

# Assessing “Preparedness Elevated”: Seismic Risk Perception and Household Adjustment in Salt Lake City, Utah

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## Abstract

Determining household earthquake risk perceptions and adjustments is important for improving our understanding of community preparedness and establishing baselines for improvements. Greater than 90% of the Utah population lives within 25 km of the Wasatch Fault System (WFS), and a 2012 FEMA report ranked seismic risk in Utah as the 6th highest in the U.S.A. We administered a geocoded, mail-out survey to households located in high-risk ground shaking and liquefaction hazard zones. We examined relationships between adoptions of 13 household adjustments and how respondents perceive risk and responsibility in the context of demographic characteristics, house location, and construction type (e.g. year built, unreinforced masonry (URM) or not, number of floors). Results characterize a population that perceives seismic risk as high, but varies significantly in its preparedness and sense of vulnerability. Further research is needed about how residents obtain information, given that fewer than 10% of respondents were aware of Utah's earthquake preparedness guide.

**Keywords:** Earthquake risk; Preparedness; Geocoded survey; Unreinforced masonry; Hazard mitigation; Hazard adjustment

## Introduction

Northern Utah's dramatic Wasatch Mountain Range is bounded by the most continuous, active normal fault in the conterminous United States. The Wasatch Fault System (WFS) is located in the intra-plate tectonic setting of the American West known as the Intermountain Seismic Belt [1]. Of Utah's 2.8 million residents, ~90% reside within 25 km (~15 miles) of the WFS, with the majority of people concentrated in a narrow urbanized corridor known as the “Wasatch Front” [2]. The U.S. Federal Emergency Management Agency (FEMA) recently ranked the state of Utah as having the 6<sup>th</sup> highest relative earthquake risk in the U.S.A. (FEMA 2012).

Since the 1970s, several strategies have been implemented at the state government level to reduce seismic risk and mitigate damage and injury in Utah. These include implementation of policies, building codes, renovations, and practices to enhance public safety and disaster preparedness [2]. An action taken to reduce seismic vulnerability is called a seismic hazard adjustment [3], and includes actions taken before an earthquake to mitigate damage, offer protection, extend relief, and assist recovery [4]. At a household level, seismic adjustments implemented in advance of earthquake events include mitigation practices, emergency preparedness actions, and insurance plans. Mitigation includes actions that protect against structural damages caused by shaking or subsidence during an earthquake, such as strapping water heaters to walls, securing furniture, or bolting a house to its foundation. Emergency preparedness actions help individuals cope after a seismic event occurs, and strategies include enacting a disaster plan and caching food items, storing bottled water, and acquiring first aid kits and other items in advance. Purchasing earthquake insurance is the most common financial strategy to help households recover from damage [3,5].

Social science research suggests that adoption of adjustment processes decreases vulnerability and enables improvements in hazard awareness, safety, public engagement, household preparedness, and community resilience [6-8]. However, most analyses of risk perception and preparedness have focused on populations at active tectonic plate margins in California, Oregon, and Washington, along with a few

studies in the New Madrid Fault area in the south-central U.S.A., an intra-plate zone that includes areas of Illinois, Indiana, Missouri, Arkansas, Kentucky, Tennessee, and Mississippi [3,9,10]. To date, there have not been any studies to characterize the demographic attributes, attitudes and preparedness of the population facing earthquake hazards in Utah, or within the larger Intermountain Seismic Belt-Rocky Mountain region.

This paper presents results of a survey designed to assess the state of household-level earthquake preparedness in Salt Lake City, Utah, and to establish a baseline for further evaluation, education and action. Although the state government has invested significant resources for preparedness outreach and education [11], little is known about the actual actions (i.e., hazard adjustments) that households have adopted. We dispensed a geocoded mail-out survey to assess seismic risk perceptions and disaster preparedness in Salt Lake City (hereafter, abbreviated SLC) households. Responses about the adjustments employed by various households were evaluated for significant relationships of geography and demographic factors. This paper begins with a description of the study area and research goals, then presents the survey methodology and results, followed by discussion, conclusions and implications.

## Study Regional Setting

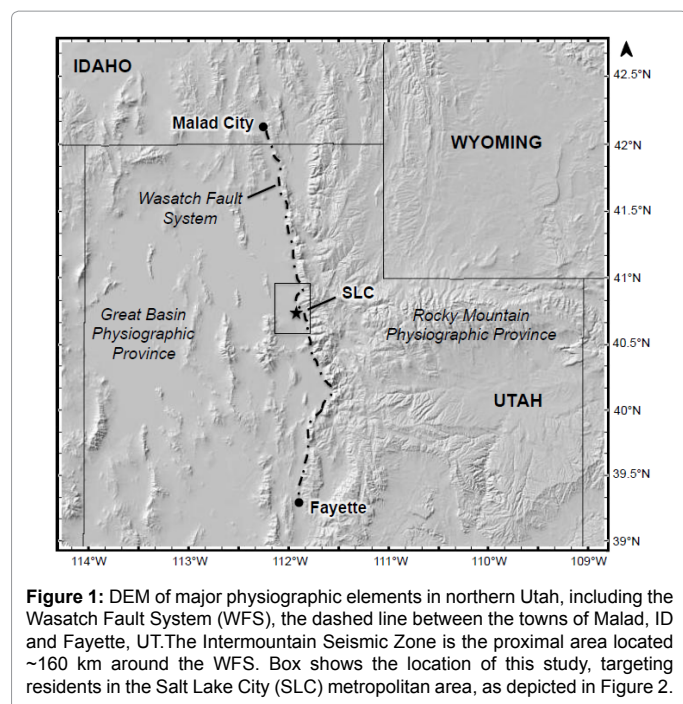
The Wasatch Fault System (WFS) is among the world's best-studied and longest normal faults [2], and it forms the eastern boundary between the Rocky Mountains and the Basin and Range physiographic province (Figure 1). The WFS is situated within the Intermountain Seismic Belt [12], a region of ongoing earthquake activity in an intra-

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**Figure 1:** DEM of major physiographic elements in northern Utah, including the Wasatch Fault System (WFS), the dashed line between the towns of Malad, ID and Fayette, UT. The Intermountain Seismic Zone is the proximal area located ~160 km around the WFS. Box shows the location of this study, targeting residents in the Salt Lake City (SLC) metropolitan area, as depicted in Figure 2.

plate tectonic setting. The WFS is a zone with a complex conjugate fault array that is broadly partitioned into 10 segments, each averaging ~40 km in length, and extending ~380 km in a north-south direction between Malad City, Idaho and Fayette, Utah [13]. The Salt Lake Segment of the WFS is in close proximity to SLC, and is part of what the locals refer to as “the Wasatch Front.”

No significant large magnitude earthquake ( $M \geq 7.0$  on the Richter scale) has occurred along the Salt Lake Segment since the modern settlement of the area by European-Americans in 1847 [11]. Along the WFS, seismic events have produced surface ruptures during earthquakes with an estimated range of  $M \sim 6.5$  to 7.5 on the Richter scale. Many large magnitude earthquakes have occurred in the distant past, with varying frequency for each segment [14-17]. Since 1847, Utah has experienced at least 16 earthquakes of  $M \sim 5.5$  to 6.6; only eight of these moderate-magnitude earthquakes caused damage [11]. Only two earthquakes with  $M > 6.0$  have occurred in Utah’s recorded history: the 1901  $M 6.5$  Richfield and the 1934  $M 6.6$  Hansel Valley earthquakes [2,18]. Over the past century, the greatest magnitude events affecting the most populated corridor near SLC include a  $M 5.5$  earthquake in 1910 and another  $M 5.5$  earthquake in Ogden in 1914. As such, current residents have not experienced a moderately sized earthquake or a large magnitude earthquake in Utah. Earthquakes occur infrequently along the WFS in comparison to the California San Andreas Fault System [19].

Various 3D numerical simulations of ground shaking motions (0–10 Hz) have been conducted to model a future disaster scenario of a  $M 7.0$  surface-rupturing earthquake occurring along the SLC Segment of the WFS [20-27]. Surface faulting, liquefaction, rupturing, seismically induced landslides, and tectonic subsidence are all related hazards that can accompany such an earthquake of high magnitude [28,29]. Based on model results, the area of Salt Lake County along the WFS has been mapped into two seismic hazard risk zones: a zone that will experience significantly strong ground shaking, and a zone at high risk of liquefaction damage [30,31]. Areas predicted to experience strong

ground shaking are along the fault and the mountain front. Strong ground motions in bedrock areas have potential to topple multi-story buildings, crumble masonry, damage foundations and destroy concrete structures and roads [22,31]. The area prone to liquefaction in the SLC area is relatively large and includes the shores of Great Salt Lake and areas with a substrate made of weakly consolidated water-saturated unconsolidated sediments. During an earthquake event, houses, buildings, and roads located above water-saturated uncompacted geologic substrates may shake violently and collapse as the sediments de-water in the process of liquefaction [32]. Liquefaction effects are rather unpredictable and highly variable in scale; damage may range from small, uniform ground settlement across a site, to extreme ground settlement and horizontal movement across tens of meters, and lateral spreading that can cause loss of foundation bearing [33]. Liquefaction and seismic shaking can cause serious structural problems and building collapse amounting to billions of dollars [34].

The future occurrence of a large magnitude earthquake ( $M 7.0$ ) along the WFS poses a significant risk to the local population [35]. A majority of Utah’s total ~2.8 million population reside within 25 km (~15 miles) of the WFS, concentrating risk in the narrow corridor of the Salt Lake Valley, where most medical centers, transportation, educational and government facilities, as well as the main airport are located [36]. Since greater than 75% of Utah’s economy is located within the SLC metropolitan area and the “Wasatch Front” corridor is bounded by the most-active fault segments [11], a major WFS earthquake event will have profound social and economic consequences.

Recent application of the FEMA loss-estimation software HAZUS has modeled the impacts of an  $M 7.0$  earthquake in the Salt Lake City segment of the WFS [37]. The model estimates the number of deaths in the thousands, and building and infrastructural economic losses that would amount to ~\$32 billion (2012 dollars). Estimated damages in the SLC region are significant due to the large number of historic buildings and other unreinforced masonry (abbreviated as URM) structures; there are approximately 130,000–150,000 URM structures in the local building stock of SLC, which could collapse during seismic shaking [38].

## Research Goals

We administered a survey to develop a preparedness baseline for Salt Lake City residents near the WFS, and to assess how households adopt adjustments and perceive seismic risk. Three questions framed our study.

1. How do earthquake risk perceptions and adoption of household adjustments in the SLC population relate to demographic attributes and the geographic location of each respondent residence by seismic risk zone?

Research about the adoption of household seismic adjustments indicates that specific factors affect risk perception of seismic hazards and disaster preparation. Many studies relate demographic attributes to risk perception [39] and disaster preparedness [40,41]. Some studies demonstrate a possible geographic relationship between location—namely, distance from a fault—and whether households intentionally adopt seismic adjustments. One assumption is that risk decreases with distance from a hazard [42]. A comparison of the relationship between a city in California with high estimated seismic risk and a city in Washington with moderate estimated seismic risk found that the associated populations differed in hazard experience and the degree of risk perception, but only slightly differed in regard to adoption

of household seismic adjustments [43]. This study of SLC residents identifies risk perception patterns and differences among household seismic adjustments by comparing two populations living near a fault system -- one that lives near a hazard zone prone to intense ground shaking, and another living in a liquefaction-prone zone.

2. How do variations in population demographics relate with household perception of vulnerability to earthquake risk, and the adoption of household adjustments by seismic hazard zone?

Vulnerability to a hazard is based on social and economic factors [44]. Review of studies on seismic hazard adjustments in households [3] demonstrates that many demographic variables significantly correlate with the implementation of seismic adjustments, including education, income, presence of children at home, and marital status [40,45,46]. Most seismic hazard response studies have focused on areas with frequent earthquakes such as the San Andreas Fault system in California; however, it is not clear if such findings are relevant for areas that experience infrequent earthquake events. SLC is an area located within an intra-plate seismic zone and has a major fault system that has not experienced large magnitude earthquakes in recent memory.

3. Does implementation of seismic adjustments by a household correlate with the construction type and age of the home, and the residents' assessment about their own survival of a large magnitude earthquake?

Construction type is a significant factor in whether a building can withstand seismic shaking, and whether occupants survive. Brick houses are typically constructed with un-reinforced masonry (URM), which is a design that is particularly susceptible to damage from ground shaking [31]. Because building codes with seismic safety provisions were not implemented in SLC until the 1970s, the age of the home and the house design (masonry type, single story, multiple story, etc.) may affect perceptions of earthquake risk and how households prepare.

## Survey Methodology

We developed a mail-out survey, a method that has been successfully employed to gather primary data about seismic risk perception and preparedness at the household level [3,47]. We mailed out 1000 surveys and a self-addressed and stamped return envelope to a random selection of addresses in the SLC metropolitan area [48]. Geocoding was employed to allow each responding household to be mapped by its hazard zone [28,31] in a geographic information system (GIS) while complying with institutional review board (IRB) requirements for privacy.

A two-page survey was designed to gather information about seismic adjustments, risk perception, household preparedness, and building type (insert url for Utah open access document here). Additionally, information was acquired about household demographics, and whether residents have taken 13 specific actions to prepare themselves for an earthquake affecting their home, including simple actions (like storing food), costly adjustments like purchasing earthquake insurance, and time-consuming activities like joining an emergency community organization [11]. To assess perceptions of self-preparedness, risk and vulnerability, the survey asked respondents to rank the degree of their opinions on a Likert scale, with 1 being "not at all" and 5 being "to very great extent." One question (#5) asked about the parties that households deemed most responsible for providing protection against earthquake hazards, with categories for themselves, state government, or federal government (FEMA), media, friends, employer, or ecclesiastical leaders, or God. Another question (#9) asked

respondents about their expectations of personal safety as a function of the actions of others, the government and community entities.

The survey also asked whether respondents know about and have the public information guide related to earthquake preparedness that was first published in 2008 by the state of Utah with FEMA funding (question 13). "Putting Down Roots in Earthquake Country" is a free booklet about earthquakes in Utah illustrated by local *Salt Lake Tribune* cartoonist Pat Bagley, and it remains available in published form and online [11]. We were interested to quantify the number of households aware of the guide, as well as the percentages that have adopted each of its recommended preparedness actions.

We applied descriptive statistical methods to assess survey data, resolve patterns, and identify significant relationships regarding risk perception, seismic adjustments, and household demographics. Simple proportional statistics were used to characterize the population and associated preparedness level regarding adoption of certain measures, as well as to compare household responses residing in the liquefaction hazard zone with those living in the ground shaking hazard zone closest to the WFS. To measure the strength of a linear association between variables, we calculated the Pearson Product Moment Correlation. We highlight selected findings, and where relevant we present the measure of correlation reported as the Pearson coefficient ( $r$ ). Accompanying tables present select relevant data listed by survey question, and the mean Likert values volunteered by the survey respondents; some correlations with the greatest absolute value are in bold. This paper discusses many results with Pearson coefficients where  $|r| \geq 0.145$ , which generally corresponds to a 95% confidence of correlation. In the survey results, we present the respondents' perceptions and adoptions (questions 1-9) in relation to the demographic elements (questions 10-22) and geocoded location of the household by seismic hazard zone.

## Results

### Demographic characteristics of the SLC survey respondents

The survey response rate was approximately 20%; a total of 1000 surveys were mailed to a random selection of SLC residents in 2010-2012, of which 198 surveys were returned, enabling results reported at a 95% confidence level. Figure 2 shows the approximate locations

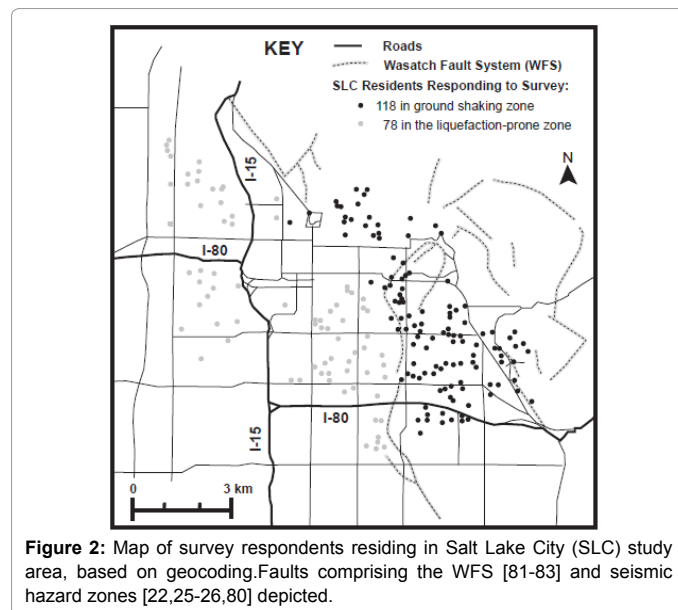


Figure 2: Map of survey respondents residing in Salt Lake City (SLC) study area, based on geocoding. Faults comprising the WFS [81-83] and seismic hazard zones [22,25-26,80] depicted.



of residences that responded to the survey, mapped by seismic zone delineated by the Utah Geological Survey within the SLC study area and the Salt Lake Segment of the WFS. Of the total respondents, 118 reside in the ground shaking seismic risk zone and 78 live in the liquefaction-prone risk zone.

Analyses of the demographic questions in the survey (questions 13-23) indicate that the ratio of male to female survey respondents is an even 50%. The average age responding is 50.3, and a majority of survey participants (95%) are Caucasian; >65% of the responding households are married, 19% have children under 6 years old, and 25% have children over 6 years old. Over half of the respondents indicate earning >\$60,000 in annual household income (Figure 3). The survey respondents are well educated, with over 70% of the sample population classifying themselves as college graduates or with additional graduate or professional education.

Although we randomly mailed out surveys, the population who returned surveys is not a representative demographic sample of SLC residents, and as a result introduces some bias into the results. The responding population in SLC does approximate the male-to-female ratio. However, the sample of survey respondents as compared with 2012 SLC census data over-represents Caucasians, homeowners, high-income earners (>\$60,000/year), and college graduates [49].

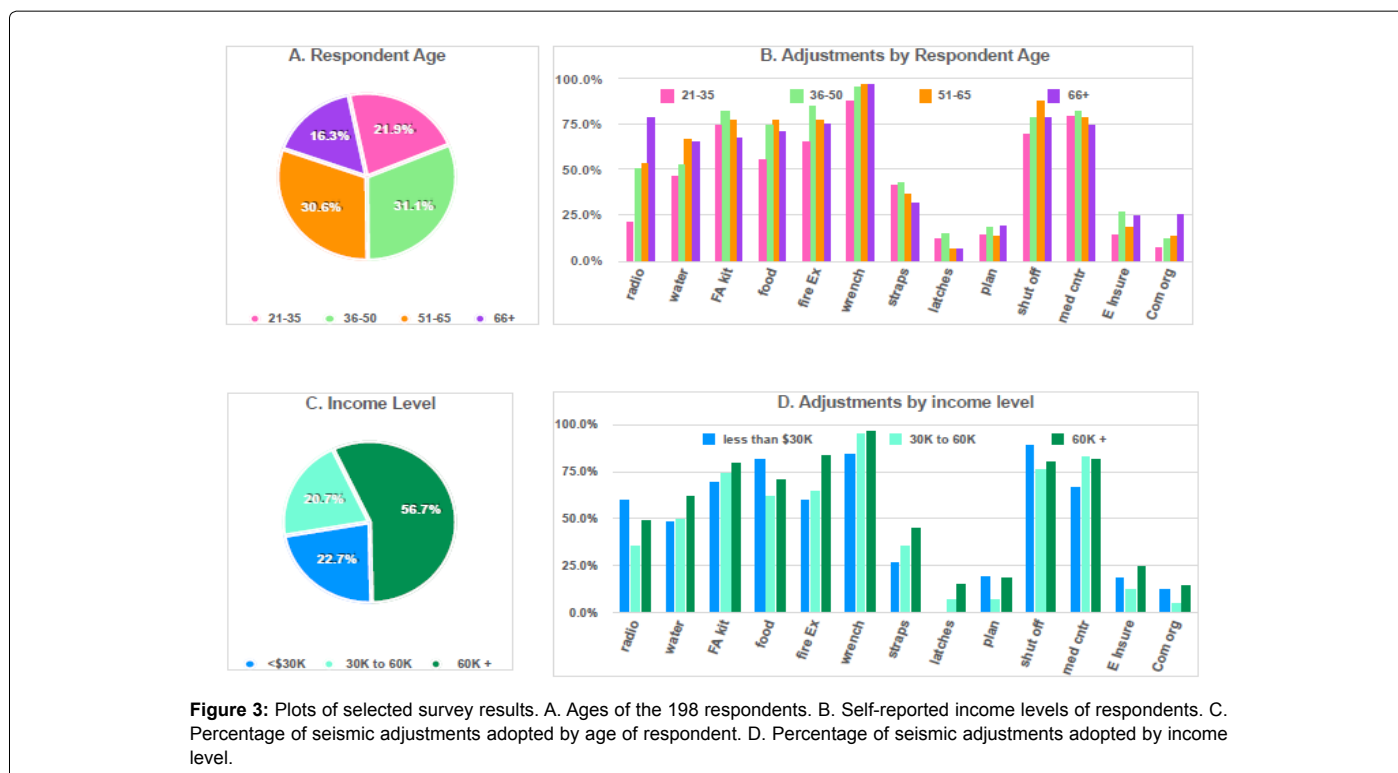
A majority of survey participants own the building they reside in, and 87% of these homes were built before 1975, prior to the implementation of earthquake codes in the state of Utah. Household respondents have lived in their residences an average of 14 years. Of the three types of house architectures specified in the survey (questions 10-11-12), 18% of the respondents indicate that they reside in homes with two or more stories with stepped floors, split levels, or large openings in floors, 36% lived in houses with two or more stories with flat floors, no steps in the floor and no large openings in floors, and 46% reported

living in one story buildings. Respondents live in a range of house construction types: the greatest population of residents amounting to 39% of the total respondents live in homes made of unreinforced masonry (URM); 30% live in wood frame houses, and 24% live in reinforced masonry (RM) houses.

### Correlations

We calculated the percentage of 13 household adjustments adopted by survey respondents (questions 6-7) to prepare themselves for an earthquake affecting their home (Table 1 and Figure 3). Given that many of these practices are also actions for emergency preparedness and mitigating other hazards, the adoption rates for only specific seismic adjustments are directly indicative for assessing earthquake preparedness: strapping the water heater and tall furniture, developing a household earthquake emergency plan, and purchasing earthquake insurance. Installing cabinet latches to keep them securely closed is an earthquake adjustment, but is also recommended for safeguarding homes with small children. In the SLC population surveyed, this adoption directly correlates with small children in the household -- 50% of the survey respondents who had installed cabinet latches also had children living at home, and 40% of those respondents have children under the age of 6 (question 22a,  $r=+0.198$ ). For the entire population responding to the survey, installing cabinet latches was the least adopted household seismic adjustment, with a 10% adoption rate.

Only ~15% of the total population responding to our survey indicates that their household is very well to well prepared should a major earthquake affect her or his home (question 3a). The three household adoptions that strongly correlate with a sense of preparedness are having a cache of food and supplies ( $r=+0.422$ ), storing water ( $r=+0.386$ ), having an emergency plan ( $r=+0.310$ ), and learning where and how to shut off water, gas, and electric utilities ( $r=+0.309$ ).



**Figure 3:** Plots of selected survey results. A. Ages of the 198 respondents. B. Self-reported income levels of respondents. C. Percentage of seismic adjustments adopted by age of respondent. D. Percentage of seismic adjustments adopted by income level.

6.7. Household Seismic Adjustment by all survey respondents (n=198)	Percentage adoption	3a: preparedness self-assessment Pearson coefficient r
6f own wrenches to operate utility shut-off valves and switches	94	0.119
7d learned where and how to shut off water, gas, and electric utilities	80	<b>0.309</b>
7e learned the location of nearby medical emergency centers	79	0.088
6e have a fire extinguisher	77	0.056
6c have a complete first aid kit	76	0.252
6d have a 4-day supply of food for yourself and family	70	<b>0.422</b>
6b have at least 4 gallons of water in plastic containers	58	<b>0.368</b>
6a have a working transistor radio with spare batteries	49	0.219
7a strapped water heaters/furniture to walls and secured heavy objects	38	0.268
7f purchased earthquake insurance	21	0.255
7c developed a household emergency plan	17	<b>0.310</b>
7g joined a community organization for earthquake preparedness	13	0.276
7b installed latches to keep cabinets securely closed	10	0.150

Table 1: Household seismic adjustments surveyed in ranked order of adoption rates.

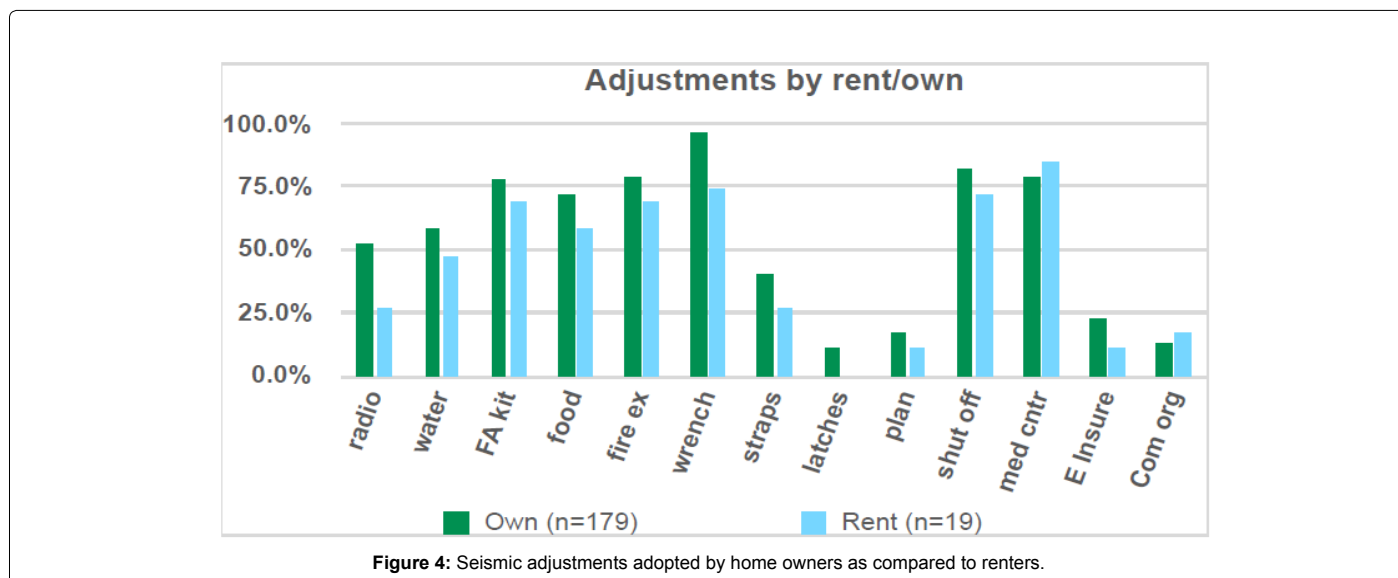


Figure 4: Seismic adjustments adopted by home owners as compared to renters.

About 90% of the respondents were homeowners; few renters returned the survey. Since the renter population is too small to be statistically significant (n=19), it is impossible to draw meaningful conclusions that involve this group. The responses suggest that renters are not as likely to own radios or wrenches (for shutting off utilities) at the same rate as homeowners (Figure 4).

**Respondent age:** Of the SLC survey respondents, 43 were younger than age 36, 61 respondents were between the ages 36-50, 60 respondents were ages 51-65, and 32 were age 66 or older. Overall adoption percentages for the range of household seismic adjustments was 45.5% for the respondents younger than age 36 (n=43); 55.1% for the 36-50 age group (n=61); 54.0% for the 51-65 population (n=60); and 55.1% for the age 66 and older (n=32).

The population of respondents older than age 66 is more likely to own radios ( $r=+0.325$ ), have a water supply ( $r=+0.152$ ) and participate in a community organization ( $r=+0.166$ ). This very strong correlation of the age 66+ population with possession of radios contrasts with the younger generations, which probably rely on smartphones and the internet to stream radio feeds and access other sources of information (Figure 3).

All age groups identify the "self" category as having the greatest

responsibility for protection from earthquake hazards (question 5h); this tendency is diminished for the group that is 66 and older, who may be more reliant on support of others. Data suggest a correlation of respondent age and assessment that the state and federal government bear responsibility for their protection and personal safety in an earthquake (question 9a). The younger respondents comparatively rate the governmental agencies as having greater responsibility for protecting them from hazards (questions 5a, 5b). The younger generations are inclined to think that state and federal government agencies play a greater determining role in their personal safety in response to an earthquake (question 9c) (Table 2).

**Income:** Of the survey respondents to the question about income (question 19), 27 respondents reported yearly incomes less than \$30,000; 42 had incomes between \$30,000-60,000 and 115 respondents indicate incomes over \$60,000. The overall adoption percentage for all 13 of the household adjustments was 55.5% for the >\$60,000 population, 47.0% for the \$30,000-60,000 population, and 49.0% for the <\$30,000 group (Tables 3 and 4).

The population with incomes >\$60,000 is statistically most likely to own fire extinguishers (question 6e,  $r=+0.243$ ) and wrenches (question 6f,  $r=+0.242$ ). Owning a wrench (for turning off utilities) is

14. Age Group of Survey Respondents	21-35	36-50	51-65	66+	Pearson r
Number of Respondents in Age Group (n=196)	43	61	60	32	
<b>6.7. Household Seismic Adjustment</b> (rate of adoption)					
6a have working radio with spare batteries	20.9%	50.8%	53.4%	78.1%	<b>0.325</b>
6b have at least 4 gallons of water	46.5%	52.5%	66.7%	65.6%	0.152
7g joined a community organization	7.1%	11.9%	13.6%	25.9%	0.166
<b>5. Extent to which each party is responsible for protecting you from earthquake hazard</b> (mean Likert score)					
5a Federal Government	2.30	2.05	2.19	2.00	-0.061
5b State and local agencies	<b>2.98</b>	2.53	2.39	2.41	-0.126
5c ecclesiastical leaders	1.49	1.49	1.46	1.96	0.150
5d news media	2.02	1.93	1.83	1.79	-0.064
5e God	1.67	1.65	1.72	2.21	0.100
5f your employer	1.65	1.48	1.36	1.19	-0.175
5g friends, relatives, neighbors, co-workers	2.07	1.84	1.91	1.86	-0.039
5h yourself and your immediate family	1.57	1.48	1.46	1.55	-0.271
<b>9. Extent you expect your personal safety in earthquake is determined by the actions of...</b> (mean Likert score)					
9a myself and my immediate family	<b>4.60</b>	4.56	4.58	3.78	-0.277
9b friends, relatives, neighbors, co-workers	2.69	2.92	2.85	2.73	-0.009
9c news media	2.16	2.15	2.08	1.93	-0.103
9d local government agencies	2.70	2.59	2.50	2.45	-0.085
9e State or Federal Government agencies	2.77	2.49	2.39	2.14	-0.182
9f God	1.98	1.77	1.98	2.43	0.093
9g ecclesiastical leaders	1.70	1.52	1.51	2.04	0.079
9h luck or chance	3.26	3.13	3.02	2.52	-0.143

Table 2: Age group of survey respondents and selected correlations.

19. Household Income of Survey Respondents	<\$30K	\$30 to 60K	>\$60K	Pearson r
Number of Respondents in Age Group (n=184)	27	42	115	--
<b>6.7. Household Seismic Adjustment</b> rate of adoption				
6e have a fire extinguisher	59.3%	64.3%	83.5%	<b>0.243</b>
6f own wrenches to shut off utility valves	84.6%	95.2%	96.5%	0.242
7b installed latches to keep cabinets closed	0.0%	7.1%	14.8%	0.169
<b>5. Extent to which each party is responsible for protecting you from earthquake hazard</b> mean Likert score				
5a Federal Government	2.04	1.95	2.26	0.072
5b State and local agencies	2.31	2.48	2.68	0.072
5c ecclesiastical leaders	1.88	1.60	1.46	-0.158
5d news media	2.00	1.79	1.91	-0.047
5e God	1.92	2.00	1.61	-0.115
5f your employer	1.44	1.40	1.46	0.004
5g friends, relatives, neighbors, co-workers	1.88	2.07	1.85	-0.030
5h yourself and your immediate family	3.78	4.26	<b>4.56</b>	0.223
<b>9. Extent you expect your personal safety in earthquake is determined by the actions of...</b> (mean Likert score)				
9a myself and my immediate family	4.15	4.36	<b>4.55</b>	0.147
9b friends, relatives, neighbors, co-workers	3.00	2.76	2.79	-0.054
9c news media	2.04	2.10	2.11	-0.002
9d local government agencies	2.67	2.46	2.56	-0.024
9e State or Federal Government agencies	2.52	2.19	2.56	0.034
9f God	2.16	1.85	1.97	-0.042
9g ecclesiastical leaders	2.19	1.50	1.59	-0.146
9h luck or chance	2.59	3.02	3.15	0.128

Table 3: Household income of the survey respondents, and selected correlations.

the most commonly adopted action, and is a seismic adjustment that correlates with home ownership (question 20,  $r=-0.231$ ). Households with incomes <\$30,000 had a 0% adoption rate for installing cabinet latches in their home (question 7b,  $r=+0.169$ ), which is both a costly and time consuming effort. It is interesting that the 46 respondents with incomes <\$30,000 had an 81.5% response rate indicating that their households stored food at a rate at least as high as the other income brackets (question 6d).

Overall, respondents across all income brackets indicate self-reliance to the question about the party who bears responsibility for protection from earthquake hazards (question 5h  $r=0.223$ ); personal safety is most determined by their own actions themselves and their immediate family (question 9a  $r=0.147$ ). Respondents in the higher income brackets are comparably less likely to consider ecclesiastical leaders as responsible for protection from earthquake hazards.

**Gender:** Survey data suggest that females responding to the survey

15. Gender of Respondents returning survey	Male	Female	delta	Pearson r
Number of Respondents (n=196)	98	98	--	--
<b>6.7. Household Seismic Adjustment rate of adoption</b>				
6b have at least 4 gallons of water	64.3%	50.0%	-14.3%	-0.144
7c developed a household emergency plan	11.2%	20.6%	9.4%	0.128
7d learned where & how to shut off water, gas, utilities	87.8%	71.1%	-16.6%	-0.206
<b>1. How likely you think that in the next 10 years, an earthquake that will cause... mean Likert score</b>				
1a major damage to your home	2.69	3.00	0.31	0.154
1b injury to yourself or immediate family members	2.44	2.68	0.24	0.129
<b>5. Extent to which each party is responsible for protecting you from earthquake hazard (mean Likert score)</b>				
5d news media	1.65	2.14	0.49	0.226
<b>9. Extent you expect your personal safety in earthquake is determined by the actions of... (mean Likert score)</b>				
9c news media	1.79	2.40	0.61	0.278
9d local government agencies	2.36	2.81	0.45	0.193
9e State or Federal Government agencies	2.93	3.22	0.29	0.228

Table 4: Gender of respondents and selected correlations.

18. Survey Respondents who are College Graduates	No	Yes	delta	Pearson r
Number of Respondents (n=198)	54	144	--	--
<b>1. How likely you think that in the next 10 years, an earthquake that will cause... (mean Likert score)</b>				
1a major damage to your home	2.98	2.78	-0.20	0.140
1b injury to yourself or immediate family members	2.66	2.52	-0.14	-0.113
<b>5. Extent to which each party is responsible for protecting you from earthquake hazard (mean Likert score)</b>				
5c ecclesiastical leaders	1.71	1.50	-0.22	-0.154
5e God	2.19	1.60	-0.59	-0.203
<b>9. Extent you expect your personal safety in earthquake is determined by the actions of... (mean Likert score)</b>				
9d local government agencies	2.37	2.65	0.28	0.129
9f God	2.24	1.88	-0.36	-0.127
9g ecclesiastical leaders	1.87	1.56	-0.31	-0.168

Table 5: Respondents indicating they are College Graduates, and selected correlations.

are significantly less likely than males to have learned where and how to shut off water, gas and electric utilities (question 7d  $r=-0.206$ ). Within the population of survey respondents, males are significantly more likely than females to have stored 4 gallons of water (question 6b  $r=-0.144$ ), while females are somewhat more likely to have developed a household emergency plan (question 7c,  $r=-0.128$ ).

In comparing male and female survey respondents (question 15), some significant differences are related to perceptions about the role of news media such as the newspaper, television, and radio in personal safety (questions 5, 9). The strongest gender correlation suggests that females have an expectation that their personal safety in an earthquake is determined by actions of news media ( $r=+0.278$ ). Women also hold news media responsible for protection from earthquake hazards ( $r=+0.226$ ), as well as state and local government ( $r=+0.179$ ). Similar correlations demonstrate that female respondents expect their personal safety in an earthquake is determined by actions of state or governmental agencies (question 9e  $r=+0.228$ ) and local government agencies (question 9d  $r=+0.193$ ). Another gender-based correlation is that females are more likely to indicate that an earthquake will cause damage to their home over the next 10 years (question 1a  $r=+0.154$ ).

**Educational background:** Survey respondents who are college graduates are significantly less likely than non-college graduates to think that an earthquake will damage their home over the next 10 years (question 1a  $r=-0.140$ ). The college graduate respondents rank God and ecclesiastical leaders lower on the Likert scales than the non-college graduate population on questions asking about which parties are responsible for protecting them from earthquake hazards, and

which parties might determine their personal safety (questions 5c, 5e, 9f, 9g). The strongest correlation of the college graduate group responses reflects their expectation that actions of local government agencies help determine personal safety in earthquakes (question 9d  $r=+0.129$ ) (Table 5).

**Respondents home address by hazard risk zone:** This survey was geocoded to enable analysis of seismic preparedness and vulnerability by respondents' residential location and associated hazard risk zone (Table 6). Comparing the responses of the respondents living in the ground shaking hazard zone to the respondents living in the liquefaction hazard zone highlights key demographic attributes and differences. The ground shaking zone residents are college graduates (87% compared to 53% in the liquefaction zone) with an income greater than \$60,000 (69% as compared to 41% in the liquefaction zone), and children are present at the home (42% in the ground shaking zone as compared to 29% in the liquefaction zone). However, few significant differences in the adoption rates were observed between the populations living in the ground shaking ( $n=118$ ) as compared with the liquefaction ( $n=78$ ) risk zones. Respondents living in the liquefaction hazard zone indicate significantly less awareness of the location of the nearest medical emergency center (question 7e,  $r=+0.156$ ).

All respondents perceive that their house is vulnerable to damage from a seismic event. No survey respondents indicated that their homes were "not at all" vulnerable (1 on the Likert scale). Respondents who reside in the liquefaction hazard zone indicate that they are more at risk for liquefaction damage (question 4a,  $r=-0.376$ ), ranking the vulnerability of their house 3.33 – 3.37 on the Likert scale (mean scores

Geocoded Location: Seismic Hazard Risk Zone of Survey Respondents	Liquefaction	Ground Shaking	delta	Pearson r
Number of Respondents (n=196)	78	118	--	--
<b>6.7. Household Seismic Adjustment rate of adoption</b>				
6a have working radio with spare batteries	41.0%	54.3%	13.3%	0.130
6b have at least 4 gallons of water	51.3%	61.0%	9.7%	0.096
6c have a complete first aid kit	76.4%	76.3%	-0.4%	-0.004
6d have a 4-day food supply for you & family	62.8%	75.2%	<b>12.4%</b>	0.133
6e have a fire extinguisher	74.4%	79.7%	5.3%	0.062
6f own wrenches to shut off gas/utility valves	94.9%	94.0%	-0.9%	-0.018
7a strapped water heaters, furniture, etc	30.8%	44.1%	13.3%	0.134
7b installed cabinet latches to secure closure	10.4%	10.2%	-0.2%	-0.004
7c developed a household emergency plan	19.2%	15.4%	-3.8%	-0.050
7d learned how/where to shut off utility valves	83.3%	78.6%	-4.7%	-0.058
7e learned location of nearby medical centers	71.8%	84.6%	<b>12.8%</b>	0.156
7f purchased earthquake insurance	16.7%	24.1%	7.5%	0.090
7g joined a community organization	10.7%	15.0%	4.4%	0.063
<b>1. How likely you think that in the next 10 years, an earthquake that will cause... mean Likert score</b>				
1a major damage to your home	3.04	2.74	-0.30	-0.149
1e God	2.62	2.54	-0.80	-0.04
<b>2. Compared to other houses in your area, how vulnerable to earthquake damage... mean Likert score</b>				
2a is your house	3.37	3.10	-0.27	-0.151
<b>3. To what extent do you think you are prepared for a major earthquake... mean Likert score</b>				
3a to hit your home	2.21	2.52	0.31	0.164
<b>4. To what extent do you think your home is vulnerable to... mean Likert score</b>				
4a. liquefaction (ground soil liquefying)	3.33	2.40	-0.93	<b>-0.376</b>
4b ground shaking	3.97	<b>4.02</b>	0.04	0.024
<b>8. To what degree do you perceive your house will survive... mean Likert score</b>				
8e. a major earthquake	2.40	2.74	0.35	0.188

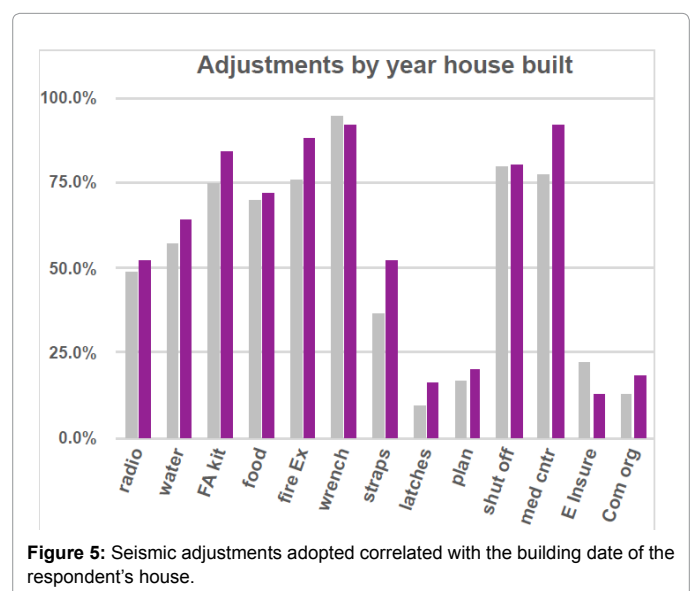
Table 6: Residence of respondents by seismic hazard zone, and selected correlations.

for questions 2a and 4a). Overall, those in the liquefaction zone are more likely to anticipate an earthquake over the next decade that will cause damage to their house (question 1a,  $r = -0.149$ ). Liquefaction zone respondents indicate that their house is at risk for major damage to a greater degree than other houses in their area (question 2a,  $r = +0.149$ ); respondents in the ground shaking hazard zone are more optimistic. Respondents in the ground shaking zone indicate that they anticipate that their house is quite vulnerable to seismic shaking (question 4b, mean Likert 4.02); however, they tend to feel comparatively more prepared for a major earthquake (question 3a,  $r = +0.164$ ), and indicate a perception that their home will survive (question 8a,  $r = +0.188$ ).

**House construction type (URM) and year house built:** All respondents answered the survey questions about home construction type and year built. Data suggest that the respondents' house plan and construction material (questions 11 and 12) are not significantly correlated with any adjustment adoption rates (questions 6 and 7), or people's perceptions of their own vulnerability (questions 1-4).

The number of respondents living in a home built after 1975 (question 10) was not a sufficient sample size ( $n = 25$ ) to draw meaningful conclusions. However, comparison of the responses suggests that those who live in more modern homes may be slightly better adopters of seismic adjustments overall (questions 6 and 7) (Figure 5). Respondents living in older homes ( $n = 172$ ) might be more likely to have earthquake insurance; 22% of the respondents living in homes built before 1975 indicate purchasing earthquake insurance, as compared to ~13% of the respondents who reside in homes built after 1975.

Given the FEMA characterization of Utah as a high seismic risk due to an abundance of URM in its building stock, we wanted to characterize the population of households that reside in URM buildings



(question 12,  $n = 77$ ). The characteristics of survey respondents that indicate they live in URM homes in SLC are rather indistinct from the remaining population of survey respondents; the URM residents have similar adoption rates for seismic adjustments (Table 7). Perspectives of the population living in URM houses are similar to the respondents who do not live in URM houses.

Only a few strong correlations are demonstrated between the URM residents and their perceptions of seismic vulnerability and risk from



Respondents indicating they live in a URM house	No	Yes	delta	Pearson r
Number of Respondents (n=195)	118	77	--	--
<b>6.7. Household Seismic Adjustment (rate of adoption)</b>				
6a have working radio with spare batteries	51.3%	44.7%	-6.5%	0.053
6b have at least 4 gallons of water	60.2%	54.5%	-5.6%	-0.013
6c have a complete first aid kit	78.6%	71.4%	-7.2%	0.068
6d. have a 4-day food supply for you & family	70.1%	71.4%	1.3%	0.063
6e. have a fire extinguisher	73.7%	81.8%	8.1%	0.003
6f. own wrenches to shut off gas/utility valves	94.1%	94.7%	0.7%	0.061
7a strapped water heaters, furniture, etc	39.0%	37.7%	-1.3%	0.019
7b installed cabinet latches to secure closure	9.4%	11.7%	2.3%	-0.048
7c developed a household emergency plan	17.8%	15.8%	-2.0%	-0.111
7d learned how/where to shut off utility valves	79.5%	79.2%	-0.3%	0.038
7e learned location of nearby medical centers	79.5%	77.9%	-1.6%	-0.031
7f purchased earthquake insurance	21.6%	19.5%	-2.1%	0.039
7g. joined a community organization	15.2%	9.5%	-5.7%	0.012
<b>1. How likely you think that in the next 10 years, an earthquake that will cause... mean Likert score</b>				
1a major damage to your home	2.80	2.93	0.14	0.059
1b injury to you or your immediate family members	2.54	2.62	0.08	0.073
<b>2. Compared to other houses in your area, how vulnerable to earthquake damage... mean Likert score</b>				
2a is your house	3.08	<b>3.42</b>	0.33	0.214
<b>3. To what extent do you think you are prepared for a major earthquake... mean Likert score</b>				
3a to hit your home	2.46	2.25	-0.21	-0.115
<b>4. To what extent do you think your home is vulnerable to... mean Likert score</b>				
4a liquefaction (ground soil liquefying)	2.57	2.91	0.23	0.085
4b ground shaking	3.85	<b>4.21</b>	0.35	0.210
<b>8. To what degree do you perceive your house will survive... mean Likert score</b>				
8e a major earthquake	2.79	2.29	-0.51	-0.260

Table 7: URM resident responses and correlations.

23c. Property of a friend, relative, neighbor, coworker or someone you know personally has been damaged in an earthquake	No	Yes	delta	Pearson r
Number of Respondents (n=194)	152	42	--	--
<b>10. Like in a house built... responses</b>				
After 1975	8.6%	26.8%	18.3%	<b>0.232</b>
<b>6.7. Household Seismic Adjustment (rate of adoption)</b>				
7a strapped water heaters & secured furniture	35.5%	50.0%	14.5%	0.122
7f purchased earthquake insurance	19.2%	29.3%	10.1%	0.101
<b>2. Compared to other houses in your area, how vulnerable to earthquake damage is... mean Likert score</b>				
2a your house	3.30	2.90	-0.39	-0.183

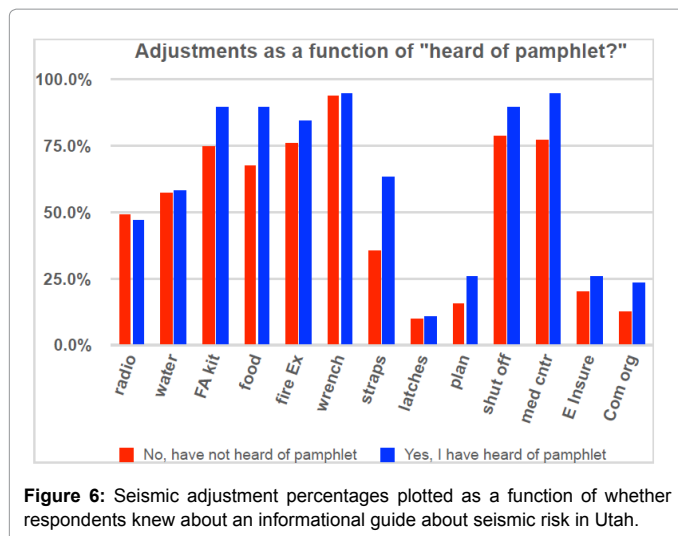
Table 8: Respondents' prior experience with earthquake property damage.

damages due to a future earthquake (questions 1-4). Respondents living in URM houses indicate a higher vulnerability in response to questions about their home as compared to others in the region (question 2a,  $r=+0.164$ , with a mean Likert score of 3.42). The sub-population living in URM houses assesses their home as being vulnerable to ground shaking (question 4b,  $r=+0.210$ , with a mean Likert score of 4.21), and perceive their home as not likely to survive a major earthquake (question 8a,  $r=-0.260$ , with a mean Likert score of 2.29).

Respondents' prior experience with earthquake damage: A majority of the survey respondents indicate that they and their personal contacts have not experienced earthquake damages. Only 22% of the survey respondents say that they know of people who have experienced related property damages (question 23c). This sub-population tends to currently live in newer homes built after 1975 ( $r=+0.232$ ). Although the other characteristics of this group with prior experience with earthquake damage are not distinctive by significant statistical correlations, these households do indicate higher adoption rates for strapping their water heaters, securing furniture and heavy objects (question 7a), as well as purchasing earthquake insurance (question 7f). The respondents who

know people who have experienced some earthquake damage are more inclined to believe their homes are less vulnerable to earthquake damages; this population indicates that they perceive their homes are less likely to be damaged in an earthquake as compared to their neighbors (question 2a,  $r=-0.183$ ) (Table 8).

**Knowledge of Informational Guide about Seismic Risk:** Of the survey respondents (total  $n=197$ ), only 19 households (~10%) indicated they had heard of a free earthquake safety awareness and informational guide called "Putting Down Roots in Earthquake Country" (question 13). Only 12 households reported that they had a copy of this document. Although this is a small population, some trends can be observed. For most of the adoptions surveyed, respondents who have heard of the guide had higher adoption rates for most seismic adjustment, adopting 61.3% of the measures overall in comparison to an overall adoption rate of 51.5% by the 178 respondents who had not heard of the guide (Figure 6). The population that had heard of the guide has a high statistically significant correlation for strapping down water heaters, and securing tall furniture and heavy objects (question 7a,  $r=+0.165$ ). Adoptions by the small sub-population that has the guide include caching food



**Figure 6:** Seismic adjustment percentages plotted as a function of whether respondents knew about an informational guide about seismic risk in Utah.

supplies (question 6d,  $r=+0.169$ ) and joining a community response organization (question 7g,  $r=+0.191$ ).

## Discussion

Many SLC households reported adopting several of the 13 seismic adjustments that were investigated in this study. High percentages of households that own a wrench (94%) and know how to shut off the utilities (80%) relate to home ownership; 90% of the survey respondents own their home and are likely to buy basic tools. Furthermore, there is minimal cost to implement these seismic adoptions. Prior earthquake preparedness surveys in California report similar high percentages of people knowing how to shut off their utilities, including an 80% adoption rate for Irvine [9] and a 63% adoption rate in San Bernardino, Long Beach, and Whittier [50]. In the New Madrid fault area of the mid-continent, survey reports a baseline 66% adoption rate in the population [51], and an 87% rate after the earthquake prediction by Iben Browning [52,53].

Survey respondents living in the SLC ground shaking hazard zone have adopted similar household seismic adjustments at comparable rates to those respondents living in the liquefaction zone. Only 79% of SLC households report knowing the location of nearby medical emergency centers, however. Because the question mentioned "medical emergency centers," but did not specify "hospitals," this question might not have been worded to effectively measure what people know. The term "medical emergency centers" may have been narrowly interpreted as specially designated places of gathering for medical attention following an emergency like an earthquake. However, the majority of survey respondents who did not know the location of nearby medical emergency centers do not live very close to any hospitals. This lack of knowledge does not seem to be linked with transience; the length of residence time the survey respondents have lived in their houses shows only 4% with 1 year and another 4% with 2 years; 22% of respondents have lived in their home for 5 or fewer years.

The 21% adoption rate of earthquake insurance reported by SLC respondents is remarkable, given that no major earthquake has affected the region in the collective memory, or since its 1847 settlement by European-Americans. A similar percentage of the survey respondents know people who have experienced related property damages from an earthquake. This adoption demonstrates that earthquake hazards are a prominent concern of certain SLC residents. Other emergency

preparedness studies report similar rates for adopting earthquake insurance in California in areas that commonly experience high magnitude seismic events: 33%, [54]; 26% [9]; 45% [49] and 22% [55]. The sub-population of SLC respondents with earthquake insurance are better adopters overall; they indicate a belief that they are more prepared for an earthquake, and that their home will survive.

The 49% adoption rate of those reporting that they have a radio with spare batteries may have important implications for emergency personnel who rely on the radio to communicate information and broadcast warnings and instructions. Our survey indicates that such communications via traditional radio will only reach about one half of SLC residents, especially if other communication methods such as the internet, phones, and television are dysfunctional following a major earthquake. Emergency preparedness surveys indicate that the possession of battery-operated radios has declined over the past several decades [46], and may continue, given the emergence of smart phones that access the internet to stream the radio.

Low adoption rates reported for strapping water heaters and securing tall furniture and heavy objects (38%), developing an earthquake plan (17%), joining a community organization dealing with earthquakes (13%), and installing cabinet latches (10%) are inconvenient and time consuming. Similar findings are reported for the New Madrid area [56]: the least adopted seismic adjustment was securing objects, which ranged from 17% before Browning's earthquake prediction and 27% after the prediction [57]. Relatively low adoption rates of seismic adjustments to earthquakes persist for years after major earthquakes [43].

Overall, SLC respondents indicate "self" as the group most responsible for protection (93%) and for determining personal safety (99%) during an earthquake. A high percentage (98%) of respondents assigning oneself as responsible for earthquake preparedness along the San Andreas Fault in California [9]. The emphasis on individuals being most responsible for preparing and dealing with earthquake hazards is recent. Survey-based research conducted 30 years ago found that only 10% of respondents indicated that individual households were responsible for coping with earthquakes [58,59].

Females responding to the survey are more likely to perceive high risk of major damage to their home and expect personal injury from an earthquake in SLC. These female respondents assign more responsibility to federal, state, local governments, and local news media for protecting and determining one's personal safety in a seismic event. This is consistent with other research [37,40,58,59].

In the Wasatch Front, households without wrenches for shutting off utilities think it is likely that a major earthquake will cause major damage to their home during the next 10 years. This sub-population sample has adopted fewer seismic adjustments. Other studies show that households that have not prepared very much for hazards fear earthquake consequences and look more to the government and outside sources for help in coping with hazard events [51,52,60].

Salt Lake City respondents who own their own home are more likely to think that their home is vulnerable to liquefaction than those who rent. This relationship may be explained by the fact that 95% of the respondents living in the liquefaction zone owned their home; only 86% of the respondents living in the ground-shaking zone were homeowners. Homeowners in SLC may take more responsibility over their place of residence in comparison with those who rent, as shown in related research [61].

The survey suggests that households with no children under the age of 6 tend to think their houses will survive a major earthquake. This is consistent with research indicating that families with children feel more vulnerable, and must overcome greater obstacles during hazards [40,62].

The SLC survey respondents who know the location of nearby medical emergency centers typically indicate that their home will likely survive a major earthquake. One possible explanation behind this correlation might relate to diminishing fears surrounding the consequences of disasters as a function of enhanced hazard awareness and preparation [63]. Similarly, those who have joined a community organization dealing with emergency preparedness tend to have the view that the actions of friends, relatives, neighbors, etc. determine their degree of personal safety during an earthquake. Community organizations in SLC, like Community Emergency Response Teams (CERT), rely upon friends and neighbors in responding to earthquakes and other disasters [64].

## Conclusions and Implications

We surveyed household residents of the Salt Lake segment of the WFS in relation to their risk perception and the adoption of 13 household seismic adjustments, and we analyzed the response patterns in context with demographic characteristics, house attributes, and residence location by seismic zones in Salt Lake City (SLC). Although this study randomly mailed out surveys, the population who returned surveys is not a representative demographic sample of SLC residents, in reference to 2012 SLC census data reports [44]. The responding population over-represents Caucasians, homeowners, high-income earners (>\$60,000/year), and college graduates. Despite this inherent bias, this research provides a valuable baseline for additional assessment because no comparable study has been conducted in Salt Lake City. Further surveys might include a version written in Spanish to achieve a more representative sample. Soliciting survey returns from renters would better represent the local population [65]. The survey can be improved by establishing more precise ranges of income categories that represent regional demographics; the existing categories were too broad to precisely assess the population.

Despite no major earthquake since European-Americans settled the area in 1847, a majority of the SLC residents responding to this survey are aware of seismic threats posed by the WFS, and most households have taken measures to become prepared. About 15% of the respondents indicate that they feel prepared to a great extent or very great extent (i.e., choosing 4-5 on the Likert scale). Having food, water, and an emergency plan are three adjustments that correlate most strongly with elevated assessments of preparedness among respondents. Household preparedness of SLC females, college graduates, and households with annual income > \$60,000 is more likely to be ranked as a 4 or 5 (great extent or very great extent) on the Likert scale, although there is not much of a statistically significant difference.

The majority of survey respondents indicate that they consider themselves as the most responsible party for dealing with earthquake risk; this sub-population has adopted the most seismic adjustments. People living in the ground shaking risk zone have similar adoption rates to those residing in liquefaction zones. Respondents living in older houses (built prior to 1975) or in URM structures perceive their houses as more vulnerable to earthquake damage from ground shaking, especially as compared to others in the region. The sub-population living in URM houses indicates the perception that their homes are not likely to survive a major earthquake.

The SLC survey corroborates studies elsewhere indicating that households typically employ seismic adjustments that do not require a lot of knowledge, cost, skill, time, effort and cooperation at the community scale [43]. Mitigation actions that are not as frequently adopted include: strapping water heaters and tall furniture, installing cabinet latches, developing a household earthquake plan, purchasing earthquake insurance, and joining a community organization dealing with earthquake preparedness. Adoption of household adjustments is related to cost and household income [66] and may not be within the purview of renters, people with low income, or those who intend to move from their households in the near future [10,23,67].

The degree of preparedness indicated by our survey of SLC households is remarkable, given that no major earthquake has affected the region in recent memory. This survey did not directly assess what specifically influences people to adopt seismic adjustments [8,68] or the various sources of their knowledge [69,70]. However, the "elevated" risk awareness and preparedness of SLC residents for seismic hazards has been attributed to actions of earthquake-safety advocates, and the involvement of concerned community, educators, business leaders, and the media [2]. Risk perception and preparedness of the local culture reflects several elements, including the high level of education in the resident population [44], the emigration of earthquake-conscious people from quake-prone California, and religion -- the Latter-Day Saints (LDS, or Mormons) are known to promote general practices of emergency "preparedness, community response, and responsibility for self and family during economic and natural hazard emergencies" [71].

Although SLC has a culture of concern about disaster preparedness, few survey respondents (~10% of the total 198 respondents) have heard of an earthquake awareness and information guide published in 2008 by the Utah Seismic Safety Commission [11]. This guide, entitled "Putting Down Roots in Earthquake County" is free and available at state offices and online. It has been heavily advertised in Utah as a comprehensive resource that provides information about the threat posed by earthquakes in Utah -- particularly along the Wasatch Front -- and explains how residents can prepare for, survive, and recover from a seismic event. Social science research suggests that access to and use of information by households and across communities is an important determinant of preparedness and mitigation [72,73]. Further research might assess how and where SLC residents obtain information about earthquakes, seismic risk and adjustment practices. Furthermore, there may be significant gaps in the perceptions of citizens and public officials, and whether the degree of preparedness is sufficient at both individual and community scales [68,74].

Many survey respondents indicated that they do not know the location of nearby emergency medical centers in SLC; female survey respondents are significantly less likely to know how to turn off their gas and other utilities, despite owning a wrench. These findings illustrate the utility of polls for identifying vulnerabilities in populations that can be addressed by knowledge dissemination in advance of a hazard event [75]. Knowledge and action-plans are essential for building resilience of households within a community that will face medical emergencies due to disastrous natural hazards, including earthquakes, floods, fires, storms, etc. [71,76-81].

To further elevate preparedness of households in Utah, additional study is recommended to assess the barriers behind the adoption of mitigations that are inconvenient, time-consuming, and/or costly, such as securing a house structure to its foundation [82]. Further assessment of the population is recommended after additional communication and targeted training efforts that emphasize knowledge building. Social



science evaluations provide insights that are critical for employing concerted and targeted efforts to further elevate community awareness, preparedness and resilience. Survey findings can inform ongoing technical and engineering studies, including the development of scenario hazard maps and urban seismic hazard maps [83] as well as resilience-based planning documents for areas in Utah [65,84,85], that can help guide urban planning and development.

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