Tornado damage mitigation: What National Weather Center visitors know and why they aren't mitigating

Kody M. Gast[1,2], Jerry A. Brotzge[3], and Daphne S. LaDue[3]

[1] *University of Northern Colorado*
Greeley, Colorado
[2] *National Weather Center Research Experiences for Undergraduates Program*
Norman, Oklahoma
[3]*Center for Analysis and Prediction of Storms, University of Oklahoma*
Norman, Oklahoma

ABSTRACT

A survey was conducted of adults touring the National Weather Center in Norman, Oklahoma during the summer of 2013 to understand what the visitors know in regards to mitigation and what factors impact mitigation behavior. Survey questions were summarized into four categories: background knowledge of tornadoes and tornado damage, knowledge of mitigation, estimation of risk, and factors impacting mitigation activities. Many visitors did not know that mitigation against tornado damage is possible and that homes can be designed or retrofitted to withstand a majority of the damage that tornadoes can cause. Among nine key terms of mitigation, only four terms were marked by more than 20% of respondents, signifying that many of the visitors did not know about mitigation. Reasons for why people are not mitigating, including not knowing what to do, not perceiving too great of a risk, and the costliness of mitigation.

1. INTRODUCTION

A key area of tornado safety is to prevent or mitigate against potential damage that a home may sustain from a tornado. However, mitigation can only go as far as what the public knows. If the public does not know much about mitigation, they probably aren't going to mitigate, and then structures receive even more damage because the damage sustained by one home turns into a potential hazard for another home in any high wind event as that damage then becomes windborne debris (BPAT 1999).

Since the tornado outbreak of 1999, engineering research has advanced to the point where almost all damage cause by EF-2 scale winds (up to 135 mph) or less can be prevented (FEMA, 2002; Coulbourne, 2011; Amini et. al, 2012). Considering the fact that almost 95% of all tornadoes are EF-2 or weaker (Amini et. al, 2012), a vast majority of all tornado damage to homes and other structures can be mitigated. Unfortunately, most people do not know what to do to mitigate or are not taking preventative measures to protect their homes for other reasons.

Most of the work prior to this work has only looked into the physical and economical aspects to mitigation, but little, if any, has been done on trying to understand the societal understanding and adoption of mitigation practices. The physical and economic sides are important and parallel understanding the social aspect.

The FEMA BPAT report from the May 3, 1999 tornado outbreak event was one of the first documents to report on how structures failed and what could be done to fix those failures. The report included damage assessments of mobile and permanent homes along with small business structures in the affected regions of Oklahoma and Kansas. Assessments were divided further into different sections of the structure of topic. Different areas of permanent homes included the roof, the garage, the walls, etc. Walls were also further divided into different types of walls such as wood frame or masonry. Within each section, the report talked about what generally went wrong within that section: roofs weren't properly attached, garage doors were too flimsy, connections along the walls did not meet standards set by building codes, masonry walls were not reinforced, etc. Many aspects failed within different houses in different areas. One concept that the report kept repeating

[1] *Corresponding author address:* Kody Gast, 120 NWC REU at CAPS, David L. Boren Blvd., Suite 2500, Norman, OK 73072.
E-mail: kody1214@msn.com

was the lack of a continuous load path within the structure. Very few homes were built to have a continuous vertical load path from the roof to the foundation which caused many of the homes to sustain even more damage.

Prevatt, Assistant Professor in the Department of Civil and Coastal Engineering at the University of Florida, and his colleagues also made mention to the continuous load path in their book pertaining to the Joplin, Missouri tornado of 2011. While the FEMA report reiterated the concept of the vertical load path, Prevatt et al. (2013) extended the concept into the lateral and made mention in the preface of his book that many homes lacked not only a vertically continuous load path, but a laterally continuous load path as well.

The cost of implementing mitigation techniques has also been explored. According to Sutter et. al, investing $500 into mitigating a home can reduce the damage that home sustains from tornadoes by an average of about 30% (2009). A more recent study by the construction company Simpson Strong-Tie showed that mitigation can be done through a minimal investment of about $0.50 per square foot, or about $1000 for a 2000 square foot home (Flickinger and Lowry, 2013).

Mitigation can be done, but it is up to the homeowners to actually mitigate. This study will utilize a survey as a first step of understanding what people know about mitigation as well as some of the reasons behind why people are not mitigating.

2. Methods

2.1 *Survey*

The tool created for data collection was a paper survey to be handed out to National Weather Center (NWC) visitors aged 18 or older after they had finished their tour of the building.

The survey consisted of 26 questions, 5 of which were follow-up questions, with 2 of the questions being open-ended. The survey consisted of three main parts: the person's knowledge and understanding about tornadoes and mitigation of damage, their reasoning for not mitigating, and demographics. The first part begins with trying to assess the person's knowledge of tornadoes and the damage they cause. Questions were then asked about what the person knows, or has heard of, in regard to mitigation, as well as the source(s) of their information.

The second area of focus for this research was on trying to understand the reasons why people are not mitigating. To do that, questions were asked on the survey about what people perceive their risk of having their home be hit by a tornado, how much they would be willing to spend in order to mitigate, if respondents have ever thought about mitigation, and what motivations or barriers are there to mitigation.

Demographics asked in this survey included participants reasoning for touring the NWC, how many children (age 18 or younger) resided in their residence, zip code, household income, highest education level, the type of structure they reside in, whether respondents owned or rented, and if their homes were insured. Reasoning behind why they visited the NWC was asked in order to group respondents by whether or not they had an interest in weather in order to contrast those with some sort of background interest with those who did not seem to have much interest in weather.

In order to test the validity of the survey, the first author went through the process of doing cognitive interviews (Willis, 2005) with family and friends. Each person interviewed was asked to fill out the survey on their own. Afterwards, the first author went through the survey with them question by question and asked them if the question made sense, if the question was interpreted as it was meant to be interpreted, if anything was missing from the question, and if anything could be done to improve the question. This process allowed the first author to make the necessary changes on the survey in order to increase its clarity and improve the validity of the results.

2.2 *Sampling procedure*

The sample chosen to be surveyed was the convenience sample of visitors to the NWC aged 18 or older. Public tours were given every Monday, Wednesday, and Friday afternoon, and other group tours were held at other times throughout the weeks. Public tours generally had approximately 30 people per tour while group tours ranged from 8 people to about 30 (both group numbers include children). On average, public tours produced 6 or 7 surveys while group tours ranged from 4 surveys to 24 surveys, depending on the group size. In total, 152 usable surveys were collected over the course of a month from people residing in 23 states, mostly east of the Rocky Mountains, with varying degrees of education level and income.

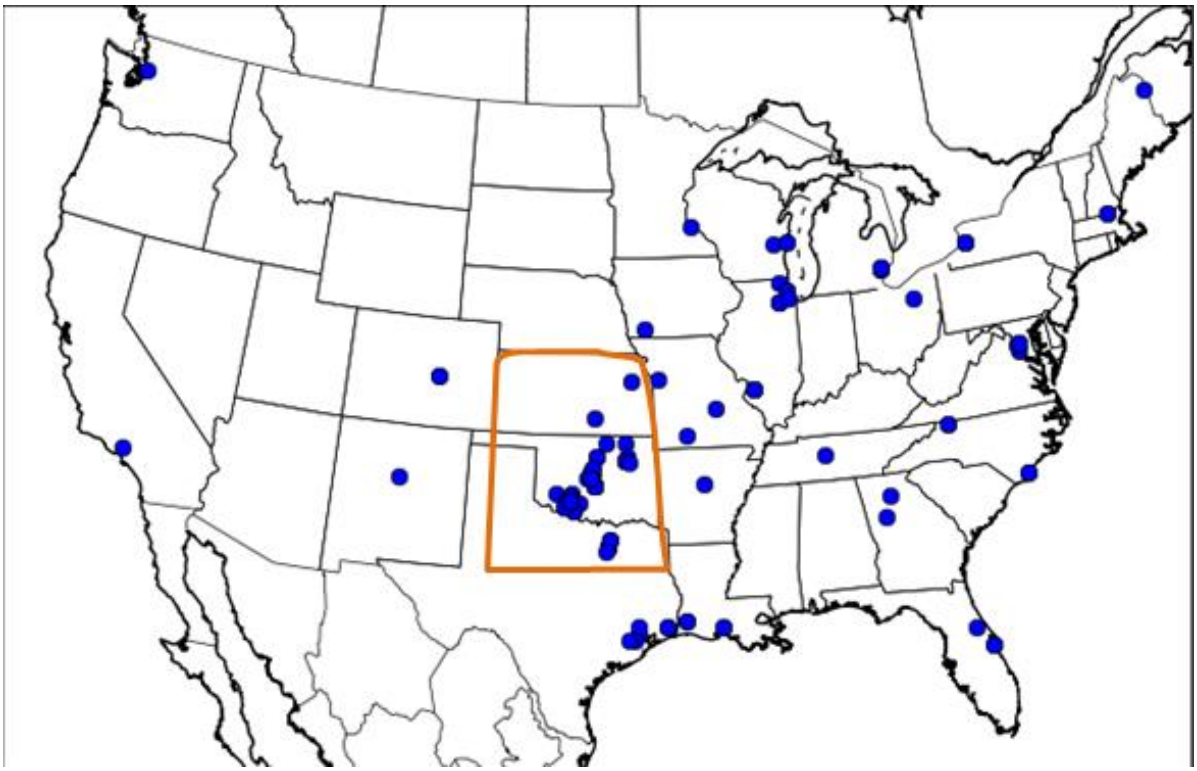

Fig. 1 The map show the location of participants based on their zip codes. The orange box encircling North Texas, Oklahoma, and Kansas is the area defined as “tornado alley” for the analyses of this study. A large concentration of participants can be seen in Oklahoma, but the population is also fairly dispersed throughout the continental U.S.

2.3 *Data analysis*

A majority of the data was analyzed using descriptive statistics for response rates, means, and medians. Two relationships were analyzed using t-tests, with all other analyses being completed using descriptive statistics.

The open ended questions were analyzed using a ‘grade scale’ depending upon what categories their writing mentioned. The “grading rubric” consisted of four main categories used to assess what the participants wrote. No points were given if the participant’s response was to open windows since opening windows can actually be more destructive in a tornadic event or for no response along with any answer that said nothing could be done or they didn’t know. Participants scored 30% for responses that included the concept of the continuous load path. An additional 25% was given for answers that addressed attachments/connections of the frame and/or if the response talked about any of the key terms relative to mitigation. If the respondent mentioned that the house should be inspected as a first step in determining what needed to be done to retrofit the home received an additional 20%. Answers that included strengthening windows or using better material/construction techniques received an additional 15%. Any response that mentioned a installing a storm shelter/safe room, building underground, or any other response were assessed an additional 10%. The maximum score was 100%. While very important to protecting lives, storm shelters/safe rooms scored low in this assessment because this study was focused on protecting structures as a whole, not just small sections of the home.

2.4 *Limitations*

Surveys were distributed from 19 June 2013 to 19 July 2013, just following the aftermath of the Moore, OK EF-5 tornado on 20 May 2013

and the El Reno, OK record breaking EF-5 tornado on 31 May 2013. Because of the timing of the survey, historical effects were unavoidable and affected the interpretation of our results. Redistributing the survey during a 'quiet' year with little tornadic activity would contextualize the reliability of the results.

With the survey being distributed at the NWC, results may not be representative of the general public since many of the participants had some sort of interest or knowledge in weather or other topics related to weather. Distribution of the survey outside of the NWC to various other sample groups would contextualize the reliability of the results.

3. Results

3.1 *Demographics*

The total number of completed surveys was 153; however, one survey was removed from the analysis as the respondent seemed to be younger than 18, reducing the sample size to 152. Of the 141 respondents who marked how many kids they had living with them, about 73% said they had no one under 18 living in their home.

The location of the respondents can be seen in figure 1, and the orange box that encircles North Texas, Oklahoma, and Kansas is what was defined as "tornado alley" for the rest of the analysis.

Household income varied amongst respondents as 7% marked that they make less than $20,000 a year and 9% marked that they make over $150,000 per year in their households. The most marked income range was $75,000 - $149,999 with about 32% of respondents marking this range. Approximately 37% of respondents marked that their highest level of education was a Bachelor's degree, with only 23% saying that they had gone further into getting their Master's degree or above.

A vast majority of respondents stated that they live in a house, 60% in a 1-story house and 27% in a two-story house. Approximately 91% of respondents said they own their residence, and about 95% stated that their structure is insured.

Fig. 2 This image was used on the survey. The damage shown is EF-2 damage from the Jones County, MS tornado of 20 December 2007

3.2 *Knowledge of tornado damage*

The first three questions on the survey related to the participants knowledge of tornado damage and of the EF-scale. Respondents, totaling 150 for the question as two responses were unusable, were first asked if they had heard of the EF-scale, and 145 (97%) said that they had while 5 (3%) said they had not.

After asking if they had heard of the EF-scale, the survey asked if respondents could correctly identify the damage scale of the picture shown in figure 2. The damage shown is high end EF-2 damage from the Jones County, MS tornado of 20 December 2007. As shown in figure 3, most participants said that the damage was EF-3 scale damage. We figured that most people would respond with EF-2 or EF-3, so the results were somewhat suspected. Of the respondents within "tornado alley", a greater percentage said that the damage was EF-4 scale damage rather than EF-2 scale damage, leading us to believe that participants within "tornado alley" may be over estimating tornado damage.

3.3 *Knowledge of mitigation*

After being asked about their knowledge relative to tornado damage, participants were then asked about their knowledge in terms of mitigation. Two questions were asked about this subject. The first question asked participants: based off of your current knowledge, what can be done to reduce tornado damage to a house? This question was open ended and saw many various responses, so the "grading rubric" described in the data analysis section was used to analyze the responses.

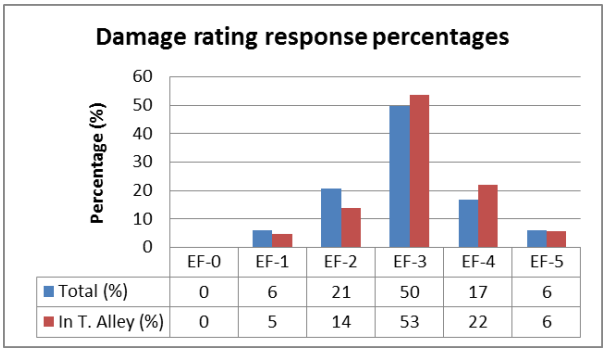

Fig. 3 The graph shows the percentage of respondents that marked each damage level. EF-3 was the most marked of all the categories. Blue bars represent the total survey population and red bars represent the respondents from "tornado alley". n=152 and n_i=86

The highest scoring response was a 70%, with the mean response score right around 25% and the median response score at 15%. The most common responses to this question were answers relating to using better building materials and/or better construction techniques.

The second question asked participants if they had heard of any of nine key terms relative to mitigation. Terms included were: anchor/j-bolts, masonry ties, laminated glass, hurricane clips, lateral load nails, face-nailing vs. toe-nailing, oriented strand board (OSB), ASCE 7-98 rated garage door, and the continuous load path. Participants could mark any and all terms that they have heard of before. The most frequently marked term was anchor/j-bolts, with just over half having said they have heard the term before. About a quarter of the respondents did not mark any of the terms (see figure 4).

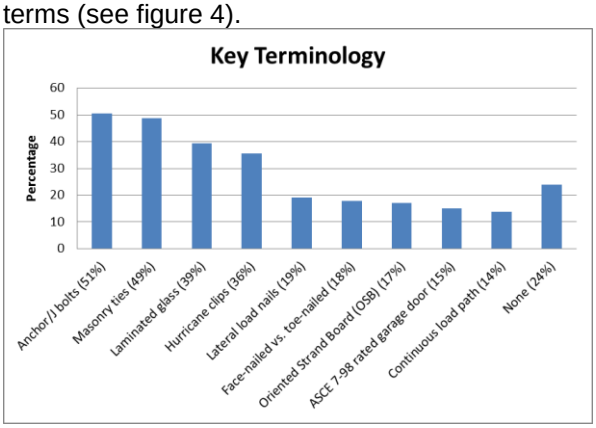

Fig. 4 The graph shows the terms (and percentage marked) that the respondents were asked if they had heard before. Only four of the terms were marked by over 20% of the participants. Almost a quarter of the participants did not mark any terms. n=152

3.4 *Risk perception*

When asked to rate how much risk they perceive of having their home be hit by a tornado, respondents were asked to rate their risk on a scale of 1-10, with 1 being “No risk” and 10 being “Guaranteed to be hit”. In between those points, a rating of 2-5 was considered “less than average” and 6-9 was considered “greater than average”. This scale was used in order to remove the middle point that we figured most people would try to default to and force them to be on the lower end or the higher end. About 23% of respondents marked their risk a 5, or just less than ‘average’. Figure 5 shows the distribution of the sample group as a whole (blue bars) along with the distribution of those in “tornado alley” (red bars) and those outside of tornado alley (green bars). The red bars are more skewed to the higher risk side with a mean and median of 6 and the green bars are more skewed to the lower risk end with a mean of 4 and a median of 3. When compared using a t-test, the two groups showed a significant difference, $t = 5.97$, $p < 0.0001$. Risk perception by location can be seen in figure 6.

3.5 *Willing to spend*

One’s ability to mitigate depends on how much one is willing to spend on mitigating. When asked how much they would be willing to spend, about 66% of participants said they would be willing to spend $1000 or more. That number was slightly greater inside of tornado alley as roughly 69% of respondents said they would be willing to spend $1000 or more. To go along with that, 82% of respondents that stated they had a higher risk (risk ≥ 6) said they would be willing to pay $1000 or more. The full distributions can be seen in table 1 with the low risk group being defined as those who stated their perceived risk was ≤ 5. The high risk group seems to be more skewed toward higher values with a mean of 4.3 and standard deviation of 1.65 while the low risk group appeared to have a more even distribution with a mean of 3.7 and s.d. of 1.76, and when compared using a t-test, the two groups differed significantly to $p < 0.1$, $t = 1.97$, $p = 0.051$.

One other relation we looked at was how much participants would be willing to spend versus their income. Of those who were willing to spend $1000 or more on mitigating, 13% made less than $39,999, 36% between $40,000 and $74,999, and

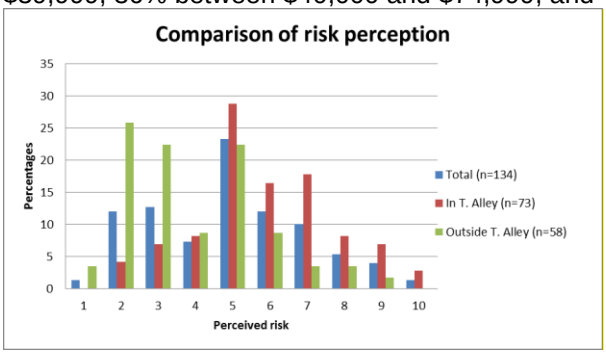

Fig. 5 The graph shows the response rates of how people perceived their risk. 1 was “No risk” and 10 was “Guaranteed to be hit”, with 2-5 being “less than ‘average’” and 6-9 being “greater than ‘average’”. Blue bars represent the total survey population, red bars represent the respondents from “tornado alley”, and green bars represent respondents from outside of “tornado alley”.

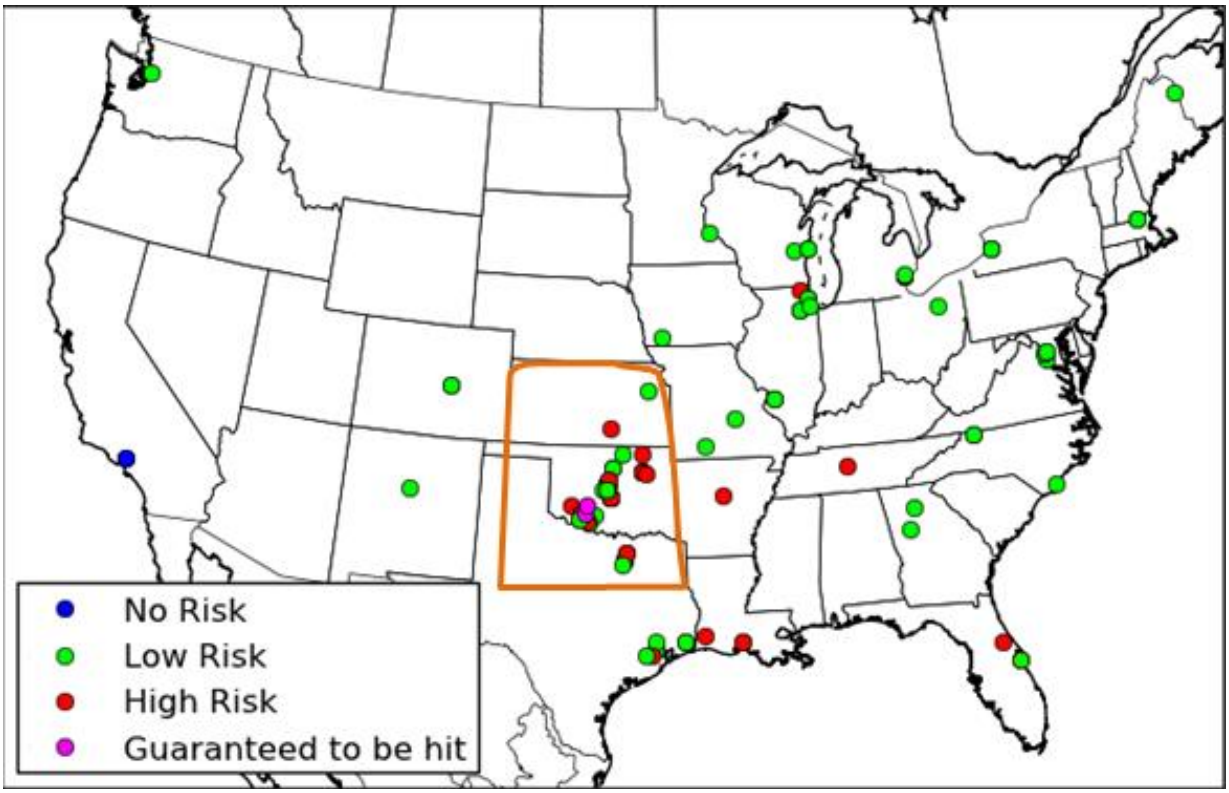

Fig.6 The map shows the location of respondents and how they perceived their risk. Blue dots represent those with no perceived risk (1), green dots represent those with a low perceived risk (2-5), red dots represent those with high perceived risk (6-9), and pink dots represent those who felt they are guaranteed to be hit (10). Green dots are scatter throughout the country, but inside "tornado alley" is primarily red dots.

51% made $75,000 or more. We had anticipated that the percentage of those willing to pay more would increase with income.

3.6 *Thoughts, motivations, and barriers*

Another question asked in relation to reasons why people aren't mitigating was whether or not people had ever even thought about mitigating before. Of the 144 total respondents on the question, 96 of them said that they had not thought about it before. In a follow up to that question, participants were asked to give their reasoning as to why they had not thought about it. Responses to reasons included not knowing they could mitigate, believing that the area they live in is an area that is generally safe from tornados (i.e. near a river confluence, in a mountainous/hilly region, or in/near a city), or other. Less than 15 people actually marked that they believed in the myths that made them generally safe from tornadoes, while 36 marked that they didn't and another 36 marked other. Of the 36 others, about half explained their reasoning to be that they lived outside of tornado alley and did not feel at risk of tornadoes and a handful of those respondents also said they were more worried about hurricanes rather than tornadoes.

The final questions asked were about the motivations and barriers that people felt they experienced when it comes to mitigation. Participants could mark multiple answers. Among the motivations included protecting family, protecting personal property, reducing the cost of insurance, and saving from having to deal with the hassle of rebuilding after a tornadic event. Protecting family was the most marked motivation, with protecting personal property and reducing the cost of insurance having the second and third most responses, respectively (see figure 7).

Responses among the barriers to mitigation included the cost of mitigation, the hassle of mitigating, not knowing what to do or how to do it, and not having the time to take preventative measures. Again, participants could mark as many as they felt applied to them. Figure

Response rates (%)	$0-199	$200-$499	$500-$999	$1000-$1999	$2000-$4999	$5000+
Total	14%	14%	6%	23%	19%	24%
In Tornado Alley	14%	11%	5%	26%	21%	22%
Outside Tornado Alley	15%	16%	7%	18%	16%	27%
High Risk Perception	13%	4%	0%	30%	22%	30%
Low Risk Perception	16%	16%	9%	21%	17%	21%

Table 1 Percentages shown are the response rates for each category. The response rates from the total survey population are on top, with the break out between respondents within "tornado alley" and out of "tornado alley" in the middle rows and the break out between those with high perceived risk and those with low perceived risk on the bottom. n=133, n_i=76, n_o=57, n_h=45, n_l=88

8 shows that the cost of mitigation was by far the number one barrier to mitigation.

4. Conclusions

4.1 *What do they know?*

From what the results showed from our survey, we found that people's knowledge of mitigation is limited. About a quarter of the participants said that they had not heard any of the key terms aforementioned, and corresponding with that, only four of the nine terms were marked by more than 20% of respondents or greater. Of the nine terms, engineers seem to stress the continuous load path more than any other term as the most important thing one could do to mitigate damage to their structure. With that being said, only 14% of all respondents marked that they had actually heard of the continuous load path before. With such low response rates, respondents displayed very limited knowledge about tornado damage mitigation, especially terminologies used by engineers. To further the point, the low average score of approximately 25% on the open ended question involving what they think can be done also shows a lack of knowledge relating to mitigation. People do not appear to be entirely clueless, though. Many participants stated that better construction techniques/ better materials could be used to mitigate tornado damage, which is a correct statement; however, such statements are also very vague. These people seem to have some idea of what can be done to mitigate tornado damage, but the knowledge is not quite at a coherent and relevant point.

4.2 *Why are they not mitigating?*

There seem to be multiple reasons as to why people are not mitigating. For the most part, it seems as if people just do not know they can, or if they do know that they can, then some don't know what to do. This cause would seem to be the likely

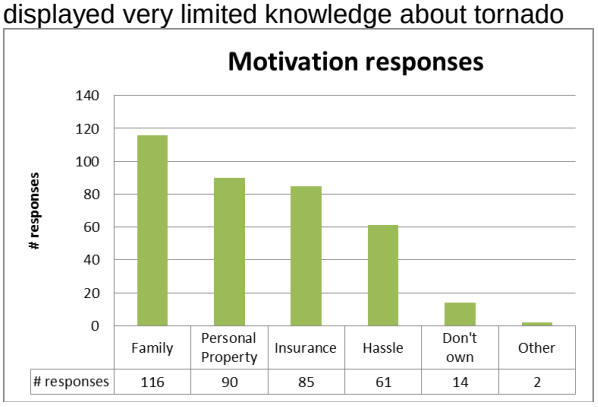

Fig. 7 The chart shows the number of responses for each motivation. Protecting family was the number one motivator, followed by protecting personal property, reducing the cost of insurance, and avoiding the hassle of rebuilding. Some respondents did mark that they did not own the structure they live in or that there were other motivating factors as well. n=147

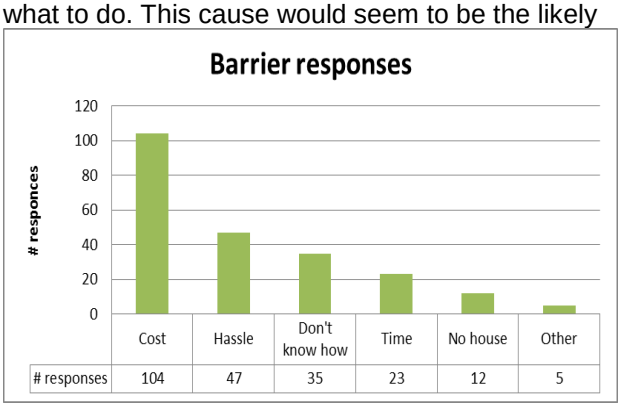

Fig. 8 The chart shows the barriers people had that may be preventing them from mitigating. Cost was the number one barrier, followed by the hassle of mitigating, not knowing what to do, and not having the time to mitigate. A few of the respondents also marked that they did not have a house or that there were others barriers for them. n=137

culprit for a good portion of people not mitigating since their overall knowledge was low, and one has to know how to do something in order to do it.

Another reason why people may not be mitigating is because they may perceive their risk to be too low. With a majority of respondents marking their risk just below average, they could be saying that they recognize the possibility of a tornado possibly passing right over or near their home, but may not think that it will happen to them. With this attitude, many people would be less inclined to actually take mitigation actions seriously.

One other reason could be because people think mitigation would be too costly. This reason stems from the fact that most respondents said that cost would be the most likely culprit for preventing them from mitigating, which also contradicted how much participants said they would be willing to pay. In fact, of the 98 respondents that marked how much they would be willing to pay and said it would be too costly, 64% said they would be willing to spend $1000 or more. It is hard to say whether or not cost is actually a reason why people are not mitigating because of the contradiction between the two responses, but it is definitely something one could look into more in depth in future studies.

4.3 *Future work*

This study was only a first look into what can be studied about people and their responsiveness to mitigation. One area of future research might be to look more in depth into how much people think mitigating will cost and whether or not those who say they would be willing to pay over $1000 think that mitigation is more costly. Other studies could look more in depth into the attitudes of people who recognize the risk and into whether or not they believe that it won't happen to them. This study did not analyze the aforementioned areas in depth, but we believe that a better understanding of these areas could help greatly improve understanding of the reasons why people are not mitigating.

Acknowledgments. The corresponding author would like to thank his mentors for all of their support, every person that assisted in the process of creating the survey, and extend a special thank you to Daphne LaDue for giving him the opportunity to participate in the Research Experience for Undergraduates Program at the National Weather Center in Norman, Oklahoma.

This material is based upon work supported by the National Science Foundation under Grant No. AGS-1062932.

REFERENCES

Amini, M.O., J. W. van de Lindt, A. J. Graettinger, and M. E. Barkley, 2012: Determination of Rational Tornado Design Wind Speed for Residential Woodframe Structures. thesis, Department of Civil, Construction, and Environmental Engineering, University of Alabama, 92 pp.

BPAT, 1999: Midwest Tornadoes of May 3, 1999: Observations, Recommendations, and Technical Guidance. FEMA 342, Federal Emergency Management Agency, Mitigation Directorate, Washington, D.C., 195 pp.

Coulbourne, B., 2011: Tuscaloosa and Joplin Tornadoes: Preliminary Observations. The Wind Engineer, 9 pp. [Available from American Association for Wind Engineering, 1415 Blue Spruce Dr., Ft. Collins, CO 80542 and on-line from http://www.davidoprevatt.com/wp-content/uploads/2011/05/aawe-2011-08.pdf]

Doswell, C. A. III, and H. E. Brooks, 2002: Lessons Learned from the Damage Produced by the Tornadoes of 3 May 1999. *Wea. Forecasting*, **17,** 611-618.

FEMA, 2002: Bracing For the Future: Construction Techniques to Protect Against Future Wind Damage in Ladysmith. September 2002 Tornadoes FEMA-DR-1432-WI, 61 pp. [Available on-line from http://emergencymanagement.wi.gov/mitigation/docs/1432_final_report.pdf]

Flickinger, G., and Lowry, M., 2013: 2NEWS Investigates: Which safe rooms are safest -- above ground or below ground?. [Available on-line from http://www.kjrh.com//dpp/news/local_news/investigations/which-safe-rooms-are-safest-above-or-below-ground]

Prevatt, D. O., W. Coulbourne, A. J. Graettinger, S. Pei, R. Gupta, and D. Grau, 2013: *Joplin, Missouri, Tornado of May 22, 2011: Structural Damage Survey and Case for Tornado-Resilient Building Codes*.

American Society of Civil Engineers, 54 pp.
Sutter, D., D. DeSilva, and J. Kruse, 2009: An economic analysis of wind resistant construction. *J. Wind Eng. Ind. Aerodyn.***97**, 113-119.
Willis, G. B., 2005: *Cognitive Interviewing: A tool for Improving Questionnaire Design*. Sage Publications, 335 pp.