Exploring the Changes in Risk Perceptions and Adaptation Behaviors Based on Various Socioeconomic Characteristics Before and After Earthquake Disasters – A Case Study in Taiwan

5   Tzu-Ling Chen[1], Tzu-Yuan Chao[2], Hao-Tung Cheng[3]

[1] Department of Urban Development, University of Taipei, Taipei City, 111, Taiwan
[2] Department of Urban Planning, National Cheng-Kung University, Tainan City, 701, Taiwan
[3] Department of Urban Planning, National Cheng-Kung University, Tainan City, 701, Taiwan

Correspondence to: Tzu-Ling Chen (skylight@mail2000.com.tw)

10   **Abstract.** Resilience, which has rapidly become an area of interest in multiple disciplines, is regarded as being key in disaster mitigation and adaptation. The objective indicator framework is a common way to evaluate resilience, but limited attention has been paid to measuring the risk perceptions and adaptation behaviors of individuals. In addition, due to limitations related to predicting potential earthquake events, past studies have placed more emphasis on predisaster discussions. Fortunately, this paper explores the changes in risk perceptions and adaptation behaviors in different socioeconomic groups through a
15   comparative analysis between pre- and postearthquake disasters, and one-way analysis of variance (ANOVA) with a post hoc test is applied to examine the changes in risk perceptions and adaptation behaviors. The results show that people tend to have greater risk perceptions of future earthquakes but were less willing to retrofit their houses after a serious disaster. Females show greater fear and worry accompanied by a higher willingness to retrofit their houses compared to males. In addition, people with a higher education level and a better occupation might be more willing than others to adopt adaptation behaviors.
20   For females and people with lower education levels, the results can serve as a reference to provide risk communication, risk education, and diverse disaster adaptation options. Although limitations exist, the results of comparative analysis between the predisaster and postdisaster conditions could serve as a reference for adequate strategies and government decisions on the prioritization of risk management policies.

1 Introduction

25   The Ring of Fire in East Asia has been regarded as the region most frequently hit by earthquake disasters because of the high rate of earthquakes that have previously occurred there compared to the global rate (USGS 2017). The call for disaster prevention and risk reduction has been made since the declaration of the International Decade for Natural Disaster Reduction in 1999 (UNISDR 1999). To mitigate dramatic losses, governments have invested a great amount of public resources to finance disaster management, and in particular, structural engineering measures are the major approaches taken to cope with
30   earthquake events. However, the risk of property damage and loss of life is possible wherever development is allowed in potential seismic areas because the occurrence of disasters may be at or below the design standard incorporated in building

codes and structural work areas (Kerr et al. 2003; Petak and Atkisson 1982; Sheaffer and Roland 1976). The disadvantage of the common reliance on structural engineering measurements has resulted in a new research focus on mediating the exposure to risk by selecting suitable adjustments. Recently, the Sendai Framework for Disaster Risk Reduction 2015-2030 has

35 stipulated that the main priorities for disaster mitigation and adaptation are minimizing disaster risk and building resilience (UNISDR 2019).

It is necessary to minimize disaster risk and build resilience by self-evaluating the capabilities and capacities in responding to risk, that is, preparedness (Jones and Tanner 2017). Being prepared for a future disaster requires various components, such as sufficient personal character, social connections, and financial affordability (Baker and Cormier, 2015). People who are

40 included in vulnerable minority groups and marginalized people might not be able to prepare in advance (Blake et al., 2017). Therefore, an increasing number of studies have emphasized measuring risk perceptions at the individual and household levels (Brown and Westaway 2011; Adger et al. 2009). The perception of disaster risk does not represent a direct function of the probability that threatening events will occur; rather, risk perception captures many other factors, such as attitude, cognition, the degree of danger comprehension, and vulnerability (Sjöberg 2000; Sjöberg 1996; Eagly and Chaiken 1993). Despite the

45 substantial literature illustrating the origin (Barrows, 1923), concept (Sjöberg 2000; Sjöberg 1996), formation (Lindell et al., 2016; Whitney et al., 2004; Wu and Lindell, 2004; Lindell and Perry, 2000), and physical and social contexts of disaster risk perceptions (Blanchard-Boehm and Cook, 2004; Peacock et al., 2005; Peacock, 2003), less attention has been paid to systematically examining changes in risk perceptions.

In fact, disaster experiences might facilitate or constrain preparedness (Becker et al., 2017; Ejeta et al., 2015; Lindell and

50 Perry, 2011; Bostrom, 2008), and such effects might be biased across disasters, cultures or regions. A disaster resulting in limited impacts or the assumption that a future disaster will not occur might encourage people to not prepare for future disasters (Paton et al., 2014; Barron and Leider, 2010). Alternatively, people might take any adaptation approaches based upon damage or losses, physical injury, emotional injury and so on (Perry and Lindell, 2008; Nguyen et al., 2006; Heller et al., 2005). The physical damage or losses (Solberg et al., 2010) and psychological fear or anxiety (Rüstemli and Karanci, 1999) resulting from

55 disaster experiences could motivate adaptation behaviors. However, socioeconomic characteristics such as income, age, and gender might encourage or discourage individuals from taking adaptive actions (Bankoff 2006; Wisner et al. 2004). For example, if people cannot act adequately to mitigate such anxiety, they might take no actions at all (Paton and McClure, 2013). Due to limited knowledge and resources, people tend not to respond to common disasters and tend to have personal preferences for disasters, such as denying disasters, denying disaster probability, and having certain beliefs about the government and

60 public infrastructure. Therefore, examining risk perceptions and adaptation behaviors based on various socioeconomic characteristics could provide important information for disaster management.

In summary, the threats in a given area posed by future earthquakes with a magnitude larger than that experienced in the past create uncertainty in regard to the ability to mitigate impacts to acceptable levels using only engineering or construction measures. Humans have the capacity to respond to the environment to reduce risk by learning from past experience, and

65 changes in attitudes and behaviors are very helpful in responding to earthquake disasters (Gifford 2014). Theoretically, a more

accurate measurement and tracking of the interactions of socioeconomic characteristics that collectively affect responses to disasters might help support the right activities and target the right people in disaster management (Oddsdottir et al. 2013; Adger 2000). Past studies have placed more emphasis on predisaster conditions to explore the interaction effects of various socioeconomic characteristics on individuals' decisions (Levine 2014). Examining predisaster and postdisaster conditions could reveal the impact of extreme events and how people's perceptions of such events and their willingness to take potential adaptation approaches might change. Therefore, this study contributes by exploring how earthquake disasters influence the risk perceptions and adaptation behaviors of residents in Taiwan and further categorizes them according to socioeconomic characteristics. The sample is of particular interest because it contains pre- and postdisaster information on residents who were directly affected by the Meinong earthquake (participants completed surveys approximately 1 year before and 3 months after the earthquake), allowing a more robust analysis of the effects of natural disasters on subjective resilience compared to previous research. Based on past studies, the interactions of socioeconomic characteristics can collectively affect responses to disasters. This study discusses such responses based on various socioeconomic characteristics to explore how such characteristics affect pre- and postearthquake risk perceptions and adaptation behaviors. In addition to the introduction, this paper is organized as follows. Section 2 provides a brief description of the research design, including the study area, the data collection, the measures for subjective resilience, and the methods. Section 3 presents the comparative analysis between pre- and postdisaster surveys based on the results of one-way analysis of variance (ANOVA). Section 4 presents the comparative analysis between our findings and those of past studies. The final section offers some conclusions.

2 Data and Methodology

2.1 Study area

The study area of Taiwan is located along the Philippine Sea Plate and the Eurasian Plate, and the orogenic belt of central-southern Taiwan has undergone intensive crustal deformation. It is exposed to earthquake events, as most active faults were confirmed after the city had already been built on them. An active fault called the Houchiali Fault trends north to south across the study area (Lin et al., 2000; Chen and Liu, 2000). Although the existing Houchiali Fault has recently been identified as a Late Pleistocene active fault, an intensified and densely built environment has developed right on and close to the fault line (see Fig. 1b). In addition, there is increasing population growth in the study area, and in particular, some areas along the fault line have a relatively densely clustered population (see Fig. 1c, 1d). In addition, the soft soil might amplify surface ground motion. In 2015, the Meinong earthquake, a local magnitude 6.6 earthquake, struck southern Taiwan, having a devastating impact and resulting in 117 deaths; additionally, numerous buildings were reported to have collapsed (National Applied Research Laboratories 2018; Tsai et al. 2017). Previously unspecified regulations resulted in a number of 5-story buildings without earthquake safety. In the study area of Yongkang, 744 buildings were reported as having been damaged, and in particular, one building fully collapsed, resulting in 115 deaths (see Fig. 1a). According to the Central Weather Bureau (Huang et al. 2009), a large magnitude earthquake occurs once every thirty years in southern Taiwan. A low willingness to make

repairs was found, even though the government encourages inhabitants with this low willingness to retrofit buildings through subsidies and tax relief. The Expediting the Reconstruction of Urban Unsafe and Old Buildings statute was quickly promulgated on May 10, 2017.

2.2 Data collection

There are thirty-nine townships within the study area. A total of 429 individuals completed the predisaster survey, which was conducted between October and December 2014. The postearthquake follow-up survey was conducted in May 2016 (3 months after the Meinong earthquake), and trained interviewers conducted the survey over the phone, asking the same questions as those in the predisaster survey. All survey sampling methods relied on voluntary response sampling. The predisaster survey was a street survey, while the postdisaster survey was a telephone survey based on phone number databases within the study area and conducted by the survey research center of a domestic academic institution. The respondents were reminded of some particular information regarding the most recent earthquake, the geographic location of the nearest fault line, the impact of the disaster event, the frequency of earthquakes in the study area, etc. Additionally, the scale of earthquake magnitude is defined as over 6.0. The content of the survey questions contained five parts: behavioral intentions to adopt residential seismic strengthening, risk perceptions, sensitivity to earthquakes, trust in the government and responsibility attribution. All parts contain at least three items. The main goal of our study is to explore the trajectory of risk perceptions and adaptation behaviors before and after the Meinong earthquake. The same questionnaire allows us to examine these issues with the same earthquake risk area 1 year before and 3 months after this disaster.

2.3 Measures for risk perceptions and adaptation behaviors

Perceived risk is not necessarily equivalent to the probability of occurrence of a disaster. Rather, it summarizes many other factors. Increasing research focuses on the risk perceptions of earthquake disasters, and such perceptions might vary. Previous studies have shown that terror often accompanies changes in the physical environment, the loss of human lives and the destruction of property. Therefore, among earthquake-related stressors, we were concerned with individuals' perceptions of the probability of an earthquake disaster occurring within ten years and the impacts they expected from such a disaster, including fear of earthquakes and worries over buildings collapsing.

Although prior disaster experiences and observation of the natural environment might form disaster perceptions, various socioeconomic characteristics might further affect such perceptions. Adaptation behavior is a way for individuals to adapt their living environment to new events that may occur and impact the existing system. People who have faith in adaptation behaviors might take whatever approaches they have, while others might take no such approaches. Therefore, in the adaptation behavior section, we were concerned with the ways in which people respond to earthquake disasters. To survive earthquakes, seismic

restraints might play important roles during such disasters. Hence, there are two items regarding house retrofitting, including the willingness to retrofit houses and house retrofitting after professional assessment.

There are five items in the survey to explore both risk perceptions and adaptation behaviors. Risk perceptions are measured by three items on the expected impacts of earthquakes, and adaptation behaviors are measured by two items on the willingness to support policies. The measurement, shown in Table 1, combines 7-point Likert-scale items and Yes/No questions (see Table 1). A transformation process is conducted to solve the problems posed by scales with different measurement systems.

2.4 Methods: one-way analysis of variance

One-way ANOVA is an extension of the independent samples t-test that can be used to compare any number of groups (Bewick et al. 2004; Whitely and Ball 2002). The core value of one-way ANOVA lies in the ability to examine means that are significantly different from each other between groups. One-way ANOVA is calculated as follows:

$$\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1} \tag{1}$$

where the variance comes from a set of n values $(x_1, x_2, \dots, x_n)$ and the degrees of freedom is n-1.

In one-way ANOVA, the F statistic test is used and represented equally among groups. A significant F statistic test result indicates a significant difference between groups, and the P-value of 0.05 is the common threshold. First, Levene's test is applied to examine the null hypothesis that the variance is equal across groups. A result of Levene's test lower than 0.05 indicates that it is necessary to apply Welch's test because there is no equal variance between groups. On the other hand, if the result of Levene's test is greater than 0.05, then we can depend on the ANOVA results. Overall, a significant F statistic in both Welch's test and ANOVA indicates that at least two groups are different, but it does not identify which groups are different from the others. However, a P-value lower than 0.05 indicates significance or the probability of a type II error, which is the possibility of incorrectly rejecting the null hypothesis or wrongly concluding a difference between groups. Therefore, a post hoc test and multicomparison analysis testing are necessary to avoid type II errors and to further examine the differences between levels. Due to the assumption of homogeneity of variance, we then apply the Games-Howell test and Benjamini-Hochberg procedure.

Quantitative data analysis was conducted using the Statistical Package for Social Scientists (SPSS) software. Each response to the items in the questionnaire survey was rated on a scale ranging from 1 to 7, with 1 as the highest level of vulnerability (or lowest level of resilience) and 7 as the lowest level of vulnerability (highest level of resilience).

3 Results

155   The number of respondents was similar across genders, which is consistent with the gender ratio in the study area. Regarding age, most respondents in the pre- and postearthquake surveys were between 16 and 60 years old and thus had the knowledge and capacity to develop their self-perceptions and adaptation behaviors. Regarding education, most residents in the study area were university graduates. Because the survey was based on voluntary response sampling, the results showed that there might be inconsistencies in the education category because most respondents graduated from high school. In terms of

160   occupation, the official statistics exclude students and home makers from the labor force. In Taiwan, we have only the national statistics of the industry and service census[1]. Therefore, the overall occupation ratio in the study area can be divided into two categories: employment and unemployment. In Taiwanese culture, owning one's house is preferred over renting. Indeed, the survey shows that less than 20% of the respondents rent their homes (see Table 2). In general, people became highly aware of earthquakes immediately after the Meinong earthquake, but people were unwilling to retrofit their houses. In the following

165   sections, the study attempts to compare risk perceptions and adaptation behaviors pre- and postdisaster based on socioeconomic characteristics such as gender, age, education, occupation, and house ownership.

3.1 Gender

In the preearthquake survey, males showed more worries than females regarding building collapsing (P-value = 0.008 < 0.05), while the results for the other items were not statistically significant. In the postearthquake survey, the probability of an

170   earthquake disaster occurring within the next ten years (P-value = 0.049 < 0.05), fear of earthquakes (P-value = 0.000 <0.05), and the willingness to retrofit houses (P-value = 0.002 < 0.05) were statistically significant, indicating variations between the gender categories. The results show that the Meinong earthquake not only increased awareness of earthquakes but also increased the risk perceptions of females (probability of an earthquake disaster: 4.74 (females) > 4.51 (males); fear of earthquakes: 5.64 (females) > 4.75 (males)). Both males and females were less willing to retrofit their houses after this serious

175   earthquake. In summary, although the coefficient of risk perception among males is higher than that among females in the preearthquake survey, the coefficient among males becomes lower than that among females in the postearthquake survey. In addition, there is significant variation between gender categories after the Meinong earthquake, and females show higher risk perceptions and a higher willingness to retrofit their houses than males (see Table 3).

3.2 Age

180   According to the F-test, the result for worries over buildings collapsing is statistically significant (P-value = 0.045 < 0.05) in the postearthquake survey (see Table 4). To examine whether there are variations, this study applied the Hochberg test to explore such variations. However, the results of the Hochberg test show that there are no statistically significant differences between age groups. Therefore, the overall results show that there are no significant variations among age categories in both

---

[1] https://eng.stat.gov.tw/np.asp?CtNode=1548

the pre- and postearthquake surveys. Because there are no variations among age groups, we use the mean value to compare the changes between the pre- and postearthquake surveys. In terms of risk perceptions, people tended to become more aware of earthquakes (probability of an earthquake disaster: 4.04 (pre) < 4.55 (post); fear of earthquakes: 4.91(pre) < 5.02 (post); and worries over buildings collapsing: 4.61 (pre) = 4.61 (post)). Regarding adaptation behaviors, people tended to become less willing to retrofit their houses. Therefore, the overall results show that there are no significant variations among age categories both the pre- and postearthquake surveys. It seems that age does not necessarily affect risk perceptions or adaptation behaviors.

3.3 Education

Again, in the preearthquake survey, there are no significant variations among education categories, indicating that different educational level groups show a similar awareness of the probability of earthquakes and a similar willingness to retrofit their houses. In contrast, the results regarding the probability of an earthquake disaster occurring within the ten years (P-value = 0.001 < 0.05), worries over buildings collapsing (P-value = 0.046 < 0.05), and willingness to retrofit houses after assessment (P-value = 0.005 < 0.05) are statistically significant, indicating significant differences among educational level categories (see Table 5). This paper further applies post hoc analysis to compare the differences between categories. The results show that different educational level categories do indeed have different levels of awareness of the probability of earthquakes and preferences for house retrofitting. For example, one variation (-0.579) shows that people who graduated from elementary or junior high school might have less awareness than people who graduated from university or graduate school. Meanwhile, another variation (-0.42) shows that people who graduated from elementary or junior high school might be less willing to retrofit their houses (see Table 6). Overall, people tended to become more aware of earthquakes after the Meinong earthquake and less willing to retrofit their houses. Although there are no significant results showing that education matters for risk perceptions and adaptation behaviors, after the Meinong earthquakes, those with a higher educational level seemed to become more aware of the probability of earthquakes and willing to retrofit their houses.

3.4 Occupation

The results show that occupation matters for both risk perceptions and adaptation behaviors in both the pre- and postearthquake surveys. According to the F statistic test, the results for the items on fear of earthquakes (P-value = 0.004 < 0.05) and worries over buildings collapsing (P-value = 0.005 < 0.05) in the preearthquake survey (see Table 7) are statistically significant. The results of the Hochberg test show that home makers have higher risk perceptions than white-collar workers, blue-collar workers, and students (see Table 8). In the postearthquake survey, the results for the probability of an earthquake disaster occurring within the next ten years (P-value = 0.016 < 0.05), fear of earthquakes (P-value = 0.000 <0.05), worries over buildings collapsing (P-value = 0.018 < 0.05), willingness to retrofit houses (P-value = 0.008 < 0.05), and willingness to retrofit houses after assessment (P-value = 0.036 < 0.05) are all statistically significant, indicating significant differences between occupation categories (see Table 7). The results of the post hoc test show that home makers have the highest awareness of the risk of earthquakes among all occupation categories. In terms of house retrofitting, there are significant variations between

white-collar and blue-collar workers. In summary, after the Meinong earthquake, regardless of occupation, people tended to become more aware of earthquakes but less willing to retrofit their houses. In addition, home makers are much more aware of earthquake risk than those holding other occupations in both the pre- and postearthquake surveys. Due to their economic status, white-collar workers tended to be more willing to retrofit their houses after the Meinong earthquake compared to blue-collar workers.

3.5 House ownership

Regarding house ownership, most categories show no statistically significant variations in the pre- and postearthquake surveys (see Table 9). In the postdisaster survey, the P-value ($0.009 < 0.05$) for the willingness to retrofit houses indicates that at least two house ownership groups have significantly different preferences. This paper further applies the post hoc test examine the different preferences for house retrofitting (see Table 10). The results show that the family-owned group has a higher willingness to retrofit houses than the self-owned group in the postearthquake survey. Overall, regardless of house ownership category, people tended to become more aware of earthquakes and more willing to retrofit their houses in the postearthquake survey. Although there are no particular variations in risk perceptions among the house ownership categories, people who owned their house still show a higher willingness to retrofit their houses compared to those who rented.

4 Discussion

According to the results, after the Meinong earthquake, people tended to have greater risk perceptions regarding future earthquakes but were less willing to retrofit their houses. The findings show that people might become less willing to prepare, which is quite similar to the result of a survey conducted after the 2011 Christchurch earthquake (Statistics New Zealand, 2012; Paton and Johnston, 2008). In fact, the relationship between disaster experience and preparedness has been regarded as a key issue based on the recommendations of the Sendai Framework (United Nations, 2015). According to past studies, it is difficult for people to imagine any consequences if they lack earthquake experience (Paton and McClure, 2013). However, the study finds that the levels of disaster preparedness become low after serious disasters. Therefore, disaster experience might not necessarily increase people's willingness to prepare. On the other hand, socioeconomic characteristics might still affect the decision-making process with regard to adopting adaptation behaviors.

In terms of gender, females show greater fear and worries regarding future earthquake disasters than males, while they have a similar willingness to retrofit their houses (see Fig. 3). According to past studies, the responses of women might be more internal and backstage, whereas those of men might be more external and front stage (Enarson 2001; Always et al. 1998; Fordham 1998). The economic status and family role of women might forbid possible adaptive choices compared to men (Tobin-Gurley and Enarson 2013). Men, in contrast, are more risk tolerant than women (Finucane et al. 2000). Although gender inequality prevails in different ways around the world, women's safety concerns for their family have been well documented in both environmental protection movements and neighborhood emergency preparedness campaigns (Litt et al. 2012; Luft

2008; Erikson 1994; Turner et al. 1986). Therefore, it is necessary to provide more diverse options for house retrofitting for families to increase their potential willingness to improve the anti-seismic resilience of their houses.

Regarding education, people tend to become aware of earthquake risk after a serious disaster event, and there are no significant variations between educational level categories. Although there is a significant decrement in the result for house retrofitting, people who have a university-level education might be more willing to retrofit their houses (see Fig. 4). There are similarities in occupation; people who are white-collar workers are still much more willing to retrofit their houses than blue-collar workers, home makers, and students. In addition, home makers have higher risk perceptions than those belonging to the other occupation categories. Available resources might be the key factor affecting whether people prepare for and respond to disasters. Social stratification plays a role in perceiving and reacting to risk, including people's understanding of disaster information, the sources announcing disaster information, and potential options to respond (Fothergill and Peek 2004).

Gender, age, and class alone do not make people vulnerable, while the interactions between factors might result in an increase in vulnerability. Overall, social characteristics do indeed affect decisions regarding disaster awareness and adaptation behaviors. In addition, disaster experience does indeed facilitate local awareness but constrains preparedness in regard to Taiwan's earthquake experience. Among gender, education, and occupation, each category shows a similar tendency of increased risk awareness of risk but decreased willingness to retrofit houses. However, over time, risk awareness might fade away. Therefore, risk communication, risk education, and diverse mitigation options are required as soon as possible after serious earthquakes to help people be ready for future events.

5 Conclusions

Our comparative analysis of predisaster and postdisaster surveys based on various socioeconomic characteristics contributes to the significant and meaningful results of this study. The results show that females have greater fear and worries, while males have a greater willingness to retrofit their houses. Elderly individuals might ignore the probability of disaster events and have less willingness to retrofit their houses. People's knowledge base might have significant impacts on both disaster awareness and house retrofitting, and people with higher knowledge levels might have higher awareness but less worries about disaster events. In addition, disaster experience does indeed play an important role in helping people become aware of earthquake risk. However, due to the occurrence of earthquakes, people might not engage in more active behaviors to prepare for future disasters. As a result, the interaction between various socioeconomic characteristics might result in an increase in vulnerability to disasters. This study has the following limitations: the results might not be applicable to any other disaster events, only earthquakes. In addition, due to time limitations, the interviewees in the pre- and postearthquake surveys were different. There are potential topics that could be extended in future studies, such as the correlation between socioeconomic characteristics and the causes and effects of risk perceptions on adaptation behaviors. Nevertheless, the results can provide a general tendency regarding changes in risk perceptions and adaptation behaviors pre- and postdisaster events and the variations between different socioeconomic characteristics. The findings can serve as a reference to formulate risk communication strategies and for governments to make decisions on the prioritization of risk management policies.

280 **References**

Adger,W.N.: Social and ecological resilience: are they related?, Prog. Hum. Geog., 24(3), 347-364, https://doi.org/10.1191/030913200701540465, 2000

Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., and Wreford, A.: Are there social limits to adaptation to climate change?, Climate Change, 93(3-4), 335-354, https://doi.org/10.1007/s10584-008-9520-z, 2009.

285 Alexander, D.E.: Natural Disasters, Springer, Netherlands, 1999.

Always, J., Belgrave, L.L., and Smith, K.: Back to normal: gender and disaster, Symb. Interact., 21(2), 175-195, https://doi.org/10.1525/si.1998.21.2.175, 1998.

Bahadur, A.V., Ibrahim M., and Tanner T.: The resilience renaissance? Unpacking of resilience for tackling climate change and disasters, Strengthening climate resilience discussion paper 1. IDS, Brighton, 2010.

290 Bankoff, G.: The tale of the three pigs: taking another look at vulnerability in light of the Indian Ocean Tsunami and Hurricane Katrina, Ssrc. Org, 2006.

Beatley, T.: Toward a normal philosophy of natural disaster mitigation, INT. J. Mass Emergen. Disaster, 7(1), 5-32. http://www.ijmed.org/articles/397/, 1989.

Belk, R.W.: Situational variables and consumer behaviour, J. Consum. Res., 2(3), 157-164, 295 https://www.jstor.org/stable/2489050, 1975.

Berkes, F., and Folke, C.: Back to the future: ecosystem dynamics and local knowledge, In: Gunderson LH, Holling CS (eds) Panarchy: understanding transformations in human and natural systems. Island Press, Washington, DC., 2002.

Berkes, F.: Sacred ecology, traditional ecological knowledge and resource management, Taylor and Francis, Philadelphia, 1999.

300 Bewick, V., Cheek, L., and Ball, J.: Statistics review 9: One-way analysis of variance, Crit. Care, 8(2), 130-136, http://doi.org/10.1186/cc2836, 2004.

Bland, M.: An Introduction to Medical Statistics, 3rd ed. Oxford, UK: Oxford University Press, 2001.

Brown, K., and Westaway, E.: Agency, capacity, and resilience to environmental change: lessons from human development, wellbeing, and disasters. Annu. Rev. Env. Resour., 36(1), 321, https://doi.org/10.1146/annurev-environ-052610-092905, 305 2011.

Chen, Y.G., and Liu, T.K.: Holocene uplift and subsidence along an active tectonic margin southwestern Taiwan, Quaternary Sci. Rev., 19, 923-930, http://doi.org/10.1016/S0277-3791(99)00076-1, 2000.

Cohen, J.: Statistical power analysis for the behavioural sciences (2nd ed.), Hillsdale, NJ: Erlbaum, 1988.

Cutter, S.: Resilience to what? Resilience for whom?, Geogr. J., 182(2), 110-113, https://doi.org/10.1111/geoj.12174, 2016.

310 Cutter, S.L., Ash, K., and Emrich, C.T.: The geography of disaster resilience, Global Environ. Change, 29, 65-77, http://doi.org/10.1016/j.gloenvcha.2014.08.005, 2014.

Dash, N., Peacock, W.G., and Morrow, B.H.: And the poor get poorer. In WG Peacock, BH Morrow, and H Gladwin, editors, Hurricane Andrew: Ethnicity, Gender, and the Sociology of Disasters, New York: Routledge, 1997.

Downs, R.: Geographic space perception: past approaches and future prospects, Progress in Geography: International Review of Current Research 2, 65-108, 1970.

Dunning, D., Heath, C., and Suls, J. M.: Flawed Self-assessment: Implications for Health, Education, and the Workplace, Psychol. Sci. Publ. Int., 5, 69-106, http://doi.org/10.1111/j.1529-1006.2004.00018.x, 2004.

Eagly, A. H., Chaiken, S.: The Psychology of Attitudes, Fort Worth, TX: Harcourt, Brace & Janovich, 1993.

Enarson, E.: Women confronting natural disaster: from vulnerability to resilience. Boulder, CO: Lynn Rienner Publisher, 2012.

Enarson, E.: What women do: gendered labor in the Red River valley flood. Environ, Hazards, 3(1), 1-18, https://doi.org/10.3763/ehaz.2001.0301, 2001.

Erikson, K.: A new species of trouble: the human experience of modern disasters, New York: W. W. Norton, 1994.

Finucane, M., Slovic, P., Mertz, C. K., Flynn, J., and Satterfield, T.: Gender, race, and perceived risk: the "white male" effect, Healthy Risk and Society, 2(2), 159-172, https://doi.org/10.1080/713670162, 2000.

Fordham, M.: Making women visible in disasters: problematizing the private domain, Disasters 22(2), 126-143. https://www.ncbi.nlm.nih.gov/pubmed/9654812, 1998.

Friedsam, H.J.: Older persons in disaster, In G. W. Baker, D. W. Chapman, editors, Man and Society in Disaster. New York: Basic Books, 1962.

Fothergill, A., Peek, L. A.: Poverty and disasters in the U. S.: a review of the recent sociological findings, Nat Hazards, 32(1), 295-321, https://doi.org/10.1023/B:NHAZ.0000026792.76181.d9, 2004.

Gifford, R.: Environmental psychology: principles and practice (5th ed.) Colville, WA: Optimal Books, 2014.

Hewitt, K.: Preventable disasters: addressing social vulnerability, institutional risk, and civil ethics, Geographischs Rundschau International Edition, 3(1), 43-52, https://www.preventionweb.net/publications/view/1058, 2007.

Huang, M. H., Hu, J. C., Ching, K. E., Rau, R. J., Hsieh, C. S., Pathier, E., Fruneau, B., and Deffontaines, B.: Active deformation of Tainan tableland of southwestern Taiwan based on geodetic measurements and SAR interferometry, Tectonophysics, 466, 322-334. https://doi.org/10.1016/j.tecto.2007.11.020, 2009.

Japan earthquake: elderly hard hit as hope for missing fades.: http://www.huffing-tonpost.com/2011/03/17/japan-earthquake-2011-elderly-hard-hit_n_837117.html, last access: 5 June 2019.

Jones, L., and Tanner, T.: 'Subjective resilience': using perceptions to quantify household resilience to climate extremes and disasters, Reg. Environ. Change., 17(1), 229-243, 2017.

Kennedy, J. M.: Overview. In Images of the 1994 Los Angeles Earthquake by the Staff of the Los Angeles Times. Los Angeles: Los Angeles Times Syndicate, 1994.

Kerr, J., Nathan, S., Van Dissen, R. J., Webb, P., Brunsdon, D., and King, A.B.: Planning for development of land, on or close to active faults: an interim guideline to assist resource management planners, New Zealand GNS Client Report, 2003.

Klinenberg, E.: Heat wave: a social autopsy of disaster in Chicago, Chicago: University of Chicago Press, 2002.

Larsen, J.: Setting the Record Straight: More than 52,000 Europeans died from Heat in Summer 2003, Washington, DC: Earthquake Policy Institute, 2006.

Lehman, D. R., and Taylor, S. R.: Date with an earthquake: coping with a probable, unpredictable disaster. Personality and Social Psychology Bulletin 23, 546-555, https://doi.org/10.1177/0146167287134011, 1987.

350 Levine, S.: Assessing resilience: why quantification misses the point, London: Overseas Development Institute, 2014.

Lin, C. W., Chang, H. C., Lu, S. T., Shih, T. S., and Huang, W. J.: An introduction of the active faults of Taiwan, Spec. Publ. Cent. Geol. Surv, 13 2185-2203, 2000.

Lindell, M. K., and Perry, R. W.: Household adjustment to earthquake hazard: a review of research, Environ. Behav., 32(4), 461-501. https://doi.org/10.1177/00139160021972621, 2000.

355 Lindell, M. K., and Perry, R. W.: Communicating Environmental Risk in Multiethnic Communities, Thousand Oaks, CA: Sage, 2004.

Linkov, I., Eisenberg, D. A., Bates, M. E., Chang, D., Convertino, M., Allen, J. H., Flynn, S.E., and Seager, T.P.: Measurable resilience for actionable policy, Envir. Sci. Tech., 47, 10108-10110, https://doi.org/10.1021/es403443n, 2013.

Litt, J., Skinner, A., and Robinson, K.: The Katrina difference: African-American women's networks and poverty in New
360 Orleans after Katrina, In E. David and E. Enarson, editors, The Women of Katrina: How Gender, Race, and Class Matter in An American Disaster, 2012.

Luft, R. E.: Looking for common ground: relief work in post-Katrina New Orleans as an American parable of race and gender violence, NWSA Journal, 20(3), 5-31, https://www.jstor.org/stable/40071294, 2008.

Marshall, N. A.: Understanding social resilience to climate variability in primary enterprises and industries, Global. Environ.
365 Chang., 20(1), 36-43, https://doi.org/10.1016/j.gloenvcha.2009.10.003, 2010.

McClure, J., Walkey, F., and Allen, M.: When earthquake damage is seen as preventable: attributions, locus of control and attitudes to risk, Appl. Psychol. -Int. Rev., 48(2), 239-256. https://doi.org/10.1111/j.1464-0597.1999.tb00060.x, 1999.

Mishra, P.: Gender differences in risk and communication behaviour: responses to the New Madrid earthquake prediction, INT. J. Mass Emergen. Disaster, 17(3), 313-338, http://ijmed.org/articles/643/, 2009.

370 Murphy, K. R., and Myors, B.: Statistical power analysis: A simple and general model for traditional and modern hypothesis tests (2nd ed.), Mahwah, NJ: Erlbaum, 2004.

Nguyen, K.V., and James, H.J.: Measuring household resilience to floods: a case study in the Vietnamese Mekong river delta, Ecol. Soc., 18(3), 13. http://dx.doi.org/10.5751/ES-05427-180313, 2013.

National Applied Research Laboratories, Earthquake Report of Hualien in 2018.02.06. Available online:
375 https://www.ncree.org/EarthquakeInfo/20180206/HualianEqTW_V7.2.pdf (accessed in 5 February 2019).

Oddsdottir, F., Lucas, B., and Combaz, E.: Measuring disaster resilience. GSDRC Helpdesk Research Report 104, UK: GSDRC, University of Birmingham, 2013.

Odeh, R. E., and Fox, M.: Sample size choice: Charts for experiments with linear models (2nd ed.), New York, NY: Dekker, 1991.

380 Palm, R., and Carroll, J.: Illusions of safety: culture and earthquake hazard response in California and Japan, Westview Press, Boulder, 1998.

Petak, W. J.,and Atkisson, A. A.: Natural hazard risk assessment and public policy: anticipating the unexpected, New York: Springer-Verlag, 1982.

Reid, T. R.: Kobe Wake to a nightmare, Natl. Geogr., 188, 112-136, 1995.

385 Sharkey, P.: Survival and death in New Orleans: An Empirical Look at the Human Impact of Katrina, J. Black. Stud., 37(4), 482-501, https://doi.org/10.1177/0021934706296188, 2007.

Sheaffer, J. R. and Roland, F. J.: Flood Hazard Mitigation through Safe Land Use and Construction Practices, Chicago: Keifer & Associates, Inc., 1976.

Sjöberg, L.: A discussion of the limitations of the psychometric and cultural theory approaches to risk perception, Radiat. Prot.

390 Dosim., 68(3-4), 219-225, https://doi.org/10.1093/oxfordjournals.rpd.a031868, 1996.

Sjöberg, L.: Factors in risk perception, Risk Anal., 20(1), 1-12, https://doi.org/10.1111/0272-4332.00001, 2000.

Tobin, G. A., Montz, B. E.: Natural Hazards: Explanation and Integration, New York: The Guilford Press, 1997.

Tobin-Gurley, J., and Enarson,: Social Vulnerability to Disasters, 2nd Edition, 2013.

Tsai, C. C., Hsu, S. Y., Wang, K. L., Yang, H. C., Chang, W. K., Chen, C. H., and Hwang, Y. W.: Geotechnical reconnaissance

395 of the 2016 ML 6.6 Meinong Earthquake in Taiwan, J. Earthq. Eng., 1-27, http://doi.org/10.1080/13632469.2017.1297271, 2017.

Turner, R. H., Nigg, J. M., and Paz, D. H.: Waiting for disaster: earthquake watch in California, Berkeley: Ubiversity of California Press, 1986.

Turner, R.: Earthquake prediction and public policy, Mass Emergencies, 1(3), 179-202,

400 https://link.springer.com/chapter/10.1007/978-94-010-0041-3_8, 1976.

UN :Sustainable Development Goals: https://www.un.org/sustainabledevelopment/sustainable-development-goals/, last access: 23 March 2019.

UNFCC: Paris Agreement on Framework Convention on Climate Change: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement, last access: 23 March 2019.

405 UNISDR: Sendai Framework for Disaster Risk Reduction 2015-2030: https://www.unisdr.org/we/coordinate/sendai-framework, last access: 23 March 2019.

UNISDR: International Decade for Natural Disaster Reduction (IDNDR) programme forum 1999 – proceedings: https://www.unisdr.org/we/inform/publications/31468, last access: 23 March 2019.

USGS (U.S. Geological Survey): Ring of Fire: https://earthquake.usgs.gov/learn/glossary/?termID=150, last access: 2

410 November 2017.

Weinstein, N. D.: Unrealistic optimism about future life events, J. Pers. Soc. Psychol., 39, 806-820, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.535.9244&rep=rep1&type=pdf, 1980.

White, G. F., Kates, R. W., and Burton, I.: Knowing better and losing even more: The use of knowledge in hazards management, Environ. Hazards, 3, 81-92, https://doi.org/10.1016/S1464-2867(01)00021-3, 2001.

415 Whitely, E., and Ball, J.: Statistics review 5: Comparison of means, Crit. Care. 6, 424-428, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC137324/, 2002.

Wisner, B., Blaikie, P., Cannon, T., and Davis, I.: At Risk: Natural Hazards, People's Vulnerability and Disasters, London: Routledge, 2004.

Zhou, H., Wang, J., Wan, J., and Jia, H.: Resilience to natural hazards: a geographic perspective, Nat. Hazards, 53, 21-41,
420 https://doi.org/10.1007/s11069-009-9407-y, 2010.

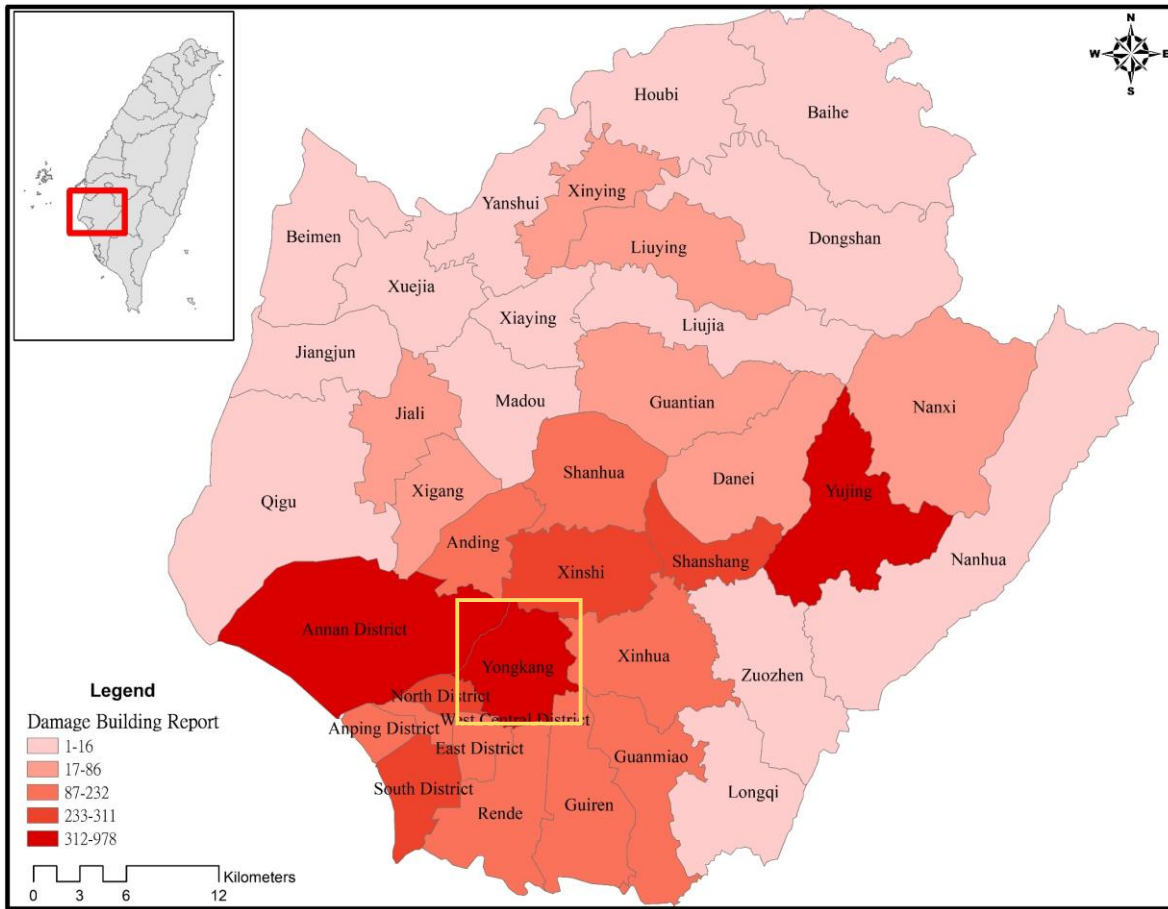
425

(a) Damaged buildings in the Meinong earthquake in Tainan City

Fig. 1. Study area

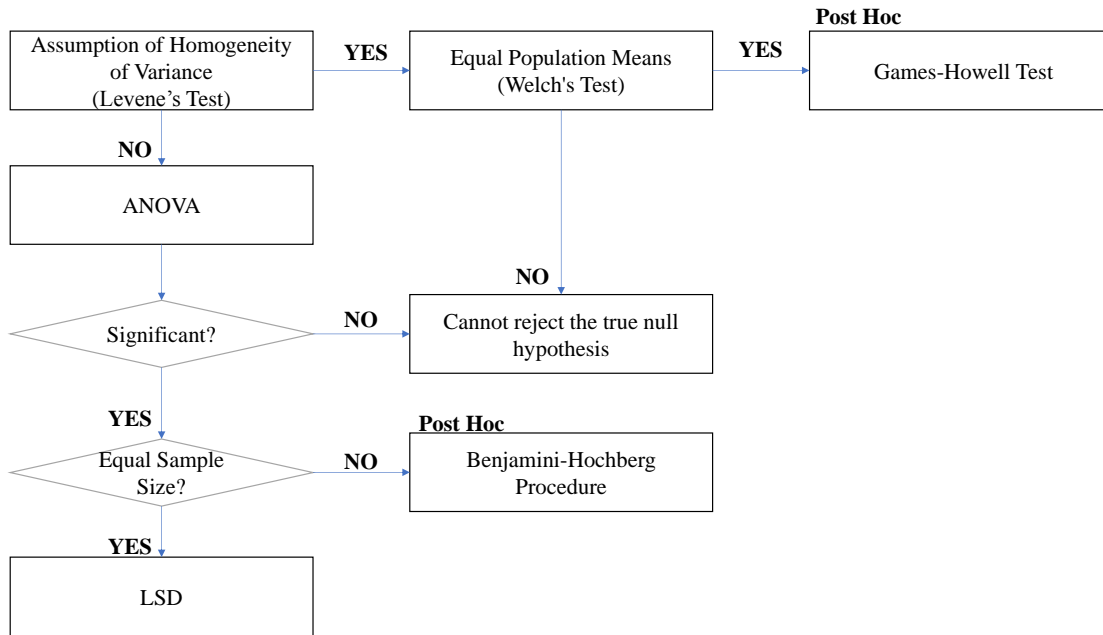
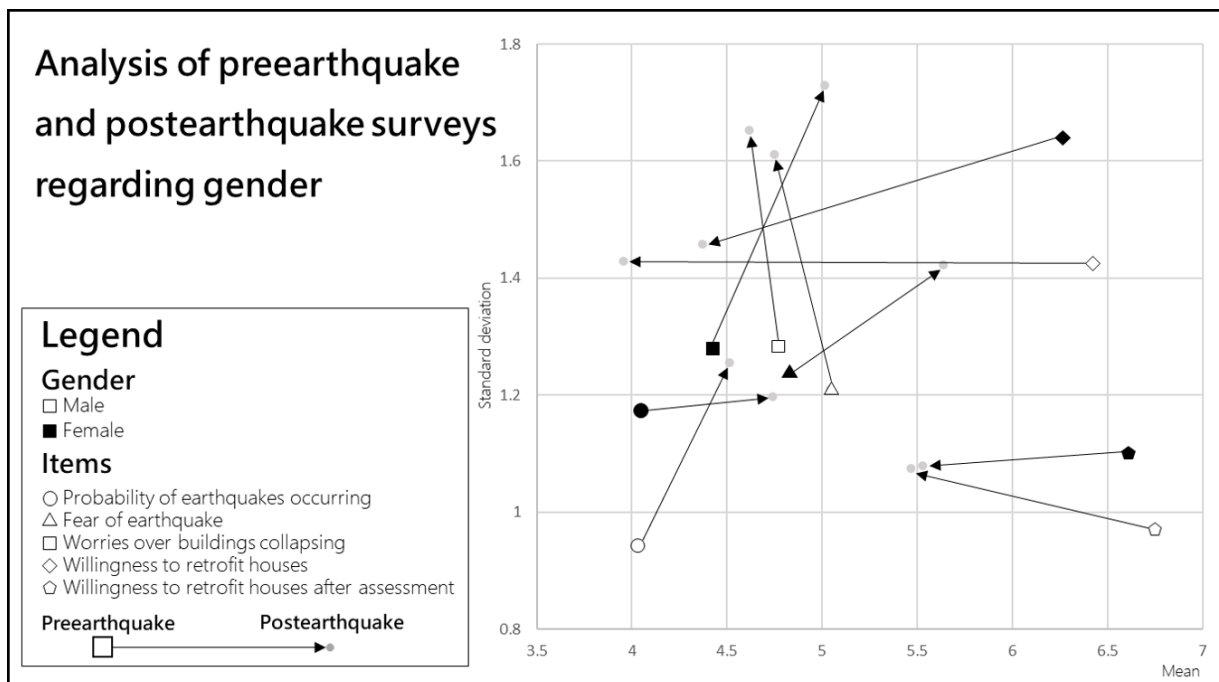



Fig. 2. Overall process of one-way analysis of variance

 Fig. 3. Comparative analysis of the pre- and postearthquake surveys regarding gender

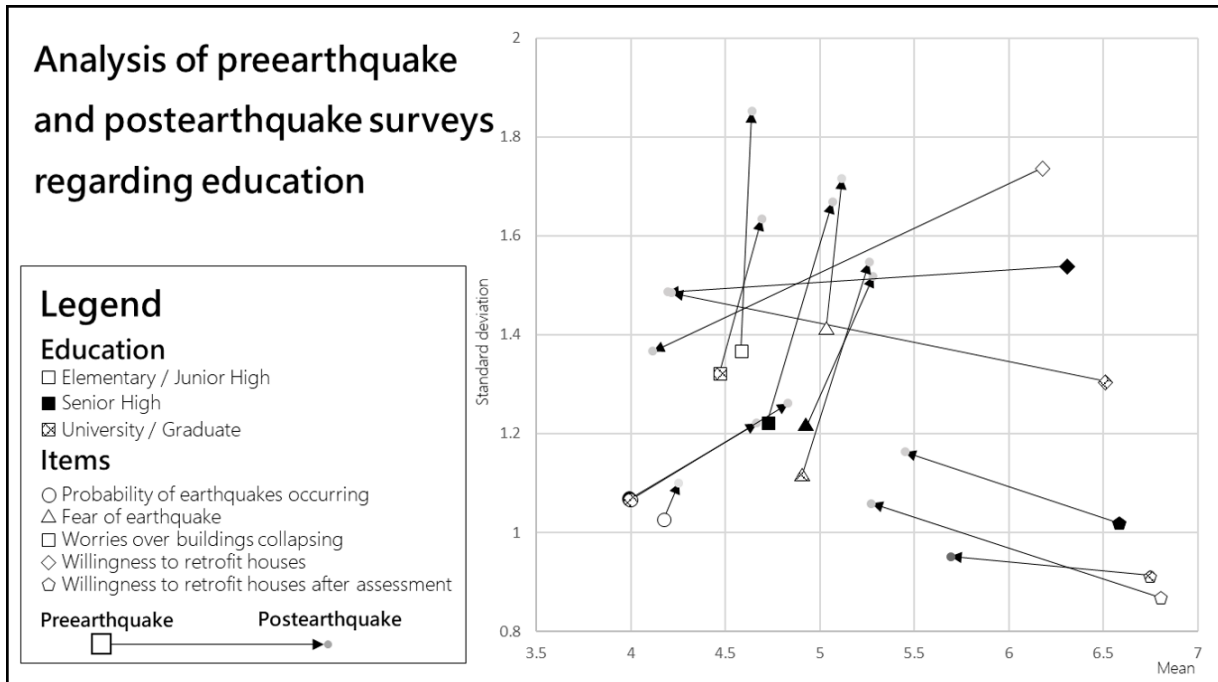



Fig. 4. Comparative analysis of the pre- and postearthquake surveys regarding education

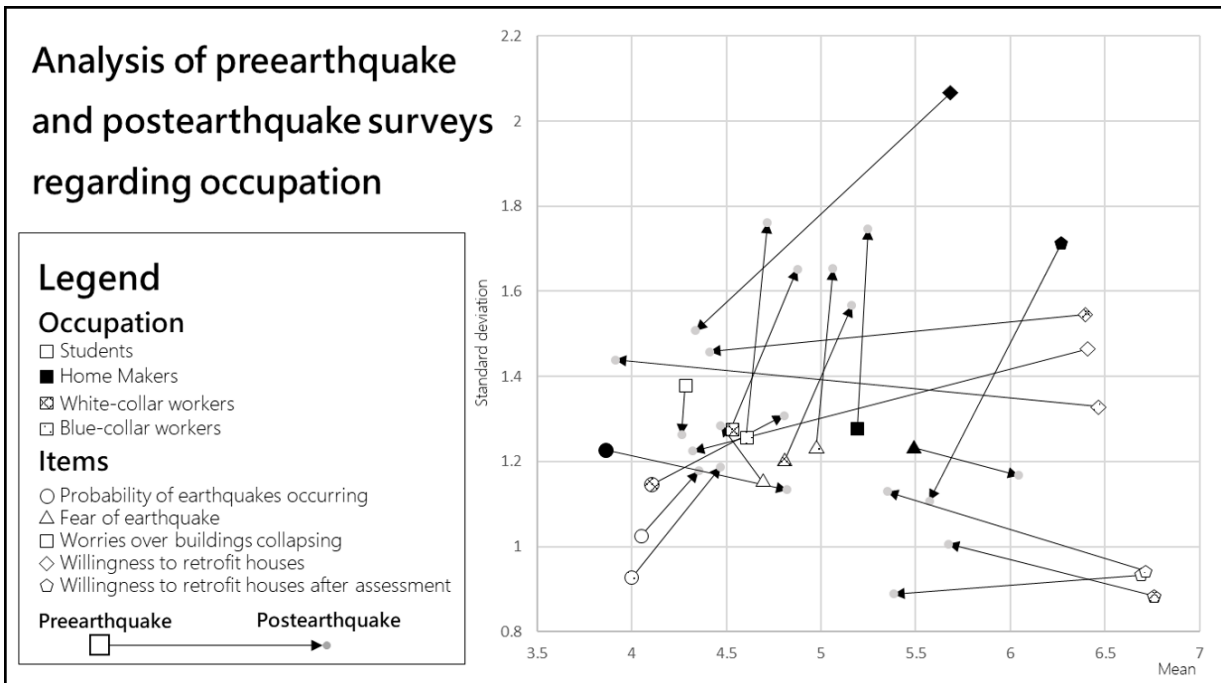



Fig. 5. Comparative analysis of the pre- and postearthquake surveys regarding occupation

435

Table 1 Measurement of the questionnaires.

Aspects	Items	predisaster	postdisaster
Risk perceptions	Probability of an earthquake disaster occurring within the next ten years	7-point	7-point
	Fear of earthquakes	7-point	7-point
	Worries over buildings collapsing	7-point	7-point
Adaptation behaviors	Willingness to retrofit houses	Yes/No	7-point
	Willingness to retrofit houses after assessment	Yes/No	7-point

Completely disagree = 1 to completely agree =7

440

Table 2 Sample characteristics in the pre- and postearthquake surveys.

Characteristics	Pre-	Post-	Study area	Characteristics	Pre-	Post-	Study area
Gender				**Occupation***			
Male	53.38%	44.89%	49.27%	Students	9.09%	7.23%	38.53%
Female	46.42%	55.11%	50.73%	Home Makers	10.96%	18.94%	
Age				White-collar Workers	37.76%	32.55%	59.08%
< 15 yr.	7.46%	1.70%	13.97%	Blue-collar Workers	41.96%	41.28%	
15-40 yr.	38.23%	28.30%	37.96%	**House Ownership***			
40-60 yr.	37.53%	51.91%	32.16%	Self-owned	48.95%	63.62%	85.93%
> 60 yr.	16.78%	18.09%	15.91%	Family-owned	32.17%	32.34%	3.20%
Education				Renting	18.65%	4.04%	7.82%
Elementary/Junior High	21.68%	21.91%	21.63%				
High School	47.32%	41.49%	30.54%				
University/Graduate	31.00%	36.60%	46.96%				

Note 1: The values without official statistics are replaced by data from the Tainan Municipality.
Note 2: The share of illiterate individuals in the study area is 0.87%.
Note 3: The official statistics for occupation are categorized into employment and unemployment, and the unemployment
445 percentage is 2.39%. In addition, neither students nor home makers are included in the labor force.

450

Table 3 P-values and means for gender.

Items	Preearthquake					Postearthquake				
	Male	Female	DF	T	P-value	Male	Female	DF	T	P-value
Probability of an earthquake disaster occurring within the next ten years	4.03	4.05	415	-0.211	0.836	4.51	4.74	468	-1.988	0.049*
Fear of earthquakes	5.04	4.85	415	1.643	0.101	4.75	5.64	468	-6.342	0.000***
Worries over buildings collapsing	4.77	4.44	415	2.644	0.008**	4.62	5.02	468	-2.539	0.011*
Willingness to retrofit houses	6.42	6.23	415	1254	0.218	3.96	4.37	468	-3.085	0.002**
Willingness to retrofit houses after assessment	6.75	6.58	415	1.485	0.123	5.46	5.53	468	-0.646	0.519

$* \ p < 0.05$; $** \ p < 0.01$; $***p < 0.001$.

Table 4 P-values and means for age.

Items	Preearthquake						
	< 15 yr.	16-40 yr.	41-60 yr.	> 61 yr.	DF	F	P-value
Probability of an earthquake disaster occurring within the next ten years	4.00	4.02	4.00	4.15	428	0.372	0.773
Fear of earthquakes	4.68	4.88	5.01	5.07	428	1.135	0.334
Worries over buildings collapsing	4.66	4.67	4.57	4.54	428	0.248	0.863
Willingness to retrofit houses	6.41	6.44	6.30	6.21	428	0.463	0.708
Willingness to retrofit houses after assessment	6.50	6.61	6.72	6.83	428	1.121	0.340

Items	Postearthquake						
	< 15 yr.	16-40 yr.	41-60 yr.	> 61 yr.	DF	F	P-value
Probability of an earthquake disaster occurring within the next ten years	4.38	4.69	4.67	4.45	466	0.935	0.424
Fear of earthquakes	4.50	5.17	5.39	5.02	466	1.955	0.120
Worries over buildings collapsing	4.13	4.72	5.04	4.54	466	2.701	0.045*
Willingness to retrofit houses	4.88	4.26	4.20	3.98	466	1.285	0.279
Willingness to retrofit houses after assessment	5.50	5.53	5.52	5.39	466	0.365	0.779

455 * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 5 P-values and means for education.

Items	Preearthquake			DF	F	P-value
	Elementary/ Junior High	Senior High	University/ Graduate			
Probability of an earthquake disaster occurring within the next ten years	4.17	4.00	4.00	428	0.999	0.369
Fear of earthquakes	5.03	4.93	4.90	428	0.338	0.714
Worries over buildings collapsing	4.58	4.72	4.47	428	1.579	0.207
Willingness to retrofit houses	6.18	6.31	6.51	428	1.361	0.258
Willingness to retrofit houses after assessment	6.80	6.58	6.75	428	1.889	0.152
Items	Postearthquake			DF	F	P-value
	Elementary/ Junior High	Senior High	University/ Graduate			
Probability of an earthquake disaster occurring within the next ten years	4.25	4.67	4.83	469	7.468	0.001**
Fear of earthquakes	5.12	5.28	5.26	469	0.402	0.669
Worries over buildings collapsing	4.64	5.07	4.69	469	3.100	0.046*
Willingness to retrofit houses	4.12	4.19	4.22	469	0.154	0.857
Willingness to retrofit houses after assessment	5.27	5.45	5.69	469	5.342	0.005**

$* p < 0.05$; $** p < 0.01$; $***p < 0.001$.

460

Table 6 Post hoc results for education.

Items	Education	Education	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Probability of an earthquake disaster occurring within the next ten years (Postearthquake) Hochberg test	Elementary/Junior High	High School	-0.414	0.148	0.015*	-0.77	-0.06
	Elementary/Junior High	University/Graduate	-0.579	0.151	0.000***	-0.94	-0.22
Retrofitting houses after professional assessment (Postearthquake) Hochberg test	Elementary/Junior High	University/Graduate	-0.420	0.133	0.005**	-0.74	-0.10

* $p < 0.05$; ** $p < 0.01$; ***$p < 0.001$.

Table 7 P-values and means for occupation.

Items	Preearthquake						
	Students	Home Makers	White-collar Workers	Blue-collar Workers	DF	F	P-value
Probability of an earthquake disaster occurring within the next ten years	4.05	3.87	4.10	4.01	427	0.654	0.581
Fear of earthquakes	4.69	5.49	4.81	4.97	427	4.430	0.004**
Worries over buildings collapsing	4.28	5.19	4.52	4.61	427	4.340	0.005**
Willingness to retrofit houses	6.41	5.68	6.39	6.46	427	3.413	0.118
Willingness to retrofit houses after assessment	6.68	6.27	6.76	6.71	427	2.795	0.40
Items	Postearthquake						
	Students	Home Makers	White-collar Workers	Blue-collar Workers	DF	F	P-value
Probability of an earthquake disaster occurring within the next ten years	4.35	4.82	4.80	4.47	469	3.475	0.016*
Fear of earthquakes	4.47	6.04	5.16	5.06	469	12.266	0.000***
Worries over buildings collapsing	4.26	5.25	4.88	4.72	469	3.392	0.018**
Willingness to retrofit houses	4.32	4.34	4.41	3.91	469	3.995	0.008**
Willingness to retrofit houses after assessment	5.38	5.57	5.67	5.35	469	2.873	0.036*

465   * $p < 0.05$; ** $p < 0.01$; ***$p < 0.001$.

Table 8 Post hoc results for occupation

Items	Education	Occupation	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Fear of earthquakes (preearthquake) Hochberg test	Students	Home Makers	-0.797	0.263	0.015*	-1.49	-0.10
	Home Makers	White-collar Workers	0.681	0.201	0.005**	0.15	1.21
Worries over buildings collapsing (preearthquake) Hochberg Test	Students	Home Makers	-0.909	0.277	0.007**	-1.64	-0.18
	Home Makers	White-collar Workers	0.667	0.212	0.010*	0.11	1.23
	Home Makers	Blue-collar Workers	0.586	0.209	0.032*	0.03	1.14
Fear of earthquakes (postearthquake) Games-Howell test	Students	Home Makers	-1.574	0.253	0.000***	-2.24	-0.90
	Students	White-collar Workers	-0.693	0.254	0.041*	-1.37	-0.02
	Home Makers	White-collar Workers	0.882	0.177	0.000***	0.42	1.34
	Home Makers	Blue-collar Workers	0.983	0.171	0.000***	0.54	1,43
Worries over buildings collapsing (postearthquake) Games-Howell test	Students	Home Makers	-0.982	0.285	0.005**	-1.73	-0.24
Willingness to retrofit houses (postearthquake) Hochberg test	White-collar Workers	Blue-collar Workers	0.499	0.156	0.009**	0.09	0.91
Willingness to retrofit houses after professional assessment (postearthquake) Hochberg test	White-collar Workers	Blue-collar Workers	0.323	0.115	0.027*	0.03	0.62

* $p < 0.05$; ** $p < 0.01$; ***$p < 0.001$.

470

Table 9 P-values and means for house ownership.

Items	Preearthquake					
	Self-owned	Family-owned	Renting	DF	F	P-value
Probability of an earthquake disaster occurring within the next ten years	4.02	4.09	3.98	427	0.317	0.728
Fear of earthquakes	5.05	4.89	4.74	427	2.087	0.125
Worries over buildings collapsing	4.64	4.65	4.46	427	0.642	0.527
Willingness to retrofit houses	6.25	6.43	6.44	427	0.806	0.447
Willingness to retrofit houses after assessment	6.75	6.57	6.66	427	1.248	0.288
Items	Postearthquake					
	Self-owned	Family-owned	Renting	DF	F	P-value
Probability of an earthquake disaster occurring within the next ten years	4.61	4.74	4.32	469	1.254	0.286
Fear of earthquakes	5.21	5.34	4.84	469	0.929	0.396
Worries over buildings collapsing	4.83	4.93	4.16	469	1.727	0.179
Willingness to retrofit houses	4.03	4.45	4.47	469	4.720	0.009**
Willingness to retrofit houses after assessment	5.47	5.55	5.63	469	0.410	0.664

* $p < 0.05$; ** $p < 0.01$; ***$p < 0.001$.

Table 10 Post hoc results for house ownership.

Items	Education	House Ownership	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Willingness to retrofit houses (postearthquake) Hochberg test	Self-owned	Family-owned	-0.424	0.144	0.014*	-0.78	-0.07
	Family-owned	Self-owned	0.424	0.144	0.014*	0.07	0.78

* $p < 0.05$; ** $p < 0.01$; ***$p < 0.001$.