EXPLORING EARTHQUAKE RESPONSE THROUGH THE LENS OF THE PROTECTIVE ACTION DECISION MODEL

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Abstract: Since the publication of the first version of PADM in 2004, scholars have been trying to understand the influential factors that impact people's response to disasters by testing the model. The third version of PADM, which includes social and environmental contexts, suggests that geolocation, physical, and social contexts influence people's disaster response. However, the ways in which these factors influence disaster response have not been fully explored, and PADM studies have yielded inconclusive results. Therefore, two overarching research questions were proposed to address this literature gap: *Do people's disaster responses differ geographically during an earthquake? Why do people respond to earthquakes in specific ways in different geographical areas?* To address these overarching research questions, household survey and interview data were collected after the 2018 Hualien earthquake in Taiwan. The Getis-Ord Gi* method was used to answer the first overarching research question. The findings suggest that geographical location, one of the environmental context factors, affects people's disaster responses (affective risk perception, cognitive risk perception, and protective action decision). The emotion of fear and nervousness, the perception of household losses, and the physical reaction of freeze and flight are clustered in some communities during the earthquake. Next, in-depth interviews were conducted among these communities to explore the possible root causes of the clusters and address the second overarching research question. Thematic analysis shows that environmental contexts, social contexts, optimistic bias, earthquake experiences, responsibility belief, hazard adjustment efforts, earthquake education, environmental cues, and cognitive risk perceptions resulted in these clusters. Based on the findings, this dissertation proposes an earthquake-oriented PADM to explain the unique nature of seismic hazards, which differ from other environmental threats in their quick onset, uncertainty in terms of location, timing, and magnitude, and geographical differences. This study offers emergency managers an opportunity to gain insight into people's earthquake responses. The findings can be utilized by emergency management professionals to help mitigate earthquake risks and promote appropriate protective actions to prevent injuries and fatalities during earthquakes.

Keywords: 2018 Hualien earthquake, protective action decision model, spatial analysis, thematic analysis, earthquake response.

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CHAPTER I

INTRODUCTION

Over the past 30 years, researchers worldwide have studied people's immediate responses to disasters. Many of these studies have utilized the Protective Action Decision Model, which explains how individuals react to various types of disasters (e.g., Choi, 2020; Hyman et al., 2022; Jon et al., 2016; Kang et al., 2007; Lindell et al., 2015; Wu et al., 2012). The model has gone through three different revisions (Lindell, 2018; Lindell & Perry, 2004, 2012). The first version of the PADM features parallel processes of protective action decision-making and information searching. While it explains the interactive nature of decision-making and information searching, it fails to provide a more linear information flow model that can help researchers better understand how various factors impact disaster responses. The second version of the PADM offers an updated model that includes a risk information searching/receiving stage, a pre-decisional stage, a psychological response stage (ARP and CRP), and a behavioral response stage (PADs). The PADM underwent another update in 2018. This latest version incorporates social and environmental context factors and relocates personal factors from the information searching/receiving stage to the decision-making stages.

Unlike meteorological hazards, households usually receive little or no warning when studying immediate earthquake responses. At best, they may receive an official warning only a few seconds before an earthquake strikes via the Early Earthquake Warning (EEW). Due to the limited space available for EEW warnings, emergency managers or local officials have limited ability to provide detailed risk information and protective action suggestions during earthquake shaking. As a result, studies have shown that people rely on additional information, such as environmental cues (the shaking itself) and social cues (observing others' behavior), to determine how to protect themselves during an earthquake. Furthermore, people's immediate response can also be influenced by their social and environmental context, such as the people they are with and the location and structure of their surroundings.

Earthquake response studies have found that people experience high levels of alert, nervousness, and fear and lower levels of depression, annoyance, and passivity as part of their ARPs (Jon et al., 2016). The same dataset also suggests that people in Christchurch and Hitachi had high levels of CRP related to expected utility loss, job loss, and home damage but relatively lower perceptions of personal injury and death. (Lindell et al., 2016).

Other studies also found protective action responses during earthquakes include protecting property (Arnold et al., 1982), searching for friends and relatives (Alexander, 1990), staying where they were (Bourque et al., 1993; Goltz et al., 1992; Rahimi, 1993), taking cover (Goltz et al., 1992), and finding protections (Bourque et al., 1993; Rahimi, 1993). If people were with children during earthquakes, they were more likely to take cover and protect the children (Bourque et al., 1993a; Goltz et al., 1992). More recently, the Prati *et al.* (2012) study of the 1997 Umbria and Marche earthquake (M_w 6.1) found that people with their families were more likely to evacuate during the shaking. The Lindell *et al.* (2015) study of the earthquake in the 2009 American Samoa earthquake (M_w 8.1) found that many respondents did not evacuate immediately after the shaking even though there was a potential tsunami threat.

Researchers also studied people's immediate response during the 2011 Christchurch and Tohoku earthquakes (Lindell et al., 2016; Wei et al., 2017). The study found that the most common response during earthquakes was for people to freeze in place. However, for those who did not freeze, respondents in Christchurch were more likely to take cover, while those in Hitachi were more likely to leave their buildings. It's worth noting that these two events occurred during the daytime, and less than 20% of the respondents were with their household members during the shaking. In addition, the Jon *et al.* (2016) study examined the PADs that people made immediately after four earthquakes. The study found that 54% of the respondents tried to contact their household members if they were not with them during the shaking.

Understanding households' immediate responses to earthquakes is crucial for disaster research, as such actions are essential for people's survival. While previous survey studies have provided emergency managers and researchers with an understanding of how households or individuals respond to earthquakes, the reasons behind their perception formation and protective action decisions are not well understood. Comparative studies have shown that location may affect how people respond to earthquakes. For example, Fraser *et al*. (2016) conducted surveys using a similar questionnaire after the 2013 Lake Grassmere earthquake (Mw 6.6) and the 2013 Cook Strait earthquake (Mw 6.5). They found that earthquake intensity and shaking duration (environmental cues) were unrelated to people's ARPs and CRPs. Respondents also reported different PADs, such as seeking information, contacting household members, and collecting children from school. In addition, how geolocation and geological context affect people's disaster response (ARPs, CRPs, and PADs) is not well studied due to the lack of using a systematic approach such as geospatial analysis.

Additionally, review studies have shown that personal characteristics have minimal impacts on ARPs, CRPs, and PADs, except for disaster experience. (Baker, 1991; Huang et al., 2016). Warning-related factors, such as social and environmental cues, warning time, warning message content, and channel accessibility, have been found to significantly affect people's disaster responses (Jon et al., 2016b; Sorensen & Mileti, 2018; Wu et al., 2020). However, the impact of disaster experience, earthquake preparedness, and education on disaster response remains inconclusive in these studies, as there are inconsistent correlations. This study proposed two overarching research questions based on the literature review to address these issues.

Do people's disaster responses geographically differ during an earthquake?

Why do people respond to earthquakes in specific ways in different geographical areas?

This mixed-method study used PADM as its theoretical lens to address the above overarching research questions. The study first collects quantitative data by surveying households after the 2018 Hualian Earthquake and then gathers qualitative data by conducting interviews with survey respondents. As no previous PADM studies have used geospatial analysis to investigate how survey respondents' disaster response is affected by location, the first overarching research question will be answered by addressing seventeen operational research questions that assess how location affects people's ARPs, CRPs, and PADs. The results of these analyses will identify the geolocation clusters of different disaster responses (ARPs, CRPs, and PADs). Next, survey participants in these clustered locations will be recruited for in-depth interviews to understand the reasons behind their response clustering.

The findings of the Getis-Ord Gi* analysis suggest that the affective risk perceptions of fear and nervousness, cognitive risk perception of household losses, and protective action decisions to flee from a building or stay in place without protection (freeze) are clustered in several communities in Hualian County.

The thematic analysis found that weak building constructions, cognitive risk perception of household losses, frequent experiencing intensive and strong earthquakes, and being with elders or children result in high fear levels. In contrast, the perception of living in a strong building structure, the awareness of living farther away from the fault line, and optimistic biases result in low fear levels. High levels of nervousness result from overwhelming aftershocks, underground rumblings, confidence in building structure integrity, cognitive risk perception of property damage, and lack of knowledge in response to earthquakes. As for CRPs, mitigation and preparedness efforts for earthquakes, lack of responsibility belief, and resilient interpretation of earthquake experiences result in low perceptions of household losses. Conversely, responsibility belief and vulnerability interpretation of earthquake experiences result in high perceptions of household losses.

Finally, regarding protective actions, the awareness of living close to a fault line, weak building constructions, being with children, feeling strong shaking, and previous severe earthquake losses contributed to the reaction of fleeing from a building.

Frequently experiencing minor earthquakes, lack of earthquake education and training, and peer pressure resulted in being frozen during the 2018 Hualian Earthquake.

Based on these findings, this study proposes an earthquake-oriented PADM that includes several additional factors to address the inconclusive findings of the previous study. Future studies could use this proposed model to develop surveys that measure these variables and verify the model using multivariate analysis such as Structural Equation Modeling. The findings of this study can also help emergency managers tailor EEW messages and provide more informative earthquake education and training.

The following chapters will begin by reviewing the evolution of PADM and earthquake response studies and stating the research objectives (overarching research questions and operational research questions) in Chapter II. Chapter III will introduce the data collection and analytical approaches, followed by two chapters reporting and discussing analysis results (Chapter IV: Getis-Ord Gi* analysis results and discussion; Chapter V: thematic analysis results and discussion). Finally, Chapter VI will propose a summary, an earthquake-oriented PADM for future disaster science studies, address study limitations, and discuss practical implications in emergency management.

CHAPTER II

REVIEW OF LITERATURE

Protecting citizens from environmental hazards has become one of the major responsibilities of governments (Schneider, 2015). The purpose of risk communication between authorities and citizens is to persuade the potentially impacted residents to take protective actions or change their attitudes toward risks (McGuire, 1985). Therefore, properly understanding people's immediate responses to emergencies can help emergency managers or government officials appropriately communicate hazard risks with them. In 2004, Lindell and Perry (2004) proposed the first version of PADM to explain people's immediate responses to emergencies within a model. Over the years, the first version of PADM was tested by various types of disasters and in different countries. It was updated to the second version in 2012 (Lindell & Perry, 2012).

The most significant change in the second version of PADM was the separation of the overall response processes into three stages. Since its publication, scholars have continued to collect disaster response survey data and test the model. During this time, earthquake and hurricane response survey data were mainly used to test the model (Huang et al., 2012; Huang et al., 2017; Jon et al., 2016; Kang et al., 2007; Lindell et al., 2015; Wu et al., 2012, 2014; Wu et al., 2015). Several review and comparison studies made significant contributions to the model (Huang et al., 2016; Wei et al., 2017; Wu et al., 2017; Wu et al., 2020). This led to the third version of PADM being published in 2018 (Lindell, 2018).

The third version of PADM includes two major changes. First, it emphasizes social/environmental context's influences on environmental cues, social cues, information sources, information channels, and warning messages. Second, the receiver characteristics are replaced by personal characteristics that are claimed to have considerable influence on the overall psychological processes.

With the review of the three versions of the PADMs, this dissertation research finds that two influential factors: geolocation contexts and disaster experiences have significant influences on people's affective risk perceptions (ARPs), cognitive risk perceptions (CRPs) and protective action decisions (PADs). However, some influential factors have shown both positive and negative associations with disaster responses (ARPs, CRPs, and PADs), and the root causes of these inconsistent findings are unclear. The following sections will review the change in different versions of PADM, the measures of these influential factors, and the inconsistent findings. Finally, research questions will be developed to address this inconsistency.

2.1 First Version of PADM

The first version of PADM was developed based on several psychological and social theories and models. For instance, the Elaboration Likelihood Model postulates that people change their minds or behaviors based on the cognitive contents or superficial cues of the messages they receive (Petty & Cacioppo, 1990). The Heuristic Model of Persuasion postulates that the means of systematic (i.e., based on the cognitive elaboration of the messages) and heuristic processing (i.e., the message sources are credited) of persuasive arguments can change people's attitudes towards a behavior (Chaiken, 1980; 1987; Chaiken, Liberman & Eagly, 1989). In light of the above theories and models, the first version of PADM aims to explain how people divert their attention to environmental and social cues of threats from their everyday activities and make decisions in response to the threats. The variables in each block, shown in Figure 2.1, show their possible effects on the decision-making processes of adopting protective actions or searching for additional information about the threats. However, not everyone would go through all the stages in this model and take protective actions.

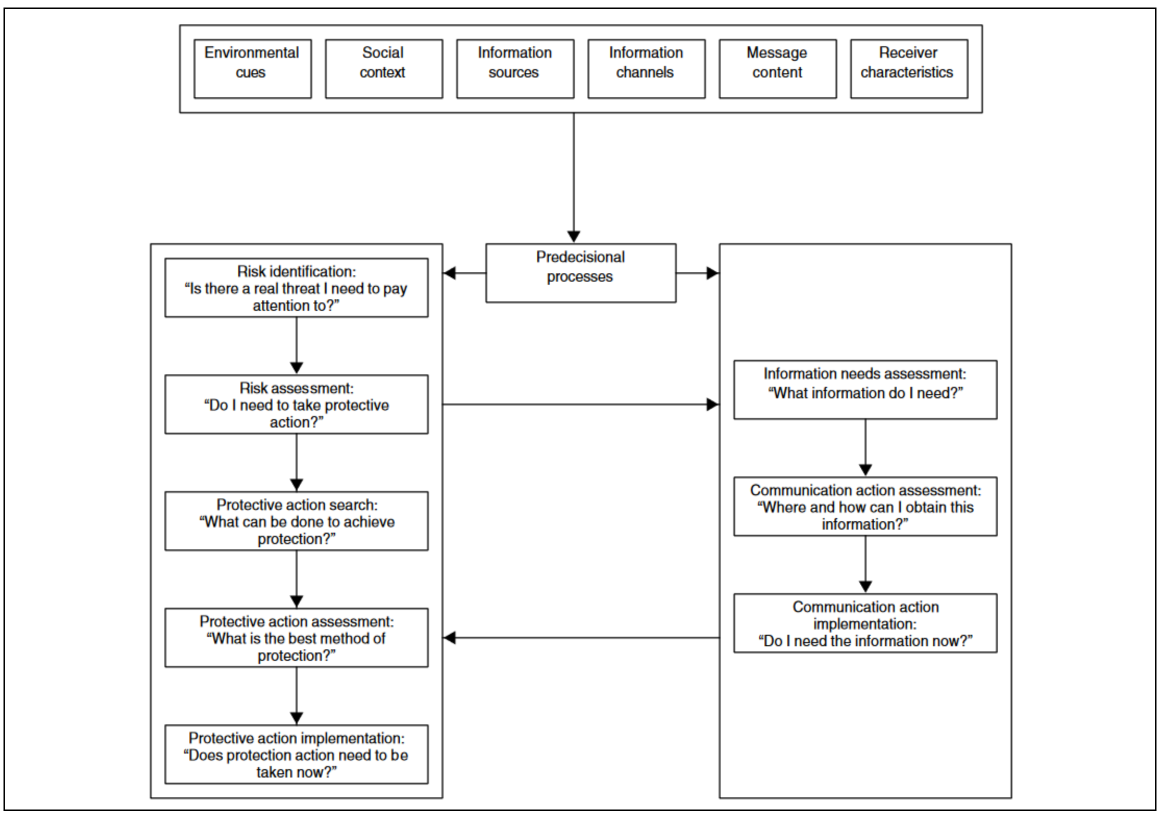


Fig 2.1 The First Version of PADM (Lindell & Perry, 2004)

For instance, if someone trusts the information source, they may immediately take protective actions instead of searching for more information (Lindell & Perry, 2004). Therefore, the receiver characteristics explain how recipients interpret environmental and social cues and ultimately influence their decisions on protective action. Once the recipients complete the pre-decisional processes, they are more likely to move to the following five stages: 1) risk identification, 2) risk assessment, 3) protective action search, 4) protective action assessment, and 5) protective action implementation (Lindell & Perry, 1992).

The first stage is *risk identification*, also known as “primary appraisal” in other studies (Lazarus & Folkman, 1984). In this stage, people try to determine whether there is a real threat instead of taking immediate protective action (Anderson, 1969; Janis, 1962; Janis & Mann, 1977; Mileti, 1975; Perry, 1979; Williams, 1964). In addition, Drabek (1986) points out that the initial responses to environmental or social cues are generally disbelief. Therefore, people need to believe that a threat will occur and are more likely to move to the risk assessment stage.

Risk assessment evaluates the probability and consequences of the potential threats that could cause harm to properties or lives (Neuwirth, Dunwoody & Griffin, 2000). In the literature, personal deaths, injuries, and property damages are the three main factors used to assess risks (Perry, 1979; Mileti & Sorensen, 1987). Other considerations such as the evaluation of uncertainty, severity, and immediacy of threats are also frequently mentioned by researchers (Perry, 1981). Note that, while earlier risk scholars used the affective bases of risk perception, such as negative feelings and stress, to understand risk-taking behaviors (Fischhoff et al., 1978; Slovic, 1992; Slovic et al., 2004), the 2004 PADM does not explicitly explain how these feelings affect protective actions. In the risk assessment stage, people may not seek additional information or take protective actions if they believe the risks have no impact on them or the magnitude is so small that it will not cause severe consequences (Glass, 1970). Therefore, some research suggests that recipients are more likely to perceive threats as real when the number of warning messages increases (Nelson & Perry, 1991; Perry, 1981).

Once the threats are confirmed and the risk level is unacceptable, respondents are more likely to move from risk assessments to the next stage — the *protective action search stage* (Lazarus & Folkman, 1984; Rowe, 1977). The primary activity in this stage is to search for feasible protective actions. Factors that influence people's protective action search include 1) resources, 2) hazard-related knowledge, 3) recommendations from warning messages, 4) personal experiences, and 5) observation of other people's behaviors (Lindell & Perry, 2004). Once respondents collect information on possible alternatives, they may move to the next stage — the *protective action assessment stage*.

There are five major factors to be considered in the process of protective action assessment, including 1) the efficacy of protective actions (Fritz, 1961; Sorensen & White, 1980; Tierney et al., 2001), 2) the time required to complete hazard reduction (Lindell & Perry, 1987; Lindell, Prater & Perry, 2002; Perry, 1979), 3) the resources and knowledge required to complete hazard reduction (Lindell & Prater, 2002; Perry, Lindell & Green, 1981; Windham et al., 1977), and 4) cost (Cross, 1980; Kunreuther et al., 1978).

The process will be moving to the next stage — *protective action implementation*. In this stage, protective action will be taken because the respondents believe at least one of the protective actions is effective and doable (Lindell & Perry, 2004). Though the above five stages in the first version of PADM have explicated the overall processes, the requirements of related information and communication also play a significant role in influencing people's decision makings. The first step is the "*information needs assessment"* corresponding to the contingency (Kates, 1976). The second step is "*Communication Action Assessment,"* which involves searching for appropriate information channels that may provide the needed information. In general, government officials and media are the two most common channels (Lindell & Perry, 1992). Finally, "C*ommunication Action Implementation***"** is the last step in which respondents contact information sources or communicate through available channels. The required time to undertake communication action implementation depends on respondents' perceived level of urgency (Drabek & Stephenson, 1971).

2.2 Second Version of PADM

The second version of PADM, shown in Figure 2.2, was proposed by Lindell and Perry (2012). Comparing the first and second versions of PADM, the factors before the pre-decision processes are generally the same, with a few minor changes. The factor of *information channels* was renamed as *channel access and preference*, and *message content was* changed to *warning messages*.

There are also some noticeable changes. First, the protective action decision-making processes were separated into the psychological process of decision formation and behavioral responses. The concept of psychological processes is followed by pre-decision processes, which elaborates on how people psychologically form their decisions in response to the threats they received before pre-decision processes. The other noticeable change is that the factors of situational facilitators and situational impediments are added to the second version of PADM. These are regarded as two influential factors that could change people's final behavioral responses.

Compared to the 2004 PADM, the overall decision-making processes are separated into three parts in the second version, which includes 1) environmental and social context, 2) psychological processes, and 3) behavioral responses. The following review section will compare the differences and evolution between the first and second versions of PADMs.

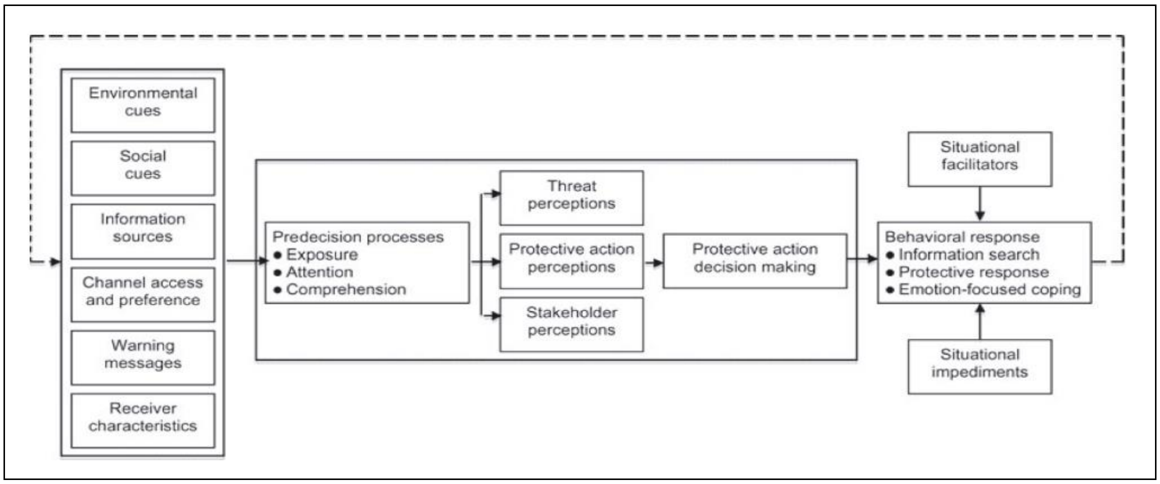


Fig 2.2 The second version of PADM (Lindell & Perry, 2012)

2.2.1 Environmental and Social Contexts

The first part of the second version of PADM is the environmental and social contexts, which include the variables of environmental cues, social cues, information sources, channel access and preference, warning messages, and receiver characteristics. While these variables are similar to those in the first version, they have been further developed in the second version. First, the factor of environmental context includes the influence of physical and environmental components, which comprise technological, meteorological, geophysical, and hydrological attributes that generates specific hazards to the residents who live in the areas (Lindell et al., 2006).

Second, the concept of a warning network is supplemental to the factor of social context in the second version, which shows the information transmission network from individuals to individuals, or organizations to organizations, and may result in the recipients receiving multiple messages at various times while others may receive no message or even conflicting messages (Gogers & Sorensen, 1988; Lindell, Prater & Peacock, 2007; Mileti et al., 1975). The third difference is information channels, which are created by the development of the Internet, social media, and communication devices (Lindell & Perry, 2012).

2.2.2 Psychological Processes

The second part of the second version of PADM is the psychological processes, which include three sets: 1) pre-decision processes, 2) environmental threat perceptions, protective action perceptions, and stakeholder perceptions, and 3) protective action decision-making.

Pre-decisional Processes

Three phases were added to the pre-decision processes in the second version of PADM. These are exposure, attention, and comprehension. Exposure means that people need to receive environmental and social cues before responding (Lindell & Perry, 2012). Exposure is followed by attention, which indicates the requirements of recipients' attention to environmental and social cues (Fiske & Taylor, 2008). However, even with recipients paying attention to the exposure to environmental and social cues, they still need to have the ability to comprehend the meaning of the messages and information. Therefore, the process moves to the third phase — comprehension (Aguirre, 1988). Consequently, respondents are more likely to move to the next perception-forming stage if they complete these three phases in the pre-decisional processes.

Perceptions of Environmental Threats, Protective Action, and Stakeholders

Secondly, the perception-forming stage includes three components: threat perceptions, protective action perceptions, and stakeholder perceptions. These variables are first proposed in the second version because they are found to be associated with people's schema or mental status about the overall hazards, and it is different from person to person (Morgan et al., 2002). Therefore, the concepts of comprehension of environmental and social cues and the perceptions of environmental threats are essentially different.

Perceptions of Environmental Threats

Cognitive risk perception (CRP) and hazard intrusiveness are two of the major factors in the perceptions of environmental threats. These factors are considered to have significant influences on people's immediate responses to environmental threats. CRPs reflect people's expectations of the consequences of death or property loss caused by disasters (Mileti & Peek, 2000; Mileti & Sorensen, 1987). Research has shown a correlation between CRPs and the adoption of protective actions. For instance, Sorensen (2000) indicates that CRPs can increase the likelihood of complying with the suggestions of warning messages. In addition, Lindell (2013) points out that protective actions are positively correlated with CRPs in most studies. However, some studies have reported contradictory findings. For instance, in research on volcanic, seismic, and wildfire hazards, Perry and Lindell (2008) find that CRPs are not statistically correlated with behavioral responses. As for affective risk perception (ARP), the second version of PADM suggests that ARP, such as fear, may be a mediating factor between environmental threats (which may include the speed of onset, potentially impacted areas, or the duration of an impact) and behavioral responses (Lindell & Perry, 2012).

Second, the term hazard intrusiveness originates from the notion of hazard salience, which refers to the degree of frequency with which people think about hazards (Perry & Lindell, 1990). Hazard intrusiveness is defined as the frequency of thinking about hazards and the thoughts generated by received hazard information through news media or vicarious experiences from peers, friends, or families (Greer et al., 2020; Lindell & Perry, 2012; Lindell & Prater, 2000; Weinstein, 1989; Wu, Greer, et al., 2017).

Third, some researchers (Preston et al., 1983) have pointed out that hazard experiences can positively or negatively correlate with proximity to geophysical hazards, such as earthquakes, hurricanes, and floods. However, these discrepancies may arise when researchers use different methods to measure hazard experiences (Becker et al., 2017).

Protective Action Perceptions

The perception of protective actions can be categorized into two types – hazard-related attributes and resource-related attributes ((Lindell et al., 2009). The hazard-related attributes include two factors. One is the efficacy of protecting individuals' lives or properties, and another is self-efficacy, which refers to individuals' self-assessment of their skills, knowledge, and ability that could be used to reduce the impact of environmental hazards (Lindell & Whitney, 2000). For instance, Norris *et al*. (1999) find that if an individual believes they can control environmental hazards, they are more likely to take protective actions. However, sometimes people believe their ability of self-efficacy is greater than their family and friends, and even equal to state or federal officials (Lindell & Perry, 1992).

The resource-related attribute is defined as the requirements of cost, time, knowledge, skills, or cooperation with other people to achieve hazard adjustments (Lindell & Whitney, 2000). For instance, Egbelakin *et al*. (2011) find that providing financial and property incentives can facilitate individuals to retrofit their houses for seismic hazards. In other words, reducing the difficulty of obtaining resources may be one way to increase the likelihood of adopting hazard adjustment. Some recent studies also found these variables are strongly associated with NechNa earthquake hazard adjustment activities in Oklahoma (Greer et al., 2020; Wu, Greer, et al., 2017).

Stakeholder Perceptions

Stakeholders can include government officials, experts, watchdogs (e.g., news media or environmental groups), households, business entrepreneurs, and other entities involved in disaster response activities. Concerning watchdogs, Wu et al. (2017) found that news media, radio, and peers are effective channels for survey respondents to receive information about the 2013 Colorado flash flood and the 2013 India flood. The research team also found that the survey respondents' reactions are positively and significantly correlated with their risk perceptions, which may be due to a well-established warning communication system.

Besides, Huang, Lindell, and Prater (2016) conducted a meta-analysis of 21 actual and four hypothetical hurricane evacuation studies to understand the factors that can trigger people's evacuation in response to hurricanes. They found that official warnings are positively correlated with evacuation behaviors. Compared to previous studies, Dow and Cutter (2000) reported that about 20% of North and South Carolina coastal residents relied on official evacuation warnings in preparation for upcoming hurricanes. Early research by Baker (1991) also suggests that public officials and their issued warning messages are the most effective ways to evacuate people from upcoming hurricanes, specifically with twice the effectiveness compared to other approaches.

Protective Action Decision Making

Furthermore, the box of protective action decision-making includes five stages, which are 1) risk identification, 2) risk assessment, 3) protective action search, 4) protective action assessment, and, 5) protective action implementation. These five stages are the same as in the first version of PADM. Therefore, the following discussion will focus only on comparing the different contents between them.

First, in the box of risk identification, the second version of PADM adds the content of the correlation between the level of threat belief and protective action adoption as one of the components of the risk identification process. This correlation has been found in various types of disasters such as floods (Perry et al., 1981), volcano eruptions (Perry & Hirose, 1991), chemical material spill accidents (Lindell & Perry, 1992), earthquakes (Blanchard-Boehm, 1998), and nuclear power plants (Houts et al., 1988; Perry, 1985).

Second, in the first version of PADM, the box of risk assessment process emphasizes people's expectation of the consequences and probability caused by environmental threats (Whitney, 1962). Additional evidence has been proposed in the second version of PADM, which is that the confirmation of warning messages can increase the possibility of adopting protective actions. However, the time people take to prepare to protect their property may also delay the implementation of personal protective actions (Lindell & Prater, 2007).

Third, though there have been almost no new factors added in the second version of PADM in the behavior of protective action search, Huang et al. (2012) reiterate how social cues influence people's decisions to take protective actions. For instance, people are more likely to evacuate from hurricanes when they observe their neighbors packing cars. Fourth, the research on Hurricane Lili shows that the evacuation routes, distances, cost, and shelter types are influential factors for respondents to evaluate the possible protective actions, which also reiterates the importance of the required time, resources, and knowledge used to assess those alternatives in the second version. (Lindell et al., 2012).

Finally, once the above four stages have been completed, the process is more likely to move forward to the protective action implementation stage. The reluctance to implement protective action has been proposed in the second version of PADM because sometimes people are not willing to disrupt their everyday activities. Therefore, they may postpone their evacuation and eventually endanger themselves when traveling to shelters. (Lindell et al., 2005).

2.2.3 Behavioral Responses

The box of behavioral response is the last stage in the PADM, which includes three components — information search, protective response, and emotion-focused coping. This section will focus on the information search set.

The information search process includes three components, which are the same as those in the first version of PADM (needs assessment, communication action assessment, and communication action implementation). No new factors are added to the information needs assessment in the second version of PADM. Similarly, the Communication Action Assessment component remains largely unchanged, with the exception that Lindell and Perry (2012) emphasize that people are more likely to rely on social media and peers as their main channels to receive the required information. The final step of Information Search is Communication Action Implementation. More research shows that when the impact of threats is uncertain, respondents are less likely to immediately seek related information (Morss & Hayden, 2010).

In addition, the factors of situational impediments and facilitators are added to the second version of PADM, and they show their impacts on behavioral response. The factor of situational impediments could have impacts on undertaking protective actions given some possible reasons such as 1) lack of a place to shelter, an appropriate route to arrive, or a vehicle to evacuate (Perry et al., 1981), 2) having physical disabilities (Van et al., 2002), or 3) waiting to reunite with families or friends (Drabek, 1968; Killian, 1952).

2.3 Third Version of PADM

The third version of PADM contains four major parts, shown in Figure 2.3, which are 1) Environmental Context, 2) Personal Characteristics, 3) Psychological Processes, and 4) Response Actions (Lindell, 2018). Compared to the 2012 version, the third version of PADM made only three major changes. This section will focus on these changes. Also, this effort will concentrate on the literature published after 2012.

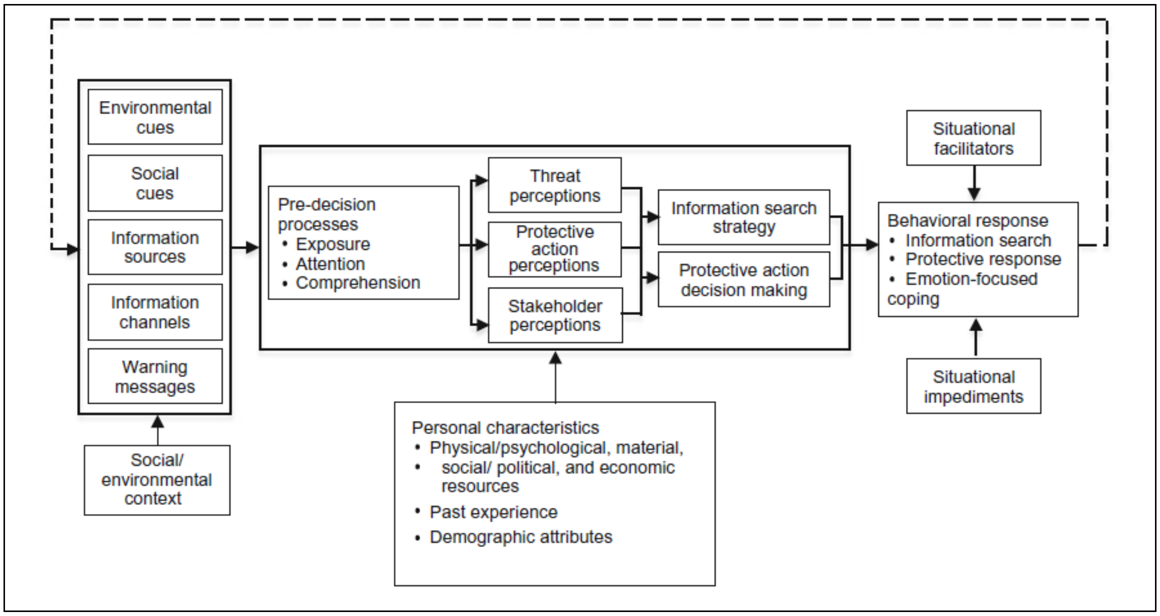


Fig. 2.3. The third Version of PADM (Lindell, 2018a)

2.3.1 Social and Environmental Context

The third version of PADM first explains the concept of social and environmental context, which is composed of physical, social, and household attributes that impact protective action decision-making (Lindell et al., 2016). The environmental contexts are environmental and human-induced hazards threatening the residents in hazard-prone areas (Lindell, 2013). Previous research also provides similar findings explaining the relationship between environmental contexts and disaster response. For instance, Mileti and Peek (2000) report that the risk perception of a nuclear power plant is formed by perceiving the environmental threats and leads to the intention of adopting protective actions. Peacock (2003) pointed out that the awareness of hurricane threats was not limited to individuals residing solely in evacuation zones but rather extended to most people living in coastal counties. More recently, Morss *et al.* (2015) indicate that the environmental contexts of hydrological and geographic attributes need to be considered when evaluating the risks of flash floods.

Social contexts also influence people's action decisions in response to disasters. For instance, people are used to looking for their family members' whereabouts (Perry et al., 1981) or tend to reunite or have an agreement to meet in a designated place (Drabek, 1968) before evacuating from an upcoming flood. Other research also mentions that neighbors' reactions to hurricanes can be influenced by each other in preparing for and responding to hurricanes (Meyer et al., 2013). However, the social contexts in response to different disasters may vary. For instance, people are more likely to respond to floods or hurricanes with their family members when compared to earthquakes. This is because floods and hurricanes are more predictable and have a slower onset than earthquakes.

2.3.2 Receiver Characteristics / Personal Characteristics

The factor of Receiver Characteristics has been proposed as an internal factor that has an impact on the overall psychological process in the third version of PADM, which includes three components: 1) demographic attributes, 2) past experiences, and 3) physical/ psychological, material, social/political/economic resources.

Although people reside in specific areas and experience similar environmental hazards, they may have different levels of risk perceptions due to the disparity of their cognitive limitation, memory capacity, hazard experiences, and emotional reactions (Lindell, 2014). For instance, Morss *et al*. (2015) find the mental models to interpret the meaning of flash flood warnings differ between forecasters, broadcasters, and public officials. Some researchers use the term hazard schema to conclude the overall risk perceptions formed by training programs, hazard experiences, and disaster subcultures (Wenger, 1978).

Demographic attributes are regarded as the principal factors for receiver characteristics. However, the literature shows weak effects of demographic attributes on protective action adoption, and most of the findings are inconsistent (Huang & Lindell, 2016). For instance, Baker (1991) indicated that the personal characteristics of age, education, occupation, marital status, sex, etc., are not correlated with hurricane evacuation. Similarly, Huang *et al*. (2016) reported that gender is not significantly correlated with hurricane evacuation. These findings are also supported by a tornado study suggesting that gender and ethnicity are not significantly correlated with evacuation (Lindell et al., 2016).

Disaster experiences are one of the most important factors influencing people's hazard schema. The positive correlations between hazard experiences and protective action adoption have been found in some tornado studies hazards (Blanchard-Boehm & Cook, 2004; Simmons & Sutter, 2007). Moreover, Wenger (1978) points out that a community frequently impacted by disasters can form a unique culture regarding certain hazards and increase the possibility of adopting protective actions. However, other research shows that people have the same level of attempts to take protective actions even when they have not experienced tornado hazards (Comstock et al., 2005). This negative correlation also has been found in hurricane hazards (Dow & Cutter, 1998). Recently, Huang et al. (2018) found that evacuation decisions are not correlated with previous hurricane experiences. As pointed out in Dillon, Tinsley, and Burns's (2014) study, people have different ways of interpreting their experiences, which can result in either an increase or decrease in the possibility they take protective actions. Consequently, the correlation between hazard experience and protective action adoption is unclear.

2.3.3 Core Perceptions / Situational Facilitators and Impediments

The core perceptions in the third version of PADM consist of three components: 1) perceptions of threat, 2) perceptions of protective actions, and 3) perceptions of stakeholders, which are similar to those in the second version. The perception of threats contains two attributes — risk perceptions and hazard intrusiveness. More research has been reported on the attribute of CRPs. For instance, Terpstra and Lindell (2013) report that the factor of gender is significantly correlated with CRPs. As for ARPs, Lindell et al. (2016) have extended their research to explore the correlation among affective reactions, and their findings show that the emotions of shock and fear are strongly correlated with each other, but the shock is uncorrelated with vigilance. Further, Lindell (2018) also points out that the correlation between ARP and behavioral responses needs to be further explored.

Second, the perceptions of protective actions include two major factors: hazard-related and resource-related attributes. Though these factors are similar to those in the second version, there is new research on them. For instance, Terpstra and Lindell (2013) focus on people's flood preparation intention in the Netherlands, and the results show that hazard-related attributes are positively correlated with hazard adjustment intention. However, the regression model failed to demonstrate a negative correlation between resource-related attributes and hazard adjustment intention. Further, Lindell (2018) points out that efficacy is the most important factor that correlates with protective actions in hazard-related attributes.

Third, little research has been added to the attribute of perceptions of stakeholders in the third version of PADM. New research published by Lindell *et al*. (2017) found that people have multiple ways to receive water contamination warning messages, such as social media, TV, Internet, telephone, and radio. However, none of them could be considered a completely sufficient information channel based on their professionalism, credibility, and accountability. In addition to the core perceptions, more research has been conducted on the factors of situational facilitators and impediments, which have revealed the issue of discrepancies between protective action intention and adoption due to impediments such as lack of a vehicle to evacuate (Wu et al., 2012), physical mobility (Stough & Mayhorn, 2013), or an appropriate place to shelter pets (Heath, Kass, Beck & Glickman, 2001).

2.3.4 Information Search and Behavioral Response

The factor of behavioral response in the third version of PADM is essentially the same as in the second version, which includes three attributes — information search, protective response, and emotion-focused coping. In the behavioral response process, people search for additional information because they cannot ensure their chosen protective option will correspond appropriately to the contingency. More research has been conducted on the contents of Information Search. For instance, Lindell *et al*. (2015) found that people have preferred channels, such as radio (55%) or face-to-face communication (41%), to seek out additional information about protective action alternatives. Howell and Sheppard (2012) reported that people might avoid seeking additional information because the risk feedback may result in certain obligations on them. However, an affirmation can reduce this avoidance. Similar research by Goodall and Reed (2013) shows that the certainty of solutions to a specific problem can encourage people to take protective actions. Some research has focused on whether people take protective action and how long it takes them to decide to take action (Meyer, Broad, Orlove & Petrovic, 2013). For instance, Wu *et al*. (2015) report that the experiment respondents failed to evacuate before a hypothetical hurricane struck, even though they knew the estimated time to get from their houses to shelters. Thus, more research may be needed to identify the factors that could delay protective actions in the last process of PADM.

As discussed above, PADM evolved from its first version in 2004 to its 2012 and 2018 versions. The empirical data used to test this model has been collected from various disasters. However, Peacock (2003) argues that some hazards have distinctive characteristics in nature. For example, the onset of an earthquake is much faster than a hurricane. Therefore, the time to respond to an earthquake warning message is far shorter than that of a hurricane. Hence, the ARPs or CRPs to earthquakes or hurricanes may have inherent differences. Not only does Peacock (2003) raise this issue, but Lindell (2013) also indicates that the association between different types of hazards and the factors shown to be statistically correlated with behavioral responses is still unclear.

2.4 Responses to Earthquakes

Earthquakes continue to threaten human beings in a wide variety of ways. Between 2010 and 2020, over 1,480 M_w6 or stronger earthquakes were detected worldwide (The United States Geological Survey, 2020). The number of casualties and property damages caused by some earthquakes is disastrous, for instance, the 1994 Northridge earthquake in California (Bolin & Stanford, 1991), the 2011 Christchurch earthquake in New Zealand, and the 2016 Fukushima earthquake in Japan. Understanding human responses to earthquakes is a crucial assignment for researchers and practitioners to reduce the possibility of deaths, injuries, or property damages, specifically for those who reside in earthquake-prone areas. Sections 2.4.1 and 2.4.2 discuss how researchers measure earthquake responses (ARPs, CRPs, and PADs). Sections 2.5 to 2.6 will discuss the possible cause of earthquake responses and list the research questions addressing these issues.

2.4.1 Affective and Cognitive Risk Perceptions to Earthquakes

The basic emotions of human beings include happiness, fear, shame, embarrassment, anger, guilt, disgust, sadness, surprise, helplessness, terror, worry, panic, enjoyment, and more (Ekman, 1992). Specifically, fear is one of the affective risk perceptions (ARPs) that disaster researchers have frequently studied. Others define ARP as the implicit meaning of dread of unknown hazards (Slovic et al., 2004). Panic is also another ARP that researchers have discussed in studies. Enrico L. Quarantelli was one of the pioneering researchers who reiterated that the ARP to a severe environmental threat was generally not panic (Quarantelli & Dynes, 1977). Panic has been defined as an extreme ARP followed by antisocial, irrational, or nonsocial fight or flight behavior (Alexander, 2007; Quarantelli, 2012). The occurrence of panic is rare, and the common behavior is altruism in a disaster situation (Mawson, 2005; Raphael, 2005).

In the recent decade, little research has focused on APRs compared to other disaster response variables. In the 1997 Fabriano earthquake study in Italy, Prati, Catufi, and Pietrantonio (2012) found that 38% of the respondents felt fearful, 9% felt helpless, 8% felt worried, 7% felt terrified, and 9% felt panicked. More recently, researchers have used the Mood Adjective Checklist (Matthews et al., 1990) to measure people's emotional responses during earthquakes. These emotions include optimistic, depressed, annoyed, nervous, fearful, relaxed, energetic, alert, and passive (Jon et al., 2016b; Lindell et al., 2015; Lindell et al., 2016; Wei et al., 2017). Among these measures, negative emotions such as feeling depressed, annoyed, nervous, fearful, and alert are negative emotions that can be used to measure ARP (Lindell, 2018).

Cognitive Risk Perceptions (CRP) can be defined as the way that people perceive threats during disasters (Arlikatti et al., 2007; Drabek, 1986; Huang et al., 2017; Lindell & Perry, 2004; Lindell et al., 2015; Mileti & Peek, 2000; Peek & Mileti, 2002; Sorensen, 2000; Tierney et al., 2001; Wu et al., 2015). Some researchers define risk perception as the possibility of experiencing an event that could cause mental, physical, or social disruptions (Lindell, 1994; Sorensen & White, 1980). CRP is the perception of possible consequences to individuals during disasters. (Mileti & Fitzpatrick, 1992). Earthquake CRP is generally measured by asking people to report their perceived likelihood of death, injury, property damage, and disruption of everyday life when experiencing an earthquake (Lindell & Prater, 2000). The disruption of everyday life includes jobs, local businesses, traffic, basic community services, and social life disruptions (Jon et al., 2016; Lindell et al., 2015; Lindell et al., 2016; Wei et al., 2017). In addition, most of these studies create a CRP index using the above-mentioned measures to conduct their analysis. Generally, there are two CRP indexes: household damage/injury and social disruptions.

2.4.2 Earthquake Protective Actions

People's protective action decisions (PADs) to earthquakes significantly influence the probability of injury or death. Shoaf et al. (1998) collected and analyzed data from three earthquakes: the 1987 Whittier Narrow earthquake, the 1989 Loma Prieta earthquake, and the 1994 Northridge earthquake. During the Northridge earthquake, younger people were more likely to move during tremors than the elderly and were, therefore, more likely to be injured by falling objects. The Federal Emergency Management Agency (FEMA) recommends that the appropriate earthquake protective action is Drop, Cover, and Hold on (Federal Emergency Management Agency, 2017). Actions such as catching falling objects or holding onto unstable furniture may cause serious injuries (Mahue-Giangreco, Mack, Seligson & Bourque, 2001).

However, some people may not follow official instructions for various reasons, and some researchers have explored these actions. For instance, Prati, Catufi, and Pietrantoni (2012) collected empirical data from 100 interviews in Fabriano, Italy. She reported that although officials have taught the Italians to shelter in place during tremors, in actuality, the common protective actions to an earthquake are 1) freezing, 2) sheltering, 3) recovering personal belongings, 4) contacting and protecting others, and 5) looking for earthquake-related information. This study also shows that less than 10% of the residents followed official recommendations, and the possible reasons for this are not reported. Consequently, understanding people's PADs during shaking has become a significant issue in improving public policy and earthquake education programs.

Previous research has shown that there are four types of human behaviors in response to an imminent emergency: fight, flight, paralysis/freezing, and affiliation (Pietrantoni & Prati, 2009; Sime, 1985). Flight is the most common response to earthquakes, and people may run out of buildings or help others (Alexander, 1990). Arnold et al. (1982) found that 36% of the respondents took cover under a desk, 15% stood in a doorway, 3% ran out of buildings, and 37% froze in place during the 1979 Imperial Valley earthquake in California. Goltz *et al*. (1992) also found similar results in the 1987 Whittier Narrows earthquake study, which showed that 40% of the respondents took cover under furniture, and 20% froze in place or evacuated out of buildings. Moreover, during the 1989 Loma Prieta earthquake, Bourque, Russel, and Goltz (1993) report that 72% of the respondents froze in place or took cover under furniture. During the 2012 Emilia-Romagna earthquake in Italy, Prati *et al*. (2013) reported that 42% of the respondents moved to other rooms, 36% evacuated buildings, 33% stayed in bed, 28% moved downstairs, 19%were getting dressed, 14% remained around a doorway, 14% sheltered close to a wall, and 2% took cover under a desk. Recently, Lindell *et al*. (2016) surveyed the 2011 Christchurch and Tohoku earthquakes and pointed out that 34% of the respondents froze in place, 20% immediately evacuated buildings, 12% adopted the action of Drop, Cover, and Hold on, 8% tried to protect others, 8% tried to protect property, and 2% continued their original activities.

As noted above, response behaviors during earthquakes can be categorized into seven types: 1) standing in a doorway, 2) protecting property, 3) helping other people, 4) taking in-place protection, 5) freezing in place, 6) keeping normal activities, and 7) running outside of buildings (Alexander & Magni, 2013; Goltz & Bourque, 2017; Lindell et al., 2015; Prati, Saccinto, Pietrantoni & Pérez-Testor, 2013). However, why people exhibit different response behaviors during earthquakes is still unclear.

2.5 Geolocation Contexts in Earthquakes

Over the years, PADM has evolved from its first version in 2004 to the most recent version in 2018. Based on the literature review, the third version of PADM includes a new factor called environmental and social context (Lindell, 2018), which includes geographical, geological, physical structure, and social context. The survey studies have examined the relationships between some of these variables (e.g., Huang et al., 2012; Lindell et al., 2005; Wu et al., 2012); however, the relationship between geographical locations and disaster responses (ARPs, CRPs, and PADs) in earthquakes is not well studied.

Only a few studies could shed light on this topic. For example, Lindell and Prater (2000) assert that similar hazard proximity can cause corresponding CRPs due to the parallel environmental and social cues and warning messages. Perry & Lindell (2007) also points out that people who reside in hazard-prone areas may have higher CRPs than those who do not. Because they not only perceive hazard information from environmental and social cues but also have higher chances of receiving warning messages from emergency managers or governmental officials. Another study also found that the CRP of the residents who reside around the Sendi refinery factory is higher than those who live far away (Yu, Cruz, & Hokugo, 2017).

In fact, Lindell (2013) asserts that this topic can be investigated by utilizing the Geographic Information System (GIS). Specifically, GIS's Getis-Ord Gi* analysis can help researchers to understand the significant differences between the hypothesized variables based on geospatial discrepancies. However, the literature shows no PADM earthquake studies use Getis-Ord Gi* analysis to test the relationships between geolocation and disaster responses. Getis-Ord Gi* has been used in some emergency management studies. For instance, Ma *et al*. (2011) found that the illegal activities in Beijing City were not randomly distributed using the Getis-Ord Gi* method, allowing the police department to deploy their forces more effectively. Kao *et al*. (2017) utilized Getis-Ord Gi* to identify clusters of Out-of-Hospital Cardiac Arrest patients in New Taipei City, Taiwan, enabling the Ministry of Health and Welfare to prioritize their medical resources. Similarly, Yi *et al*. (2019) utilized Getis-Ord Gi* to identify the hotspots of emergency calls in Shanghai City, China, which helped local emergency services to allocate their ambulances in advance. Also, Singh *et al*. (2021) adopted the Getis-Ord Gi* approach to analyze fire risks in Nagpur City, India, and found that the riskiest areas were clustered in specific locations. Furthermore, in the study of super cyclone Amphan in Bangladesh, researchers utilized the Getis-Ord Gi* method to identify the highest inundation areas, which could be used for flood mitigation plans (Hassan et al., 2020).

Consequently, one of the literature gaps in PADM studies is the absence of utilizing the Getis-Ord Gi* method to examine people's disaster response and identify whether these factors differ geographically. Therefore, the first overarching research question of this dissertation is

—Do people’s disaster responses (ARPs, CRPs, and PADs) geographically differ during an earthquake?

Three groups of operational research questions are listed below to address this overarching research question.

Geolocation and ARPs:

ARPRQ1: Do people's feelings of depression geographically differ during an earthquake?

ARPRQ2: Do people's feelings of annoyance geographically differ during an earthquake?

ARPRQ3: Do people's feelings of nervousness geographically differ during an earthquake?

ARPRQ4: Do people's feelings of fear geographically differ during an earthquake?

ARPRQ5: Do people's feelings of alert geographically differ during an earthquake?

Geolocation and CRPs:

CRPRQ1: Do people's perceptions of household losses differ geographically during an earthquake?

CRPRQ2: Do people's perceptions of social and life disruptions differ geographically during an earthquake?

Geolocation and PADs:

PADRQ1: Do people's unresponsive reactions vary depending on their geographic location?

PADRQ2: Do people's reactions to freeze vary depending on their geographic location during an earthquake?

PADRQ3: Do people's actions of staying put and using soft items for head protection vary depending on their geographic location during an earthquake?

PADRQ4: Do people's drop-cover-and-hold-on actions vary depending on their geographic location during an earthquake?

PADRQ5: Do people's responses to an earthquake in terms of dropping to the ground near solid structures vary depending on their geographic location?

PADRQ6: Do people's responses to an earthquake in terms of protecting those around them vary depending on their geographic location?

PADRQ7: Do people's responses to an earthquake in terms of protecting nearby buildings/structures vary depending on their geographic location?

PADRQ8: Do people's responses to an earthquake regarding turning off the utilities differ based on their geographic location?

PADRQ9: Do people's responses to an earthquake regarding standing in a doorway, holding onto, and keeping the door frame from out of shape during an earthquake differ based on their geographic location?

PADRQ10: Do people's responses to an earthquake regarding fleeing from buildings differ based on their geographic location?

2.6 Other Influential Factors in PADM

Addressing the RQs in Section 2.5 could help understand the geolocation influences on people's earthquake responses by identifying if disaster responses are geographically different using geo-spatial analysis; however, it does not provide an in-depth reason for the differences other than the location itself. The 2018 PADM updates also include other personal characteristic factors affecting people's disaster response. However, hurricane review studies have shown that most personal characteristics have minimum impacts on disaster response (Baker, 1991; Huang et al., 2016). Earthquake response studies also show a similar pattern. Shapira *et al*. (2018) collected earthquake response data in Tiberias, Israel, after a series of earthquakes struck the area in 2014. The study found other than residential building types and respondents' preparedness levels, none of the demographic characteristics (gender, age, marital status, income, etc.) explained earthquake response behaviors. Lindell and his colleagues collected data from Christchurch, New Zealand, and Hitachi, Japan, following the 2011 earthquakes in the areas (Lindell et al., 2016). Their correlation analyses show some demographic variables correlate with ARP and CRP, but very few correlate with earthquake PADs.

Researchers also collected data from four earthquake events in 2011 and 2013 from Christchurch, Cook Strait, and Lrassmere in New Zealand and Hitachi, Japan (Jon et al., 2016). Using a correlation matrix, the study analyzed all the earthquake response survey data from these four events. Among demographic characteristics, ARP, CRP, and PAD, 135 correlation coefficients were reported. The finding suggests the absolute value of these correlation coefficients all range from .23 to .00, with only six correlation coefficients above .10. The above studies also conducted regression analyses to predict PADs after their exploratory correlation analyses. The R-squares of these regressions are all less than .20 (Jon et al., 2016; Lindell et al., 2016; Shapira et al., 2018). This implies new measures should be introduced in the model.

2.6.1 Environmental/Social Context

In the PADM, the environmental context includes geographical, geological, meteorological, hydrological, or technological processes that generate hazard agents; on the other hand, the physical context mainly focuses on the integrity of the structure in which people are located while experiencing a disaster (Lindell, 2018). In earthquake studies, environmental context is measured by comparing studies in different geographic areas (Bourque et al., 1993; Fraser et al., 2016; Jon et al., 2016; O'Brien & Mileti, 1992; Ohta & Ohashi, 1985; Wei et al., 2017) or locations with different Mercalli magnitude (Bourque et al., 1993). Very few have touched on the geological issues or, as mentioned above, used geospatial analysis to investigate the concentrations of disaster response (Prati et al., 2013).

As for physical context, studies have been using measures such as at different locations (own home, peers'/friend's homes, workplace, or public spaces) (Jon et al., 2016; Lindell et al., 2015). Some researchers measure the type of buildings/locations during the earthquake (O'Brien & Mileti, 1992; Shapira et al., 2018), building codes (Palm, 1998), home context (Prati et al., 2013), different areas in a building (Arnold, Durkin & Whitaker, 1982), architectural elements (ceiling, lights, plasters) (Rahimi, 1993), etc. Generally, physical context is a good predictor of earthquake responses, including ARP, CRP, and PADs. For example, in the Shapira *et al*. (2018) study, the type of building is one of the two predictors that significantly affects the behavior of fleeing from a building with the highest standardized regression coefficient. Another study found that people are more likely to freeze or flee from a building when they are in a public place than at home, at work, or in transit; in addition, people are more likely to find protection if they are home or at the workplace (Bourque et al., 1993).

Social context is measured by asking study participants to report if they were with children, someone they knew (co-workers, friends, neighbors), strangers, or elders (Bourque et al., 1993b; Jon et al., 2016). These predictors are usually weak predictors of ARP, CRP, and PADs. Being with children is an interesting variable that, in some studies, shows a very strong association with CRPs and PADs (e.g., Jon et al., 2016), but a study reported that having children in the household was not a significant predictor of the behavior of fleeing from a building. There might be cultural differences since these studies are done in different countries.

2.6.2 Personal Characteristics

Social science studies have long been using basic demographic variables to examine how these personal characteristics affect their choice of dependent variables, and earthquake response study is no exception. Typical demographic variables, as mentioned earlier, are gender, age, education, income, marital status, race, disability, occupation, car ownership, employment status, family size, etc. (Jackson, 1981; Major, 1999; O'Brien & Mileti, 1992; Palm, 1998). While these are essential variables to include in earthquake response studies, they generally are poor predictors like what was mentioned in the Hurricane evacuation studies. In addition, Lindell *et al*. (2016) report that gender is not a significant factor that correlated with risk perception and emotional responses in the 2011 Christchurch and Tohoku Earthquake research. Only 11% of the demographic variables correlate with behavioral responses in the same study.

In earthquake studies, past experiences are measured in different ways and have different findings. Disaster experience can be operationalized by measuring the number of experienced disasters (Russell et al., 1995), by the dollar amount of previous disaster losses (Jackson, 1981), or by the experience of life or property loss oneself or close contacts (Turner et al., 1986). Overall, the literature shows the effect of disaster experience on disaster responses is not conclusive. A study shows disaster experience is positively correlated with the frequency of earthquakes (Palm et al., 1990). It also positively correlates with disaster responses (for instance, Blanchard-Boehm & Cook, 2004; Simmons & Sutter, 2007). Research has shown that people who have experienced earthquakes would be more likely to have higher risk perception and respond appropriately to earthquakes than those who have not (Goltz, Russell & Bourque, 1992). Sometimes, these experiences can be transmitted through generation-to-generation in seismic-prone areas (Gaillard, Clave, Vibert, Denain, Efendi, Grancher, Liamzon, Sari & Steiawan, 2008).

Studies have also focused on the issue that past disaster experiences positively correlate with people's protective actions. For instance, Mileti *et al.* (1990) found that people are more likely to take protective actions if they have experienced considerable earthquake damage. Further, Quarantelli (1994) suggest that people tend to change their attitudes and behaviors to imminent hazards if they have experienced disasters in communities. However, there are some studies also showing contrary findings regarding the relationship between disaster experience and response.

For instance, Baker (1991) finds that the lack of experiencing severe damages could form a “false experience” in hurricane hazards, which may eventually lead to a negative correlation between hurricane experience and evacuation. Also, Goltz *et al*.(1992) have found similar results in seismic hazards in Italy, which shows that people did not take cover during tremors even though they experienced more earthquakes than those who do not. Instead, people are more likely to take cover if they are afraid of earthquakes.

More research, such as Comstock and Mallonee (2005) find that no matter whether the respondents experienced tornadoes or not, the possibility to take protective actions for the subsequent tornadoes is at the same level, and the same situation is also found in hurricane studies (Dow & Cutter, 1998).More research shows a negative correlation between disaster experiences and PADs after 2012. For instance, Jon *et al*. (2016) pointed out that though people who have received earthquake-related information are more likely to turn off utilities and help others, there is no correlation between disaster experience and response. Baytiyeh and Naja (2016) also support this phenomenon by identifying a significantly negative correlation between fatalism and earthquake preparedness. Shapira *et al*. (2018) also support the negative correlation between earthquake experience and disaster response. Lindell (2018) suggests that the inconsistent findings in the literature may be caused by the discrepancy in how people interpret their hazard experiences. However, these speculations of inconsistent findings have not been evidenced yet. Studies found that individuals rate their earthquake hazard knowledge higher than their peers (Murphy et al., 2018), indicating an optimistic bias.

There may be other factors that influence this relationship. Based on the literature, six types of beliefs can negatively impact protective action decisions, including 1) fatalism, 2) optimistic bias, 3) normalization bias, 4) damage belief, 5) effectiveness belief, and 6) responsibility belief. First, the definition of fatalism means an individual's belief that suffering from a disaster or mishap is caused by nature or an Act of God, and therefore people have little or no way to ameliorate them (Quarantelli, 1998; Sims & Bauman, 1972).

Other research shows that people may think earthquake magnitudes cause earthquake damage, not deficient building designs (McClure et al., 1999; McClure et al., 2001; Plapp & Werner, 2006). Consequently, people with a fatalistic mindset are less likely to take protective actions (Turner et al., 1986).

Second, optimistic bias refers to people's belief that they have greater knowledge, abilities, or intelligence than their peers or are less likely to suffer from adverse events than the lay public (Weinstein, 1980); previous research also supports this proposition (Dunning et al., 2004; Weinstein & Klein, 1996). Optimistic bias makes people believe they are less likely to be harmed by hazards (Helweg-Larsen, 1999). To overcome optimistic bias, Burger and Palmer (1992) found that survey respondents lowered their optimistic bias level after the Loma Prieta earthquake. Still, their optimistic bias level only took three months to return to their pre-earthquake levels. Thus, Burger and Palmer's (1992) research supports part of Weinstein and Nicolich's (1993) claim that “time” is an important factor that reduces people's risk perception level.

Third, normalization bias refers to the belief that people who lack the experience of main-shock damages will not suffer from earthquake damages similarly as before. For instance, Mileti and O’Brien (1992) delivered two waves of questionnaires to the residents who live in San Francisco County. The results show that people who lack the experience of main-shock damages tend to keep the normalization bias and believe they will not suffer earthquake damages like before.

The fourth is damage belief. For instance, people who do not believe that their homes or communities are likely to be struck by earthquakes are less likely to purchase earthquake insurance than those who do (Palm, 1995). The fifth is effectiveness belief. For instance, people who believe that retrofitting buildings effectively reduces seismic hazards are more likely to take protective actions (Egbelakin et al., 2011). The sixth is responsibility belief. For instance, some people believe that local or federal governments should take on more responsibility to protect them from or reduce the risk of seismic hazards than themselves. If individuals believe it is the responsibility of governments to mitigate seismic hazards, they are less likely to take protective actions (Jackson, 1981). This tendency has been supported by the research of Lindell and Whitney (2000). Additional research shows that when individuals have children or own a house, they are more likely to have a higher risk perception and take protective actions (Turner et al., 1986).

To sum up, the review shows that, for earthquake response studies, environmental context (geological and physical) is not well studied, and the relationship between personal characteristics and response is either weak or inconclusive. The root causes of these discrepancies are unclear. One might argue that the inconsistent findings are due to the different measuring approaches; however, even studies using the same surveys and analytical methods still show inconsistent findings. For example, to model disaster responses to earthquakes in different countries, Lindell and his colleagues collected data from Christchurch, New Zealand, and Hitachi, Japan, using the same survey instrument and analytical approach. The study participants are both from earthquake-prone areas with relatively similar earthquake experiences, and the earthquake intensities in the two study areas are also very similar. The research findings suggest that Hitachi residents had statistically higher CRP but were less likely to drop, cover, and hold onto sturdy furniture during the earthquakes than Christchurch respondents.

Some studies suggest there might be other variables that should be included in the PADM to explain these inconsistencies. Becker *et al*. (2012) reported that people could become effective in responding to an earthquake when they have been educated, trained, and had group discussions before the shaking. To date, how these educational programs influence people's disaster responses to earthquakes is not clear. More speculation may be raised from other studies. For instance, studies suggest time is an intervening variable that can change the correlation between warnings and disaster response (Mileti & Fitzpatrick, 1992; Sorensen & Mileti, 2018; Weinstein & Nicolich, 1993). Thus, the question of how time influences the relationships between experience, warning, and disaster response remains to be explored.

While quantitative approaches, such as mediation analysis or Structure Equation Modeling, might be able to provide some insights, a qualitative approach is needed to dive deep into the root cause of these inconsistencies. Thus, the second overarching research question in this dissertation research is

— ***Why do people respond to earthquakes in specific ways in different geographical areas?***

This research question will be addressed by first identifying people who respond to an earthquake differently in a location (the first overarching research question) and then conducting an in-deep interview to unfold the root cause of these inconsistencies (the second overarching research question). This study collected survey data and interview data after the 2018 Hualien earthquake in Taiwan. The next chapter will discuss how a mixed research method is carried out to address the two overarching research questions.

CHAPTER III

METHODOLOGY

The study collected data after the 2018 Hualien Earthquake in Taiwan to address the research questions. Section 3.1 introduces the local context of the study area. Sections 3.2 and 3.3 describe how survey and interview data were collected and analyzed.

3.1 Hualien Earthquake

Taiwan is an Asian country situated on the tectonic boundaries between the Philippine Sea Plate and the Eurasian Plate (U.S. Geological Survey, 2013). It experiences an average of about 2,200 earthquakes annually, with nearly 200 being perceptible (Central Weather Bureau, 2020). In recent decades, the 1999 Chi-Chi Earthquake was one of the largest earthquakes in Taiwan, causing 2,329 fatalities, 8,722 injuries, and $124 billion in property losses (Dong et al., 2000). The disaster resulted in the adoption of new seismic-resistant building codes from other countries, such as Japan and the United States. Since then, building structures and physical environments have been fortified by enforcing new building codes in Hualien County (Ministry of Health and Welfare, 2000).

Hualien County is situated east of Taiwan, as shown in Figures 3.1 and 3.2. Each year, the area is subject to multiple hazards, such as typhoons, landslides, and earthquakes, due to its geological and meteorological characteristics (Hualien County Government, 2021). Specifically, earthquakes are one of the hazards that frequently and constantly threaten Hualien County, with eight active fault lines penetrating the region. Earthquakes in Hualien County are typically characterized by a main shock followed by several aftershocks, which can continue to occur for hours, days, or even weeks (Hua, 2022). Currently, Hualien County has the highest incidence of earthquakes in Taiwan, and facing the threat of earthquakes has become part of the residents' daily lives.

On February 6th, 2018, an M_w 6.4 earthquake struck Hualien County. The epicenter was located 20 kilometers (12.4 miles) south of Hualien City, resulting in partial collapses of the Yun Men Tsui Ti apartment and the Marshal Hotel (Central Geological Survey, 2018). At the time of the earthquake, about 80 residents were trapped inside the Yun Men Tsui Ti apartment, and 55 were reported missing. Additionally, around 20 tourists were trapped or missing in the Marshal Hotel after the main shock. Most residents were asleep or preparing to sleep because the earthquake occurred at 11:50 p.m. Following the main shock, more than 120 patients were transported to the emergency room at Hualien Tzu Chi Hospital within two hours (New Taipei City Fire Department, 2018).

The weather was cold that night, so some residents could not bear the low temperature and returned to their houses despite fear of the intense and intermittent aftershocks. After the local authorities set up temporary shelters in parks and stadiums, residents started to move out of their houses to the shelters. Most non-governmental organizations and volunteers converged on disaster sites and shelters to assist the survivors and their families. The causes of the building collapse in the Yu Men Tsui Ti apartment and Marshal Hotel were officially claimed by the government due to the illegal alteration to the building structures (New Taipei City Fire Department, 2018). Ultimately, the earthquake resulted in 295 injuries and 17 fatalities, leaving hundreds homeless (Central Disaster Prevention and Response Council 2019).

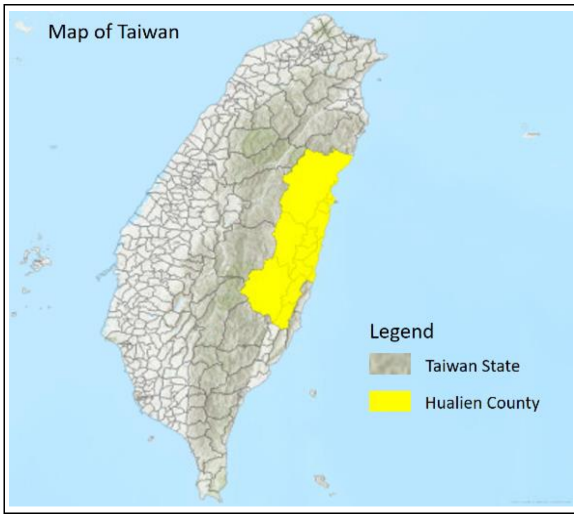


Figure 3.1. Map of Taiwan

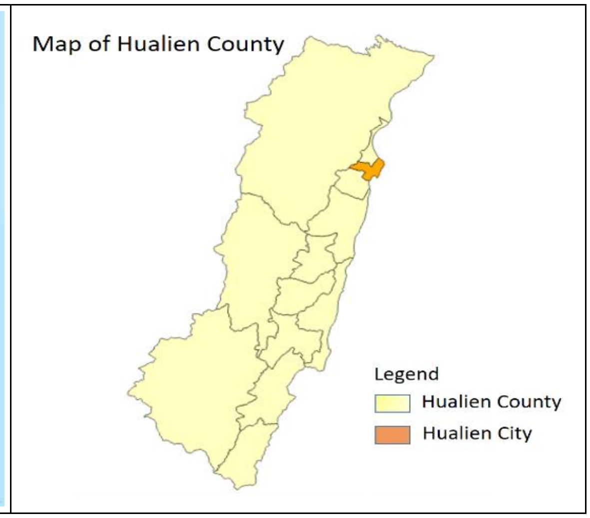


Figure 3.2. Administrative districts in Hualien County

In this dissertation research, we aim to address the research objectives of identifying the root causes of inconsistent findings in the PADM. This study employs a quantitative approach to identify potential geographic differences in people's responses to earthquakes and a qualitative approach to explore the underlying reasons for these discrepancies. A mixed methods approach is being used because neither the quantitative nor the qualitative method alone is superior to the combination of the two (Hesse-Biber, 2017).

The first research method involves collecting the 2018 Hualien Household Earthquake Response Survey data and analyzing them by using Getis-Ord Gi* analysis in ArcGIS. This enables the researcher to identify whether people's affective risk perceptions (ARPs), cognitive risk perceptions (CRPs), and Protective Action Decisions (PADs) vary geographically. The second research method involves conducting in-depth interviews with individuals selected based on the Getis-Ord Gi* approach, which can identify hot spots or cold spots in particular communities. This qualitative research method provides insight into the reasons behind the observed geographic discrepancies. Finally, using a mixed method can help the researcher to explore the possible root causes of the inconsistent findings in the PADM.

3.2 Survey Data Collection

3.2.1 Sampling

This dissertation research utilizes part of the household earthquake survey data collected after the 2018 Hualien Earthquake in Taiwan by a research team comprised of researchers from Oklahoma State University, the University of North Texas, Jacksonville University, and Central Police University, Taiwan. The research team surveyed residents' earthquake risk perceptions, experiences, hazard adjustment, salience, and people's protective action decisions during shaking.

The enumeration of Hualien County residents' addresses and names were obtained from the Hualien County Civil Management Agency. The researchers randomly selected 3,000 potential participants to include in the initial mailing list. A total number of 2,989 questionnaires were distributed in Hualien County from December 15th, 2018, to January 28th, 2019. There were 228 undeliverable survey packages. Eventually, the project received 807 completed questionnaires from Hualien County, with 35 respondents not located within the impact areas, 14 duplicates, and six blank responses. The survey was conducted in three waves with 7 USD 7-11 gift cards (210 NTD) for each respondent, and the response rate was 29.11%. Due to the purpose of the study, this dissertation research only uses the survey data collected from the most earthquake-prone areas in Hualien

County to address the research hypotheses, specifically whether the ARPs, CRPs, or PADs are geographically different.

Hualien County consists of 13 administrative districts, as shown in Figure 3.3, including Hualien City and the boroughs of Fenglin, Yuli, Fengbin, Fuli, Guangfu, Jian, Ruisui, Shoufeng, Xincheng, Wanrong, Xiulin, and Zhuoxi. The county covers an area of 4,268 km^2 (1645.5 square miles) and has a population of 350,000. The urbanized area is mainly located in Hualien City, where 106,335 residents live within an area of 29.41 km^2 (11.35 square miles)(The Tourism Bureau of Taiwan, 2022). Geologically, there are eight fault lines, including Milun, Lingding, Ruisui, Chimei, Yuli, Chishang, Lichi, and Luyeu, which penetrate most of the boroughs and can trigger earthquakes with their movements. Specifically, an eight-kilometer Milun fault line starts northeast of Xincheng borough. It ends in the southeast of Hualien City, considered the primary cause of earthquakes in the area (The Geological Research Institution of Hualien County, 2007).

From 2010 to 2020, Taiwan experienced over 25,996 earthquakes greater than M_2 per year, including seven earthquakes greater than M_5 that occurred explicitly in Hualien County within the administrative districts of Xincheng, Jian, and Hualien City boroughs (Central Weather Bureau of Taiwan, 2020). Therefore, this research focuses on the resident responses to earthquakes in these regions, as shown in Figure 3.4.

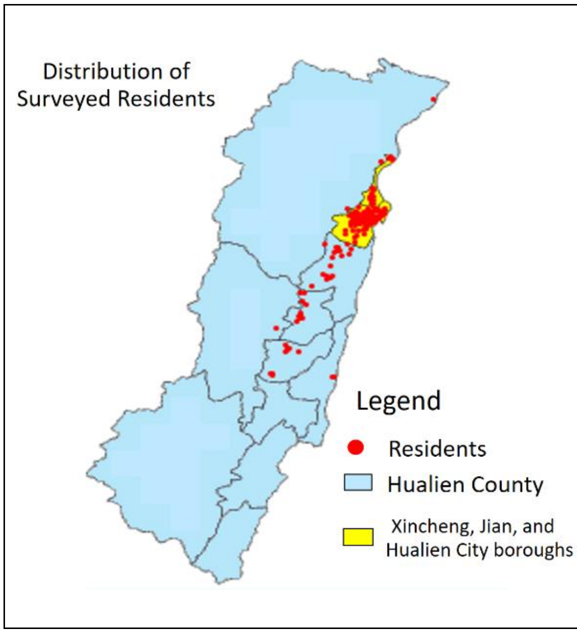


Figure 3.3. Distribution of surveyed residents

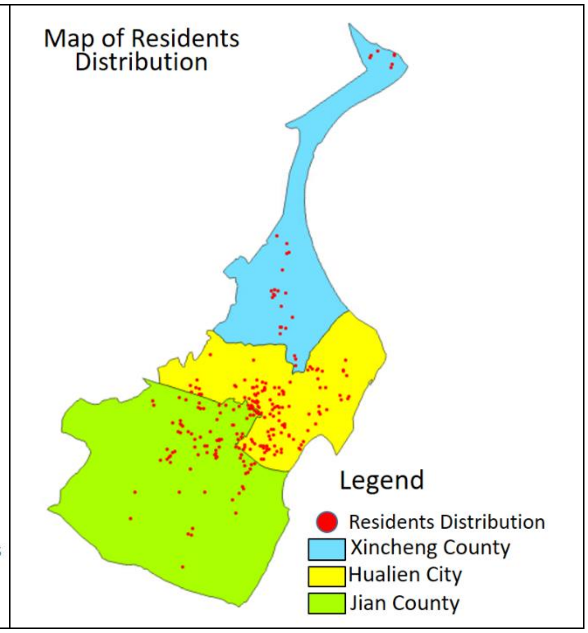


Figure 3.4. Mainly surveyed areas

3.2.2 Survey Measures

The survey instrument used in the 2018 Hualien Earthquake study was derived from an earthquake questionnaire that was used after the 2011 Christchurch Earthquake and the 2011 Tōhoku Earthquake (Lindell, Prater, et al., 2016). The questionnaire has been used to collect PADM variables in previous earthquake and tsunami studies (Jon et al., 2016; Lindell et al., 2015; Wei et al., 2017). The survey questionnaire consists of four sections that include the Hualien earthquake experience (Q1-Q16), previous earthquake experience (Q17-Q19), earthquake impact (Q20-Q22), and personal information (Q23-Q33). The research team revised the questions regarding demographic characteristics to reflect the local context in Taiwan. The questionnaire can be found in Appendix A.

Since this dissertation research primarily focuses on the respondents' ARPs, CRPs, and PADs, questions ten, eleven, and twelve were selected for further analysis. In question ten, respondents were asked about their likelihood to immediately take a specific response behavior on a 5-point Likert scale ranging from 1 (very unlikely) to 5 (very likely). The types of response behaviors include 1) continuing what they were doing before the earthquake, 2) staying where they were without taking any protective actions, 3) using their hands or soft items to cover their head, 4) dropping, covering, and hold on, 5) staying near solid furniture or a solid building structure, 6) protecting other people nearby, 7) protecting property nearby, 8) trying to turn off the utilities, 9) keeping the door frame from out of shape, and 10) immediately left the building.

In question eleven, respondents were to rate their ARP on a 5-point Likert scale ranging from 1 (not at all) to 5 (very great extent), which includes the ARPs of feeling1) depressed, 2) nervous, 3) annoyed, 4) fearful, and 5) alert. In question twelve, respondents were asked to rate their CRPs on a 5-point Likert scale ranging from 1 (not at all) to 5 (very great extent). This question includes a wide variety of CPRs related to different aspects such as 1) home damage, 2) family members in danger, 3) home damage caused by secondary impacts, 4) family members in danger caused by secondary impacts, 5) job disruption, 6) local business disruption, 7) traffic disruption, and 8) utility disruption.

Since the first four items were related to the CRPs of live or property damages and the last four times were linked to social and life disruptions, they were used to develop two new CRP variables: 1) household losses and 2) social and life disruptions. To ensure the reliability of the measures, the researcher utilizes Cronbach's α analysis to ensure the internal consistency and reliability between them.

The results indicate that Cronbach's α score for CRP of household losses and CRP of social and life disruptions are 0.86 and 0.87, respectively. These scores are higher than

0.75, indicating these two measures' high internal consistency and reliability (Cronbach, 1951; Cronbach et al., 2004; Hinton & Brownlow, 2004). Thus, the first four items can be merged into the CRP of household losses, and the last four items can be merged into the CRP of social and life disruptions. Finally, survey respondents' addresses were recoded into geo-coordinates (latitude and longitude) for spatial analyses.

3.2.3 Analytical Method

To identify the spatial features statistically clustered in specific areas, Getis and Ord developed an equation to test spatial autocorrelation and named the cluster of high-high values as hot spots and low-low values as cold spots (Ord & Getis, 1995; Silverman, 2018). These clusters are measured based on the sample's relative distances (Anselin, 1995). In the equation below, W_{ij} represents the spatial weighted values between the events of i and j, X_j represents the event j with its attribute values, and n is the number of overall events. Besides, $\overline{X}$ is the mean of the event j, and S is the standard deviation of the event j. The G_i^* is a z score representing an event's concentration level. A hot spot indicates that a specific attribute is surrounded by similar positive-high values. In contrast, a cold spot refers to a specific attribute surrounded by similar negative-low values. If a z score is close to zero, it means that an event is randomly distributed spatially.

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \overline{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2 \right]}{n-1}}}$$

Since the z scores follow a standard normal distribution, they are useful for testing spatial autocorrelation (Yi et al., 2019). In this dissertation research, the G-statistic z scores are used to determine whether an attribute value of ARPs, CRPs, or PADs is significantly higher or lower than the critical value of 2.54 or -2.54 based on a confidence level of 0.99.

To test the ARPs, respondents rated their emotion levels on a scale of one to five, where one indicates "not at all," two means "small extent," three means "moderate extent," four means "great extent," and five means "very great extent." These scores are calculated using the Gi* equation and considering the relative distances among respondents. As a result, the researcher can identify whether the ARP of fear, depression, annoyance, nervousness, and alertness are concentrated in specific communities. Similarly, the CRPs and PADs are tested using the same method.

The analysis is conducted at the community level because the study aims to distinguish the differences in ARPs, CRPs, and PADs between communities. In other words, this study attempts to determine if people who reside in different communities have statistically significant differences in ARPs, CRPs, and PADs to earthquakes. Therefore, the Getis-Ord Gi* method in ArcGIS measures hazard proximity and geospatial contexts that generate earthquake hazards to the people who reside in seismic risk areas.

3.3 Interview Data Collection

Qualitative research's interpretive worldview and constructivism posit that the body of knowledge is constructed through interactions with participants who possess different knowledge and perspectives (Hesse-Biber, 2017). The epistemology of symbolic interactionism describes how people interact with each other or react to environments. The reasons for their different attitudes and behaviors toward different situations eventually coin the meanings researchers seek (Blumer, 1969; Cooley, 1902; Morris, 1934). This dissertation research finds that the residents' ARPs, CRPs, and PADs vary by geographic location in specific communities. Please see Chapter 4, Sections 4.2 and 4.3 for findings. However, the reasons for these discrepancies need clarification. Therefore, face-to-face interviews were conducted to understand these phenomena. The participants' perspectives in this research are represented through narrative, and the researcher tends to present the natural settings of these meanings from them (Creswell, 2014).

To contact the potential interviewees, the researcher visited several local community leaders in Hualien County in March 2020 and built a rapport with them. The trust and relationship between the researcher and potential participants were built through the local community leaders who served as "gatekeepers" (Mertens & Ginsberg, 2008). However, in May 2020, the COVID-19 pandemic spread globally and affected Taiwan. Face-to-face interviews became intimidating to potential interviewees. However, with the increasing vaccination coverage for COVID-19 in 2021, the Taiwan Centers for Disease Control agreed that face-to-face interviews were permitted under the rule of masking up and keeping social distance.

The Institutional Review Board of Oklahoma State University officially approved this research on February 25th, 2021. The researcher contacted the local community leaders during March and April to further set up face-to-face interviews. Finally, the researcher collected the interview data from June 1st to July 31st, 2021, in Xincheng, Jian, and Hualien City boroughs in Hualien County. Some interviewees reside in or around the most devastated areas along the Milun fault line in the Hualien City borough.

The community leaders gave potential interviewees a hard copy of the informed consent (Appendix B) and interview questions. The researcher provided his contact information in advance for any further questions. The informed consent mentions an incentive of a 10 US dollar gift. However, to ensure the participations are voluntary, the researcher notified each interviewee that if they did not complete the interview or declined to answer some of the questions, they could receive the incentive.

3.3.1 Sampling

The sampling was based on the findings in Chapter 4, Sections 4.2 and 4.3. The ARP of fear was found among forty-four residents clustered in four distinct communities and distributed across two different geographic locations, as shown in Figure 3.5. Among them, twenty-nine residents were concentrated in two hot spots within the same geographic location, of whom eleven were interviewed. The remaining fifteen residents were clustered in two cold spot areas within one similar geographic location, of whom eight were interviewed.

In addition, the ARP of nervousness was found among twenty-five residents who clustered in two distinct communities and were located within the same geographic location, as shown in Figure 3.6. Ten of them were interviewed in the two hot spot areas.

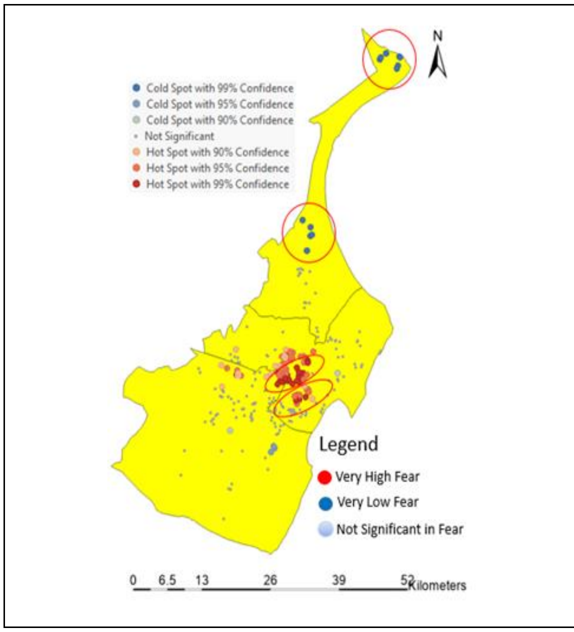


Figure 3.5. Sample distribution of ARP of fear

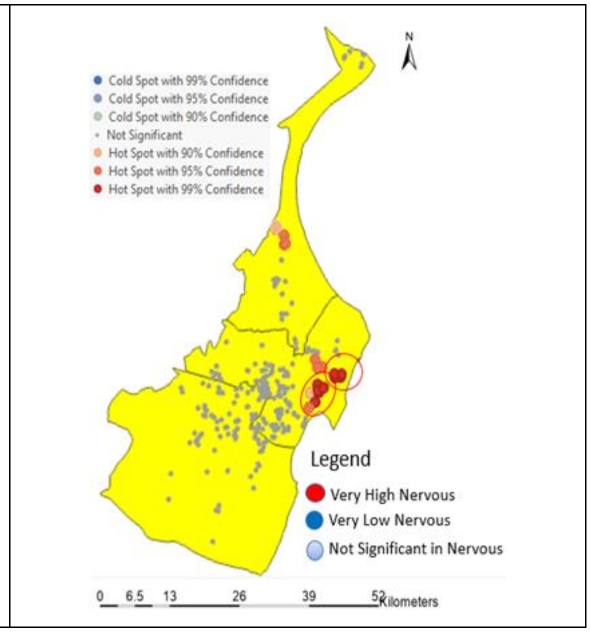


Figure 3.6. Sample distribution of ARP of nervousness

In regards to the type of CRP of household losses, forty-nine residents were clustered in four distinct communities, as shown in Figure 3.7. Among them, twenty-two residents were located in two hot spot areas within the same geographic location, and eleven were interviewed. The remaining twenty-seven residents were clustered in two cold spots in another geographic location, of whom twelve were interviewed.

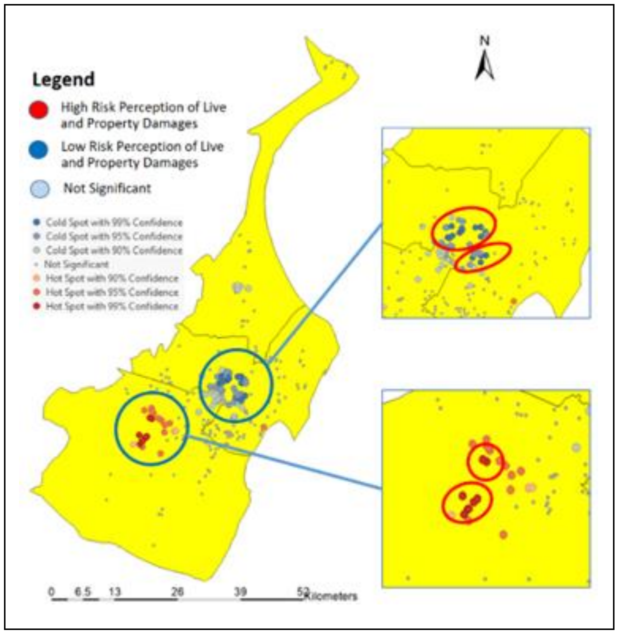


Figure 3.7. Sample distribution of CRP of live and property damages

The PAD of immediately leaving the buildings where they were staying during shakings was observed among twenty-four residents who were clustered in three distinct communities and located in the same geographic area, as shown in Figure 3.8. Twelve of them were interviewed.

The PAD of deciding to stay in place without taking any protective actions was found among twenty-seven residents who were clustered in three distinct communities and located in one similar geographic area, as shown in Figure 3.9. Thirteen of them were interviewed.

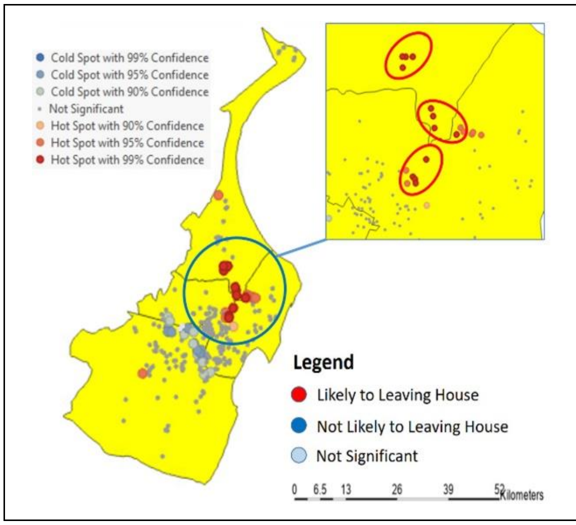


Figure 3.8. Sample distribution of PAD of evacuating from buildings

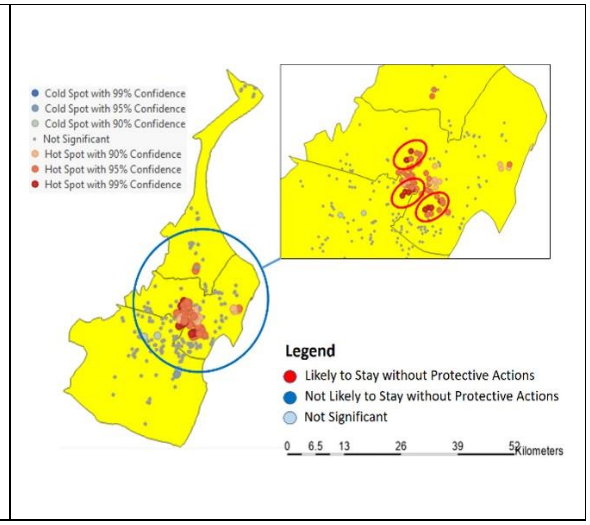


Figure 3.9. Sample distribution of PAD of staying in a place without taking any protective actions

3.3.2 Interview Data Collection

This researcher conducted interviews with seventy-seven residents who exhibited specific characteristics within clustered areas. The same set of questions was used for all interviewees. Interviews were conducted with five types of residents until each type had no more topics or issues being raised, indicating data saturation theoretically (Guest, Bunce & Johnson, 2006), and the researcher stopped to look for more interviewees.

The questions (Appendix C) used in this research include the initial inquiries about the 2018 Hualien Earthquake during shaking, which contain three questions: 1) Could you describe the overall experiences of the 2018 Hualien Earthquake? 2) Could you describe your immediate response behaviors during shakings, and why did you do that? 3) Could you describe your overall feelings about the 2018 Hualien Earthquake and your emotional feelings during shakings?

The second question focuses on the respondents' earthquake experiences and their beliefs about environmental hazards, which also includes three questions: 1) Could you describe the earthquake experiences you had before the 2018 Hualien Earthquake? 2) Could you describe how you prepare for earthquakes and how you receive earthquake preparedness information? 3) Could you describe the beliefs about earthquake hazards? For instance, in your opinion, what kind of people are more likely to suffer from earthquakes? Or, who will be the major stakeholders to be responsible for earthquake preparedness?

The third question mainly concentrates on cognitive risk perception. It contains two questions: 1) Could you describe your feelings about an earthquake that may or may not threaten your lives, properties, or social activities? 2) Could you describe how you receive the information related to earthquake risks? The fourth question is about earthquake warning messages and channels, which include the following questions: 1) Could you describe your major channels to receive earthquake warnings and why? 2) What are the most important parts of an earthquake warning message for you, and why? Further, generally what were your reactions to these warnings?

At the beginning of each interview, the interviewer told the participants that their responses to the questionnaires in 2018 or 2019 indicated distinctive reactions to the 2018 Hualien Earthquake. Therefore, the researcher intended to learn more about their earthquake risk perceptions and experiences (Weitz, 1987). Also, their reflections may eventually become part of governments' earthquake preparedness and response policies. Semi-structured and open-ended questions were used as an interview protocol. The interviewees were encouraged to discuss their earthquake experiences and perceptions of seismic hazards. The informed consent was individually explained by the researcher and signed by each interviewee before the interview.

The face-to-face interviews primarily took place at the participants' houses or offices.During each interview, the conversation was recorded using a digital device. The researcher informed the participants that the entire interview process would be recorded and that they had the right to decline to answer any questions or terminate the interview at any time. Even if they refused to answer specific questions, they would still receive a 10 USD gift card. Each interview lasted approximately 20-30 minutes. All digital data was stored on a password-protected computer. Only the researcher could get access to the information. All identifiers were substituted with anonymous numbers and removed permanently after the data analysis. The digital data were transcribed verbatim and coded by the researcher himself.

Participants during the interview may find it distressing to recall earthquake damages or losses. The researcher observed the participants' reactions and provided positive feedback and reflections to minimize potential distress. To protect the participants, individuals under the age of eighteen were not recruited. In addition, the memory capacity issue has also been raised in studies that do not collect empirical data immediately after an earthquake. However, some researchers, such as Norris and Kaniasty (1992), Bourque, Shoaf, and Nguyen (1997), and Wu (2020), find that the respondents' memories of events are generally stable even after a long period.

Studies by Neisser *et al*. (1996) and Brown (1977) suggest that people can retain accurate memories of significant events, even after a long period. Neisser *et al*. (1996) found that respondents who completed a survey about the 1989 Loma Prieta earthquake 18 months after the event had better memory accuracy than students who learned about it in their classes. 'Flashbulb memory' is a phenomenon in which people can remember precise details of significant events, even if they occurred years ago. Christianson (1989) found that people could accurately recall the event of Olof Palme's assassination a year later. Edery-Halpern and Nachson (2004) showed that the distinctiveness of terrorist attacks was necessary for people to recollect details in their memories. Sotgiu and Galati (2007) found that people could recall the critical parts of their experiences and emotional reactions to the traumatic flood disaster in 2000. These studies support the validity of interviewing people who experienced the 2018 Hualien Earthquake.

3.3.3 Data Analysis

The qualitative data in this research include the transcription of in-depth interviews and field notes that capture the participants' facial expressions, body language, and voice tones taken by the researcher. The overall data analysis is assisted through the software of ATLAS.ti. The researcher created a codebook based on a literature review explicitly focusing on references to PADM fields (Lindell, 2018). The codes used in this research are primarily theory-driven, but any codes that emerged from the data were also coded as data-driven fields (DeCuir-Gunby, Marshall & McCulloch, 2011).

The main goal of first-cycle coding was to obtain an extensive picture understanding of the overall data. The first coding cycle involves analyzing words, phrases, or sentences into paragraphs. In the first coding cycle, the researcher took notes and created memos that could be used to identify possible codes, categories, themes, concepts, and connections between factors later. The transcriptions were directly coded in Mandarin to minimize the discrepancy between English and Mandarin translations during the coding processes. The codebook was reviewed and checked by Dr. Li, who graduated from the

National Taiwan University of Science and Technology and was proficient in both English and Mandarin, to ensure an accurate interpretation of the contexts in the codebook.

Moreover, one participant's transcription was coded simultaneously by both the researcher and Dr. Li. By comparing the coding discrepancies of the exact words, phrases, sentences, and paragraphs, the researcher gained insight into how different researchers interpret the definition of the codes and the possible issues generated from other languages. Based on the first coding cycle and the coding process with Dr. Li, the researcher altered, refined, and reconfigured these codes and definitions in the codebook.

To ensure the reliability of the codebook, this research utilized Cohen's Kappa coefficient (Cohen, 1960) to test it. The calculation of Cohen's Kappa is based on the following equation.

$$K = \frac{Po - \ Pe}{1 - Pe}$$

K: Cohen's Kappa coefficient

P_o: the proportion of identical judgments

P_e: the expected proportion of identical judgments

The level of agreement indicated by Cohen's Kappa values can be classified as shown in Table 3.1 (Landis, Richard & Koch, 1977). K values within the range of 0.21-0.4 are rated as 'fair,' K values of 0.41-0.6 are rated as 'moderate,' K values of 0.61-0.8 are rated as 'substantial,' and K values greater than 0.81 are rated as 'almost perfect.'

Table 3.1. Strength of agreement in Cohen's Kappa

Value of Cohen's Kappa (K)	Strength of agreement
0.21-0.40	Fair
0.41-0.6	Moderate
0.61-0.8	Substantial
> 0.81	Almost perfect

To apply Cohen's Kappa method, the researcher provided a new transcription to two raters for further rating. Dr. Li was represented as rater A, and Dr. Fong, who graduated from National Taiwan University and was proficient in English and Mandarin, was represented as rater B. There were a total number of eight-one coded words, phrases, sentences, and paragraphs. Before rating, the researcher explicated each code, definition, and example to the raters. Rater A and Rater B independently rated these eighty-one contexts as either 'identical' or 'non-identical'. In turn, sixty-five items were rated as 'identical' by both raters, and twelve items were rated as 'non-identical.' One item was rated as 'identical' by rater B but 'non-identical' by rater A. Three items were rated as 'non-identical' by rater B but 'identical' by rater A, as shown in Table 3.2.

Table 3.2. Scores of two raters

Rater B / Rater A	Identical	Non-identical	Total
Identical	65	3	68
Non-identical	1	12	13
Total	66	15	81

The next step is to calculate the K value and assess the strength of the agreement. The proportion of identical judgments P_O is 0.95, and the expected proportion of identical judgments P_e is 0.71. Therefore, according to the equation, the K value is 0.82, indicating that the strength of agreement is rated as 'almost perfect'.

$$\text{Po} = \frac{65 + 12}{81} = 0.95$$

$$\text{Pe} = \frac{68}{81}\text{X}\frac{66}{81} + \frac{13}{81}\text{X}\frac{15}{81} = 0.71$$

$$\text{K} = \frac{0.95 - 0.71}{1 - 0.71} = 0.82$$

The third coding process aimed to reorganize and group these codes into themes. These themes were further analyzed using the thematic analysis approach (Attride-Stirling, 2001). First, the researcher identified themes by comparing and distinguishing the characteristics of repetition, similarity, difference, transition, metaphor, and analogy in the contexts (Ryan & Bernard, 2003). Second, the researcher refined these basic themes into organizing themes based on their relationships, connections, and similarities. Third, the organizing themes were further abstracted into global themes to find a larger concept or idea that could encompass these organizing themes. The overall thematic analysis was oriented and structured by the research questions.

CHAPTER IV

GEOLOCATION DIFFERENCES

This chapter reports the findings regarding the first overarching research questions. It starts with a short description of the survey sample demographics in Section 4.1. The results of Getis-Ord Gi* analysis for ARPs, CRPs, and PADs is discussed in Sections 4.2 and 4.3. These results are compared with the previous research findings in Section 4.4. Overall, the Getis-Ord Gi* results indicate that the ARPs of fear and nervousness, the CRP of household losses, and the PADs of flight and freeze have geo-statistical differences.

4.1 Descriptive Statistics of Demographic Characteristics

Descriptive statistics of the survey sample's demographics are shown in Table 4.1. The surveyed regions include Hualien City, Xinchen County, and Jian County. The number of surveyed samples is 311. First, the survey respondents' median ages in the three regions are slightly higher than in the census data. Second, the table also shows no major differences between the sample and census regarding gender.

Third, the ratios of marriage are 65.43%, 76.66%, and 65.57% in the samples, which are generally higher than in the census data. Specifically, the marriage percentage in Xinchen County is much higher in the sample than in the census. Fourth, the respondents' education levels are generally higher than in the census. Lastly, the income levels in the samples range from 14K to 20K, which shows no major differences compared to the census, which is 17.5K in Hualien City and 15.39K in Jian County.

Table 4.1. Demographics in samples and census

Demographics		Hualien City		Xinchen County		Jian County	
		Survey	Census	Survey	Census	Survey	Census
Age (median)		52.35	41	57	42	52	44
Gender (%)	Male	50%	48%	42%	51%	52%	50%
	Female	50%	52%	58%	49%	48%	50%
Married (%)		65%	52%	77%	44%	66%	58%
College graduate or higher(%)		40%	28%	44%	20%	32%	25%
Income level (median)		3=14K to 20K	$17.542	3=14K to 20K	N/A	3=14K to 20K	$15.391

4.2 Findings of Risk Perceptions

This dissertation research focuses on two types of risk perception: affective risk perceptions (ARPs) and cognitive risk perceptions (CRPs). The test results of Getis-Ord Gi* show that the ARPs of fear and nervousness, and the CRPs of household losses, are statistically significant differences among communities. Sections 4.2.1 and 4.2.2 will illustrate these differences on maps.

The Getis-Ord Gi* analysis results show clusters of risk perceptions (APRs and CPRs) in specific communities. There are two types of clusters: hot and cold spots. A hot spot cluster indicates survey participants in the area are likely to feel a certain kind of risk perception measure. The maps illustrate these hot spots with red, dark orange, and light orange dots. Red dots indicate an attribute with high Gi* values at a 99% confidence level. Dark orange dots represent an attribute with high Gi* values at a 95% confidence level. Light orange dots indicate an attribute with high Gi* values at a 90% confidence level.

In contrast, a cold spot indicates survey participants in the area are less likely to feel a certain kind of risk perception measure. The maps illustrate these hot spots with dark blue, regular blue, and light blue dots. Dark blue indicates an attribute with low Gi* values at a 99% confidence level. Regular blue represents an attribute with low Gi* values at a 95% confidence level. Light blue indicates an attribute with low Gi* values at a 90% confidence level. Lastly, grey indicates that an attribute is not statistically significant.

4.2.1 Findings of ARPs

Getis-Ord Gi* is used to answer ARPRQ1, ARPRQ2, ARPRQ3, ARPRQ4, and ARPRQ5. The test results show that except for fear and nervousness, depression, annoyance, and alertness are not significantly clustered in any communities during shaking. The findings are listed below.

The results of ARPRQ1 (*Do people's feelings of depression geographically differ during an earthquake?*) show that the feeling of depression's GiZ scores ranges from -2.34 to 2.55, with a mean of 0.53 (Figure 4.1). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that the residents' feeling of depression is not surrounded by the residents who keep the same feeling of very low or high depression levels during shaking. In other words, the results indicate the feeling of depression has no significant geographical variation in the area.

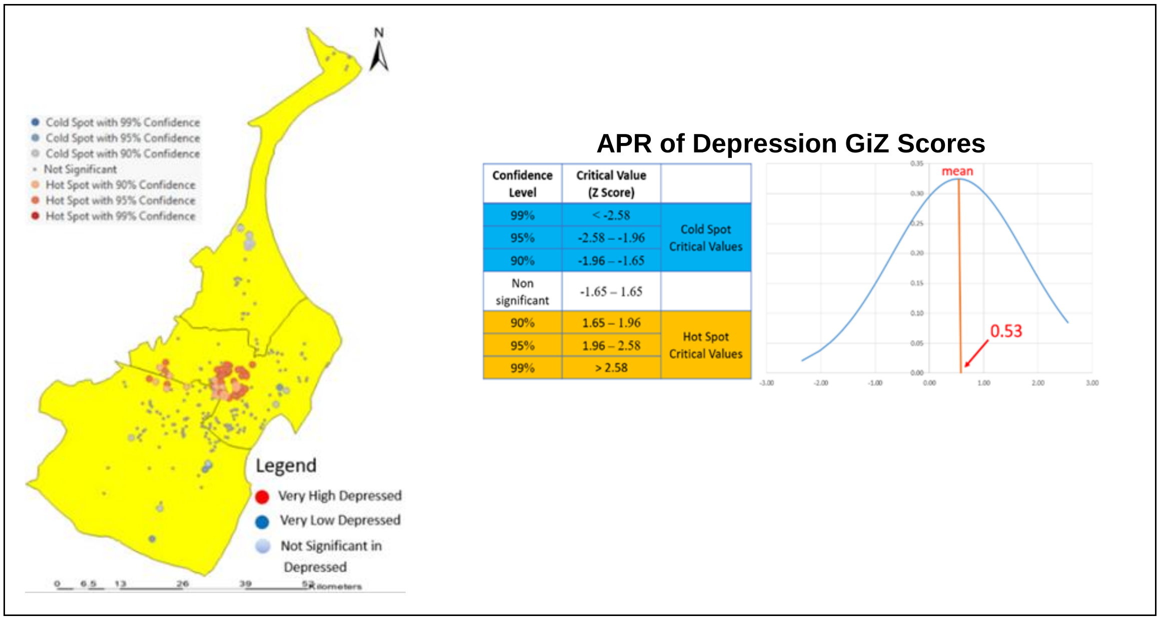


Figure 4.1 The distribution of the feeling of depression and its GiZ Scores

The results of ARPRQ2 (*Do people's feelings of annoyance geographically differ during an earthquake?*) show that the feeling of annoyance's GiZ scores ranges from -2.27 to 2.54, with a mean of 0.31 (Figure 4.2). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that the residents' feeling of annoyance is not surrounded by the residents who keep the same feeling of very low or high annoyance levels during shaking. In other words, the results indicate the feeling of annoyance has no significant geographical variation in the area.

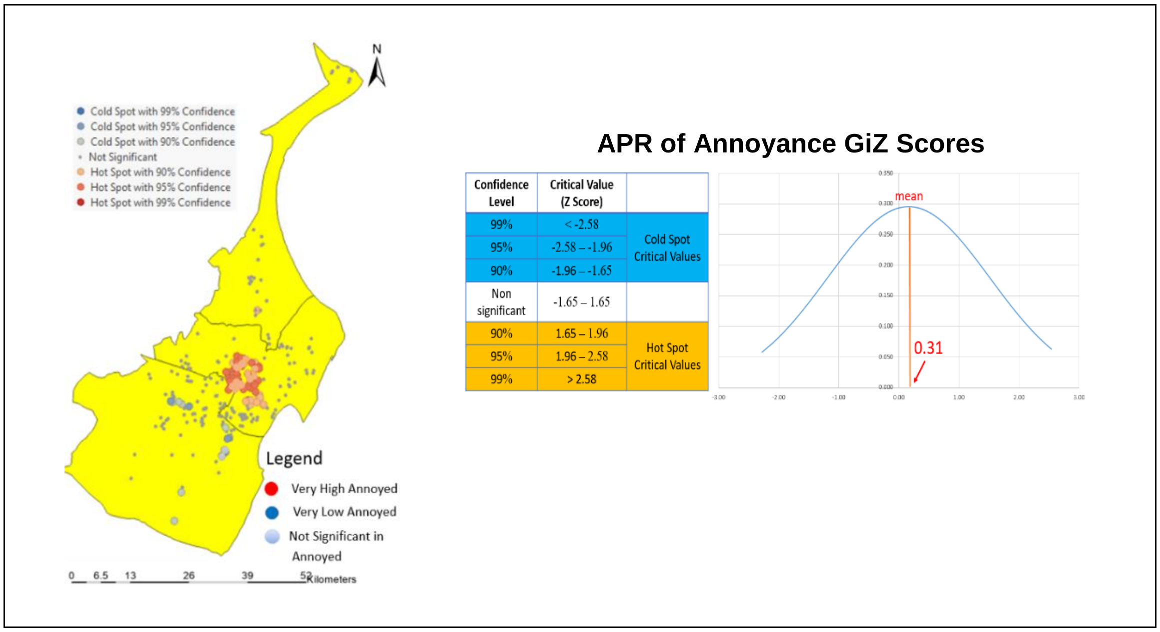
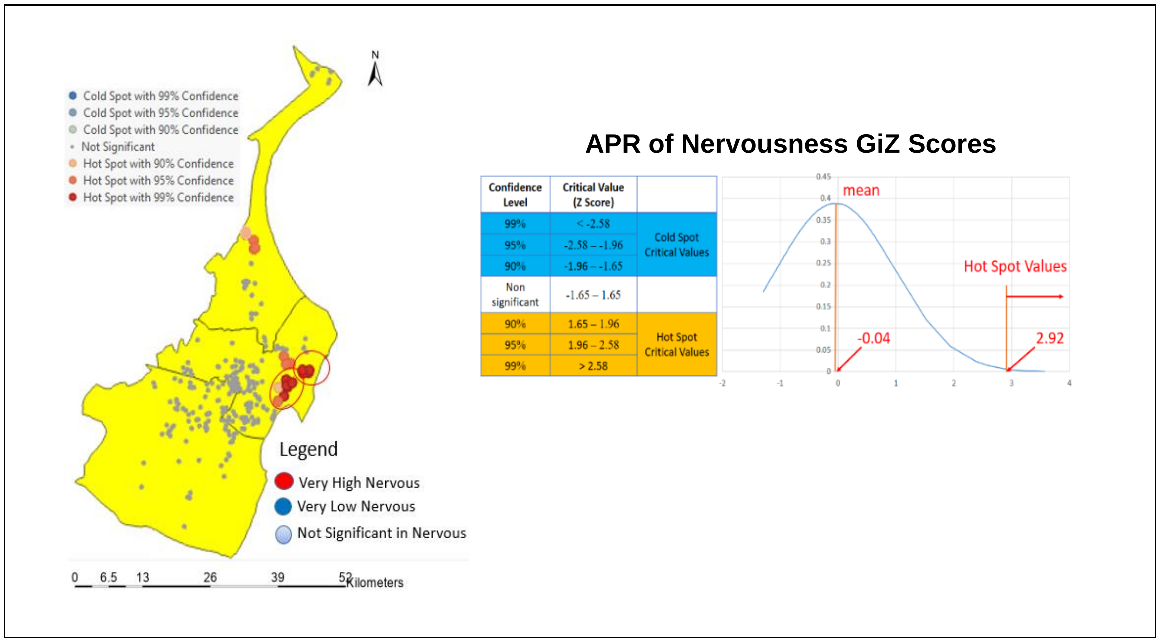


Figure 4.2 The distribution of the feeling of annoyance and its GiZ Scores

The results of ARPRQ3 (*Do people's feelings of nervousness geographically differ during an earthquake?*) show that the feeling of nervousness's GiZ scores ranges from -1.29 to 3.56, with a mean of -0.04 (Figure 4.3). The high GiZ scores range from 2.92 to 3.56, exceeding the critical value of 2.58, indicating that the residents who feel intensely nervous during shaking are surrounded by those with the same feeling of intense nervousness (hot spot). On the other hand, the lowest GiZ score is -1.29, which does not exceed the critical value of -2.58. Overall, the results indicate the feeling of nervousness has significant geographical variation in the area (hot spot).



Confidence Level	Critical Value (Z Score)	
99%	< -2.58	Cold Spot Critical Values
95%	-2.58 – -1.96	
90%	-1.96 – -1.65	
Non significant	-1.65 – 1.65	
90%	1.65 – 1.96	Hot Spot Critical Values
95%	1.96 – 2.58	
99%	> 2.58	

Figure 4.3 The distribution of the feeling of nervousness and its GiZ Scores

The results of ARPRQ4 (*Do people's feelings of fear geographically differ during an earthquake?*) show that the feeling of fear's GiZ scores ranges from -3.57 to 3.01, with a mean of 0.69 (Figure 4.4). The high value of GiZ scores ranges from 2.59 to 3.01, exceeding the critical value of 2.58, which means that the residents who feel a high level of fear during shaking are surrounded by the residents who also feel a high level of fear (hot spot). In addition, the GiZ scores range from -2.75 to -3.75, lower than the critical value of -2.58; therefore, the residents with low levels of fear during shaking are surrounded by the residents who also have low levels of fear (cold spot). Overall, the results indicate the feeling of fear has significant geographical variation in the area.

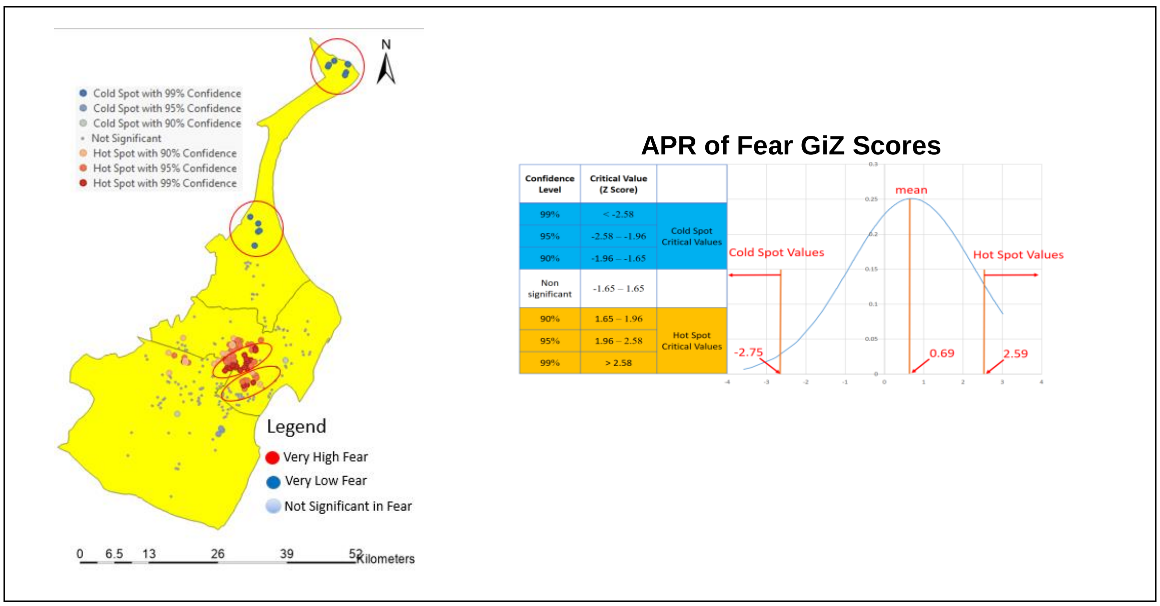


Figure 4.4 The distribution of the feeling of fear and its GiZ Scores

The results of ARPRQ5 (*Do people's feelings of alert geographically differ during an earthquake?*) show that the feeling of alert's GiZ scores ranges from -1.9 to 2.5, with a mean of 0.32 (Figure 4.5). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical value) indicates that the residents' feeling of alertness is not surrounded by the residents with the same feeling during shaking. In other words, the results show the feeling of alertness has no significant geographical variation in the area.

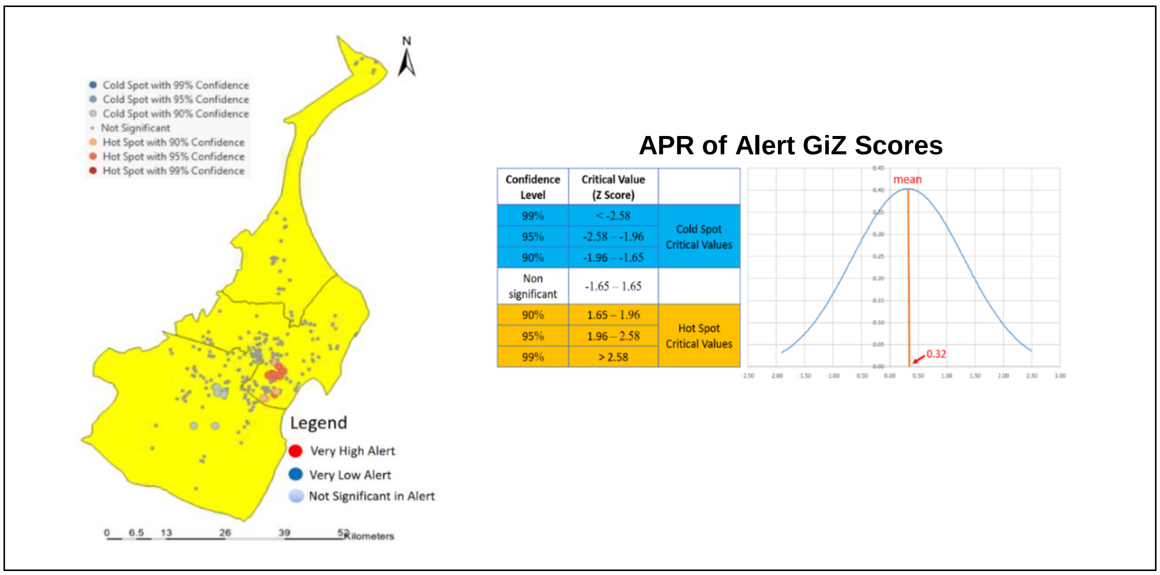


Figure 4.5 The distribution of the feeling of alert and its GiZ Scores

4.2.2 Findings of CRPs

The Getis-Ord Gi* results show that the perception of household losses clustered in specific communities, but the perception of social and life disruptions does not show any hot spots or cold spots.

The results of CRPRQ1 (*Do people's perceptions of household losses differ geographically during an earthquake?*) show that the perception of household losses' GiZ scores ranges from -3.08 to 3.74, with a mean of -0.28 (Figure 4.6). The high GiZ scores range from 2.82 to 3.74, exceeding the critical value of 2.58, indicating that the residents who perceive high household losses during shaking are surrounded by those who perceive the same way (hot spot). Also, the GiZ scores range from -2.60 to -3.08, lower than the critical value of -2.58; therefore, the residents who perceive low levels of household losses during shaking are also surrounded by the residents with low levels of household losses perception (cold spot). Overall, the results indicate the perception of household losses has significant geographical variation in the area.

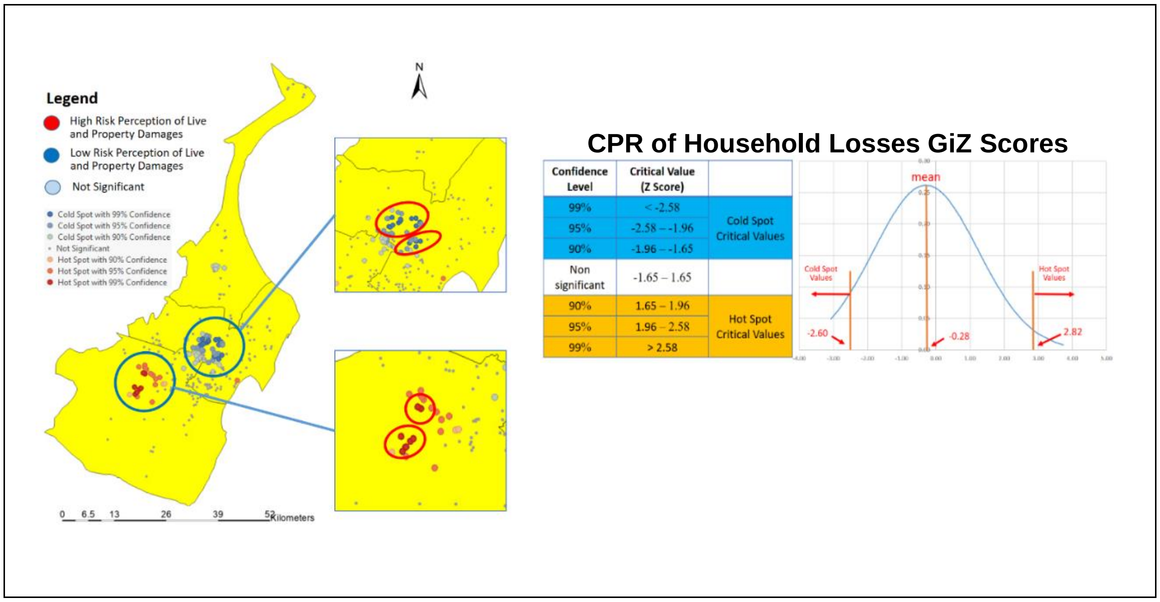


Figure 4.6 The distribution of the CRP of household losses and its GiZ Scores

The results of CRPRQ2 (*Do people's perceptions of social and life disruptions differ geographically during an earthquake?*) show that the CRP of social and life disruptions' GiZ scores ranges from -2.10 to 2.39, with a mean of 0.35 (Figure 4.7). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that the residents' CRP of social and life disruptions is not surrounded by the residents who have the same perception during shaking. In other words, the results indicate the perception of social and life disruptions has no significant geographical variation in the area.

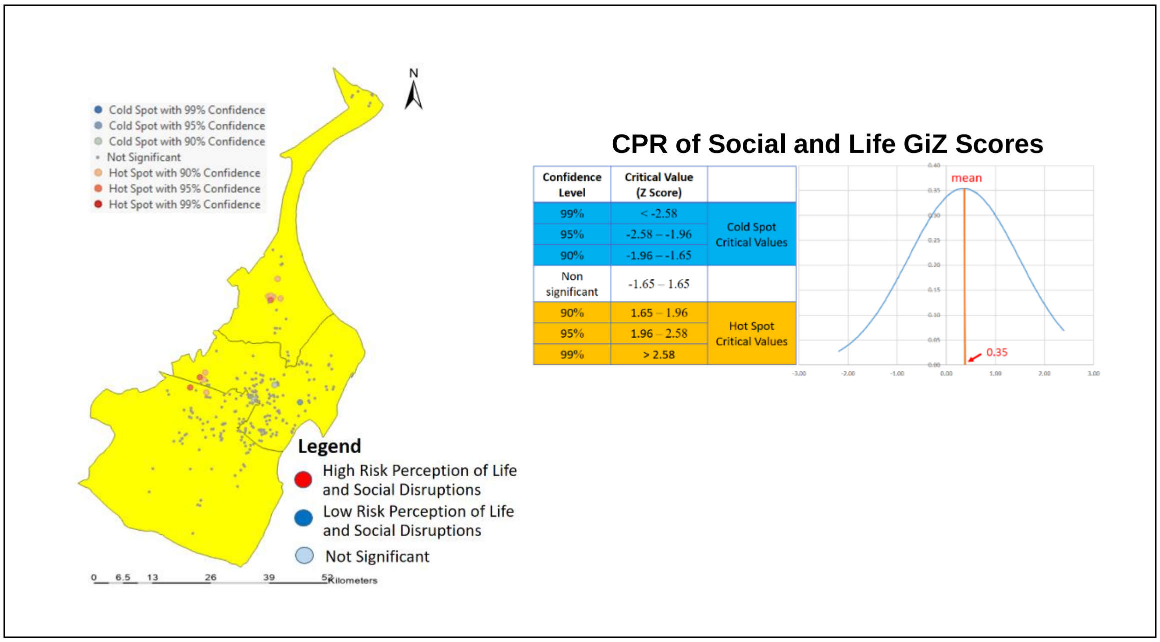


Figure 4.7 The distribution of the CRP of social and life disruptions and its GiZ Scores

4.3 Findings of Protective Action Decisions

The same approach was used to answer PADRQ1 to PADRQ9. Findings suggest the behavior freeze (PADRQ2) and flight (PADRQ10) were clustered in some communities (hot spots). The findings are listed below.

The results of PADRQ1 (*Do people's unresponsive reactions vary depending on their geographic location?*) show that the unresponsive reactions' GiZ scores range from -2.40 to 2.51, with a mean of 0.31 (Figure 4.8). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that the residents who did not have any reactions were not surrounded by the residents who had the same behavior. In other words, the results indicate the PAD of unresponsive reaction has no significant geographical variation in the area.

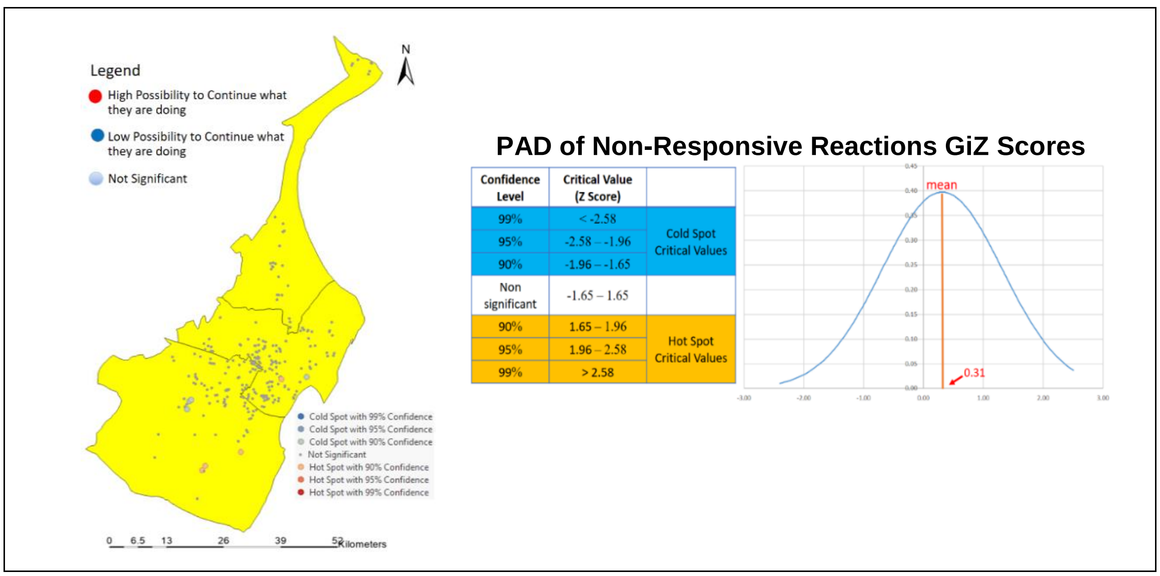


Figure 4.8 The distribution of the PADs of non-responsive reactions and their GiZ Scores

The results of PADRQ2 (*Do people's freeze reactions vary depending on their geographic location during an earthquake?*) show that the freeze's GiZ scores range from -2.1 to 2.99, with a mean of 0.54 (Figure 4.9). The high GiZ scores, ranging from 2.63 to 2.99, exceed the critical value of 2.58. This suggests that the residents who froze during the earthquake were surrounded by other residents who also froze (hot spot). The lowest GiZ score is -2.1, which does not exceed the critical value of -2.58. Overall, the results indicate the freeze reaction has significant geographical variation in the area.

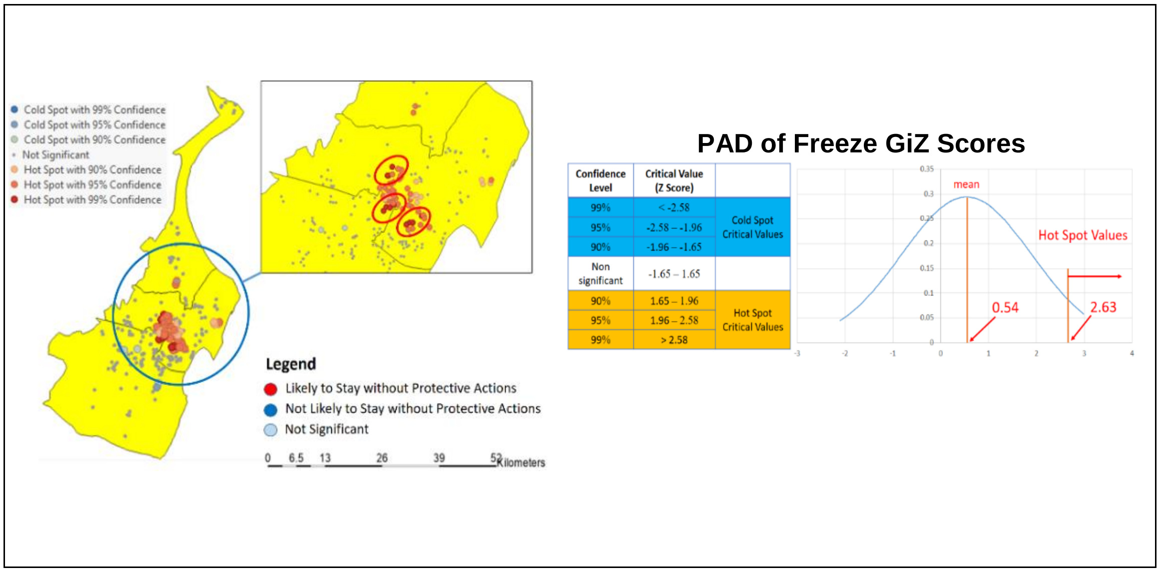


Figure 4.9 The distribution of the PAD of freeze and its GiZ Scores

The results of PADRQ3 (*Do people's actions of staying put and using soft items for head protection vary depending on their geographic location during an earthquake?*) show that this action’s GiZ scores range from -2.13 to 2.50, with a mean of 0.16 (Figure 4.10). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that the people who stayed put and used soft items for head protection were not surrounded by the residents who did the same thing. In other words, the results indicate that this protective action has no significant geographical variation in the area.

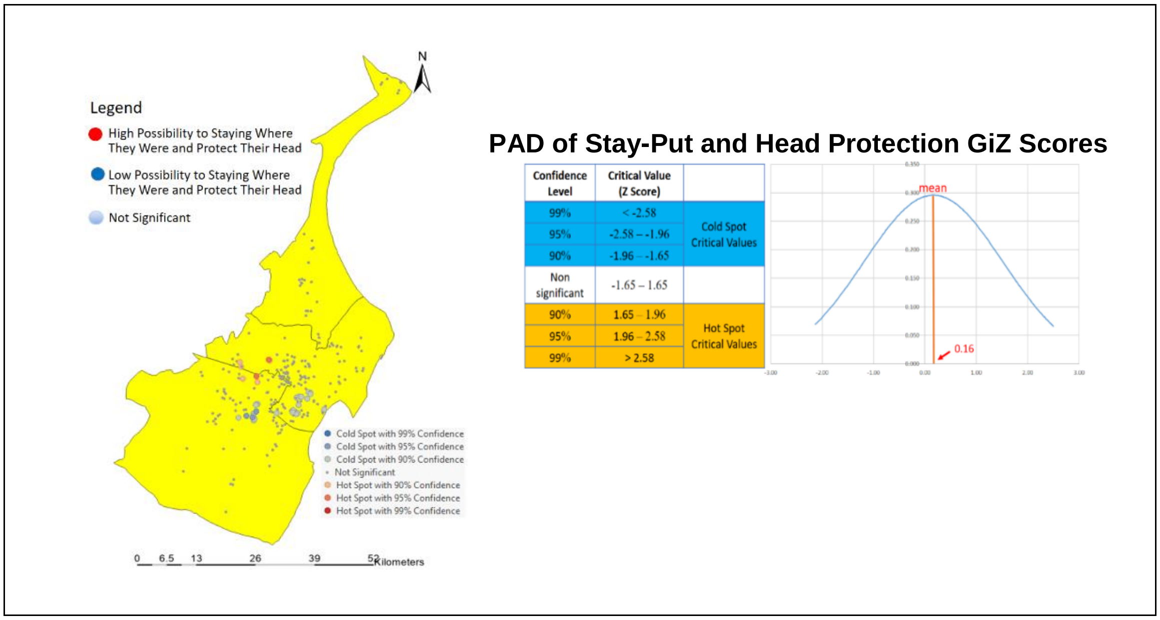


Figure 4.10 The distribution of the PAD of stay-put and head protection and its GiZ Scores

The results of PADRQ4 (*Do people's drop-cover-and-hold-on actions vary depending on their geographic location during an earthquake?*) show that the PAD of drop-cover-and-hold-on's GiZ scores ranges from -1.91 to 2.48, with a mean of 0.16 (Figure 4.11). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that people who did drop-cover-and-hold-on were not surrounded by the residents who did the same thing. In other words, the results show the action of drop-cover-and-hold-on has no significant geographical variation in the area.

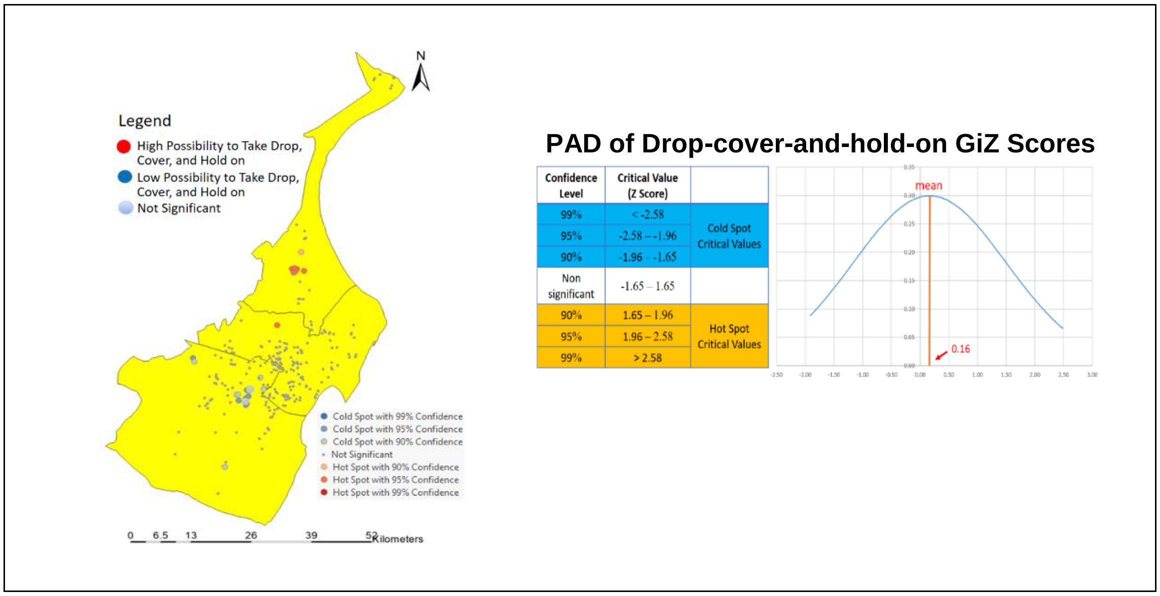
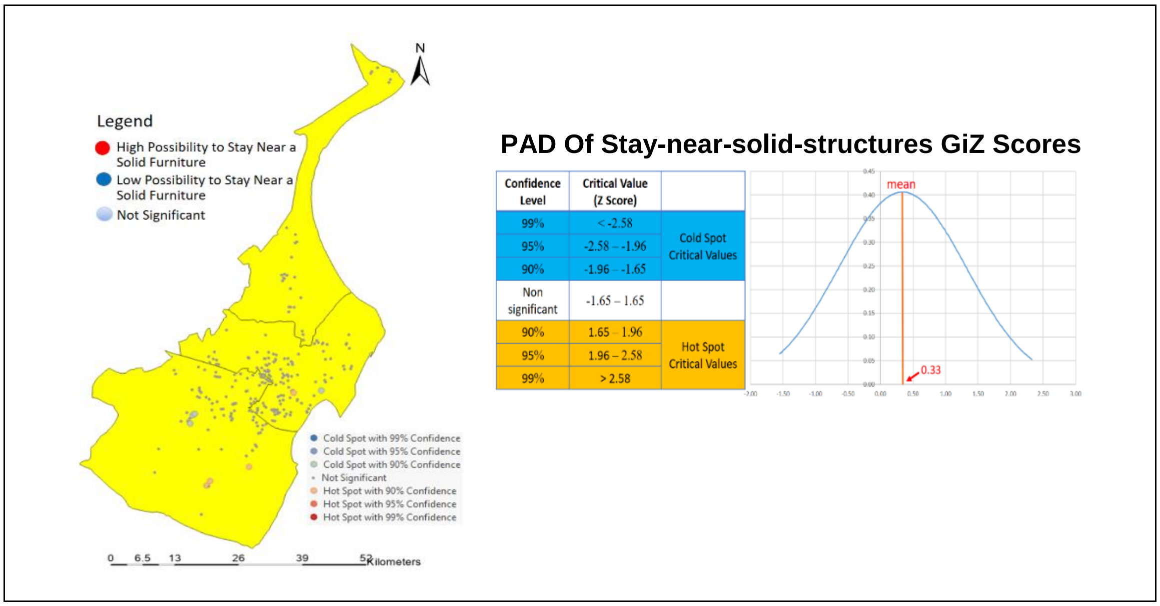


Figure 4.11 The distribution of the PAD of drop-cover-and-hold-on and its GiZ Scores

The results of PADRQ5 (*Do people's responses to an earthquake in terms of dropping to the ground near solid structures vary depending on their geographic location?*) show that the GiZ scores of this behavior range from -1.55 to 2.33, with a mean of 0.33 (Figure 4.12). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that the residents' behavior of staying near solid structures was not surrounded by the residents did the same. In other words, the results indicate the behavior of dropping to the ground and staying near solid structures without additional cover has no significant geographical variation in the area.



Confidence Level	Critical Value (Z Score)	
99%	< -2.58	Cold Spot Critical Values
95%	-2.58 – -1.96	
90%	-1.96 – -1.65	
Non significant	-1.65 – 1.65	
90%	1.65 – 1.96	Hot Spot Critical Values
95%	1.96 – 2.58	
99%	> 2.58	

Figure 4.12 The distribution of the PAD of stay-near-solid-structures and its GiZ Scores

The results of PADRQ6 (*Do people's responses to an earthquake in terms of protecting those around them vary depending on their geographic location?*) show that the GiZ scores of this behavior range from -2.10 to 2.45, with a mean of 0.53 (Figure 4.13). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that the behavior of protecting others nearby was not surrounded by the residents who behaved the same. In other words, the results indicate the PAD of protecting others nearby during shaking has no significant geographical variation in the area.

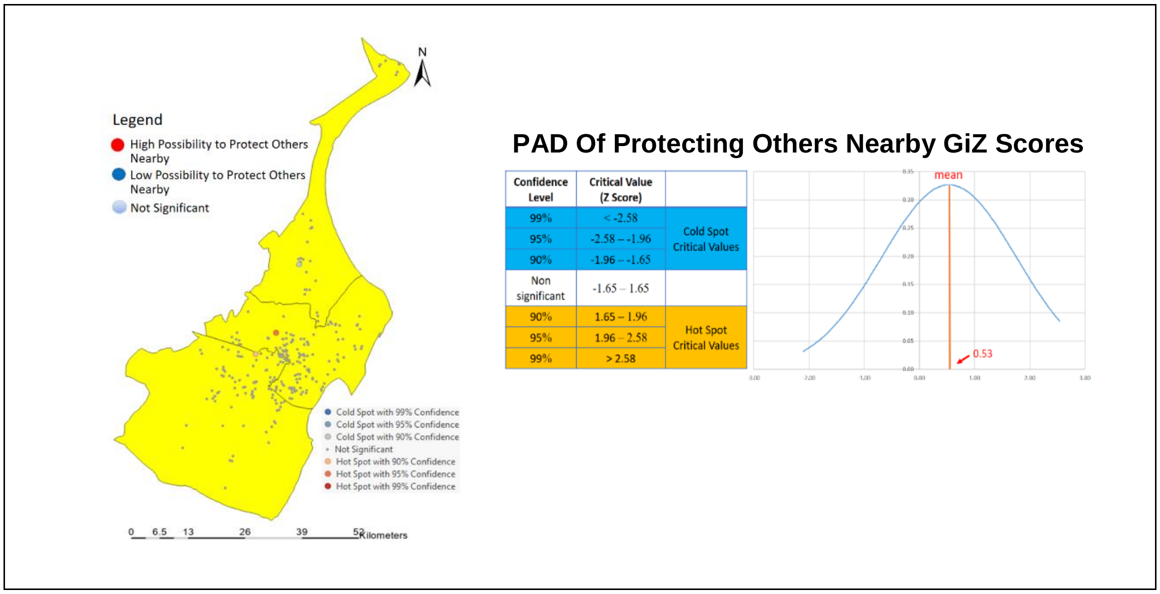


Figure 4.13 The distribution of the PAD of protecting others nearby and its GiZ Scores

The results of PADRQ7 (*Do people's responses to an earthquake in terms of protecting nearby buildings/structures vary depending on their geographic location?*) show that the GiZ scores of this behavior range from -2.39 to 2.31, with a mean of -0.21 (Figure 4.14). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that the people who tried to protect nearby property were not surrounded by others who had the same behavior. In other words, the results indicate the behavior of protecting others nearby during shaking has no significant geographical variation in the area.

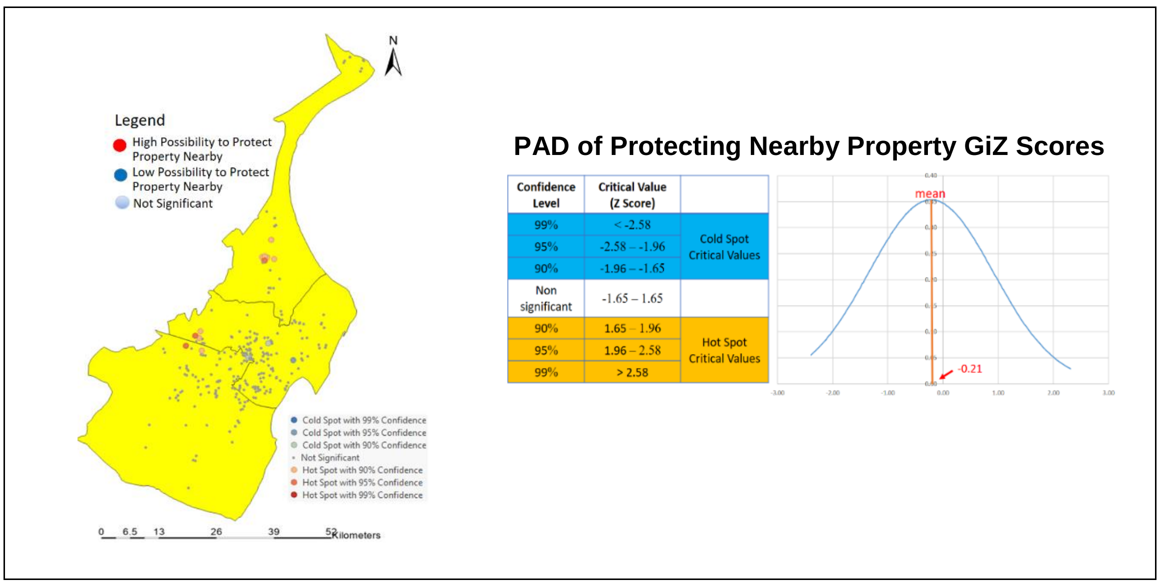


Figure 4.14 The distribution of the PAD of protecting nearby property and its GiZ Scores

The results of PADRQ8 (*Do people's responses to an earthquake regarding turning off the utilities differ based on their geographic location?*) show that the GiZ scores of this behavior range from -2.34 to 2.46, with a mean of 0.1 (Figure 4.15). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), indicating that residents who tried to turn off utilities were not surrounded by those who had the same behavior. In other words, the results indicate the behavior of turning off utilities during shaking has no significant geographical variation in the area.

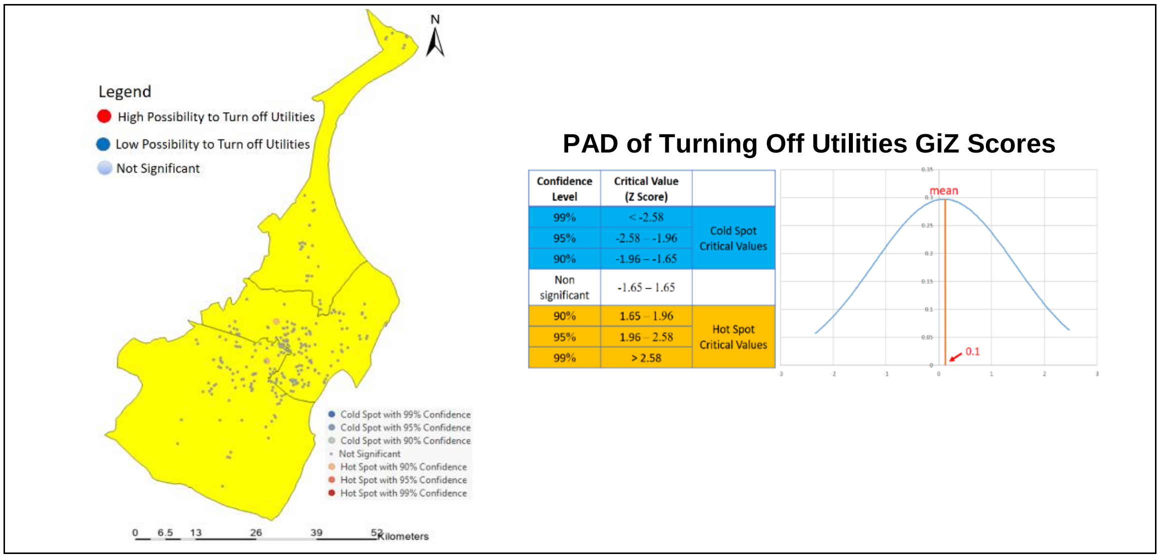


Figure 4.15 The distribution of the PAD of turning off utilities and its GiZ Scores

The results of PADRQ9 (*Do people's responses to an earthquake regarding standing in a doorway, holding onto, and keeping the door frame from out of shape during an earthquake differ based on their geographic location?*) show that the GiZ scores of this behavior range from -2.34 to 2.46, with a mean of 0.21 (Figure 4.16). The GiZ scores are neither higher than 2.58 nor lower than -2.58 (the critical values), which indicates that people who tried to keep the door frame from going out of shape were not surrounded by those who behaved the same. In other words, the results indicate the behavior of standing in a doorway, holding onto, and keeping the door frame from out of shape during shaking has no significant geographical variation in the area.

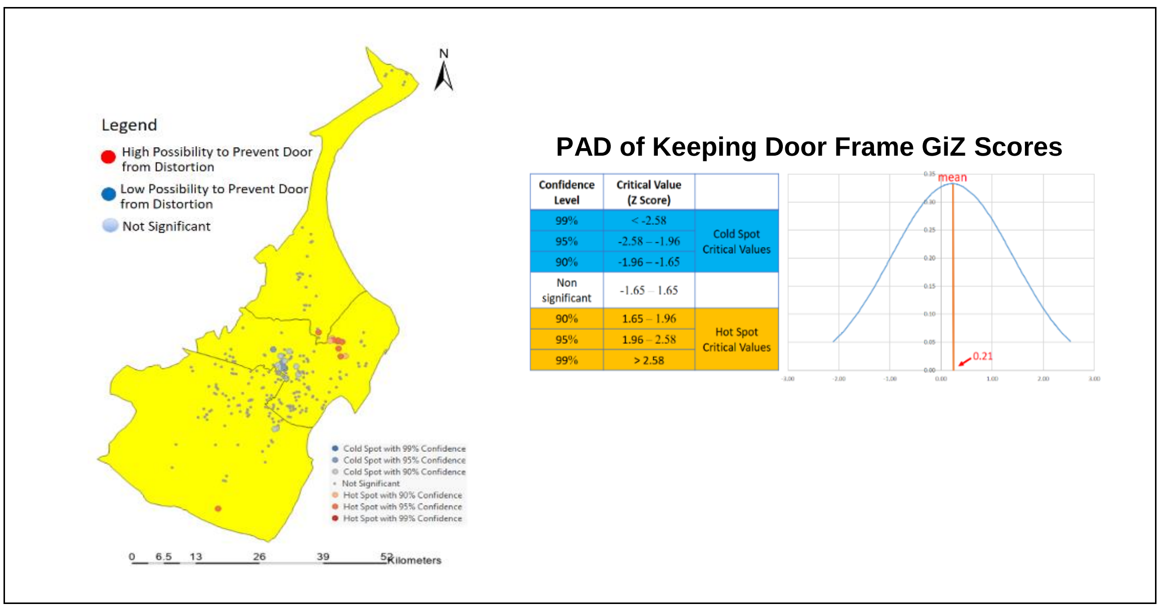


Figure 4.16 The distribution of the PAD of keeping the door frame from out of shape and its GiZ Scores

The results of PADRQ10 (*Do people's responses to an earthquake regarding fleeing from buildings differ based on their geographic location?*) show that this fleeing behavior's scores range from -2.51 to 4, with a mean of -0.1 (Figure 4.17). The high GiZ scores range from 2.75 to 4, exceeding the critical value of 2.58, indicating that the residents' fleeing behavior during shaking is surrounded by the residents who also fled from buildings (hot spot). On the other hand, the lowest GiZ score is -2.51, which does not exceed the critical value of -2.58. Overall, the results indicate that flight behavior has significant geographical variation in the area.

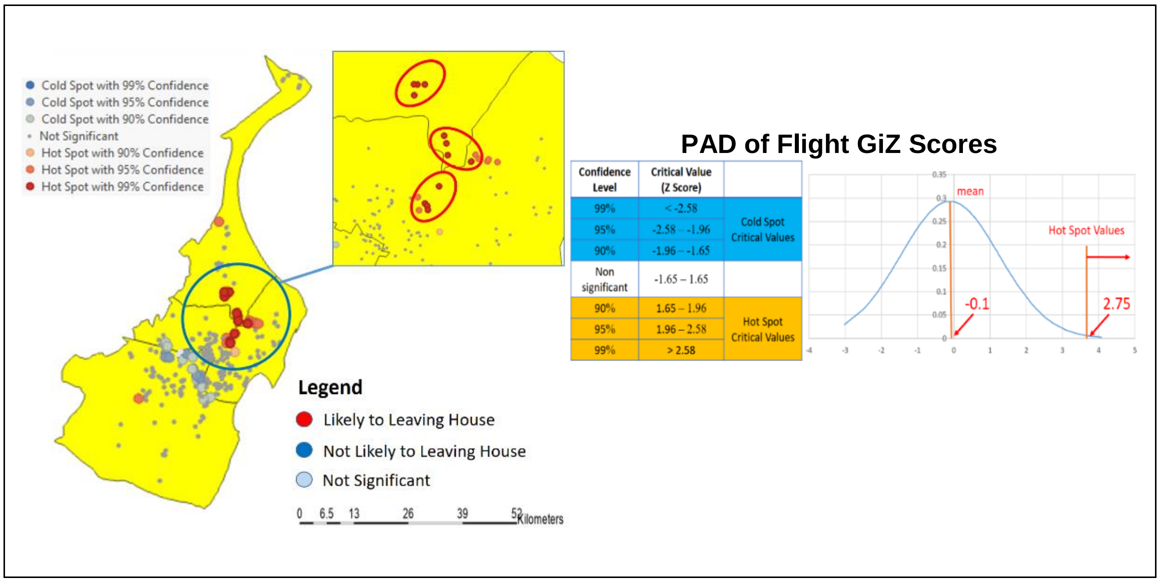


Figure 4.17 The distribution of the PAD of flight and its GiZ Scores

4.4 Discussion

Environmental context is a new factor added in the third version of PADM (Lindell, 2108). The model suggests it is an important factor that influences people's disaster response. However, no PADM studies have investigated how environmental contexts influence people's protective action decision-making using geospatial analysis. Therefore, this dissertation research utilizes ArcGIS's Getis-Ord Gi* method to test whether people's ARPs, CPRs, and PADs are geographically different during the 2018 Hualien Earthquake. The test results show that only some ARPs, CRPs, and PADs are geo-statistically clustered in a few communities. These results partially support previous research that protective action decision-making is congruent with geophysical factors (Lindell et al., 2016). The following sections will discuss these findings separately.

4.4.1 Clustered Risk Perceptions

Sections 4.2 suggest the APRs of fear and nervousness and the CRPs of household losses are clustered in some communities.

ARPs reflect people's emotional reactions to suddenly occurring threats (Ekman, 1992). The previous research by Lindell and Perry (2012) pointed out that ARP, such as fear, can be affected by geo-locations. This dissertation research confirmed that people who reside in Guo-Lian and Guo-Fang communities had a similarly high level of fear (hot spot) during the 2018 Haulan Earthquake compared to other communities in the study area. Additionally, people who resided in Xin-Cheng and Kang-Le communities had a similarly low level of fear (cold spot) compared to other communities in the study area. Interestingly, the intensity of the earthquake shake and the duration were the same across these communities. Therefore, it is unclear why the findings suggest such disparity. For a major earthquake (Mw 6.4), it is also interesting that the analysis identified a group of people with low fear levels. Moreover, high nervousness levels are also significantly clustered in Min-Le and Min-De communities (hot spots).

Similar to the ARP of fear, the CRP of household losses is simultaneously shown with hot spots (Ji-An and Fu-Xing communities) and cold spots (Guo-Yu (1) and Guo-Fu communities). These findings supported previous research. For instance, Lindell and Prater (2000) pointed out that similar hazard proximity can cause corresponding CRPs due to the parallel environmental cues. Perry and Lindell (2007) also reported that people who reside in hazard-prone areas have higher CRPs than those who do not because they would be more likely to receive social and environmental cues.

More questions are to be found in this dissertation research. First, why would people who reside in similar physical environments have similar perceptions of household losses but are not other CRP types? Second, previous research generally shows that high-risk perceptions are generated along with major disasters (Lindell et al., 2016; Perry & Lindell, 2007). However, this dissertation research finds that participants in Guo-Yu (1) and Guo-Fu communities showed a low level of perceived household losses.

4.4.2 Clustered Protective Action Decisions

The reaction of freeze (*stopped what they were doing but stayed where they were without taking any protective actions while the ground was shaking*) is found to be geo-statistically clustered in Guo-Yu (2), Guo-Cheng, and Min-Zu communities. Previous research suggested this is not an uncommon reaction during earthquakes. For instance, Pietrantoni and Prati (2009) and Sime (1985) suggest freezing is the most common response when people encounter an imminent emergency. Several earthquake studies also found freeze is the most common earthquake response action (Arnold, Durkin & Whitaker, 1982; Bourque et al., 1993; Goltz, Russell & Bourque, 1992; Lindell et al., 2016b; Prati et al., 2012), but none of these studies did explain the reasons that caused this reaction. The findings of this study further identified that the people who froze in place were only clustered in three particular communities but not others.

Another behavior clustered in Min-Xin, Jia-Li, and Jia-Xin communities is fleeing/evacuating from buildings. In the context of earthquakes, evacuation is considered the behavior of "flight," which is an intuitive response to avoid a suddenly occurring environmental threat (Pietrantoni & Prati, 2009; Sime, 1985). While it is not the most common protective action decision during earthquakes, it is still a type of behavior that has been documented in previous studies (Arnold, Durki & Whitaker, 1982; Lindell et al., 2016; Prati, Saccinto, Pietrantoni & Pérez-Testor, 2013).

Overall, this study found some earthquake risk perceptions and response actions clustered in some specific communities. These include fear (hot/cold spots), nervousness (hot spots), perception of household losses (hot/cold spots), freeze reaction (hot spots), and flight reaction (hot spots). As to why this is the case, the above quantitative analyses cannot explain these findings other than that geo-location affects some types of disaster responses. Thus, as discussed above, this dissertation research' second overarching research question will be addressed in Chapter 5, which employs an in-depth interview method to address this issue.

CHAPTER V

The Cause of Disaster Response Disparities

According to the analysis in Chapter IV, residents in some communities have particular ARPs, CRPs, and PADs clusters but not others. The reasons for these discrepancies have not been answered. Thus, the second research question in this study is — *Why do people respond to earthquakes in specific ways in different geographical areas?* This question is addressed in this Chapter. Seventy-seven participants were recruited for face-to-face in-depth interviews. Table 5.1 shows that 29 residents with high fear emotion responses were clustered in Guo-Lian and Guo-Fang communities (hot spots), and 11 were interviewed. In addition, 15 residents with low fear emotion responses clustered in Xin-Cheng and Kang-Le communities (cold spots), and 8 were interviewed. The emotion of nervousness has 25 residents clustered in Min-Le and Min-De communities (hot spots), 10 were interviewed. The high perceptions of household losses have 22 residents clustered in Ji-An and Fu-Xing communities (hot stops), and 11 were interviewed. On the other hand, 27 residents with low perceptions of household losses were clustered in Guo-Yu (1) and Guo-Fu communities (cold spots), and 12 of them were interviewed. Regarding protective action decisions (Table 5.2), 27 residents who responded to the earthquake with the freeze reaction were clustered in Guo-Yu (2), Guo-Cheng, and Min-Zu communities (hot spots), and 13 were interviewed. Finally, 24 residents who fleet from buildings were clustered in Min-Xin, Jia-Li, and Jia-Xin communities (hot spots), and 12 were interviewed.

Table 5.1. Interview Samples of ARPs and CRPs

	ARP of Fear	ARP of Nervousness	CRP of Household Losses
Hot Spots	29 potential interviewees 11 interviewed	25 potential interviewees 10 interviewed	22 potential interviewees 11 interviewed
Cold Spots	15 potential interviewees 8 interviewed	- -	27 potential interviewees 12 interviewed

Table 5.2. Interview Samples of PADs

	Freeze	Flight (fleet from buildings)
Hot Spots	27 potential interviewees 13 interviewed	24 potential interviewees 12 interviewed

5.1 Reasons for Clustered Risk Perceptions

5.1.1 Reasons for Clustered ARP of Fear

The cluster of fear is found in Guo-Lian and Guo-Fang (hot spot) and Xin-Cheng and Kang-Le (cold spots) communities. Overall, intensive and strong earthquakes, weak building constructions, being with elders or children, and the perception of household losses results in high fear levels. The thematic analysis shows the reasons for clustered high fear levels in Table 5.3.

Table 5.3 Thematic category of reasons for clustered high ARP of fear

Theme	Category	%*	Example
Environmental contexts	intensive and strong earthquakes	23.5%	Earthquakes are quite frequent here and some of them can be quite strong. The magnitude of the earthquake on that day scared me, and I was afraid. (Participant A5)
Physical Contexts	weak building constructions	17.6%	I do not have enough money to repair or demolish my house and rebuild it…… I can

			feel the strong shaking when a strong earthquake strikes and I feel fear. The feeling is just like my house is going to be completely ruined. (Participant A3)
Social contexts	being with elders or children	23.5%	When I am alone, most of the time, I am not afraid. Sometimes, I may feel nervous. However, when my grandson is at home, I am afraid that he might get hurt. (Participant A9)
Cognitive risk perceptions	CRP of injury	17.6%	I rent this apartment… and it's not practical to fix every piece of furniture on the walls. It's too burdensome. During an earthquake, I'm afraid of getting hit by falling objects. (Participant A4)
	CRP of property damage	17.6%	I was afraid the display cabinets would fall and there were valuable items inside. I was afraid there would be significant losses if they were damaged. (Participant A7)

* The percentage indicates the proportion of the coding that falls under the respective category within the interview transcripts.

High ARP of Fear

Environmental and Physical Contexts

The long-term impacts of environmental and physical contexts influence the high ARP of fear. Earthquakes are intensive and frequent in Guo-Lian and Guo-Fang communities. Residents feel wall or ground shakings once or twice a week on average. These earthquakes are generally minor or moderate, but some are strong.

> "*Earthquakes are quite frequent here and some of them can be quite strong. The magnitude of the earthquake on that day scared me, and I was afraid*."

The critical problem in building structures in the Guo-Lian and Guo-Fang communities can be traced back to a devastating earthquake, the 1999 Chi-Chi Earthquake. This earthquake had a Richter Scale of 7.4, caused 2,494 fatalities, 11,305 injuries, 51,712 buildings totally collapsed, and 53,768 buildings were seriously damaged in Taiwan (National Center for Research on Earthquake Engineering, 1999). During the earthquake, the prevalence of using reinforced brick as the base of constructions showed its vulnerability to withstand horizontal forces generated by severe earthquakes. Most participants in the Guo-Lian and Guo-Fang communities have shown they fear earthquakes causing building collapses. Mostly, minor or moderate earthquake shakings could not result in fear. However, if the shake suddenly turns from minor or moderate to strong, the ARP of fear would tremendously increase. The fear of building collapse is commonly triggered by earthquakes stronger than Richter Scale 5. Locals believe it has a high possibility of causing building collapse. As the researcher further probes why a strong shake could trigger their fear, most participants point out the problem of the weakness of building structures. A participant reflects that —

> "*I do not have enough money to repair or demolish my house and rebuild it. A government official says that my house does not meet the standard to request financial assistance from the government because the appraisal of building structures shows my house is not rated as seriously damaged. I can feel the strong shaking when a strong earthquake strikes and I feel fear. The feeling is just like my house is going to be completely ruined.*"

In essence, three reasons can engender the fear of building collapses. First, if the residents who reside in a vulnerable construction for a long period and lack the financial ability to repair their houses or move out to other safer places, they are more likely to respond with the ARP of fear during shaking. The second reason is living next to a high-rise building that local governments have deemed unsafe. Despite being abandoned by the owners, the neighbors still live near these dangerous structures. The third reason is residents' vicarious earthquake experiences. The average duration of residency in the Guo-Lian and Guo-Fang communities is about 25 years. Thus, most residents have some form of earthquake experience in the course of their life. Even if earthquakes have not seriously damaged some of their houses, they have heard stories of vicarious building collapses from their family members, friends, coworkers, etc. For instance, a participant says that –

> "*I do not think earthquakes could have influenced our daily life. But most of the residents worry about the strong earthquakes striking our houses because it has a high possibility to cause collapses. Though…I have not experienced building collapses on my own, I heard lots of cases from my peers and friends. You see… just two years ago, the Marshal Hotel and Yun Men Tsui Ti building collapsed. I think that is all the fault of illegal structural alteration. If you were a resident here, you would hear lots of similar stories like I said, and …*"

Social Contexts

The household social context can result in the ARP of fear. In Guo-Lian and Guo-Fang communities, it is a tradition that grandparents take care of their grandchildren. This is because many parents have full-time jobs. The tuition and fees of a preschool, kinder garden, or daycare center are not commonly affordable for young couples. If people are alone, they generally do not have a strong ARP reaction when experiencing minor or moderate shakings. However, once they have children in the house or serve customers in a store, a minor or moderate shaking would cause a high fear level. Most participants reflect that they tend to prepare flashlights, radio, food, etc. when living with young kids or toddlers. A participant says —

> "*You know… when the earthquake occurred, my first reaction was to rush to my grandson's room because I am responsible for taking care of him. Since he is my only grandchild, when I saw that he was okay, I felt relieved. When I am alone, most of the time, I am not afraid. Sometimes, I may feel nervous. However, when my grandson is at home, I am afraid that he might get hurt*."

Cognitive Risk Perception

The perception that they might get injuries from falling objects and the dread of property damage are two factors that result in fear. Some participants reflect that securing all furniture to walls or floors is burdensome. Therefore, when the grounds start to shake, these unprepared respondents are afraid of getting hurt by falling objects.

> "*I rent this apartment… and it's not practical to fix every piece of furniture on walls. It's too burdensome. During an earthquake, I'm afraid of getting hit by falling objects*."

In addition, if the residents are afraid of property damage, they are more likely to fix their furniture on walls using latches or angle bracket bars and fasten their appliances with coil chains. Specifically, they are reluctant to install natural gas pipelines for the facility of water heaters or stoves in their houses due to the dread of gas leakage after a violent shaking. Instead, propane gas tanks are more common in the Guo-Lian and Guo-Fang communities than natural gas.

> "*I was afraid the display cabinets would fall and there were valuable items inside. I was afraid there would be significant losses if they were damaged*."

Low ARP of Fear

In contrast, this study also finds residents with low fear levels clustered in Xin-Cheng and Kang-Le communities (cold spots). Living farther away from the Milun fault line, confidence in building structure integrity, low population density, normalization bias, and optimistic bias result in low fear levels during earthquakes. The thematic analysis shows the reasons for clustered low fear levels in Table 5.4.

Table 5.4 Thematic category of reasons for clustered low ARP of fear

Theme	Category	%*	Example
Geological contexts	living farther away from the fault line	28.5%	We live far away from the Milun fault line…You know… the shaking type here is mostly high frequency and low shaking intensity. (Participant A12)
Physical contexts	confidence in building structure integrity	28.5%	Our constructors are very obedient to building codes. They are so good.. and despite frequent earthquakes in the past, there have been no major losses even struck by the 1999 Chi-Chi Earthquake. (Participant A17)

Social contexts	low population density	20.2%	The population density in the cold spots is 690/km² and is 3,500/km² in the hot spots. It is easy to evacuate the buildings and go to open areas.
Optimistic bias	earthquakes generally cause minor damages	15.5%	We have experienced several violent earthquakes and there have nothing happened. I would believe it will just be the same next time. (Participant A16)
	earthquake damage happens to the elder, kids, or disabilities	7.3%	Thus, I believe the earthquake damage mostly occurred in the elderly and kids instead of the youth like me. (Participant A19)

* The percentage indicates the proportion of the coding that falls under the respective category within the interview transcripts.

Geological Contexts

A salient geospatial difference is that, compared with the Guo-Lian and Guo-Fang communities, Xin-Cheng and Kang-Le communities are much farther away from the Milun fault lines. The types of earthquakes that frequently happen in Xin-Cheng and Kang-Le communities are high frequency but low intensity, which subconsciously forms the low fear level of earthquakes. Some participants even suggest that only the tourists would run out of buildings during shaking in their community.

> "*I have lived here for so long, and I have noticed that only newcomers or tourists tend to run outside of buildings during earthquakes. We live far away from the Milun fault line…You know… the shaking type here is mostly high frequency and low shaking intensity. There is nothing to do with feeling fear.*"

Physical Contexts

The confidence in building structure integrity is a noticeable reason to keep a low ARP of fear during shaking. The residents in the Guo-Lian and Guo-Fang communities have constantly mentioned the cracking in walls, ceilings, and beams that the 1999 Chi-Chi Earthquake damaged. However, the residents who clustered in Xin-Cheng and Kang-Le communities reflect that their buildings could withstand the severe strike in the 1999 Chi-

Chi Earthquake; therefore, their constructions can withstand the next severe earthquake. Their trust in building structures in their houses decreases their fear level during shaking.

> "*Our constructors are very obedient with building codes. They are so good.. and despite frequent earthquakes in the past, there have been no major losses even struck by the 1999 Chi-Chi Earthquake. I believe every house in Hualien County can withstand any strike of earthquakes.*"

Social Contexts

The population density is an obvious discrepancy in social context between the cold and hot spot areas. The population density in the Xin-Cheng and Kang-Le communities is 690/km^2 and is 3,500/km^2 in the Guo-Lian and Guo-Fang communities. Residents in the Xin-Cheng and Kang-Le communities have low fear because even if a strong earthquake strikes, they can easily evacuate the buildings and go to open areas.

Optimistic Bias

The combination of high-frequency seismic activity and low-magnitude earthquakes in Xin-Cheng and Kang-Le communities creates a distinct seismic hazard pattern for the residents. This earthquake frequently generates social cues from colleagues or friends and environmental cues such as subterranean rumblings; it also leads to optimistic biases because these earthquakes generally cause minor damages and eventually imply that earthquakes are not harmful. Some residents may not believe shakings could cause damage to them given their past earthquake experiences, which reflects the phenomena of optimistic bias. One participant says —

> "*You see…The structure of our buildings is so strong...that is strong enough right... and that can withstand severe earthquakes in the whole region of Hualien County. The seismic-resistant structures built in Hualien County are the best in Taiwan. We have experienced several violent earthquakes and there have nothing happened. I would believe it will just be the same next time.*"

In addition, some residents believe the severe damages caused by earthquakes mostly occur in the elderly, kids, or people who have disabilities instead of them, which also reflects optimistic bias. A participant says —

> "*The appropriate response behavior that you have to do is depended on your instinct and intuition. Thus, you know… the elderly may realize how to react but they mostly have physical disabilities. This would be a problem, right? And, most kids have not conscious of environmental hazards. Thus, I believe the earthquake damage mostly occurred in the elderly and kids instead of the youth like me*."

5.1.2 Reasons for Clustered ARP of Nervousness

The ARP of nervousness is another emotional reaction clustered in the Min-Le and Min-De communities (hot spots). Overall, aftershocks, confidence in building structure integrity, underground rumblings, and lack of knowledge to react to earthquakes result in the ARP of nervousness. The thematic analysis shows the reasons for the clustered ARP of nervousness in Table 5.5.

Table 5.5 Thematic category of reasons for clustered high ARP of nervousness

Theme	Category	%*	Example
Environmental cues	underground rumbling	36.3%	You'll hear the sound of the subterranean rumbling, and if it's not the sound of cars outside, you can hear the sound is heavy and ominous. Then you need to be careful. I usually get very nervous when I sense an earthquake is coming. (Participant B10)
	aftershocks	27.2%	The aftershocks in my house were like being on a ship that keeps rocking and swaying. It was so bad that I felt nauseous, and my autonomic nervous system was out of balance. Every time there was an aftershock, I got very nervous. (Participant B5)
Physical contexts	confidence in building structure integrity	27.2%	I couldn't go outside… I was extremely nervous……Fortunately, my house was built after the 1999 Chi-Chi earthquake. It was built around 2003, and at that time, all seismic and building regulations had been updated. (Participant B3)
Cognitive risk perceptions	CRP of property damage	5.2%	The shaking...of course, for those of us who have glasses in closets in a store, we

			are nervous that the glass will shatter and fall, we want to reduce property losses, right? so we tend to be a little nervous. (Participant B4)
Earthquake education	lack of knowledge in response to earthquakes	4.1%	I have never been able to adapt to earthquakes. I get very nervous when there is shaking. Especially, I don't know what the best reaction is. (Participant B2)

* The percentage indicates the proportion of the coding that falls under the respective category within the interview transcripts.

Environmental Cues

Underground Rumbling: Most residents in the Min-Le and Min-De communities have experienced the sounds and shakings generated by underground rumblings, which is an important factor resulting in the high ARP of nervousness. Underground rumblings are one of the most common environmental cues received in the Min-Le and Min-De communities. At the beginning of an underground rumbling, residents can hear the sounds and feel the tremors coming from windows, tables, chairs, etc. Specifically, the sounds are clear when the ambient noise level is low. Residents describe the sound of an underground rumbling like a heavy tri-axle flatbed trailer driving through in front of someone. An underground rumbling can result in nervousness because a main shock generally comes right after it. The reflection from participants shows that most migrants need to spend time adapting to underground rumblings if they expect to keep their everyday routine activities.

> "*After the subterranean rumbling occurs, even though it only takes a few seconds, maybe one, two, or three seconds, you can feel it. You'll hear the sound of the subterranean rumbling, and if it's not the sound of cars outside, you can hear the sound is heavy and ominous. Then you need to be careful. I usually get very nervous when I sense an earthquake is coming. You need to find a place to hide quickly.*"

Aftershocks: Aftershock is an environmental cue resulting in the high ARP of nervousness in the Min-Le and Min-De communities (hot spots). Residents in the communities regularly encounter an intense main shock, and the resulting aftershocks can extend the recollection of the main shock for a prolonged duration. On average, aftershocks could be perceived from days to weeks, even months, and some of them are larger than magnitude 5. Thus, residents may occasionally be unable to distinguish the differences between the minor shakings before a main shock and the aftershocks generated by the previous main shock. This confusion is subconsciously embedded in the ARP of nervousness. A participant says —

> "*I remember it was like that, and then I moved out right after the 2018 Hualien Earthquake. I only moved back to live here seven days after the earthquake happened. That's because...I would...there were still aftershocks. The aftershocks in my house were like being on a ship that keeps rocking and swaying. It was so bad that I felt nauseous, and my autonomic nervous system was out of balance. Every time there was an aftershock, I got very nervous. I felt a burning sensation in my chest and stomach.*"

Physical Contexts

Unlike fear, the findings suggest strong confidence in building structures is actually a reason for experiencing high nervousness during shaking. An earthquake-resistant construction consolidates the reaction of a high level of nervousness in the Min-Le and Min-De communities. When comparing how the structural conditions affect fear and nervousness, this study finds that people are more likely to feel nervous in the Min-Le and Min-De communities because the buildings have adopted the new Seismic-Protection Building Codes after the 1999 Chi-Chi Earthquake. Conversely, people tend to feel fear in the Guo-Lian and Guo-Fang communities (as suggested in Section 5.1.1) because they reside in non-seismic protective buildings. A participant says —

> "*I was in bed when the 2018 Hualien Earthquake happened, and it was shaking violently. I couldn't go outside… I was extremely nervous……Fortunately, my house was built after the 1999 Chi-Chi earthquake. It was built around 2003, and at that time, all seismic and building regulations had been updated.*"

This study found when responding to the survey, participants often treat nervousness as a lower level of fear. If they do not have confidence in their buildings, they feel a high level of fear; on the other hand, if they have confidence in their buildings, they only feel a strong nervousness, not fear.

Cognitive Risk Perception and Earthquake Education

Other factors that can result in the APR of nervousness include the high perception of property damage and the lack of knowledge to appropriately react to earthquakes. In the first case, residents are nervous about property losses and tend to protect their properties during shaking.

> "*The shaking...of course, for those of us who have glasses in closets in a store, we are nervous that the glass will shatter and fall, we want to reduce property losses, right? so we tend to be a little nervous.*"

In the second case, residents usually lack formal earthquake training or drills. Once an earthquake occurs, respondents feel nervous because they wonder what they should do. They lack sufficient knowledge to react.

> "*Since I have never been able to adapt to earthquakes, I get very nervous when there is shaking. Especially... since I don't know what the best reaction is, or what to do in different situations to minimize harm.*"

5.1.3 Reasons for Clustered CRP of Household Losses

The analysis in Chapter 4 found that the perception of household losses was clustered in the Ji-An and Fu-Xing communities (hot spots) and the Guo-Yu (1) and Guo-Fu communities (cold spots). Overall, mitigation for earthquakes, responsibility belief, and vulnerability or resilience interpretation of earthquake experiences can result in high or low perceptions of household losses. The thematic analysis shows the reasons for these discrepancies (Table 5.6).

Table 5.6 Thematic category of reasons for clustered CRP of household losses

Theme	Category	%*	Example
Physical contexts	earthquake mitigation	45.3%	Because televisions are all LCD and very large, they have only one leg that is fixed on the TV cabinet. It must be secured by a metal wire tied to the wall behind it……we have some ways to reduce the possible losses in earthquakes. (Participant C21)
Belief	responsibility belief	30.9%	The government always says that we should take photos first and then apply for government subsidies. But in the end, we had to bear the cost ourselves. I didn't get any subsidies. We think that the government is good at deceiving people, so in the future, we have to rely on ourselves for everything. (Participant C15)
Earthquake experiences	vulnerability or resilience interpretations	23.8%	I was a civil engineer. I am good at identifying the level of damage in a building. In general, I can observe if cracks are occurring on beams or columns, and realize the vulnerability of a house. I can feel they are slowly damaged each time. (Participant C8)

* The percentage indicates the proportion of the coding that falls under the respective category within the interview transcripts.

Physical Contexts

The first factor that can increase or decrease the CRP of household losses is the mitigation level for earthquakes. In general, respondents do not want to stop their everyday activities in the Guo-Yu (1) and Guo-Fu communities (cold spots) because they have been mitigating their earthquake risks in the previous earthquakes. For instance, some residents mount their closets or TVs on the ground or wall. Some use alloy cable chains coil around gas tanks in the kitchen. Other circumstances include avoiding hanging chandeliers or having ceilings when decorating a house. In other venues, a small business owner may fix a heavy machine on the ground in a factory or replace a glass window with tempered glass. Many believe severe damages could be avoided because of their mitigation strategies. Thus, these earthquake mitigation strategies reduce the perception of household losses. Conversely, residents who have not adopted any mitigation strategy due to previous earthquakes are more likely to have a higher perception of household losses.

> "*The most important thing is the television. Because televisions are all LCD and very large, they have only one leg that is fixed on the TV cabinet. It must be secured by a metal wire tied to the wall behind it. We would tie two wires together and fix them to the wall. Some smart people would directly fix the TV to the wall. In Hualien County, we have some ways to reduce the possible losses in earthquakes. We let the TV shake during the earthquake, and it's okay. I can continue what I am doing. We close our shop at night, so I would lay the mirror flat to prevent it from falling. The shelves are replaceable, so it doesn't matter if they fall..*."

Belief

Responsibility belief is the second reason that can increase or decrease a person's perception of household losses about earthquakes. In Guo-Yu (1) and Guo-Fu communities (cold spots), if residents believe the local governments should take the responsibility of protecting or helping their citizens during and after earthquakes, he/she is more likely to have a low perception of household losses. Conversely, the residents in the Ji-An and Fu-Xing communities (hot spots) believe that a household or a business owner should take more responsibility than the government to protect their properties. Therefore, they are more likely to perceive higher household losses.

> "*The government always says that we should take photos first and then apply for government subsidies. But in the end, we had to bear the cost ourselves. I didn't get any subsidies. We think that the government is good at deceiving people, so in the future, we have to rely on ourselves for everything.*"

Earthquake Experiences

The residents' interpretation of earthquakes is the third reason that can increase or decrease the perception of household losses. Two types of interpretation about earthquakes are found in this research: vulnerable interpretation and resilient interpretation. The differences between these two types are mainly due to how respondents feel and interpret the hazardous environments caused by earthquakes. In the resilient interpretation type, the respondents in the Guo-Yu (1) and Guo-Fu communities (cold spots) believe an earthquake is generally a natural phenomenon that can help to release underground energy, and which could reduce the frequency of violent earthquakes. Thus, the respondents have a low perception of household losses in earthquakes. This type of resident suggests that they reside in a resilient physical environment that can provide sufficient protection as long as they have fixed most of the furniture or facilities on walls or grounds beforehand. The interpretation of seismic hazards is safe, and these residents have a low perception of household losses.

Conversely, the vulnerable interpretation type was found in the Ji-An and Fu-Xing communities (hot spots). They showed high perceived household losses even though they reside in similar physical and/or geological environments compared to the resilient interpretation type in the Guo-Yu (1) and Guo-Fu communities (cold spots). The residents in the vulnerable interpretation type suggest that earthquake is generally a serious environmental threat that could cause severe damage to lives and properties. The residents of this type suggest that the structure of their houses is gradually damaged by earthquakes each time, no matter what magnitude of the earthquakes. Residents believe the physical environments around them become increasingly vulnerable over time, which can eventually cause severe damage once a violent earthquake strikes. A participant says —

> "*I was a civil engineer. I am good at identifying the level of damage in a building. In general, I can observe if cracks are occurring on beams or columns, and realize the vulnerability of a house. I can feel they are slowly damaged each time.*"

5.2 Reasons for Clustered PADs

5.2.1 Reasons for Clustered PAD of Freeze

As discussed in section 4.3, the Getis-Ord Gi* analysis found hot spot clusters of freeze behavior in the Guo-Yu (2), Guo-Cheng, and Min-Zu communities. It shows some residents stopped what they were doing but stayed there without taking any protective actions while the ground was shaking (freeze). The thematic analysis found that high-frequency but low-magnitude earthquakes, lack of earthquake education and training, and peer pressure result in the PAD of freeze. It is listed in Table 5.7.

Table 5.7 Thematic category of reasons for clustered high PAD of freeze

Theme	Category	%*	Example
Environmental cues	High Frequency but Low Magnitude Earthquakes	48.2%	Mostly, it's just a small tremor, so we just observe first and don't need to react immediately. (Participant E12)
Earthquake education	Lack of Earthquake Education and Training	35.9%	Because it's just some minor shakings, everyone just stopped what they were doing and freeze in place. After a few seconds, it was like nothing had happened...... I feel like we haven't had any earthquake response training...no one told us what to do if there's a violent earthquake. (Participant E6)
Social contexts	Peer Pressure	15.9%	I used to get laughed at by my colleagues for doing so. Now, we've been living here for a few decades, I mostly just stay put and wait for the earthquake to pass. (Participant E7)

* The percentage indicates the proportion of the coding that falls under the respective category within the interview transcripts.

Environmental Cues

Compared to people who live in Min-Xin, Jia-Li, and Jia-Xin communities, the Guo-Yu (2), Guo-Cheng, and Min-Zu residents live farther away from the Milun fault line. This results in them experiencing high-frequency but low-magnitude earthquakes regularly. This gives them a mindset that minor shakings are not harmful. Thus, as suggested by interview participants, this leads to a freeze reaction. While their body reaction appears to be frozen, they were, in fact, observing the situation and deciding what to do next. The local children have been taught that earthquakes are not an intimidating hazard since their high frequency combined with low life and property damage. The common protective action is to wait and observe the shaking.

> "*I think the residents in Hualien County have accustomed to earthquakes. We are really used to it because earthquakes have been happening in Hualien County all the time….. the magnitude of these earthquakes is generally minor…... There are at least 50 earthquakes each year, but they are usually minor tremors or shakings. I think everyone is used to it……. Mostly, it's just a small tremor, so we just observe first and don't need to react immediately…*"

Earthquake Education

The absence of earthquake-related education or programs contributes to the lack of reaction (freeze) in these communities during the earthquake. Though the residents in the Guo-Yu (2), Guo-Cheng, and Min-Zu communities have commonly experienced several earthquakes, the lack of formal earthquake education and periodical practices largely reduces the possibility of appropriately responding to earthquakes. Participants reflect that the local governments do not have official earthquake education or programs specifically after they graduate from middle or high school. The factor of earthquake education or program contributed to the reaction of freeze.

> "*Because it's just some minor shakings, everyone just stopped what they were doing and freeze in place. After a few seconds, it was like nothing had happened. To be honest, we didn't have any proactive reaction because earthquakes frequently happen. So I just waited for these shakes to pass. I feel like we haven't had any earthquake response training...no one told us what to do if there's a violent earthquake.*"

Social Contexts

The reaction of staying where they were without taking any protective actions can result from observing other people reacting the same way during the earthquake. Our findings suggested when new residents had just moved into the communities, they usually tried to protect themselves during earthquakes by taking protective actions. However, whenever new residents attempted to evacuate buildings or exercise Drop, Cover, and Hold-on during earthquakes, their peers, friends, or colleagues would often laugh at them. Some people who have been living in the community for years even try to demonstrate their bravery to the new residents by showing no reactions. To avoid this embarrassment, many new residents have gradually changed their way of responding to earthquakes over the years and tried to act "cool." Especially when people are with others, they tend to stay where they are and observe the shaking intensity without taking any protective actions.

> "*When my wife and I first moved to Hualien County, being from Taipei, we were both very afraid of earthquakes, so we would quickly run outside when earthquakes occurred. But you know, it's usually not the locals who run outside during earthquakes. I used to get laughed at by my colleagues for doing so. Now, we've been living here for a few decades, I mostly just stay put and wait for the earthquake to pass…*"

This peer pressure can also happen within a family. For example, while local elementary or middle school students are taught to exercise Drop, Cover, and Hold on during earthquakes, their parents believe this protective action is only suitable at school. Kids only do this when participating in schools' annual earthquake response drills. They rarely do it in their houses because their parents and/or grandparents think it is ineffective or unnecessary. One participant said —

> "*I have heard lots of ways to respond to an earthquake. When I was a kid, my parents told me just to stay where I was and kept calm down, observed the shaking*

intensity, and waited for the shake to stop. When I was in the Ming Yi elementary school, the teacher said we needed to Drop, Cover, and Hold on. But… do you know how high is the earthquake frequency here? I have the subconscious to stay where I am and I do not think taking immediate reaction is necessary for Hualien County....I believe this reaction is pervasive among residents... ”

5.2.2 Reasons for Clustered PAD of Flight

As discussed in section 4.3, a high level of flight is clustered in the Min-Xin, Jia-Li, and Jia-Xin communities (hot spots). Overall, the thematic analysis found strong shaking, residing close to the Milun fault line, the weakness of building structures, experiencing severe live or property damage, and accompanying children can result in flight (Table 5.8).

Table 5.8 Thematic category of reasons for clustered high PAD of flight

Theme	Category	%*	Example
Environmental cues	strong shaking	60.4%	once the shaking intensity suddenly turns strong, I would run outside of the building immediately (Participant D5)
Geological contexts	residing close to the Milun fault line	10.4%	This entire area is part of the Milun fault line……Whenever an earthquake strikes. I would like to ask my husband to take our children to go outside (Participant D3)
Physical contexts	the weakness of building structures	10.4%	I believe the weakness of building structures is an issue……I and my wife were also moving outside immediately……A friend sent a text message saying that the Marshal Hotel behind us had collapsed. I thought he was joking, but soon realized it was true…(Participant D9)
Social contexts	accompanying children	8.3%	Because I have children, I would have to think about protecting them and that's why I start to go out. (Participant D4)
Earthquake experiences	experiencing severe live or property damage	10.4%	I knew that during an earthquake, cabinets could fall and cause injuries. That's why I knew we have to quickly run outside (Participant D8)

* The percentage indicates the proportion of the coding that falls under the respective category within the interview transcripts.

Environmental Cues

Shaking intensity takes the most considerable role, resulting in fleeting the buildings in the Min-Xin, Jia-Li, and Jia-Xin communities. Minor and moderate ground shakings commonly occur in the course of their life. So, they generally start by observing the intensity of the shake and decide if they need to leave. Participants suggest that taking cover or evacuating from buildings for each earthquake is not reasonable nor possible due to the high frequency of earthquakes. However, once the shakings suddenly turn strong, the intent to evacuate would tremendously increase.

> "*As long as it's not as big as the earthquake of the 2018 Hualien Earthquake, where the ground was shaking heavily, most Hualien residents are used to waiting and observing the shaking intensity. However, once the shaking intensity suddenly turns strong, I would run outside of the building immediately..*."

Geological Contexts/Physical Contexts/Social Contexts

The Milun fault line is a major environmental context penetrating the Min-Xin, Jia-Li, and Jia-Xin communities. The high frequency of perceptible earthquakes (some earthquakes are strong or violent) has commonly occurred in these communities. The residents in these communities are fully aware of the location of the Milun fault line. Some can even identify which buildings are directly above the fault line. Therefore a hazard schema among residents leads to a higher likelihood of fleeing the buildings during earthquakes.

> "*We are well aware that all of our industries are located on the Milun fault line. It extends from Hua Wu street to the Amis Hotel, spanning from the sea in the east to the mountain side in the west. This entire area is part of the Milun fault line……Whenever an earthquake strikes. I would like to ask my husband to take our children to go outside….*"

The weakness of building structures is another environmental context that results in fleeting the building. The buildings where the residents stayed in the Min-Xin, Jia-Li, and Jia-Xin communities have undergone several strong earthquakes, particularly the 1999 Chi-Chi Earthquake. People living in these buildings can still see cracks in the columns, beams, and ceilings. Residents are afraid of building collapse and decide to evacuate during shaking.

> "*…my computer had fallen. We then realized that the shaking was so strong and didn't stop. At that moment, we saw many people downstairs had already evacuated. I believe the weakness of building structures is an issue. A friend sent a text message saying that the Marshal Hotel behind us had collapsed. I thought he was joking, but soon realized it was true……I and my wife were also moved outside immediately….*"

Generally, people are familiar with the building structures of their houses. Once they perceive or feel the shakings may exceed the capacity of the constructions where they stayed, the intent of evacuating from a building is increased. This type of protective action can be reinforced if one takes the role of a household lead or a small business owner. This also shows that protecting close ones can increase the possibility of evacuating from the buildings in these communities.

> "*If I were alone, I probably wouldn't be so scared. Because I have children, I would have to think about protecting them and that's why I start to go out. We would probably go to the back where there are small and low-rise buildings. In the front, we have mostly tall buildings.*"

Earthquake Experiences

This study found that many Min-Xin, Jia-Li, and Jia-Xin residents have suffered severe home damage or were injured in previous earthquakes. Therefore, they are more likely to recall those adverse events during shaking and evacuate from buildings. For instance, a participant said a heavy wood closet crushed her husband's leg in an earthquake a few years ago. She cooperated with local firefighters to help her husband to move out from the debris. With the experience of that earthquake, she always recalls the accident on that day whenever an earthquake strikes. Therefore, her PAD during shaking is to avoid falling objects and evacuate from buildings. The severe damages in earthquakes indeed increase the possibility for her to take protective actions even though the reaction may not be appropriate given a specific situation. Though these residents have similar PAD of flight in these three communities, other factors may facilitate or impede it. For instance, a household may need to take care of several children at the same time, which leads to difficulty in reuniting these kids in a short period and evacuating from buildings. Other facilitators may include staying close to an open space, staying on the first floor, or standing close to an exit.

> "…*More than 40 years ago, in a violent earthquake, my husband got hurt under a cabinet and was injured quite seriously. I knew that during an earthquake, cabinets could fall and cause injuries. That's why I knew we have to quickly run outside*…"

5.3 Discussion

Overall, the thematic analysis results suggest some environmental contexts, social contexts, personal characteristics, and other factors (CRP and environmental cues) affected the discrepancies of the ARP of fear and nervousness, CRP of household losses, and the PADs of flight and freeze. The following subsections discuss these findings.

5.3.1 Environmental Contexts

Geological Contexts

The literature review reveals that previous earthquake studies often overlook geological contexts. However, our study found that many interviewees were able to identify the fault line passing through their own or neighboring communities. Living close to or directly above the Milun fault line increased the likelihood of experiencing high ARP fear or triggering a PAD flight response during the 2018 Hualian Earthquake. In other words, individuals who were aware of their proximity to the Milun fault line tended to feel anxious and evacuate buildings during earthquakes. As previously mentioned, Hualian is the most earthquake-prone region in Taiwan, and seismic activity is a regular occurrence for its residents. As a result, many Hualian residents are curious about the geological features of their communities. After the 1999 Chi-Chi earthquake, local governments and media began sharing information on fault line locations with residents, leading to increased awareness of the Milun fault line in Hualian.

Physical Contexts

Shapira *et al*. (2018) reported that residential building types significantly affect people's flight behavior. In addition, Bourque *et al*. (1973) find that respondents are less likely to freeze when they are home during earthquakes. These studies help us identify the possible physical context that could affect people's response during earthquakes, but it does not explain the reasons. This study finds that people's confidence in building structure integrity is a potential reason that leads to the freeze reaction. In fact, as suggested by many previous studies, freeze is a common reaction (Bourque et al., 1973; Lindell et al., 2016). The earthquake survey studies have used a survey question asking participants if they stopped what they were doing without taking protective action to measure freeze behavior (Goltz & Bourque, 2017). Previous studies have suggested that some individuals may experience behavioral freeze during emergencies, which can be attributed to the limited time available for cognitive information processing in a high-stress environment, making it difficult to take appropriate actions. (Leach, 2004; Prati, 2013). However, the finding of this research suggests differ. This study suggests that our interviewees had confidence in the building structures they were in, and therefore, they simply stopped what they were doing when they first felt the shake and observed the situation to see if taking protective action was necessary.

Additionally, our study found that participants' confidence in the building structure is associated with lower fear and higher nervousness levels. This finding may seem contradictory, but during our interviews, participants indicated that they viewed fear and nervousness as two different levels of negative emotional reactions (ARPs), with fear being higher and nervousness being lower. This discrepancy in terminology could also be due to how fear and nervousness are expressed in Mandarin Chinese.

5.3.2 Social Contexts

Being with elderly individuals or children during earthquakes has been found to result in higher levels of fear during shaking in this study. This is different from Jon et al. (2016), who found no significant correlation between fear and being with children. The differences may be attributed to cultural differences across Taiwan, New Zealand, and Japan. Moreover, this study also found that being with children prompts individuals to quickly flee from buildings, which is consistent with previous studies (Jon et al., 2016), but not all of them. For instance, Shapira et al. (2018) reported that being with children did not affect individuals' flight behavior. This could be because the Shapira et al. (2018) study was based on a series of minor earthquakes in Isarai in 2014. During such minor earthquakes, evacuating buildings may not be deemed necessary. Previous research has also reported other earthquake responses associated with being with children, such as a lower likelihood of freezing (Lindell et al., 2016), actively protecting children (Jon et al., 2016), and having a high-level perception of being injured (Turner et al., 1986). However, this study did not identify these patterns.

5.3.3 Personal Characteristics

Earthquake Experiences

This study proposes two interpretations of earthquake experiences: vulnerable and resilient. The vulnerable interpretation is associated with a higher perception of household losses, which is consistent with previous research (Blanchard-Boehm, Cook, 2004; Goltz, Russell & Bourque, 1992; Mileti & Sorensen, 1990; Russell et al., 1995). On the other hand, a resilient interpretation of earthquake experience suggests that individuals with more experience tend to perceive lower household losses. One possible reason for this resilience is that the Taiwanese Central Weather Bureau often classifies non-major earthquakes as "Normal Seismic Energy Release," which can help alleviate citizen worries and prevent panic (Lin, 2022). Regardless of the reasons behind it, this finding suggests that previous disaster experiences hold different meanings for different people. Thus, even if researchers use similar survey questions to measure earthquake experience, they may still obtain different results because individuals interpret their earthquake experiences differently.

Earthquake Education

This study found that people not knowing what to do during earthquakes resulted in high nervousness and freeze in place (a potentially inappropriate earthquake response behavior) during the 2018 Hualien Earthquake. This finding somewhat align with a previous study suggesting that hazard education can increase people's risk perception of environmental hazards but does not encourage appropriate protective actions such as evacuation in the case of a tsunami (Fraser et al., 2016). As previous research and the Protection Motivation Theory suggest (Azizam et al., 2020; Floyd et al., 2000), knowing what to do or having a high-risk perception (regardless of ARP or CRP) does not necessarily lead to appropriate protective actions. This is because other factors also contribute to whether or not people take protective actions. In our case, as mentioned earlier, the freeze response is a stage where people are still deciding what to do next. While this response may potentially harm individuals, it is important to recognize that every action has an opportunity cost. Some of our interviewees noted that they could not simply stop what they were doing every time they felt an earthquake. The freeze response allows them to decide if exercising the "drop-cover-and-hold-on" technique or evacuating the building is necessary, considering the opportunity cost of disrupting their current activities.

Optimistic Bias

Optimistic bias has long been documented in risk or health studies to explain risk-taking behaviors such as motorcycle riding (Fischhoff et al., 1978; Slovic, 1992). In the disaster since literature, optimistic bias is usually used to explain why people do not take mitigation, preparedness, or protective actions. The findings of this study suggest that optimistic bias may have contributed to a low fear level among individuals during the 2018 Hualien Earthquake. This is consistent with previous research on the topic. For instance, Helweg-Larsen (1999) reported that optimistic bias resulted in a low perception of harm during a tsunami. Burger and Palmer (1992) suggested that individuals who had not experienced earthquake damage in the past were more likely to have an optimistic bias and a low fear level during earthquakes. Similarly, Mileti and O'Brien (1992) found that the absence of damage from a mainshock created an optimistic bias, leading to a lower earthquake risk perception.

Belief

This study found that the types of responsibility belief can affect one's risk perception of household losses. Individuals who believe they have a greater responsibility to protect their own lives and property tend to have a higher perception of household losses. Conversely, those who believe that governments should assume more responsibility in this regard tend to have a lower perception of household losses. These findings are partially supported by Jackson's (1981) research, which showed that a lack of personal responsibility belief is linked to a lower perception of household losses.

Hazard Adjustment

Households' earthquake mitigation and preparedness levels can affect the perception of household losses. This finding is partly supported by Shapira *et al*. (2018), who report that high-hazard adjustment leads to low-risk perception. However, Shapira *et al*. (2018) report that people with higher hazard adjustment are more likely to evacuate from the building. It differs from the findings in this research, which may result in differences in custom or earthquake education in response to earthquakes.

5.3.4 Other factors affecting earthquake response

Cognitive Risk Perception

While CRP is one of the outcome variables of GIS analyses (Chapter IV), the thematic analysis also indicates CRP influences ARP. Our study participants suggest the perception of injury results in a high emotional fear response. This finding is similar to Jon *et al*.

(2016), who found that cognitive risk perception is moderately strong intercorrelated with fear and shock. In addition, the perception of property damage is also found to contribute to a high level of nervousness. The relationship between CRP and PAD is not found in this study, but Lindell *et al*. (2016) find that high CRP is negatively correlated with the freeze-in-place reaction. Several mediating factors may influence the relationships between cognitive risk perceptions and protective actions in Hualien County, including mitigation and preparedness strategies, a resilient interpretation of earthquake experiences, and beliefs about individual and collective responsibility.

Environmental Cues

Environmental cues play a significant role in shaping ARPs and PADs during the 2018 Hualien Earthquake. For instance, strong and intense earthquakes tend to trigger high levels of fear among people, as evidenced by Alexander's (1990) study, which found a positive correlation between shaking intensity and fear. Moreover, strong shaking has been shown to influence people's willingness to flee from buildings, as documented in several previous studies (Alexander, 1990; Arnold, Durkin & Whitaker, 1982; Quarantelli, 1976; Takuma, 1972). In contrast, high-frequency but low-magnitude earthquakes can result in a freeze-in-place reaction. As suggested in the previous discussion, residents stop their activities and observe the shaking intensity before deciding on their next response. Notably, our study also identified a unique factor contributing to high nervousness levels: hearing underground rumbling. This finding has not been reported in previous studies and may be specific to earthquakes in Hualien, Taiwan.

CHAPTER VI

CONCLUSION

Since the first version of PADM was published in 2004, scholars have tried to understand the influential factors that impact people's response to disasters by testing the model. The addition of social and environmental context in the third version of PADM introduced how geolocation and physical contexts influence people's disaster response. However, little research has focused on this new factor. Thus, this study's first overarching research question is: ***Do people's disaster responses (ARPs, CRPs, and PADs) geographically differ during an earthquake?*** This overarching research question examines how geographical location, one of the environmental context factors, affects people's disaster response. Getis-Ord Gi* is used to answer this first question. The test results show that the ARPs of fear and nervousness, the CRPs of household losses, and the PADs of flight and freeze have shown hot and cold spots in some communities.

Further, the influential factors of other environmental contexts, social contexts, and personal characteristics are neither fully explored nor have inconclusive results in the PADM studies. This leads to the second overarching research question —***Why do people respond to earthquakes in specific ways in different geographical areas?*** In-depth interviews were conducted among these hot and cold spot communities to explore the possible root causes. The thematic analysis shows that the environmental contexts (residing close to fault lines and building structure integrity), the social contexts (being with children or elderly, peer pressure, and population density), optimistic bias (damage levels), earthquake experiences (vulnerability interpretation and resilient interpretation), responsibility belief, earthquake mitigation efforts, resource-related attribute (lack of knowledge in response to earthquakes), earthquake education, environmental cues (shaking intensity, aftershocks, and underground rumblings), and cognitive risk perceptions (household losses) have significant influences on the clustered ARPs, CRPs, and PADs.

Based on the findings, this dissertation proposes an earthquake-oriented PADM to explain the unique nature of seismic hazards, which differ from other environmental threats in their quick onset, uncertainty in terms of location, timing, and magnitude, and geographical differences.

6.1 Theory Contributions

Based on the literature review and the results from Getis-Ord Gi* and thematic analyses, this study suggests the overall process of people's protective action decisions to earthquakes can be explained by an earthquake-oriented PADM, which includes three stages: the information-gathering stage, risk perception stage, and behavioral response stage, shown in Figure 6.1.

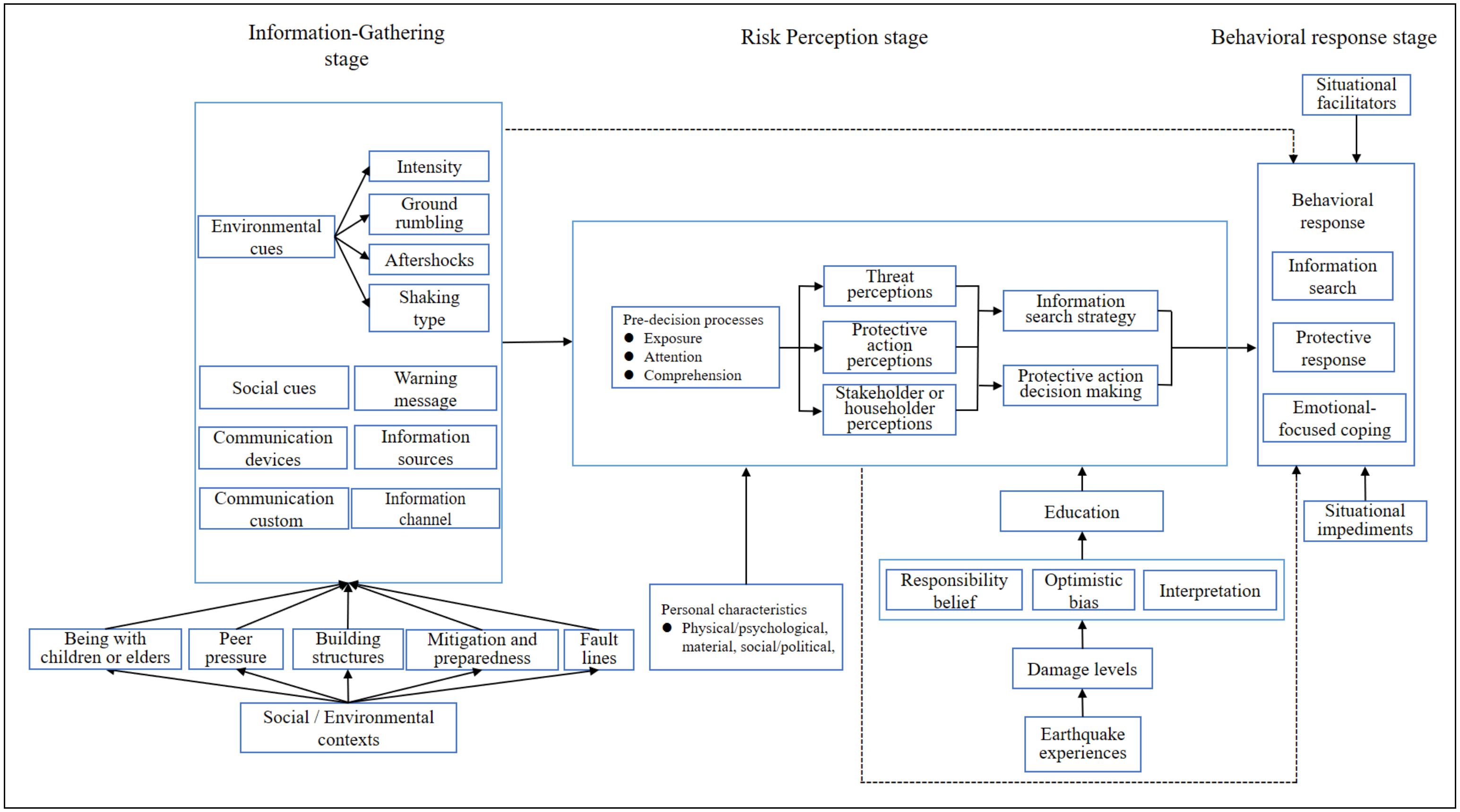


Figure 6.1 Earthquake-Oriented PADM

First, social and environmental contexts play an important role in influencing all other factors in the information-gathering stage and forming an earthquake schema for the people who reside in earthquake-prone areas. The social contexts of being with children or older people significantly impact the emotional reaction of fear and flight behavior. In addition, the social contexts from the interaction of respondents' peers, coworkers, or colleagues also considerably influence people's earthquake behavioral responses. For instance, youths may hesitate to immediately take cover because they tend to pretend bravely or pluck up courage in front of their peers, even if they have observed other people undertaking protective actions. Or customers in a store tend to follow other people's reactions during shaking, specifically when unfamiliar with the venues. Particularly, peer pressure shows its influence on freeze-in-place behavior. This finding shows that social contexts with others do not increase the likelihood of taking protective actions.

Confidence in building structure integrity can result in low fear and high nervousness. On the other hand, a lack of confidence in the structural integrity of buildings can lead to a higher level of fear and an increased likelihood of individuals fleeing from buildings during earthquakes. Mitigation and preparedness efforts can result in a low cognitive risk perception of household losses. In addition, residing close to fault lines can result in flight behavior. Conversely, living farther away from fault lines and experiencing high frequency but low magnitude shakes regularly can result in a freeze-in-place reaction and a low fear emotion level during earthquakes.

People rely more on social and environmental cues than warning messages when facing earthquake threats. The factor of shaking intensity is one of the important environmental cues that can immediately trigger flight behavior. People may stay where they are, continuing jobs on their hands and observing the shaking intensity when they first feel the earthquake shake. However, once a shake turns violent, people would immediately take action, no matter whether their protective behaviors are appropriate or not. Other environmental cues, such as aftershocks and underground rumblings, can result in the emotion of nervousness.

In the second stage, the quick onset of an earthquake leaves a very short period for residents to consider possible protective actions. Thus, some people may intuitively decide to protect their children or customers during shakings once they take the role of parents or small business owners. Others may decide to flee the building immediately when an earthquake is violent and might cause the building to collapse. The short response time makes people feel earthquakes are difficult to cope with, particularly when the social and environmental contexts are complex. For instance, a parent may simultaneously care for two children and cook in the kitchen. Once an earthquake strikes, he/she must decide the priority of turning off the gas valve, reuniting for kids, or exercising Drop, Cover, and Hold on in a limited time. These dilemmas could make the responders feel more nervous and/or fearful than other types of environmental hazards. While earthquake experiences show significant influences on protective action decision-making, the resilient interpretation of earthquake experiences, responsibility disbelief, low damage levels, and lack of earthquake education can decrease the possibility of adopting protective actions. Conversely, vulnerability interpretation, responsibility belief, severe damages, and earthquake education can increase the relationship between them. Lastly, some people may freeze in place due to the lack of earthquake education/training, peer pressure, and the types of earthquakes they have been experiencing.

6.2 Practical Implication

First, geolocation contexts are found to have significant influences on certain types of affective risk perceptions, cognitive risk perceptions, and protective action decisions. For instance, residents living in Min-Xin, Jia-Li, and Jia-Xin communities (hot spots) tend to flee from a building in earthquakes due to the fear of building collapse. However, in the research on the 1987 Whittier Narrow earthquake, the 1989 Loma Prieta earthquake, and the 1994 Northridge earthquake, Shoaf *et al*. (1998) found that cuts and bruises are the most common causes of injuries. The youths were more likely to move during shakings than the elderly and were more likely to get injuries from falling objects. In addition, people were more likely to fall over or be struck by objects during nighttime. These earthquake studies show that flight during shaking keeps a high possibility of getting injured. Therefore, emergency managers may rethink if a one-fit-all earthquake education or program is appropriate for residents living in diverse environmental contexts.

Second, optimistic bias has been found in this research, mainly due to the lack of experiencing severe earthquake damage or overestimating the respondents' ability to respond to earthquakes. To reduce optimistic bias, emergency managers might want to show the residents the severe earthquake damages caused by keeping these mindsets.

Third, intriguingly, peer pressure is one of the reasons for freeze-in-place behavior during earthquakes. Specifically, the youths in middle school are worried about being laughed at for showing they are afraid of earthquakes. Also, some parents or grandparents regard dropping, covering, and holding onto a sturdy table as unnecessary and teach their children or grandchildren not to do such a thing. These phenomena show that a long-term earthquake education or program, such as increasing earthquake salience, is important for students and adults to minimize these issues.

6.3 Study limitation

There are some limitations to this research project. First, the hard copy survey data was collected in Hualien County, Taiwan, in 2018. This research project may overlook a certain group of residents who are not accustomed to responding to hard-copy questionnaires because of the difficulties in returning them via the postal system in Taiwan. Second, 44.26% of Xinchen County study participants have an education level higher than a college degree, but this number is only 20.15% in census data. This may be because the residents with higher education levels are more likely to respond to questionnaires. Therefore, the sampling processes may neglect the residents with lower education levels.

Third, since the building type, population density, and lifestyle in big cities such as Taipei City differ from Hualien County, the findings in this study may only apply to rural areas in Taiwan. For example, this study did not find locating at a higher floor contribute to any ARP, CRP and PAD clusters. This might be different in city areas with buildings with 10 or more floors. In addition, the in-depth interviews were mainly collected in Taiwan. Yet, most PADM studies have been studied in the United States. Thus, to what level the findings in this research could be generalized to other countries with diverse cultures (Wildavsky & Dake, 1990) may need further confirmation.

6.4 Future Study

First, since different environmental hazards have distinct characteristics in nature, the approach of Getis-Ord Gi* used in this dissertation may need to be further applied in other types of disasters, such as hurricanes, volcanic hazards, or floods, and also in other countries. Therefore, researchers can compare, identify, and distinguish the differences between various types of hazards and reflect on improving the PADM. Second, the unit of analysis for the spatial analysis in this study is community. Whether a smaller or larger scale unit of analysis would change the results may need to be further studied. Third, a structural equation model (SEM) may be used to test the proposed earthquake-oriented PADM and identify their relationships. For instance, a researcher could include new factors such as aftershock and detectable underground rumbling in the analysis to examine the correlation between environmental cues and risk perceptions during shaking. Or, a survey can have participants rate their intention to adopt protective actions when in the presence of classmates, coworkers, or family members. This would allow researchers to identify how different types of peer pressure influence people's intentions to take protective actions.

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APPENDICES

Appendix A: Survey Questionnaire

Dear Madam/Sir,

This is a questionnaire of households' immediate responses during 0206 Hualien Earthquake which is prepared by Central Police University (TW) together with Jacksonville State University (US), and Oklahoma State University (US). When you complete and return the following questionnaire, you will receive A convenience store gift card (wroth TWD $200).

Now, please read following questions carefully, and then tick your answer.

Section A: Earthquake Experience

In this section (Q1-Q16), please recall your memories about the 6 February Earthquake and then answer the following questions:

1. When the 6 February earthquake occurred, in which neighborhood were you located?	
____	
2. When the earthquake occurred, in which of the following places were you located? (Tick one)	
☐ In the bed of your home	☐ Walking on a street (Go to Q5)
☐ Elsewhere at your home	☐ At an open space (e.g., park, Go to Q6)
☐ At the home of friends or family	☐ Driving a vehicle (Go to Q6)
☐ At your workplace	☐ Passenger in a vehicle (Go to Q6)
☐ Inside a public building (e.g., shopping or recreation)	
☐ Other (please explain) ______________________	
3. If you were at home, do you how old the building is? (Tick one)	
☐ Older than 30 years ☐ Less than 30 years, but built before the 921 Earthquake (1999)	
☐ Less than 30 years, and built after the 921 Earthquake	
4. If you were inside a building, which floor were you on? (Tick one)	
☐ Ground floor	☐ Between second and fifth floor
☐ Between fifth and fifteenth floor	☐ Higher than fifteenth floor
5. If you were inside a building or walking on a street, to which of the following best describes the type of the building construction you were in or near? (Tick one)	
☐ Steel construction or reinforced concrete structure	☐ Wood made or bamboo made house
☐ Brick concrete construction or brick construction	☐ Sheet metal house or mobile home
6. When the earthquake occurred, which of the following best describes your household? (Tick one)	
☐ All household members were together	

☐ Some household members were absent but I knew they were in a safe location
☐ Some household members were absent and I knew they were in danger
☐ Some household members were absent and I didn't know if they were safe

7. When the earthquake occurred, what was your social context? (Tick all that apply)

☐ I was alone ☐ I was with children under 18 years of age
☐ I was with adults I knew ☐ I was with adult strangers

8. When the earthquake occurred, did you receive the text message of early earthquake warning? (Tick one)

☐ No
☐ Yes, I received the message earlier than 30 seconds before the shaking
☐ Yes, I received the message within 30 seconds before the shaking
☐ Yes, I received the message during the shaking
☐ Yes, I received the message after the shaking

9. How strong was the earthquake shaking that you felt? (Tick one)

☐ Not felt ☐ Weak shaking ☐ Mild shaking
☐ Moderate shaking ☐ Strong shaking ☐ Violent shaking

10. To what extent did you tend to react while the earthquake was shaking	Not at all	Small extent	Mode rate extent	Great extent	Very great extent
a. Continued what I was doing before the shaking	☐	☐	☐	☐	☐
b. Stopped what I was doing but stayed where I was without any protective actions	☐	☐	☐	☐	☐
c. Stayed where I was and only used hand or soft items (e.g., pillow, bag) to cover my head.	☐	☐	☐	☐	☐
d. Dropped to the ground, covered under a sturdy piece of furniture (e.g., table or desk), and held on to it	☐	☐	☐	☐	☐
e. Dropped to the ground, but stayed near solid furniture (e.g., couch, refrigerator, or washing machine) or solid building structure (e.g., structural wall or column) without additional cover	☐	☐	☐	☐	☐
f. Tried to protect other people nearby	☐	☐	☐	☐	☐
g. Tried to protect property nearby (e.g., prevent things from falling)	☐	☐	☐	☐	☐
h. Tried to turn off the utilities (e.g., gas or electricity)	☐	☐	☐	☐	☐
i. Stood in a doorway, held onto the door frame, and prevent it from out of shape	☐	☐	☐	☐	☐
j. Immediately left the building I was in or walking near	☐	☐	☐	☐	☐

11. To what extent did you feel each of the following emotions during the earthquake shaking?	Not at all	Small extent	Mode rate extent	Great extent	Very great extent
k. optimistic	☐	☐	☐	☐	☐
l. depressed	☐	☐	☐	☐	☐
m. annoyed	☐	☐	☐	☐	☐

	Not at all	Small extent	Moderate extent	Great extent	Very great extent
n. nervous	☐	☐	☐	☐	☐
o. fearful	☐	☐	☐	☐	☐
p. relaxed	☐	☐	☐	☐	☐
q. energetic	☐	☐	☐	☐	☐
r. alert	☐	☐	☐	☐	☐
s. passive	☐	☐	☐	☐	☐

12. To what extent did you believe each of the following during the earthquake shaking?	Not at all	Small extent	Mode rate extent	Great extent	Very great extent
a. Your home would be severely damaged or destroyed directly by the shaking?	☐	☐	☐	☐	☐
b. You and your family would be injured or killed directly by the shaking?	☐	☐	☐	☐	☐
c. Your home would be severely damaged or destroyed by secondary impacts (e.g., landslide or fire)?	☐	☐	☐	☐	☐
d. You and your family would be injured or killed by secondary impacts (e.g., landslide or fire)?	☐	☐	☐	☐	☐
e. There would be disruption to your job that would prevent you from working?	☐	☐	☐	☐	☐
f. There would be disruption to the local businesses that would prevent stores from opening?	☐	☐	☐	☐	☐
g. There would be disruption to the traffic that would prevent you from traveling?	☐	☐	☐	☐	☐
h. There would be disruption to electrical, telephone, and other basic services?	☐	☐	☐	☐	☐

13. During the first 30 minutes after the earthquake shaking stopped, which of these did you do? (Tick all that apply)

☐ Returned to what I was doing before the shaking	☐ Tried to find out what had happened
☐ Turned off utilities (gas, electricity, or water)	☐ Tried to contact household members
☐ Cleaned up broken or fallen items	☐ Helped people near me
☐ Went to a clinic or hospital for treatment	☐ Pitched tent
☐ Went to my home	☐ Went to the home of a friend or relative
☐ Went to a private shelter (e.g., temple or church)	☐ Went to a public shelter (e.g., school or park)
☐ Went somewhere else (please explain)______________________________	

☐ Other (please explain) ______________________________

14. During the first 30 minutes after the shaking stopped, which communication channels did you use? (Tick all that apply)		
☐ None	☐ Face to face conversation	☐ Television
☐ Radio	☐ Telephone or Cellphone	☐ The Internet
☐ Social Media (e.g., FB, IG)	☐ Instant Messaging (e.g., FaceTime, Line, WeChat)	
☐ B.B.S.		
15. How much damage did the 6 February earthquake do to your home? (Tick One)		
☐ None	☐ Slight	☐ Moderate
☐ Severe	☐ Totally destroyed	
16. What infrastructure did the 22 February earthquake interrupt in your home? (Tick all that apply)		
☐ Electric power	☐ Tap water	☐ Sewer
☐ Gas	☐ Cable TV access	☐ Internet access
☐ Cellphone signal	☐ Other (please explain) ______________________	

Section B: Previous Experience

In this section (Q17-Q19), please recall your daily memories and then answer the following questions:

17. Before the 6 February earthquake, did you ever experience an earthquake that…	No	Yes
a. caused a landslide?	☐	☐
b. caused a fire?	☐	☐
c. damaged property in your community?	☐	☐
d. damaged your home?	☐	☐
e. injured or killed a member of your family?	☐	☐
f. injured you?	☐	☐
18. Before the 6 February earthquake, did you ever…	**No**	**Yes**
a. attend a meeting about earthquake hazard in your community?	☐	☐
b. participate in an earthquake response drill?	☐	☐
c. receive a brochure about earthquake hazard?	☐	☐

d. have your house inspected for seismic safety?	☐	☐
e. discuss emergency responses with your family?	☐	☐
f. purchase earthquake insurance?	☐	☐
19. At the time of the 6 February earthquake, which of these did you have on hand?	No	Yes
a. At least a 3 day supply of drinking water	☐	☐
b. At least a 3 day supply of non-perishable food	☐	☐
c. A complete first-aid kit	☐	☐
d. A whistle	☐	☐
e. A battery powered radio with spare batteries	☐	☐
f. Flashlight and spare batteries	☐	☐
g. Household emergency plan	☐	☐
h. Predetermined place to evacuate	☐	☐

Section C: Earthquake Impacts

In this section (Q20-22), please tell us the real impacts of the 6 February Earthquake to you and your family:

20. Were you or your family injured or killed in the earthquake? (Tick all that apply)

☐ No (go to Q23)

☐ Yes, some family members got lacerations

☐ Yes, some family members got bruises

☐ Yes, some family members got fractures

☐ Yes, some family members got burns

☐ Yes, some family members got head trauma

☐ Yes, some of my family got heart attack

☐ Yes, some family members got asphyxia

☐ Yes, some family members got crush syndrome

☐ Yes, some family members were injured, but the reason is not listed above.

(please explain) ____

21. How serious was your or your family member's injury? (Tick One)

☐ We could take care of the injuries at home

☐ We needed to go to a hospital or clinic for treatment, but could go by self

☐ We needed emergency medical service, but the patient was conscious

☐ We needed emergency medical service, and the patient was in a coma, but could breathe

☐ We needed emergency medical service, and the patient was in a coma and could not breathe

22. What was the cause of your or your family's injury? (Tick One)

☐ Hit/trapped by building parts	☐ Hit/trapped by flying objects or falling items
☐ Contact burn by hot fluid, fire, or hot items or electrocuted	☐ Slipped or fell
☐ Cut/punctured by broken pieces	☐ Injured in a traffic accident due to this earthquake
☐ Other (please explain) ____________________	

Section D: Personal Information

In this section (Q23-33), please report your personal information:

23. What is your age?	____________________		
24. What is your gender?	☐ Male	☐ Female	
25. What is your marital status?			
☐ Married	☐ Single	☐ Divorced	☐ Widowed
26. How many people (including yourself) in your household are:			
______Under 15 years	______15-18 years	______19-65 years	______Over 65 years
27. At the time of the earthquake, was there anyone in your household that had a disability requiring assistance from others?	☐ No	☐ Yes	
28. Which ethnic group do you identify yourself?			
☐ Hoklo Taiwanese	☐ Hakka	☐ Native Taiwanese	
☐ Mainlander	☐ Immigrant resident	☐ Foreigner	
☐ Other (please explain) ____________________			
29. What is your highest level of education?			
☐ Illiterate	☐ Elementary school graduate	☐ Junior high school graduate	
☐ Senior high school graduate	☐ Vocational school graduate	☐ Junior college	
☐ Bachelor	☐ Master	☐ Doctor	
30. What is your occupation?			
☐ Agriculture, Forestry, Fishing and Animal Husbandry	☐ Mining and Quarrying	☐ Manufacturing	
☐ Construction	☐ Wholesale and Retail Trade	☐ Transportation and Storage	
☐ Accommodation and Food Service Activities	☐ Financial and Insurance Activities	☐ Education	

☐ Other Service Activities	☐ Government Agencies	☐ Other ____________________
31. What is your monthly household income? (in NTD)		
☐ Less than $22,000	☐ $22,000-34,999	☐ $35,000-49,999
☐ $50,000-74,999	☐ $75,000-99,999	☐ $100,000 or more

32. Do you own or rent the home where you now live?	☐ Rent	☐ Own
33. How long have you lived in the community where you now reside?	___________years and ___________months	

Do you have any other comments about your earthquake experience on 6 February 2018? Please use this space to write about any good or bad aspects of your experiences.

THANK YOU FOR PARTICIPATING IN THIS STUDY

Appendix B: Consent Form

Fire and Emergency Management Administration

CONSENT FORM

Possible Root Causes of the Inconsistent Findings in the Protective Action Decision Making

<u>Background Information</u>

You are invited to be in a research study of people's immediate response behaviors during earthquakes. We ask that you read this form and ask any questions you may have before agreeing to be in the study. Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time. You can skip any questions that make you uncomfortable and can stop the interview/survey at any time. Your decision whether or not to participate in this study will not affect your personal or work relationship with the research team .

This study is being conducted by: Tu Jung (Chris) Hung, in Fire and Emergency Management Administration at Oklahoma State University, under the direction of associate professor Dr. Haley Murphy, in Fire and Emergency Management Administration at Oklahoma State University.

<u>Procedures</u>

If you agree to be in this study, we would ask you to do the following things: The participants will describe their immediate response behaviros and emotions during earthquakes. A telephone interview will be used to collect the data from interviewees and the overall conversation will be recorded for further analysis.

Participation in the study involves the following time commitment: An overall interview takes about 30-40 minutes.

<u>Compensation</u>

You will receive a ten dollar gift card as compensation for your participation. You will receive payment two weeks after your completetion of a telephone interview. But if you do not finish the interview thoroughly or refuse to answer some questions, you wil still reveive the gift card. You may need to provide your mail address to receive payment.

<u>Risks</u>

There is a potential risk of breach of confidentiality which is minimized by the researcher and his research team to carefully conduct and store the collected data.

Confidentiality

The information that you give in the study will be handled confidentially. Your information will be assigned a code number/pseudonym. The list connecting your name to this code will be kept in a locked file. When the study is completed and the data have been analyzed, this list will be destroyed. Your name will not be used in any report.

We will collect your information through a telephone interview with a digital recorder. This audio data will be stored in a password protected computer. When the study is completed and the data have been analyzed, the code list linking names to study numbers will be destroyed. This is expected to occur no later than Fall 2022. The audio recording will be transcribed. The recording will be deleted after the transcription is complete and verified. This process should take approximately by the end of 2021.

Contacts and Questions

The Institutional Review Board (IRB) for the protection of human research participants at Oklahoma State University has reviewed and approved this study. If you have questions about the research study itself, please contact the Principal Investigator at 886+1+926809641, tuhung@ostatemail.okstate.edu. If you have questions about your rights as a research volunteer or would simply like to speak with someone other than the research team about concerns regarding this study, please contact the IRB at (405) 744-3377 or irb@okstate.edu. All reports or correspondence will be kept confidential.

Statement of Consent

I have read the above information. I have had the opportunity to ask questions and have my questions answered. By participating in the interview I understand I am giving my consent to participate and be audiotaped during the study. Also, I agree the interview data can be used in future research studies.

Appendix C: Interview Protocol

Immediate Response Behaviors to Earthquakes Project

Interview Protocol

1-30-2021

Question1: Introductory inquiries about the 2018 Hualien earthquake.

1.1 Could you describe the overall experiences of the 2018 Hualien earthquake?
1.2 Could you describe your immediate response behaviors during shakings? And why did you do that?
1.3 Could you describe your overall feelings about the 2018 Hualien earthquake? And your emotional feelings during shakings?

Question2: The second question tries to understand how people's earthquake experiences and beliefs about earthquakes.

2.1 Could you describe your earthquake experiences that you had before the 2018 Hualien earthquake?

2.2 Could you describe how you prepare for earthquakes? And generally, how do you receive earthquake preparedness information?

2.3 Could you describe the beliefs of earthquake hazards? For instance, in your opinion what kind of people are more likely to suffer from earthquakes? Or, who will be the major stakeholders to be responsible for earthquake preparedness?

Question3: The third question tends to understand how people perceive earthquake risks.

3.1 Could you describe your feelings about an earthquake that may or may not threaten your lives, properties, or social activities?

3.2 Could you describe how you receive the information related to earthquake risks?

Question4: The fourth question is about earthquake warning messages and channels.

4.1 Could you describe what are your major channels to receive earthquake warnings, and why?

4.2 For an earthquake warning message, what are the most important parts for you and why? Further, generally what were your reactions to these warnings?

Appendix D: Institutional Revew Board approval form

Oklahoma State University Institutional Review Board

Date:	02/25/2021
Application Number:	IRB-21-96
Proposal Title:	Possible root causes of the inconsistent findings in the Protective Action Decision Making
Principal Investigator:	Chris Hung
Co-Investigator(s):	
Faculty Adviser:	Haley Murphy
Project Coordinator:	
Research Assistant(s):	
Processed as:	Exempt
Exempt Category:	

Status Recommended by Reviewer(s): Approved

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in 45CFR46.

This study meets criteria in the Revised Common Rule, as well as, one or more of the circumstances for which continuing review is not required. As Principal Investigator of this research, you will be required to submit a status report to the IRB triennially.

The final versions of any recruitment, consent and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any unanticipated and/or adverse events to the IRB Office promptly.
4. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 405-744-3377 or irb@okstate.edu.

Sincerely,
Oklahoma State University IRB

VITA

TU-JUNG HUNG

Candidate for the Degree of

Doctor of Philosophy

Dissertation: EXPLORING EARTHQUAKE RESPONSE THROUGH THE LENS OF THE PROTECTIVE ACTION DECISION MODEL

Major Field: Fire and Emergency Management Administration

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Fire and Emergency Management Administration at Oklahoma State University, Stillwater, Oklahoma in May, 2023.

Completed the requirements for the Master of Science at Central Police University, Taoyuan City, Taiwan in 2013.

Completed the requirements for the Bachelor of Science in Fire Science at Central Police University, Taoyuan City, Taiwan in 2002.

Experience:

Professional Memberships:
International Association of Emergency Managers
National Fire Protection Association