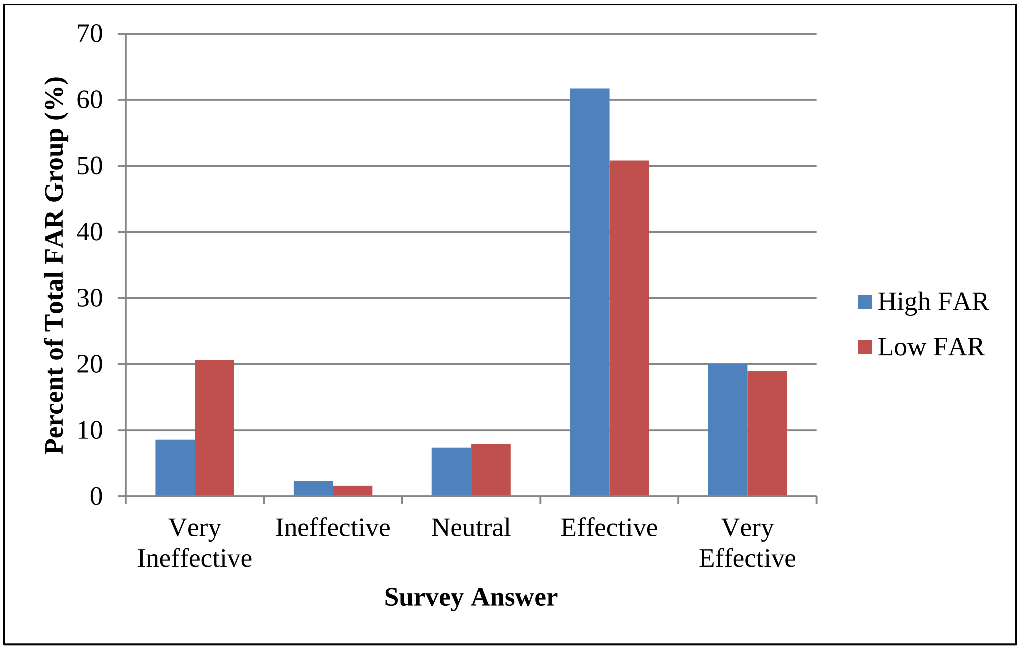

Figure 4.24: Warning Effectiveness by False Alarm Rate Group

While most, regardless of FAR category, believe warnings to be effective, overall, EMs from locations of lower FARs believe warnings to be less effective as compared to EMs from locations of higher FARs. In fact, 8.6% of EMs from locations of higher FARs find warnings to be very ineffective whereas more than double that percentage (20.6%) of EMs from locations of lower FARs believe warnings to be very ineffective. This may be counter-intuitive as false alarms are thought to decrease people's perceptions of warning effectiveness, however, this shows (to a certain degree) that that may not be the case here.

Although each survey question that produced statistically significant results was highlighted in this chapter, it is important to remember that the majority of the questions from each analysis had no significant differences in response. It is from both the differences and similarities in survey response that conclusions can be made.

# CHAPTER 5: DISCUSSIONS AND CONCLUSIONS

Because tornadoes will continue to impact a large portion of the United States, it is important that people know the threat that is present from them and respond accordingly. The general public has help in determining the appropriate actions that should be taken because of EMs—the people in charge of distributing weather alerts and making decisions for their jurisdictions. Past research on how EMs make their decisions and go about their tasks during severe weather is very limited, however. Therefore, the current study supplements the little research that has been produced and fosters further research in this area.

## *Summary of Results*

Overall, differences among the EMs surveyed here are very slight for all of the analyses conducted. The first three socio-demographic questions (job classification, age, and tenure) together had the most statistically significant differences. There were five survey questions on which the EMs responded significantly differently based upon job classification. After analyzing each of those five questions, it is the Emergency Management job class (i.e. respondents who gave themselves the title of "emergency managers") that answered differently from the other two job classes. First, the Emergency Management job class needed to receive a weather warning in order to alert other agencies much more so than the Public Safety and Other job classes. Second, the Emergency Management job class overall had more contact with the NWS than the other job classes. Third, information from the NWS proved to be the source that conveys urgency about weather threats best and TV meteorologists the least for the Emergency Management class. Finally, when considering whether or not the survey respondents were receiving exactly what they needed to know about both timing and hazard details of a storm, the Emergency

Management job class had overall higher satisfaction as compared to the other job classifications.

The next sociodemographic variable considered was respondent's ages and whether or not it influenced the way the EM responded to the survey questions. It was found that responses to only three survey questions were potentially due to the age of the EM. First, EMs who are older than 60 years of age responded that information from the NWS was the best source for depicting urgency about impending weather as compared to the younger EMs who had a more uniform distribution between the NWS, broadcast meteorologists, radar imagery, and spotter reports. Second, older EMs (51 years of age or older) had a tendency to agree more than the younger EMs that they were receiving satisfactory forecaster confidence information from the NWS. Lastly, there was a much larger proportion of younger EMs than older EMs who said that they would prefer to have two warnings, one for the EM and one for the general public.

When considering the survey questions based upon tenure, there were also just three survey questions that produced significant results. EMs who have been on the job longer find warnings to be more useful than EMs with less experience. This idea is further emphasized when it is seen that longer tenured EMs believe they are receiving exactly what they need to know from the NWS about the present hazard and its size. Lastly, EMs with 20 years or more of experience responded that any percentage of confidence for a forecasted tornado track is satisfactory, whereas the EMs who have not been on the job for a long time would prefer to have 50% or higher forecaster confidence rather than just any confidence level.

Each of the survey questions that asks about the influence of past tornadic activity or past tornado warnings showed no significant differences in response based upon the EM's WFO location. Further, when determining if urbanization, tornado experience, and false alarm rate influenced how these three survey questions were answered, no significant differences were found.

The second research question considered if EMs of different locations have different priorities regarding warning elements. Similar to the results seen for the first research question, differences are minimal. In fact, only one survey question showed significant differences. Specifically, the proportion of EMs in Chicago and Detroit who needed to receive a weather warning in order to activate sirens was much higher than the other WFO locations. Analyses of the influence of each background variable produced no significant results, meaning the variables did not influence response.

The last research question regarding the effectiveness of warning messages based upon location produced many more significant differences. When analyzing the extent of differences between each WFO, it was found that the EMs in Northern Indiana are dissatisfied with information about a storm's duration from the NWS. When considering differences based upon the WFO's urbanization grouping, it was found that non-metro EMs find warnings to be more useful than metro EMs, non-metro EMs contact their local NWS offices during severe weather more than metro EMs, and non-metro EMs are slightly more satisfied with locational information than metro EMs. The tornado experience analysis showed that EMs from locations of higher tornado experience are in contact with their local NWS office less than EMs from locations of lower tornado experience. Lastly, the false alarm rate analysis showed that EMs from locations of relatively higher FAR find warnings to be more effective than do EMs from locations of lower FAR.

## *Implications*

The results from the first three sociodemographic questions are perhaps slightly more intuitive than the geographic results. The fact that the Emergency Management job class needs to receive warnings to alert their jurisdictional areas via sirens, that they have much more contact with the NWS during severe weather, and that they believe urgency is conveyed through that contact, simply shows the duties of emergency managers as compared to the other job classes. For instance, first responders do not have the responsibility of alerting the public of severe weather, nor would they look directly to the NWS for decision-making support as would an emergency manager. Further, survey respondents from the Public Safety job class reported being overall less satisfied with information about the timing of the hazard descriptions of impending weather as compared to the other job classes. It is therefore recommended that EMs (those with the title of emergency managers) communicate with those in the public safety sector and modify the message or the source of information so that those in public safety have a better understanding of the situation and can act more efficiently.

Results from the analysis based upon the EMs' age and tenure are also fairly intuitive: older EMs prefer to believe that NWS information conveys urgency adequately and that one warning message is sufficient for both the EM and the public, and more experienced EMs find warnings to be more useful than less experienced EMs. This perhaps suggests the comfort that EMs gain with age and tenure. Another possible explanation for these results is that EMs with more experience perceive a NWS warning message to be sufficient as they understand it is their job to interpret the NWS warning messages for their jurisdictions as opposed to those with less experience who desire something different (either in the message itself or through other sources). The recommendation here is less direct as it is hard to compensate for first-hand experience in making decisions in high-stress severe weather events. However, just as Baumgart et al. (2008)

found, EMs, no matter their age or length of experience, are highly influenced by communicating with the scientists at the NWS where they not only get valuable information, but also interpret perceptual cues from the forecasters. It is therefore recommended that EMs, especially those new to the job with little experience, are able to build strong working relationships with their local Warning Coordination Meteorologists.

It can be concluded from the results of the research question regarding past tornadic activity that there are no geographic differences in decision-making whether or not prior warnings go unverified. When EMs hear of a tornado warning for their area, whether in a region that is rural or urban, that has high or low tornado experience, and that has a high or low FAR, response about the influence of past tornado warnings remains the same across the survey locations.

From the second research question, it can be concluded that EMs at any location surveyed have generally the same priorities when it comes to the content of the warning message. Regardless of the EM's location, preferences about tornado pathcasts and details of the hazard and its source are generally the same. The only exceptions—Chicago and Detroit responding that they need to receive a warning so that they can activate sirens—showcase the urban characteristics of those locations. Because vulnerability is much higher in urban areas where population and infrastructure are concentrated, EMs need to be able to get information from a warning message so they can decide whether or not to alert people in their jurisdictional area.

Effectiveness of warning messages across locations is not as similar as the previous analyses. Most of the differences in response arise from differences in urban characteristics. Non-metro EMs find warnings to be more useful than metro EMs perhaps due to the fact that metro EMs often times need to make decisions well before the warning is issued in order to alert their highly vulnerable jurisdictions. Further, metro EMs have less direct contact with their local

NWS office, perhaps because they have more safety procedures and regulations in place that need to be undertaken, which minimizes the time they have to talk with the NWS. A larger proportion of non-metro EMs also believes that the information coming from the NWS is exactly what they need as compared to metro EMs, again signifying an overall greater satisfaction in the NWS from the non-metro EMs. Warning effectiveness was geographically related to only one survey question from the tornado experience analysis—that EMs with higher tornado experience in general contact the NWS less during severe weather. This shows that the less often EMs get to test their decision-making capabilities, the more they are going to rely on direct contact with meteorologists at the NWS. Lastly, warning effectiveness was related to one question from the FAR analysis. EMs from areas with higher FAR find warnings to be more useful at conveying urgency to a greater degree than EMs from areas with lower FAR. This builds upon the work presented in Chapter 2 about the "cry-wolf" effect or rather its lack of effect.

Overall, geographic differences in EM decision-making are slim. The biggest differences came from the urbanization analysis illustrating the needs that EMs with large populations have when it comes to initiating standard severe weather procedures in order to protect people. However, since so few geographic differences were found, this suggests that separate warnings for different locations, including large cities, may not be necessary, or, at least, more research should be done to investigate this further.

### *Limitations of Research*

This study is not without some limitations, however. Since analysis of geographic differences in emergency management decision-making is the goal of this study, differences in survey response were based on respondents' WFO locations and provided the results of the study. The spatial extent of the entire study area is limited, however, to a relatively small portion of the

United States. Ideally, the study area would encompass a much larger spatial area to analyze geographic differences. Also, it would be beneficial to have two study locations. For instance, one study site could be the current study area, but then in addition, a study area of similar size in another part of the country would allow for analyzing differences between completely separate locations.

Also, as mentioned in Chapter 3, it was not possible to calculate a response rate for this study, something that is ideal to have for a study involving survey research. However, since the SBI team left the distribution of the survey up to the Warning Coordination Meteorologists at each WFO, they were unaware of the total number of people to whom the survey was sent and therefore the response rate is unknown.

The survey itself also presents some limitations. First, there is only one question that asks about the EM's location, their primary WFO location. If this survey were to be done again, more explicit sociodemographic questions could benefit this type of research. For instance, questions asking about the spatial extent of the EM's jurisdictional area would be helpful in order to distinguish county-level EMs versus city-level EMs versus federal EMs, for example. The population of the EM's jurisdiction would also be useful information. In addition, the survey asked about how long EMs have been in their current position; it does not specifically ask if that position has been held in the same location for the duration of their career. For instance, a survey respondent could have started his/her career in Florida as an EM, but then moved into the study area to continue working as an EM. Therefore, they have different experiences in different locations. When it comes to the other survey questions, none of the survey answers were open-ended, meaning that the EM had to choose one of the answers given. Providing more open-ended questions might better reflect how an EM would respond.

Finally, one of the survey questions asks for the reasoning as to why the EM needs to receive a weather warning. One of the responses is “activate sirens” and some EMs chose this as their response. However, it is unknown how many communities in the study area use sirens as a means to notify their jurisdictions, let alone even have sirens, which would affect response. This needs to be remembered when looking at the results as this question had significant differences in multiple analyses.

### *Contributions to Knowledge and Future Work*

Several key conclusions resulted from this study, all of which contribute to knowledge of emergency management decision-making. First, past false alarms were shown to have no significant influence on decision-making and response to tornado warnings, suggesting that the “cry-wolf” effect may not be relevant, at least in this region. Second, when asked about whether or not two warnings would be useful, one for EMs and one for the public, something that has been considered in the past, results showed that one warning is satisfactory for all. Finally, the sociodemographic questions and analyses showed that age and tenure, specifically, have a large influence on decision-making and response.

This case study is unique in that it not only focuses on emergency management decision-making during severe weather, but also geographic differences in decision-making. This highlights tornado warning needs and effectiveness (or lack thereof) for EMs in different locations. While there is vast literature on tornado warning response of the public, the emergency management community has been much less of a focus. However, EMs have an immense responsibility of taking information from the meteorologists and communicating that information to the public, essentially being the liaison between the two groups as seen in Figure 2.2. Since the results of this case study revealed that, in general, EMs are receiving satisfactory information and are able to make decisions from that information, it appears that the link between the “detection” subsection and “management” subsection is working effectively, and further, that false alarms do not seem to affect EMs as they make decisions. However, since it is known that the general public still makes inappropriate decisions during severe weather to some extent, the second link in Figure 2.2, the link connecting the EMs and the general public, needs to be a focus of further research. By focusing on the EM community as the current study does, both of those links in the warning process can be analyzed.

There are several ways in which to build on this case study. First, a survey population that is restricted to just individuals with the job title “emergency managers” rather than also including first responders, school officials, and mitigation experts would allow for differences to be seen from only EMs who share the same duties and responsibilities. Second, simply increasing the number and content of questions on the survey will allow for more comprehensive analyses and conclusions about decision-making. For example, in this study, only three survey questions were related to the research question about the influence of past tornadic activity. Third, if and when a major tornado occurs in this region, a follow-up survey should be conducted. This will provide insightful information about the influence of a major tornadic event on emergency management decision-making. Finally, a similar survey should be conducted in another region of the country to compare to the results found in the Midwest.

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# APPENDIX A: IRB DOCUMENTATION

**EAST CAROLINA UNIVERSITY**
**University & Medical Center Institutional Review Board Office**
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · www.ecu.edu/irb

## Notification of Initial Approval: Expedited

From: Social/Behavioral IRB
To: Burrell Montz Covey
CC:
Date: 11/26/2012
Re: UMCIRB 12-001912
Social and Behavioral Influences

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) is for the period of 11/26/2012 to 11/25/2013. The research study is eligible for review under expedited category #6 and #7. The Chairperson (or designee) deemed this study no more than minimal risk.

Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The Investigator must adhere to all reporting requirements for this study.

The approval includes the following items:

| Name | Description |
|---|---|
| Informed-Consent_SBI.doc \| History | Consent Forms |
| Sample Focus Group Script.doc \| History | Interview/Focus Group Scripts/Questions |
| SBIFinal.pdf \| History | Study Protocol or Grant Application |
| Survey Sample.docx \| History | Surveys and Questionnaires |

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

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IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418 IRB00004973

# APPENDIX B: THE SURVEY

Q1 What is your primary job classification?

Q2 How old are you?

○ Under 30 (1)
○ 30-40 (2)
○ 41-50 (3)
○ 51-60 (4)
○ Older than 60 (5)

Q3 How long have you been in your current position?

○ Less than a year (1)
○ 1-5 years (2)
○ 6-10 years (3)
○ 11-20 years (4)
○ 20+ years (5)

Q4 What is your primary National Weather Service Office?

○ Chicago (1)
○ Detroit (2)
○ Grand Rapids (3)
○ Milwaukee (4)
○ Northern Indiana (5)
○ I don't know (6)

Q5 What is the primary reason you need to receive a weather warning?

- ○ Alert other agencies of impending weather (1)
- ○ Activate sirens (2)
- ○ Deploy resources (3)
- ○ Initiate standard operating safety actions (4)
- ○ Personal/family safety (5)
- ○ Just to be informed (6)

Q6 How effective is an NWS warning message in conveying urgency to you?

- ○ Very Ineffective (1)
- ○ Ineffective (2)
- ○ Neither Effective nor Ineffective (3)
- ○ Effective (4)
- ○ Very Effective (5)

Q7 How useful is this warning to you when making an operational decision?

- ○ It doesn't tell me what I need to know (1)
- ○ It tells me some of what I need to know, but not enough (2)
- ○ It tells me much of what I need to know but not everything (3)
- ○ It tells me exactly what I need to know (4)

Q8 Compared to the current warnings, which of these might be better in expressing urgency about a tornado?

- ○ Color scale: Green is least urgent, Red is most urgent (1)
- ○ Number scale: 1 is least urgent, 5 is most urgent (2)
- ○ Word based: No word tag is least urgent, Catastrophic as a word tag is most urgent (3)
- ○ Some other way (please specify) (4) ____________________

Q9 Reflecting on the suggested "scales" in the question above, how likely do you think it is that people will become complacent if a warning has a Green color, or is classified as a 1 or a 2, or does not have a damage threat word tag?

○ Very Unlikely (1)
○ Unlikely (2)
○ Undecided (3)
○ Likely (4)
○ Very Likely (5)

Q10 What would be most helpful to your decision-making to have in a warning message?

○ Hazard (1)
○ Source (2)
○ Impact (3)
○ All are equally helpful (4)
○ None would be used in my decisions (5)

Q11 Does it matter that a tornado is "radar-indicated," as compared to a tornado being "observed?"

○ Yes, we respond to "observed" but not necessarily "radar-indicated" (1)
○ We respond to all warnings the same, regardless of how it was indicated (2)
○ We verify the tornado report from other sources before responding (3)
○ We have responded based on the tornado watch conditions, well before the warning (4)

Q12 If you hear a tornado warning for your area, what do you think is the likelihood that a tornado will impact your immediate area?

○ Very Unlikely (1)
○ Unlikely (2)
○ Undecided (3)
○ Likely (4)
○ Very Likely (5)

Q13 If there was a tornado warning for your area and a tornado did not occur, how do you think it might influence your decision-making the next time a tornado warning is issued for your area?

○ Definitely will not influence my decision-making (1)
○ Probably will not (2)
○ Don't know (3)
○ Probably will (4)
○ Definitely will influence my decision-making (5)

Q14 Based on past tornado occurrences in your vicinity, what is your opinion about the number of warnings issued?

○ Too many tornado warnings issued (1)
○ Too few tornado warnings issued (2)
○ The warnings have been appropriate (3)
○ The number of warnings issued is not a concern to me (4)

Q15 What is the primary way you receive warnings, in your job?

○ NWS webpages (1)
○ From other staff members (2)
○ TV or other media (3)
○ NOAA Weather Radio (4)
○ NWSChat (5)
○ iNWS (6)
○ NWS Briefings (phone, multi-media, etc.) (7)
○ Third-party software or service (8)
○ Other means (9)
○ I don't use warnings in my job (10)

Q16 Do you pass warnings along to others?

○ Always (1)
○ Sometimes (2)
○ Never (3)

Q17 How often are you in contact with your local NWS office during a severe weather event?

○ Every event (1)
○ Most events (2)
○ Occasionally (3)
○ Rarely (4)
○ Never (5)

Q18 Why would you contact your local NWS office?

○ To make sure I didn't miss anything (1)
○ To ask questions about something I'm unsure of (2)
○ To confirm my understanding (3)
○ Other reason (please specify) (4) ____________________
○ I am not in contact with my NWS office, but probably should be (5)
○ I have little to no need to be in contact with my local office (6)

Q19 Why wouldn't you contact your local NWS office?

○ I didn't know I could call or contact them (1)
○ I'm usually confident in my understanding of the weather (2)
○ I'm not sure what I need to ask (3)
○ I don't want to bother the NWS (4)
○ I get my information from other sources (5)
○ I have found calling to be unproductive (6)
○ Other reason (please specify) (7) ____________________

Q20 Which of these best conveys urgency about a tornado to you?

○ Warning message only (1)
○ Broadcast meteorlogist (2)
○ Radar imagery of the storm (3)
○ NWS phone calls or multimedia briefings (4)
○ Talking with spotters or first responder reports (5)
○ Some other way (please specify) (6) ____________________

Q21 Do you know what a warning polygon is?

○ Yes (1)
○ No (2)

Q22 Do you routinely view them when a warning is issued for your county?

○ Yes (1)
○ No (2)

Q23 Are sirens activated for your jurisdiction if it is in a polygon?

○ Yes (1)
○ No (2)
○ Not sure (3)
○ N/A (4)

Q24 Based on our discussions with other EMs, we have heard that these elements are critical to decision making during severe weather. Though they are all important, rank these critical elements of information in order from highest priority to lowest priority. (1-highest priority, 7-lowest priority).

______ Timing (when the storm will hit my area) (1)
______ Location (where the storm will hit) (2)
______ Storm history (what damage or impacts has the storm had so far) (3)
______ Duration (how long the storm will last) (4)
______ Confidence (how confident is the NWS forecaster) (5)
______ Potential impacts (6)
______ Potential size (7)

Q25 Are there any critical elements that are missing from the previous question? If so, what are they?

Q26 Choose your level of agreement with the following statements.

| | Strongly Disagree (1) | Disagree (2) | Neither Agree nor Disagree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|
| Given that timing information about a tornado is critical, I am receiving exactly what I need to know about the timing of the storm from the NWS. (1) | ○ | ○ | ○ | ○ | ○ |
| Given that location information about a tornado is critical, I am receiving exactly what I need to know about the location of the storm from the NWS. (2) | ○ | ○ | ○ | ○ | ○ |
| Given that I need to know as much about the storm's history as possible, I am receiving exactly what I need to know about the storm history from the NWS. (3) | ○ | ○ | ○ | ○ | ○ |
| Given that I need to know how long the storm will last, I am receiving exactly what I need to know about the duration of the storm from the NWS. (4) | ○ | ○ | ○ | ○ | ○ |
| Given that I | ○ | ○ | ○ | ○ | ○ |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| need to know a forecaster’s confidence to make a decision, I am receiving exactly what I need to know about the confidence of the forecaster from the NWS. (5) |  |  |  |  |  |
| Given that I need to know what the hazard is and its size, I am receiving exactly what I need to know about what the actual hazard is from the NWS. (6) | ○ | ○ | ○ | ○ | ○ |

Q27 If you could get more precise information on size or impact of the hazard, which would it be?

○ Size (1)
○ Impact (2)
○ Other (please specify) (3) ____________________

Q28 NWS is experimenting with adding more information into tornado warnings, such as the damage threat tags “catastrophic” and “significant” to express a potential threat. Specifically: Damage threat tags for tornado warnings · TORNADO...RADAR INDICATED · TORNADO...OBSERVED · TORNADO DAMAGE THREAT...SIGNIFICANT · TORNADO DAMAGE THREAT...CATASTROPHIC Impacts statements for tornado warnings · Impact statement for tornado warning: Significant house and building damage possible. Mobile homes completely destroyed if hit. Some trees uprooted or snapped. Vehicles will likely be thrown by tornadic winds. · Impact statement for TORNADO DAMAGE THREAT...SIGNIFICANT tornado warning: Major house and building damage likely and complete destruction possible. Numerous trees snapped. Major power outages in path of tornado highly likely. Some roads possibly blocked by tornado debris. Complete destruction of vehicles likely. · Impact statement for TORNADO DAMAGE THREAT...CATASTROPHIC tornado warning (Tornado Emergency): This is a life threatening situation. You could be killed if not underground or in a tornado shelter. Complete destruction of entire neighborhoods is likely. Many well built homes and businesses will be completely swept from their foundations. Debris will block most roadways. Mass devastation is highly likely making the area unrecognizable to survivors.

Choose your level of agreement with the following statements.

| | Strongly Disagree (1) | Disagree (2) | Neither Agree nor Disagree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|
| Damage threat tags convey urgency to the public. (1) | ○ | ○ | ○ | ○ | ○ |
| Damage threat tags convey severity to the public (2) | ○ | ○ | ○ | ○ | ○ |
| People will become complacent after hearing these damage threat tags after a certain number of times. (3) | ○ | ○ | ○ | ○ | ○ |
| People will only take notice of a tornado warning when the damage threat tag is significant or catastrophic and not when there is no damage threat tag. (4) | ○ | ○ | ○ | ○ | ○ |

Q29 Click all that apply when you hear or read “Tornado…possible” in a severe thunderstorm warning.

- ☐ It is useful information because that means NWS thinks a tornado may form. (1)
- ☐ It is not useful information because nothing is indicated on radar and nothing has been spotted – why is NWS telling me? (2)
- ☐ NWS uses the phrase to cover all their bases. (3)
- ☐ I have to set my sirens off even though it’s a severe thunderstorm warning just because the word “tornado” is mentioned. (4)
- ☐ It’s not necessary because a tornado is always assumed to be possible in a severe storm. (5)
- ☐ Other (please specify) (6) ____________________

Q30 How many minutes in the future would you like to see a forecasted tornado track (“pathcast”)?

- ○ 5 min (1)
- ○ 10 min (2)
- ○ 15 min (3)
- ○ 20 min (4)
- ○ 25 min (5)
- ○ 30 min or more (6)

Q31 What is the lowest level of forecaster confidence at which you’d like to see a forecasted tornado track (“pathcast”) issued?

- ○ Above 70% (1)
- ○ 60-70% (2)
- ○ 50-60% (3)
- ○ 40-50% (4)
- ○ 30-40% (5)
- ○ 20-30% (6)
- ○ 20% or lower (7)
- ○ Any confidence, it doesn't matter how low, I can use it (8)

Q32 Severe thunderstorm watches should be eliminated completely

- ○ Strongly Disagree (1)
- ○ Disagree (2)
- ○ Neither Agree nor Disagree (3)
- ○ Agree (4)
- ○ Strongly Agree (5)

Q33 Severe thunderstorm warnings should be eliminated completely

○ Strongly Disagree (1)
○ Disagree (2)
○ Neither Agree nor Disagree (3)
○ Agree (4)
○ Strongly Agree (5)

Q34 Severe thunderstorm watches and warnings should only be issued for:

☐ This wind speed (specify) (1) ____________________
☐ This hail size (specify) (2) ____________________
☐ Other reason (specify) (3)

Q35 Given that EMs need more, earlier, and different information than the public, should there be two different warnings created, one for EM and one for the public?

○ Yes (1)
○ No (2)