

Perceived Stakeholder Information Credibility and Hazard Adjustments: A Case of Induced Seismic Activities in Oklahoma

Hao-Che Wu, Ph.D.¹; Alex Greer, Ph.D.²; and Haley Murphy, Ph.D.³

Abstract: Oklahoma residents have experienced an increase in moderate-scale earthquakes (magnitude 3–5) regularly since 2011. Recently, several scientific reports showed that seismic activities are likely associated with oil companies' wastewater injection wells. Given that residents have little experience with this induced earthquake hazard and the potential for significant earthquakes, there is considerable risk. Additionally, while residents experience these earthquakes, little is known regarding how they perceive the credibility of different earthquake information sources. To explore these issues, this study uses a mail-based survey of residents in two Oklahoma communities that have experienced earthquakes. The findings suggest that survey participants perceive the credibility of the federal government as an information source higher than state and local governments. Results further suggest that education and income levels are statistically significantly related to individual perception that an information source is credible. Finally, the findings suggest that the association between the credibility rating of government stakeholders and hazard adjustment intention are weaker if people have direct earthquake experience. DOI: [10.1061/\(ASCE\)NH.1527-6996.0000378](https://doi.org/10.1061/(ASCE)NH.1527-6996.0000378). © 2020 American Society of Civil Engineers.

Introduction

While Oklahoma is host to a number of hazards, earthquakes are an emerging issue for the area, with the frequency and severity of earthquakes increasing considerably from 2009 to 2015. According to the USGS (2015), in 2014 and 2015, Oklahoma was the most seismically active state in the contiguous United States. While these numbers have steadily declined since 2015, the state still experienced 304 magnitude (M) 3+ earthquakes in 2017 (Office of the Secretary of Energy & Environment 2018), and there is still potential for relatively large earthquakes in the area. Of note, two earthquakes reached M5.0 or greater in 2016, causing considerable damage, including one in Cushing, Oklahoma, the largest crude oil storage center in North America and a critical hub for oil and gas storage and pipeline transportation (McNamara et al. 2015c).

This study examines whether or not residents of Oklahoma view stakeholder information as credible related to seismic hazards. While similar projects have been done using samples from earthquake prone areas such as California and Washington state (e.g., Arlikatti et al. 2007; Lindell and Whitney 2000), the earthquake hazard in Oklahoma is qualitatively different due to its recent emergence and etiology. There is a general consensus within the scientific community that this increase in earthquake activity is most likely due to faults being reactivated by wastewater injection

wells, a byproduct of oil and gas extraction (Ellsworth 2013; Holland 2013; Keranen et al. 2013; McGarr et al. 2015; McNamara et al. 2015a, b, c). Gill and Ritchie (2018) introduced the idea of *natech* and *techna* disasters. A *natech* disaster happens when a natural disaster triggers a technological hazard, such as the Tōhoku earthquake and tsunami that triggered a nuclear plant meltdown in 2011. A *techna* event occurs when a hazard traditionally defined as natural triggers a technological failure. In the case of Oklahoma, it is widely agreed that wastewater injection wells are triggering earthquakes. As a *techna* event, a natural disaster triggered by technology, the earthquakes that the state is experiencing represent a relatively understudied, yet important type of event (Gill and Ritchie 2018). The unique nature of the hazard may lead to a difference in where residents receive information about the hazard and whether or not they believe those are credible sources.

This study uses general public household survey data from two communities in Oklahoma—Shawnee and Sapulpa (Fig. 1). Shawnee and Sapulpa are both located inside the earthquake hazard zone according to the 2016 Oklahoma earthquake hazard map published by the USGS during 2017 (Fig. 1). The survey asks respondents about their perceptions of the accuracy of earthquake information from a number of potential sources along with their demographic characteristics, such as marital status, education level, and gender. While previous research has examined how those at risk evaluate the credibility of information resources (Apatu et al. 2015; Arlikatti et al. 2007; Basolo et al. 2009; Han et al. 2017; Paton 2003; Rogers and Prentice-Dunn 1997; Tyler and Sadiq 2018), this study expands on that literature by exploring the relationships among perceived credibility of seismicity information sources, individual characteristics, and an emerging hazard experience in Oklahoma. This is critical because past studies have shown that perceptions of information sources influence whether individuals adjust to hazards or not (Arlikatti et al. 2007; Han et al. 2017; Paton 2003).

We briefly discuss the literature regarding hazard information flow, perceived stakeholder information credibility, and how demographics and hazard experience affects the relationship

¹Associate Professor, Dept. of Emergency Management and Disaster Science, Univ. of North Texas, Denton, TX 76203 (corresponding author). Email: tristan.wu@unt.edu

²Assistant Professor, College of Emergency Preparedness, Homeland Security and Cybersecurity, Univ. at Albany, Albany, NY 12222. Email: agreer@albany.edu

³Assistant Professor, Fire and Emergency Management Administration Program, Oklahoma State Univ, Stillwater, OK 74078. Email: haley.c.murphy@okstate.edu

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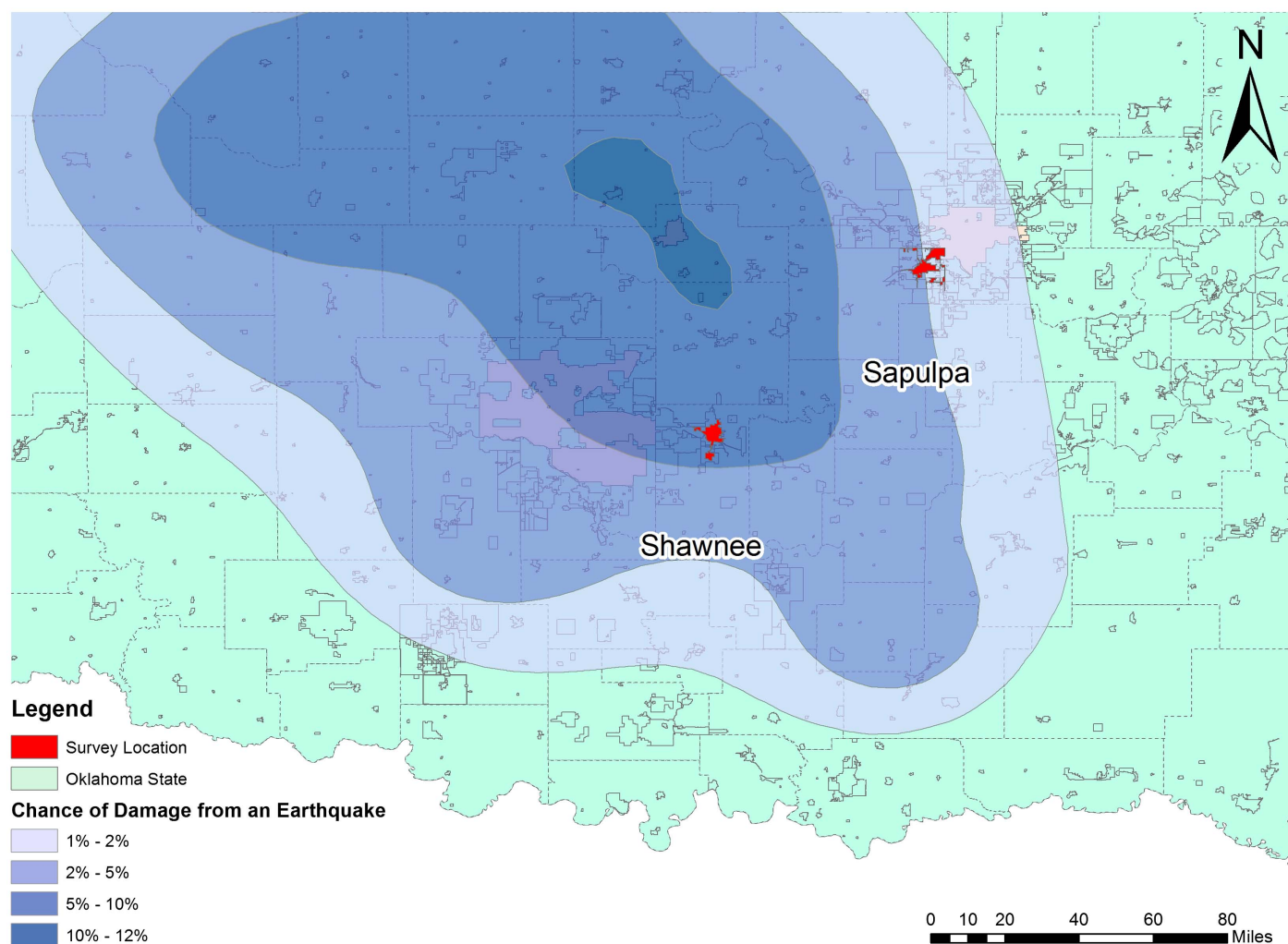


Fig. 1. 2017 Oklahoma earthquake hazard map and survey locations.

between perceived stakeholder information credibility and hazard adjustment adoption. We use this past research to inform the development of a series of hypotheses and research questions. Then, we describe our survey instrument and methodology. Finally, we discuss the practical implications of the findings and conclusions, as well as how they contribute to our understanding of theory.

Hazard Risk Information Flow

The relationship between stakeholder perception and protective actions is explained in the Protective Action Decision Model (PADM). The model was first introduced in 2004 (Lindell and Perry 2004, 2012), and later updated in 2018 (Lindell 2018). According to PADM, individuals receive hazard information or warnings from different cues, channels, and sources. This is particularly relevant with the rise of social media and the availability of a variety of sources disseminating hazard information (Wu et al. 2017). Information is filtered through a predecisional process that details how people are exposed to different information, pay attention to different information sources, and comprehend the information (Meyer et al. 2013; Wu et al. 2015). Next, an individual's perceptions of stakeholders (i.e., government officials, media, and peers), protective actions (or hazard adjustments), and the threat influence their protective action or hazard adjustment decision-making process. Note that in the updated PADM model, individual

characteristics, such as demographics and previous experience with hazards, also influence the relationships between stakeholder perceptions and individual decisions about hazard adjustment. The second edition of this model showed how it can be used to explain the decision-making process of hazard adjustment adoptions (Lindell and Perry 2012). Hazard adjustment activities, such as having emergency plans or buying disaster related insurance plans, are also broadly defined as protective actions. For this study, we are specifically isolating and testing the relationship between information sources, stakeholder perceptions, demographic characteristics, and protective action decisions, as described in the PADM.

Perceptions of Stakeholder Information and Hazard Adjustment

Decisions to adjust to hazards are not made in a vacuum. Instead, they are made in a complex environment where individuals and households receive information from a number of stakeholders. These stakeholders include their peers, government agencies, social media, websites, and news media, among others. Robinson et al. (2019) describe the diversity of information sources for warning messages as an information ecology. They find a number of differences in what medium individuals use to access and share information about tornado threats based on severity of the storm, gender, and age. Research on information seeking and information

processing has shown that individuals typically process information efficiently (Eagly and Chaiken 1993; Kahneman 2011), relying on heuristics or biases to make quick, situational decisions. Individuals may choose to seek more information when they realize they have a lack of knowledge (Kuhlthau 1991) or when they have insufficient information about an issue (Griffin et al. 1999, 2008; Kahlor 2007; Lindell 2018; Mileti and Sorensen 1990) in order to make a protective action decision.

In terms of stakeholder perceptions, this study focuses on whether individuals believe a source is credible or not regarding earthquake hazard. Information credibility can be defined as the accuracy or honesty of information communicated about a hazard (Arlíkatti et al. 2007; Frewer et al. 2003). Determining whether a source is credible is at least partly determined by the level of trust an individual has in the information source. When individuals perceive the risk information to be credible, they are more likely to take protective action or undertake an appropriate hazard adjustment with regard to a hazard or risk (Lindell and Perry 2000; Siegrist and Cvetkovich 2000; Solberg et al. 2010). A number of factors have been found to influence whether a source is considered credible, including source expertise (Hovland and Weiss 1951), trustworthiness (Berlo et al. 1969; Hovland and Weiss 1951; Whitehead 1968), and lack of bias or objectivity (Gaziano and McGrath 1986; Whitehead 1968). Much of this research focused on newspapers and other traditional media as sources of information, but these factors can be extended to other stakeholders as well. In the area of risk communication specifically, studies have examined perceived accuracy of stakeholders and found a mix of competency, caring, and honesty or trustworthiness as important factors (Basolo et al. 2009; Kaspersen et al. 1992; Renn and Levine 1991; Siegrist and Cvetkovich 2000).

When faced with deep uncertainty, such as an emerging hazard, individuals may turn to a number of different sources for information. Several studies have established the importance of trust in these organizations in hazardous settings. For example, studies found that individuals and emergency managers are more likely to turn to local experts for risk information in times of uncertainty, and trust in those local experts is a strong determinant of hazard adjustments (Arlíkatti et al. 2007; Provencio et al. 2015). Multiple studies have found that higher levels of trust in emergency management stakeholders increases the intention to adopt hazard adjustments (Lindell and Perry 2000; Solberg et al. 2010). Trust in seismic experts also influences individual mitigation decisions with regard to seismic retrofitting (Egbelakin et al. 2011). As indicated in Wu et al. (2012), information from credible stakeholders leads to further protection action; thus, we need a fuller understanding of which stakeholders individuals view as credible.

Beyond perceived expertise, the credibility of an information source may also be built upon an individual's sense of shared identification with the source (Eagly and Chaiken 1993). Godschalk et al. (1994) used the imagery of an onion to describe different trust levels between individuals and a variety of stakeholders. The theory suggests that an individual's perceived credibility would be highest for the people that individuals shared their daily lives with (i.e., household members and peers), because this close contact builds understanding and credibility. Beyond this, they are often exposed to the same hazards, sharing elevated stakes when considering information accuracy. In other words, individuals might find their family members and peers are willing to provide them with information they immediately perceive as credible. Government agencies, media, and other sources outside of the household, in comparison, do not share the same regular, intimate interactions or even fate with an individual. Given this, the perceived credibility levels of those stakeholders may be lower. Using this theory, we

expect that individuals would rate the credibility of earthquake information from family and peers before media sources and government.

This theory was expanded and applied specifically to disaster studies in which researchers found that, on average, individuals believe family, friends, and local government are more willing to provide them with accurate information about natural hazards than federal or state level government (Arlíkatti et al. 2007; Tyler and Sadiq 2018). The easy availability of information is also an important factor that influences where individuals seek information (O'Reilly 1982). After Superstorm Sandy, citizens relied on television and radio for information until communication systems allowed the use of social media and other connections with peers (Burger et al. 2013). Social media and the internet provide an outlet for a number of news sources, including official sources, news media, and family and peers. While the medium itself makes information easily accessible, researchers are still exploring how individuals will perceive the credibility of the information they receive from social media, as the different sources of social media information cut across the layers of the onion as previously discussed.

Individual Characteristics

The PADM also suggests that individual characteristics, such as demographics, will also have an effect on individual hazard adjustment decision-making. While most previous research in this area has included demographic factors, findings are inconclusive at best. Lindell and Whitney (2000) found that correlations among demographic variables and risk perceptions and adjustment adoption are small and, from a practical perspective, even if these relationships exist, they are not of much value because they often involve characteristics that emergency managers cannot alter. That said, previous research suggests that white ethnicity (Lindell et al. 2009; Lindell and Perry 2000; Prater and Lindell 2000), being female (Kung and Chen 2012; Lindell and Prater 2000), bigger household size (Lindell and Perry 2000; Russell et al. 1995), homeownership (Lindell and Perry 2000; Russell et al. 1995), a higher education level (Russell et al. 1995), years of tenure in an area (Lindell and Hwang 2008; Russell et al. 1995), a higher income (Lindell et al. 2009; Lindell and Perry 2000; Russell et al. 1995), being older (Lindell et al. 2009), and being married (Prater and Lindell 2000; Russell et al. 1995) are all more likely to result in increased adoption of adjustments to natural hazards. Interestingly, Prater and Lindell (2000) found that women had lower likelihood of adjustment adoption, while Lindell et al. (2009) found that women thought that adjustments would cost more and be more effective than men did. Other research has found that white males are less likely to adopt adjustments in the case of technological hazards. Termed the *white male effect*, this suggests that white males are more likely to be highly skeptical of risk and less likely to adopt hazard adjustments (Henwood et al. 2008; Kahan et al. 2007) because they benefit from the current status quo (Tierney et al. 2001). Studies have found ambiguous results with regard to the relationships between ethnicity and hazard adjustment level.

Other than gender and ethnicity, studies have also found that age (Lindell and Whitney 2000) and tenure in a community (Dooley et al. 1992; Turner et al. 1986) are both positively correlated with hazard adjustment. Dooley et al. (1992) also found that marital status and household size are positively associated with earthquake adjustment. Other personal characteristics, such as education and income level, are also found to be positively correlated with earthquake hazard adjustment (Edwards 1993). Renting, in contrast, is negatively correlated with hazard adjustment (Lindell and

Whitney 2000). Finally, a number of studies have explored the relationship between hazard experience and hazard adjustment (Lindell 2018; Morgan et al. 2002; Mulilis and Duval 1995; Rogers 1983), measuring hazard experience in different ways: direct, indirect, vicarious, and life (cf. Becker et al. 2017). Findings suggest that individuals that have direct and indirect experience are more likely to adopt adjustment measures for a future disasters (Becker et al. 2017).

Research Objectives

Based on the aforementioned literature, this study explores individual perceptions of credibility across different stakeholders regarding earthquake hazard information in Oklahoma and how those perceptions might relate to hazard adjustment intentions. In addition, as indicated in PADM (Lindell 2018), this study examines how personal characteristics mediate the relationship between perceptions of information source credibility and hazard adjustment intention. The following are the research hypotheses (RH) and questions (RQ).

RH1: Mean ratings of perceived credibility of information sources will be highest for household members, next highest for peers, and lowest for federal government authorities.

RH2: Females will have a higher mean rating of perceived information credibility for government agencies and news media compared to males.

RQ1: Do different ethnic groups have different perceived hazard information credibility ratings for stakeholders?

RQ2: Do people with different marital statuses have different perceived hazard information credibility ratings for stakeholders?

RQ3: Do people with different education levels have different perceived hazard information credibility ratings for stakeholders?

RQ4: Do people with different income levels have different perceived hazard information credibility ratings for stakeholders?

RQ5: What are the correlations between perceived stakeholder information credibility, personal characteristics, and hazard adjustment intention variables?

RQ6: Do personal characteristics mediate the relationship between perceived stakeholder information credibility and hazard adjustment intentions.

The next section will discuss the ways in which the data were collected, how the variables were measured, and the analytical analyses used to test the RHs and RQs.

Data and Methods

This study used a stratified sampling procedure to identify household samples in Shawnee (zip codes 74801, 74802, and 74804), and Sapulpa (zip codes 74066 and 74067), Oklahoma. These two cities were chosen because their demographic factors are generally representative of communities within the earthquake risk zone in Oklahoma. The survey was sent out following procedures outlined in Dillman et al. (2014). Each household was sent as many as four survey packages (Waves 1, 3, 4, and 5) and one reminder postcard (Wave 2). The mailing list was obtained from Experian Information Solutions, Inc. Due to relocations and inaccurate addresses, 34 addresses were removed from the original mailing list. 1,476 survey packages were mailed to Sapulpa and 1,490 were mailed to Shawnee. The survey was completed in September and October 2016. There were 461 household respondents (436 mailed back and 25 online), 44 households refused, and 273 undeliverable survey packages; the response rate was 17.40%. Table 1 provides the basic demographics descriptive statistics of the sample. A Box's M

Table 1. Survey respondents' demographics descriptive

Demographics	Descriptive statistics
Age (mean)	60.60 years old
Female (%)	38.30
White (%)	84.60
Married (%)	72.50
Education level (mode)	3 = Some college/vocational school
Income level (mode)	3 = \$55,000–\$79,000
Home ownership (%)	98.90
Household size (mean)	2.50 people
Home duration	18.25 years
Community duration	30.50 years
State duration	45.41 years
Earthquake damage level (mean)	1.75

(homogeneity) test was performed to test unequal correlations between the Shawnee and Sapulpa samples. The results shows no difference [Box's $M = 275.45$; F -value = 1.18, nonsignificant (ns)]. Therefore, the two samples were combined to test the RHs and RQs.

This study uses a portion of the questionnaire that was not analyzed previously in Murphy et al. (2018). The data included measures of eight information sources: federal government, state government, local government, news media (paper, TV, and radio), websites, social media (Facebook and Twitter), peers (friends, relatives, neighbors, and coworkers), and household members (summarized subsequently as household members). Survey respondents were asked to report to what extent they think that each source is willing to provide residents with accurate information about earthquake hazards. Responses were reported on a five-point Likert Scale with anchors *not at all* (=1) and *very great extent* (=5). Gender was coded as 1 for female and 0 for male. Ethnic groups was categorized as 1 for white and 0 for other ethnicity. Marital status was categorized as 1 for married and 0 for single, divorced, and widowed. Education level was categorized as 1 for less than high school or high school graduate, 2 for some college/vocational school, 3 for college graduate, and 4 for graduate school. Respondents were asked to provide their income level based on 2015 household income level before taxes. Income level is categorized as 1 for less than \$30,000, 2 for \$30,000–\$54,999, 3 for \$55,000–\$79,999, 4 for \$80,000–\$104,999, 5 for \$105,000–\$129,999, and 6 for more than \$130,000. Home ownership was categorized as 1 for owning a home and 0 for renting a home. Respondents were asked to report the number of people in the family (household size) and the duration of living in their current home, community, and state. Respondents were also asked to report their property damage levels from local earthquakes using a seven-point Likert scale with anchors *no damage* (=1), *moderate damage* (=3), and *total collapse of home* (=7). Finally, earthquake hazard adjustment intentions were measured by asking respondents to report the likelihood of adopting 12 different earthquake hazard adjustment activities using a five-point Likert scale with anchors *not at all* (=1) and *very great extent* (=5). These adjustment activities included strapping heavy items in the house, installing earthquake latches, developing emergency plans, learning how to shut off utilities, purchasing earthquake insurance, contacting the Red Cross for earthquake information, contacting nonprofit organizations for earthquake information, contacting local government agencies for earthquake information, attending meetings about earthquake hazards, joining community preparedness activities, and contacting government officials or media to support action about earthquake hazards. These 12 items were used to construct the hazard adjustment intention index (Cronbach's $\alpha = 0.89$).

Table 2. Mean ratings of perceived information credibility for all sources ($n = 281$)

Stakeholders	Mean	Standard deviation
Federal government	2.61	1.24
State government	2.58	1.17
Local government	2.40	1.18
News media	2.67	1.21
Website	2.44	1.32
Social media	2.14	1.18
Peers	2.49	1.18
Self/family	2.88	1.26

Note: Wilks' $\Lambda = 0.66$; $F_{(274)} = 20.383$, $p < 0.01$; and $n =$ sample size.

Mean ratings were computed for survey respondents' perceived accuracy of hazard information from different stakeholders. Repeated measure analysis of variance (ANOVA) was used to test RH1. For the repeated measure ANOVA, a multivariate test was used because the household data violated the sphericity assumption. Under this circumstance, a multivariate approach is suggested (Vasey and Thayer 1987). T -tests were used to test RH2, RQ1, and RQ2. ANOVA was used to test RQ3 and RQ4. Correlation analyses were used to test RQ5 and RQ6.

Results

The results of repeated measure ANOVA partially support RH1 (mean ratings of perceived credibility of information sources will be highest for household members, next highest for peers, and lowest for federal government authorities), as indicated in Table 2. Although the post hoc comparison analyses results show that the mean of perceived information credibility for immediate family is the highest ($p < 0.05$), the perceived information credibility rate for peers is not the second highest. In fact, the post hoc comparison analyses shows that the mean credibility of peers is significantly higher than social media but lower than news media and immediate family member ($p < 0.05$). In addition, we hypothesized that the federal government would be ranked lowest for information credibility, but the mean for federal government is the third highest and rises above that of local and state governments (Table 2).

RH2 (females will have higher mean rating of perceived information credibility for government agencies and news media compared to males) is not supported. The results of t -tests show nonsignificant differences between females and males in reporting their perceived information credibility rates for different sources. Similar to RH2's results, the t -test results for RQ1 (Do different ethnic groups have different perceived hazard information credibility ratings for stakeholders?) shows nonsignificant differences. As for RQ2 (Do people with different marital statuses have different perceived hazard information credibility ratings for stakeholders?), the results show that marital status influences the rating of information credibility provided by news media ($t_{(431)} = -2.58$, $p < 0.05$). Unmarried respondents have higher mean rating of news media's information credibility than married couples do ($M_{\text{single}} = 3.06$ and $M_{\text{married}} = 2.73$).

Several one-way ANOVA tests are used to test RQ3 (Do people with different education levels have different perceived hazard information credibility ratings for stakeholders?). The results show that the perceived information credibility rating of federal government, social media, and peers are significantly different based on survey respondents' education levels (Tables 3–5). The post hoc analyses results suggest survey respondents with graduate school degrees have the highest mean ratings of perceived

Table 3. Mean ratings of perceived information credibility of federal government by level of education

Education levels	Mean	Standard deviation	Sample size (N)
High school graduate or less	2.36	1.15	100
Some college/vocational school	2.70	1.20	142
College graduate	2.64	1.21	109
Graduate school	2.94	1.28	89

Note: $F_{(3,436)} = 3.76$, $p < 0.05$.

Table 4. Mean ratings of perceived information credibility level of social media by education levels

Education levels	Mean	Standard deviation	Sample size (N)
High school graduate or less	2.31	1.21	84
Some college/vocational school	2.35	1.18	131
College graduate	1.98	1.10	99
Graduate school	2.00	1.07	79

Note: $F_{(3,389)} = 3.00$, $p < 0.05$.

Table 5. Mean ratings of perceived information credibility level of peers by education levels

Education levels	Mean	Standard deviation	Sample size (N)
High school graduate or less	2.87	1.32	99
Some college/vocational school	2.94	1.30	141
College graduate	2.63	1.15	102
Graduate school	3.05	1.20	88

Note: $F_{(3,389)} = 3.00$, $p < 0.05$.

Table 6. Mean ratings of perceived information credibility level of news media by income levels

Household income levels	Mean	Standard deviation	Sample size (N)
Less than \$30,000	2.58	1.24	60
\$30,000–\$54,999	2.44	1.13	86
\$55,000–\$79,999	2.45	1.16	97
\$80,000–\$104,999	2.33	0.99	57
\$105,000–\$129,999	2.38	1.41	40
More than \$130,000	2.48	1.19	50

Note: $F_{(5,383)} = 4.02$, $p < 0.05$.

information credibility level of the federal government and it is significantly different from the participants with high school diploma or less ($p < 0.01$). Respondents with associate degrees (some college/vocational school) as their highest degree tend to rate the information credibility of social media at higher than college graduates ($p < 0.01$). Finally, people with college degrees give significant lower ratings to their peers in terms of information credibility than their less educated counterparts ($p < 0.01$).

One-way ANOVA tests were also used to test RQ4 (Do people with different income levels have different perceived hazard information credibility ratings for stakeholders?). The findings suggest that only the ratings of news media are significantly different across different income levels (Table 6). The post hoc results show that the mean rating of news media's information credibility rating is the highest in the less than \$30,000 household income group; and significantly higher than the groups with household income higher than \$80,000 ($p < 0.01$).

Table 7. Intercorrelations among variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. FedCr	—																			
2. StateCr	0.65	—																		
3. LocalCr	0.54	0.77	—																	
4. NewsMediaCr	0.37	0.40	0.46	—																
5. WebsiteCr	0.27	0.33	0.36	0.50	—															
6. SocialMediaCr	0.19	0.22	0.30	0.54	0.57	—														
7. PeerCr	0.19	0.18	0.26	0.40	0.41	0.66	—													
8. HouseMemberCr	0.13	0.13	0.22	0.36	0.42	0.50	0.71	—												
9. Age	−0.05	0.05	0.01	0.00	−0.10	−0.04	0.00	0.00	—											
10. Female	0.00	−0.02	0.02	0.07	0.01	0.08	0.08	−0.05	−0.16	—										
11. Ethnicity	0.02	0.06	0.01	−0.04	−0.08	−0.04	−0.07	0.01	0.15	−0.01	—									
12. Marital	−0.01	0.00	−0.04	−0.12	0.03	−0.07	−0.04	0.05	−0.01	−0.21	0.04	—								
13. Education	0.14	0.05	−0.01	−0.08	0.02	−0.13	−0.11	0.01	−0.09	−0.02	0.08	0.12	—							
14. Income	0.03	0.04	−0.03	−0.18	−0.01	−0.09	−0.05	0.00	−0.20	−0.17	0.01	0.34	0.35	—						
15. Home duration	0.03	0.09	0.07	0.09	−0.05	0.04	0.00	0.00	0.43	−0.09	−0.02	−0.09	−0.16	−0.29	—					
16. Community duration	−0.02	0.02	−0.03	0.09	−0.03	0.03	0.02	0.00	0.31	−0.10	−0.07	−0.06	−0.15	−0.20	0.59	—				
17. State duration	−0.09	−0.02	−0.05	0.04	−0.08	−0.04	−0.08	−0.13	0.41	−0.07	−0.04	−0.04	−0.11	−0.07	0.42	0.60	—			
18. HHSIZE	0.01	0.00	0.06	0.05	0.04	0.02	0.07	0.08	−0.31	−0.06	−0.03	0.13	0.04	0.16	−0.13	−0.07	−0.05	—		
19. EarthExp	−0.04	−0.15	−0.08	0.16	0.10	0.26	0.28	0.24	−0.13	0.11	−0.13	−0.01	−0.10	−0.07	0.03	0.08	−0.03	0.01	—	
20. AdjIntention	0.17	0.09	0.14	0.20	0.28	0.24	0.22	0.27	−0.10	0.12	−0.10	0.04	−0.02	−0.08	−0.05	−0.02	−0.12	−0.03	0.29	—

Note: Bold values indicate the correlation is significant at $p < 0.05$ level. FedCr = Federal Government credibility; StateCr = State Government credibility; LocalCr = Local Government credibility; NewsMediaCr = news media credibility; WebsiteCr = website credibility; SocialMediaCr = social media credibility; PeerCr = peer credibility; HouseMemberCr = house member credibility; HomeDuration = the duration of living in the current Home; Community duration = the duration of living in the community; State duration = the duration of living in the state; HHSIZE = household size; EarthExp = earthquake experience; and AdjIntention = earthquake hazard adjustment intention.

Table 8. Partial correlation results with hazard adjustment intention index

Variable	Zero-order correlation	Correlation after controlling for earthquake experience	Correlation change
FedCr	0.172 ^a	0.192 ^a	Increase
StateCr	0.093	0.142 ^a	Increase
LocalCr	0.136 ^a	0.166 ^a	Increase
NewsMediaCr	0.197 ^a	0.160 ^a	Decrease
WebsiteCr	0.279 ^a	0.263 ^a	Decrease
SocialMediaCr	0.238 ^a	0.175 ^a	Decrease
PeerCr	0.222 ^a	0.155 ^a	Decrease
HouseMemberCr	0.265 ^a	0.210 ^a	Decrease

Note: FedCr = Federal Government credibility; StateCr = State Government credibility; LocalCr = Local Government credibility; NewsMediaCr = news media credibility; WebsiteCr = website credibility; SocialMediaCr = social media credibility; PeerCr = peer credibility; and HouseMemberCr = house member credibility.

^aThe correlation is significant at $p < 0.01$ level.

Correlation analyses are used to answer RQ5 (What are the correlations between perceived stakeholder information credibility, personal characteristics, and hazard adjustment intention variables?). Table 7 provides that earthquake property damage experience is positively correlated with the perceived information credibility of news media ($r = 0.16$, $p < 0.01$), social media ($r = 0.26$, $p < 0.01$), peers ($r = 0.28$, $p < 0.01$), and household members ($r = 0.24$, $p < 0.01$). Conversely, damage experience is negatively correlated with state government's earthquake information credibility rating ($r = -0.15$, $p < 0.01$). As for the correlations among the hazard adjustment intention variable and demographic variables, the results show some significant correlations. Hazard adjustment intention is negatively correlated with age ($r = -0.10$, $p < 0.05$), white ethnicity ($r = -0.10$, $p < 0.05$) and household size ($r = -0.12$, $p < 0.05$). It is positively correlated with female gender ($r = 0.12$, $p < 0.01$) and earthquake experience ($r = 0.29$, $p < 0.01$).

Finally, partial correlation analyses are used to answer RQ 6 (Do personal characteristics mediate the relationships between perceived stakeholder information credibility and hazard adjustment intention?). In Table 7, it is clear that earthquake experience is correlated with both stakeholder credibility variables (Variables 1–8) and the hazard adjustment intention index (Variable 20). Therefore, several partial correlation analyses are performed to detect the mediation effect of earthquake experience. Table 8 gives the change in correlation coefficient after controlling for earthquake experience. The findings indicate that earthquake experience acted as a suppressor variable in the relationship between perceived government stakeholder information credibility and hazard adjustment intention. Curiously enough, the earthquake experience acted as a mediator variable in the relationship between perceived credibility of nongovernmental stakeholder information and hazard adjustment intention.

Discussion

In general, the results of this study do not support broader theory or previous findings. Godschalk et al.'s (1994) onion metaphor suggests that individuals will give higher information credibility to family or peers with whom they have a stronger relationship and history (Godschalk et al. 1994; Tyler and Sadiq 2018) or a shared identity (Eagly and Chaiken 1993). In this study, family members and peers were measured separately. As provided in Table 2, family members do have the highest mean ratings of

credibility when compared to all other information sources; on the other hand, this study found that peers' mean rating of credibility is not what we expected. The credibility rating of peers is, in fact, lower than the ratings of news media and the federal and state government. Therefore, while the rating of family members supports the onion metaphor, the rating of peers does not. In the context of this paper and the survey, we are specifically asking about information credibility by asking participants to rate stakeholders' earthquake information credibility. In the case of family members and peers, it is possible that the participants equate information with opinion, but the finding did partially support the onion theory and found that family members are the most credible information source. So, the survey participants may be gaining more information from family members and peers, but they may not view them as experts, and thereby question their credibility. Arlikatti et al. (2007, p. 234) found that residents of California and Washington, where earthquakes have a long history, gave state government and news media higher ratings on trustworthiness than self and family. Additional studies had suggested that individuals were more likely to rate federal government lower than state and local government as far as trustworthiness (Kasperson et al. 1992; Mushkatel et al. 1990; Wray et al. 2006). Interestingly, Oklahoma residents rated federal government higher than state and local government. This is odd in the context of previous research, and given the conservative nature of Oklahoma politics, these findings, on their face, seem even stranger.

We believe there are two likely explanations for this finding. First, earthquakes are a new phenomenon in the state, and while state and local government officials are knowledgeable about the more common hazards in the state (i.e., tornadoes, flooding, and wildfires), residents may not trust state and local government to understand the emerging earthquake hazard. On the other hand, the federal government has experience dealing with earthquake prone areas, which may lead residents to perceive information from the federal government as more accurate. Furthermore, Mileti and Sorensen (1990) suggest that the content of a message may also affect source credibility. While this study does not measure information quality, it may be that the federal government, with more experience with this hazard than the state and local governments, is disseminating better quality information leading to higher levels of credibility. This question warrants future attention. Second, Oklahoma earthquakes are likely induced by wastewater injection wells as a part of oil and gas extraction. This industry makes up a large part of Oklahoma's economy, and residents may not trust the accuracy of information coming from state and local agencies that must balance the task of protecting citizens while promoting good economic conditions. This suggests, however, that messaging in Oklahoma would have more credibility when the state or local government cite federal sources, such as the USGS, when conveying information regarding the seismic risk in the state. On the other hand, perhaps, USGS and the Oklahoma Geological Survey (OGS) could work together when sharing earthquake information with Oklahoma residents.

We also examined differences in ratings of information credibility based on a number of sociodemographic variables. Contrary to previous findings (Arlikatti et al. 2007; Major 1999), we find no differences in perception of information credibility by source based on gender differences. In addition, ethnicity (white versus non-white) did not contribute to differences in perception of information credibility by source. This is not completely surprising, as ethnicity has been found as a weak explanatory variable in previous studies (Turner 1991).

Marital status, education, and income levels do make a difference in individual perceptions of the credibility of an information

source. Although not all mean ratings were statistically significant, people with higher education levels did find the earthquake information from federal government and their peers more likely to be accurate. This confirms previous research that suggests that individuals with higher education levels are more likely to think the government provides accurate information (Cook and Gronke 2005; Van deWalle and Bouckaert 2003). On the other hand, the findings on information provided by peers suggest that people with lower education level are more likely to think the information from their peers is more credible. In addition, unmarried individuals are more likely to give higher ratings to earthquake information provided by news media. This result is new and needs further investigation.

Individuals with no college degree rated the information credibility of social media higher than other sources. It is difficult to make any concrete conclusions from this finding, because of the number and diversity of social media sites. Different social media sites do have different types of audiences (Kemp 2018), and the information content is shared by those audiences. Furthermore, without breaking the category of social media down into its separate parts, we cannot know what kind of information individuals are getting from social media. It may be that individuals are receiving information from news media on social media, or they could be seeking information from family and peers. Future research should examine this question in more detail. In addition, the less than \$30,000 household income and more than \$130,000 annual income groups have higher news media information accuracy ratings. This finding also needs further investigation. Provencio et al. (2015) found that residents with higher income level were more likely to use news media to receive flood risk information during the 2013 Colorado floods. While it does not necessary mean that people with higher income rated news media high on accuracy, it does imply it to a certain degree.

While the findings of this study and the studies previously mentioned show that demographic variables are not strong predictors of information credibility, it is important to share these findings for future meta-analyses. Similar to the findings of a previous meta-analysis study by Huang et al. (2016), it is possible that demographic variables are weak predictors of both evacuation decisions and information credibility. This study uses a correlation matrix to demonstrate the intercorrelations among variables. Earthquake hazard adjustment intention is correlated with a number of social demographic variables. While the literature shows ambiguous findings, unlike the findings reported by Edwards (1993) and Lindell and Prater (2000), the Oklahoma sample suggests that white ethnicity is negatively correlated with the hazard adjustment intention index. This finding aligns more with the literature around the *white male effect* (Henwood et al. 2008; Kahan et al. 2007) and may be attributable to the human-induced nature of the earthquakes in Oklahoma. In addition, similar to previous findings (Kung and Chen 2012; Lindell and Prater 2000), being female is positively correlated with the hazard adjustment intention index. The correlation analyses also show other findings that are different from previous studies. For example, years of tenure in the state and age are both negatively correlated with the hazard adjustment intention index. This is different from studies that were carried out in traditionally earthquake prone states (Lindell and Prater 2000; Russell et al. 1995). In addition, several nonsignificant findings are also somewhat surprising as they are not in line with previous findings. The Oklahoma sample shows that demographic variables that capture a household's social status such as education, income, and household size are not correlated with hazard adjustment intentions. This may be due to the newness of the earthquake hazard. Some hazard adjustment activities protect individuals from several different

hazards, but hazard adjustments for earthquakes are still new in Oklahoma and individuals may not fully understand what hazard adjustments they should be making.

Finally, as indicated by PADM (Lindell 2018), earthquake experience facilitates the relationship between stakeholder perceptions and hazard adjustments. These analyses examined how experience with the earthquake hazard, as measured by experience with property damage from earthquakes, affects the relationship between perceptions of stakeholder information credibility and hazard adjustment intentions. The findings suggest that the correlation between government stakeholder information credibility and hazard adjustment intentions strengthened when earthquake experience is a control variable. This finding indicates that, quite interestingly, individuals who have experienced property damage because of earthquakes have weaker correlations between the two variables. In another words, the connections between the credibility rating of government stakeholders and hazard adjustment intention are weaker if people have direct earthquake experience. On the other hand, a totally opposite effect is found when using earthquake experience as a control variable to examine the correlations between nongovernment stakeholder's earthquake information credibility and hazard adjustment intention. The findings suggest that the connection between the credibility rating of nongovernmental stakeholders and hazard adjustment intention is stronger if people have direct earthquake experience.

This is likely due to the role that the state government plays in regulating the oil and gas industry in Oklahoma. State law bars local governments from regulating oil and gas operations within city limits. The job of regulating waste-injection wells falls to the Oklahoma Corporation Commission, which must simultaneously protect state residents from this hazard while balancing the economic impact of shutting down oil and gas activities in a state so heavily reliant on the oil and gas industry. It is likely that individuals with direct earthquake experience are less likely to trust the accuracy of information provided by government with potentially divergent interests.

Conclusion

This study examined how Oklahoma residents rated the willingness of different stakeholders to provide credible earthquake information and its relationship with hazard adjustment intentions. A few studies have examined the credibility/accuracy of information sources with regards to earthquakes in the past, but these studies have focused on areas with a long history of earthquakes (Arlikatti et al. 2007; Lindell and Whitney 2000). Earthquakes in Oklahoma are unique, because they are an emerging hazard and they are human induced. The findings of this study have potential to help risk communicators understand what sources to utilize when disseminating information regarding emerging hazards. This issue, while most prominently discussed in regard to Oklahoma, is not isolated to Oklahoma. Due to environmental concerns, France, Germany, and Scotland have all banned fracking, with a number of other countries instituting temporary moratoria until concerns can be assuaged (Inman 2016). There is also evidence of seismicity induced by fracking in Canada and by wastewater injection wells in California (Bao and Eaton 2016; Goebel et al. 2016).

As with all studies, this one has a number of weaknesses. First, this study is a cross-sectional examination of individual perceptions from a single point in time. As oil prices have fallen, the number of wastewater injection wells has fallen. This has caused a decrease in the overall number of moderate earthquakes in the state, which may change perceptions of information sources; however, as oil prices

rise, it is likely that oil and gas activities will grow in the state and will likely lead to a future increase in the number of earthquakes. Second, this study only examines the perceptions of residents in Oklahoma. Other states and localities are also experiencing human-induced earthquakes from wastewater injection wells. Oklahoma has a conservative political culture, and states and localities with more moderate or liberal political leanings may have different views of the accuracy of information, particularly from local, state, and federal government. Third, our sample lacked enough diversity to allow us to make suggestions for targeting different populations with different information sources. Future studies should consider oversampling population subgroups to further investigate this issue. Additionally, since we do not ask respondents specifically about the Oklahoma Corporation Commission, this study is not able to make conclusions about whether or not respondents think there is a conflict in the commission's dual role of protection and economic/resource management. We do think this is an area that is ripe for research, particularly in Oklahoma, where natural resources are so closely tied to economic strength.

Despite these weaknesses, this study adds important insights to our understanding of how individuals perceive information source accuracy with regard to emerging and human-induced hazards. Based on recent trends, such as the emergence of technica and natech disasters like the detrimental impacts resulting from human-induced climate change and the Tōhoku earthquake, tsunami, and radiological incident, the line between natural and technological disasters is blurring. These worldwide occurrences lend more importance to the understanding of how residents conceptualize these events and how they see the credibility of the hazard information they receive from different entities (e.g., government agencies, media, friends, and household members), thereby extending the generalizability of this study.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available from the corresponding author by request, including earthquake information source credibility, earthquake hazard adjustment intention, and self-reported property damage level. To ensure the anonymity of participants whose data are included in the data set, demographic data are not available. The data sharing process will follow Oklahoma State University Institutional Review Board regulations.

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