Evaluation of Compliance with and Effectiveness of Disaster Risk Reduction Measures Enacted in Remote Mountainous Rural Areas Affected by Debris Flows Induced by the 2008 Wenchuan Earthquake: Case Studies of Two Counties

Ching Yee Rhea Leung

University College London

2024

This thesis is submitted for the degree of Doctor of Philosophy

To those affected by secondary geohazards induced by

the Wenchuan earthquake.

Declaration:

I, Rhea Leung, confirm that the work presented in this thesis is my own.

Where information has been derived from other sources,
I confirm that this has been indicated in the thesis.

Abstract

After the 2008 Wenchuan earthquake, the Chinese Government implemented risk avoidance and risk reduction measures to protect residents from secondary geohazards. However, comprehensive investigations and evaluations of such measures are so far limited.

This thesis investigates the relocation decisions, risk perceptions and disaster responses of populations threatened by secondary geohazard. It evaluates the compliance level and effectiveness of government measures, together with demographic variables, in influencing such decisions, perceptions and behaviour. The core of this study consists of a survey of debris flow risk reduction measures imposed by the government and their impact on risk perception and anticipated disaster response. Analysis of vulnerability indicators and compliance with mitigation directives is also performed. The focus is on rural remote mountainous areas where debris flow risks are tolerated but needed to be managed. Comparisons are made between two Sichuan counties: Pingwu and Wenchuan.

This research identifies ethnicity as the variable that has great influence on people's moving decisions and risk perceptions. Risk exposure, cultural factors and individual competencies also affected moving decisions. Village affiliation, debris flow experience and perception of substantial debris flow all affected risk perceptions. People's roles in their villages particularly influenced their responses.

Significance and limitations of government impacts are revealed. People's coping capacities influenced by government is crucial to relocation decision making. For risk perception, awareness of the gong as an early warning tool was impactful in both study areas. Awareness of designated evacuation routes significantly influenced disaster response. The degree of accessibility of government information affected risk perception and disaster response.

This research concludes that, although the overall reasons behind the relocation decisions, risk perceptions and disaster responses of respondents from the two counties varied, some factors were influential in both places. The government should allocate more resources to distinguish in detail the most useful measures

to alleviate vulnerability and promote risk reduction. Disaster policies should be tailored to the needs of particular ethnic groups.

Impact statement

Most of the current influential vulnerability models focused on what factors and how such factors contributed to vulnerability. These models and literatures noted that some demographic characteristic are the key aspects leading to vulnerability. However, not all factors can be applied to the post-Wenchuan earthquake situation. The impacts of government disaster risk reduction measures are also seldom addressed.

By analysing the data collected in the five villages of the two study areas, not only the applicability of the selected vulnerability indicators of the existing models is evaluated, but an all-rounded understanding of the effectiveness of government disaster risk reduction measures on relocation decisions, risk perceptions and disaster responses are revealed. The findings can tell whether and how crucial the state and political influence have particularly affected post-earthquake relocation decisions, debris flow risk perceptions and anticipated disaster behaviour in remote mountainous rural communities, hence alleviating the vulnerability of the debris flow affected population.

It is hoped that this research can fill in some empirical gaps on how the government measures and the various vulnerability indicators are related to relocation decisions, risk perceptions and disaster responses.

Based on the empirical findings of this research in a China context, a new model that can contribute to the understanding of vulnerability in relation to government disaster mitigation, preparedness and response measures, is developed. The new model is capable in explaining the relations of vulnerability indicators and government measures on one hand, and relocation decision, debris flow risk perception and behavioural response on the other. References can be made to other remote mountainous areas in China, and other regions with similar contexts. By doing so, advances in theoretical understanding of vulnerability is achieved and any missing theoretical gaps is filled.

With the completion of this thesis, it is hoped that more attention can be brought to the remote mountainous rural population in China and other places in terms of their

earthquake induced debris flow risk exposure and vulnerability. Recommendations on how the Chinese measures can be improved to affect relocation decision, risk perception and disaster response of the populations influenced by secondary geohazard risks are also provided. In turn, more care and resources can be distributed to relevant disaster mitigation, preparedness and response measures whenever and wherever appropriate. Vulnerability of the affected population can ultimately be alleviated.

Acknowledgements

First and foremost I am extremely grateful to my primary supervisor, Professor David Alexander, for his invaluable guidance, great support and patience during the course of my PhD study. His knowledge, wisdom and experience have encouraged me in all the time of my research. I would also like to thank Professor Ilan Kelman and Dr. Simon Day for their supervision and advice. My gratitude extends to Professor Chan Lung-Sang and Professor Zhao Guochun for their treasured support. In particular, I would like to thank all those who helped me in the field. Without their kind support and assistance, it would be impossible for me to complete my field work. My appreciation also goes out to my mother, sisters and friends for their encouragement all through my studies. Lastly, I would like to thank UCL-IRDR for giving me the opportunity that allowed me to conduct this research.

Contents

Declaration 2
Abstract..... 3
Impact statement 5
Acknowledgements..... 7
Contents 8
List of Tables..... 13
List of Figures..... 16
Acronyms 24

Chapter 1 Introduction, Research Objectives and Hypotheses..... 26
1.1 Introduction…….....26
1.2 Objectives of the research.....28
1.3 Hypotheses of the research.....30
1.3.1 Hypothesis 1.....30
1.3.2 Hypothesis 2.....30
1.3.3 Hypothesis 3.....30
1.4 Significance of the research.....31
1.5 Theoretical contribution of the research.....32
1.6 Structure of the research thesis.....34

Chapter 2 Literature review..... 37
2.1 Debris flows 37
2.1.1 Characteristics of debris flows and conditions causing debris flows 37
2.1.2 Classification of debris flows 40
2.2 Mass movements and debris flows in China 41
2.2.1 Causes of mass movements in China 41
2.2.2 Classification of mass movements in China 41
2.2.3 Debris flows in China and their impacts 42
2.2.4 Causes of mass movements in Sichuan after the Wenchuan earthquake……..... 44
2.2.5 Classification of mass movements in Sichuan after the Wenchuan earthquake……..44
2.2.6 Relevance of mass movement classifications in Sichuan to this research……..45
2.2.7 Debris flows in Sichuan after the Wenchuan earthquake 46
2.2.8 Significance and long-term impact of the study of debris flows 47
2.3 Post-disaster relocation, risk perception and disaster response ...49
2.3.1 Disaster loss, recovery, reconstruction and relocation 49

2.3.2 Risk perception....59
2.3.3 Disaster response behaviour....61
2.4 Development of vulnerability research....64
2.4.1 The discussion of “naturalness” in disaster research and the relevant prevention and mitigation to alleviate vulnerability....64
2.4.2 The concept of vulnerability....67
2.4.3 Dimensions of vulnerability....69
2.4.4 Multi-dimensions of vulnerability....75
2.5 Theoretical development of vulnerability studies....76
2.5.1 This research thesis and the need of a general model of vulnerability....76
2.5.2 Reviews of the models....76
2.5.3 Which model, or which aspects of the various models, are most useful to this research....86
2.6 Disaster risk reduction measures....90
2.6.1 Disaster mitigation measures....90
2.6.2 Disaster preparedness measures....91
2.6.3 Disaster response measures....94
2.7 Conclusions of literature review....102

Chapter 3 Methodology....103
3.1 Data collection....103
3.1.1 Documentary research, desk study of background information and literature review....103
3.1.2 Analysis of satellite imagery....106
3.1.3 Field studies and interviews....107
3.1.4 Questionnaire surveys....108
3.2 Questionnaire survey design....109
3.2.1 Planning....109
3.2.2 Contents of the survey....110
3.3 Study areas....125
3.4 Target population, sampling and the selected villages....127
3.4.1 Sample size....128
3.4.2 The selected villages....128
3.5 Administering the questionnaire in the field....130
3.5.1 Consent from respondents....130
3.5.2 Conduct of the survey....131
3.5.3 Limitations and implications....132
3.6 Data analysis....134
3.6.1 Descriptive statistics....134
3.6.2 Test of hypotheses....134
3.7 Problems encounter, limitations of this research and possible solutions....136

Chapter 4 Case study areas..... 139
4.1 Case study area 1 -- Pingwu County.....142
4.1.1 Pingwu County -- Nanba Township.....145
4.1.2 Pingwu County -- Nanba Township -- Xingping Gully Debris Flow.....146
4.1.3 Pingwu County -- Nanba Township -- Xingping Gully Debris Flow affecting Xinjian Village.....149
4.1.4 Pingwu County -- Pingtong Township.....160
4.1.5 Pingwu County -- Pingtong Township – Niufei Village.....161
4.1.6 Pingwu County -- Pingtong Township – Niufei Village -- Huanglianshu Gully Debris Flow.....163
4.1.7 Non-geotechnical preparedness and response measures in Nanba and Pingtong under Pingwu County.....169
4.2 Case study area 2 -- Wenchuan County.....180
4.2.1 Wenchuan County – Gengda Township.....183
4.2.2 Wenchuan County – Gengda Township – Xingfu Village.. 187
4.2.3 Wenchuan County – Gengda Township – Longtan Village..... 195
4.2.4 Wenchuan County – Wolong Township 204
4.2.5 Wenchuan County – Wolong Township – Wolongguan Village..... 207
4.2.6 Non-geotechnical preparedness and response measures in Gengda and Wolong under Wenchuan County 222
4.3 Conclusions of the case study areas..... 231

Chapter 5 Results..... 232
5.1 Descriptive statistics.....232
5.1.1 Dependent variables.....232
5.1.2 Independent variables.....237
5.1.3 Summary and reflection.....275
5.2 Hypothesis 1.....277
5.2.1 Relocation decisions.....278
5.2.2 Demographic/Socioeconomic factors.....278
5.2.3 Relationship between demographic factors and respondents' decision to move or not.....279
5.2.4 Factors directly affecting the decision to move or not.....291
5.2.5 Results of Pingwu County and Wenchuan County.....291
5.2.6 Summary and reflection of Hypothesis 1 results.....297
5.3 Hypothesis 2.....300
5.3.1 Results of study area 1 – Pingwu County.....300
5.3.2 Summary of Hypothesis 2 results in Pingwu.....326
5.3.3 Results of study area 2 – Wenchuan County.....330
5.3.4 Summary of Hypothesis 2 results in Wenchuan.....350
5.3.5 Reflection of Hypothesis 2 results.....353

5.4 Hypothesis 3 353
5.4.1 Results of study area 1 – Pingwu County 354
5.4.2 Summary of Hypothesis 3 results in Pingwu 367
5.4.3 Results of study area 2 – Wenchuan County 371
5.4.4 Summary of Hypothesis 3 results in Wenchuan 388
5.4.5 Reflection of Hypothesis 3 results 391

Chapter 6 Discussion 393
6.1 Hypothesis 1 393
6.1.1 Introduction 393
6.1.2 Results from Pingwu and Wenchuan 393
6.1.3 Discussion of the results 397
6.1.4 Conclusions of Hypothesis 1 discussion 417
6.2 Hypothesis 2 420
6.2.1 Introduction 420
6.2.2 Results from Pingwu and Wenchuan 420
6.2.3 Discussion of the results 424
6.2.4 Conclusions of Hypothesis 2 discussion 453
6.3 Hypothesis 3 458
6.3.1 Introduction 458
6.3.2 Results from Pingwu and Wenchuan 460
6.3.3 Discussion of the results 467
6.3.4 Conclusions of Hypothesis 3 discussion 487

Chapter 7 Conclusions 489
7.1 Relocation decisions 490
7.2 Debris flow risk perceptions 492
7.3 Anticipated disaster responses 494
7.4 Implications for debris flow risk reduction and model development 497
7.4.1 Impact on vulnerability study 497
7.4.2 This research thesis and a model to explain the China context 498
7.5 Recommendations 501
7.5.1 Recommendations on influencing future risk perception and actual risk exposure 501
7.5.2 Recommendations on influencing future disaster response behaviour 504
7.5.3 Recommendations on evacuation 509
7.5.4 Recommendations on emergency practices 510
7.6 Scope and constraints of the research 510
7.6.1 From whom, how and when did the respondents become aware of government disaster risk reduction measures? 510
7.6.2 Perceived effectiveness of government disaster risk reduction measures 511

7.6.3 Impact of mitigation measures on vulnerability 512
7.6.4 Effectiveness of geotechnical engineering mitigation measures 512
7.6.5 Other research opportunities 513
7.7 Insights for future research 514
7.7.1 More research in the light of ethnicity and cultural characteristics 514
7.7.2 More research on governance and the role of other parties in the society in impacting vulnerability 515
7.7.3 More research on the impact of citizen science 515
7.8 Concluding remarks 515

Appendix 1 The pilot and the main surveys 516
Appendix 2 Further analysis on each ethnic group and the combination of factors influencing their moving decisions 538

References 542

List of Tables

Table 2.1 Four levels/scales of geohazard disaster threat in China

Table 3.1 The number of village, population and occupied areas of the four townships under Pingwu and Wenchuan counties

Table 4.1 Areas and populations of the two townships in Pingwu County
Table 4.2 Nine groups of Xinjian Village and their household numbers
Table 4.3 Basic situations of geohazard risk sites affecting Xinjian Village in 2015
Table 4.4 Potential threats of secondary geohazard risks in Niufei Village and disaster prevention/preparedness measures imposed by the government in 2010
Table 4.5 Investigation, examination, design of engineering mitigation and management imposed (for emergency risk reduction) on geohazards in Niufei Village and effectiveness review
Table 4.6 Total number of geohazard risk sites on different levels of jurisdiction in year 2010 and 2016 respectively
Table 4.7 Proposed preventive and mitigation measures for all geohazards risk sites in Pingwu County in 2014
Table 4.8 Geohazard risk sites threatening Xinjian Village in 2015/16 and the disaster monitor and prevention measures proposed and imposed by the government
Table 4.9 Household number and population of Xingfu Village in 2015/16
Table 4.10 Potential threats of debris flows in Xingfu Village in 2010
Table 4.11 Basic situations of geohazard risk sites affecting Xingfu Village in 2016
Table 4.12 Debris flows found in Xingfu Village in year 2010 and 2016 respectively
Table 4.13 Household number and population of Longtan Village in 2016
Table 4.14 Potential threats of debris flows in Longtan Village in 2010
Table 4.15 Basic situations of geohazard risk sites affecting Longtan Village in 2016
Table 4.16 Debris flows found in Longtan Village in year 2010 and 2016 respectively
Table 4.17 Household number and population of Wolongguan Village in 2013
Table 4.18 Potential threats of debris flows in Wolongguan Village in 2010
Table 4.19 Basic situations of geohazard risk sites affecting Wolongguan Village in 2016
Table 4.20 Debris flows found in Wolongguan Village in year 2010 and 2016 respectively
Table 4.21 Total number of geohazard risk sites on different levels of jurisdiction in year 2010 and 2016 respectively

Table 5.1 Summary statistics of the 12 demographic variables in the two study areas

Table 5.2 Mean age, standard deviation and standard error of Pingwu and Wenchuan respondents
Table 5.3 Population and distribution of selected ethnic groups in China and Sichuan
Table 5.4 Educational attainment of population in China and Sichuan (aged 6 and above)
Table 5.5 Mean household size, standard deviation and standard error of respondents in the two counties
Table 5.6 Distribution of agricultural and non-agricultural registered permanent residence population in China and Sichuan
Table 5.7 25 Likert items measured in five groups
Table 5.8 Mean, standard deviation and standard error of substantial debris flow perception
Table 5.9 Relationship between Pingwu respondents' demography and their decision to move or not
Table 5.10 Factors associated with moving decision in Pingwu
Table 5.11 Relationship between Wenchuan respondents' demography and their decision to move or not
Table 5.12 Factor associated with moving decision in Wenchuan
Table 5.13 25 Likert items measured in five constructs
Table 5.14 Statistical relationships between each demographic/socioeconomic factor and existing community debris flow risk perception in Pingwu
Table 5.15 Demographic/Socioeconomic variables having statistical significant relationships with perception of existing community debris flow threat in Pingwu
Table 5.16 Statistical relationships between Pingwu respondents' perceptions of each of the seven substantial debris flow characteristics and their perceptions of existing community debris flow threat
Table 5.17 Statistical relationships between Pingwu respondents' awareness of / accessibility to each government disaster preparedness measure and their perceptions of existing community debris flow threat
Table 5.18 Statistical relationships between Pingwu respondents' awareness of / accessibility to each government disaster response measure or facility and their perceptions of existing community debris flow threat
Table 5.19 Relation between early warning tools awareness and debris flow risk perception
Table 5.20 Statistical relationships between each demographic/socioeconomic factor and existing community debris flow risk perception in Wenchuan
Table 5.21 Statistical relationships between Wenchuan respondents' perceptions of each of the seven substantial debris flow characteristics and their perceptions of existing community debris flow threat
Table 5.22 Statistical relationships between Wenchuan respondents' awareness of / accessibility to each government disaster preparedness measure and their perceptions of existing community debris flow threat

Table 5.23 Statistical relationships between respondents' awareness of / accessibility to each government disaster response measure or facility and their perceptions of existing community debris flow threat – Pingwu VS Wenchuan
Table 5.24 Statistical relationships between each demographic/socioeconomic factor and anticipated disaster responses in Pingwu
Table 5.25 Statistical relationships between each non-demographic factor and anticipated disaster responses in Pingwu
Table 5.26 Statistical relationships between Pingwu respondents' awareness of / accessibility to each government disaster preparedness measure and their anticipated disaster responses
Table 5.27 Statistical relationships between Pingwu respondents' awareness of / accessibility to each government disaster response measure or facility and their anticipated disaster responses
Table 5.28 Statistical relationships between each demographic/socioeconomic factor and anticipated disaster responses in Wenchuan
Table 5.29 Statistical relationships between each non-demographic factor and anticipated disaster responses in Wenchuan
Table 5.30 Statistical relationships between Wenchuan respondents' awareness of / accessibility to each government disaster preparedness measure and their anticipated disaster responses
Table 5.31 Statistical relationships between Wenchuan respondents' awareness of / accessibility to each government disaster response measure or facility and their anticipated disaster responses

Table 6.1 Factors that could positively or negatively affect existing community debris flow risk perceptions in Pingwu and Wenchuan
Table 6.2 Respondents' awareness of community imposition of the five early warning tools in the two counties
Table 6.3 Population of Sichuan and number of phone users from year 2015 to 2020
Table 6.4 Factors that could affect anticipated disaster responses when see debris flow signs at home – a comparison of Pingwu and Wenchuan
Table 6.5 Relations between perception of substantial debris flow and anticipated disaster responses among Wenchuan respondents
Table 6.6 Relations between disaster preparedness measures awareness or accessibility and anticipated disaster responses among Pingwu respondents
Table 6.7 Relations between disaster preparedness measures awareness or accessibility and anticipated disaster responses among Wenchuan respondents
Table 6.8 Relations between disaster response measures awareness or accessibility and anticipated behaviour among Pingwu respondents
Table 6.9 Relations between disaster response measures awareness or accessibility and anticipated behaviour among Wenchuan respondents

List of Figures

Figure 2.1 Relations among demographic factors, social vulnerability and disaster recovery
Figure 2.2 Landslide early warning websites in the USA and Japan
Figure 2.3 Geohazard early warning website by Ministry of Natural Resources, China
Figure 2.4 Sichuan geological environment information site

Figure 3.1 The five constructs composed of 25 Likert items that might affect the decision to move or not
Figure 3.2 Possible factors associated with perception of existing community debris flow risk
Figure 3.3 Possible factors associated with anticipated behavioural response when see debris flow signs at home

Figure 4.1 Earthquake intensity of the M8.0 Wenchuan earthquake in year 2008 by China
Figure 4.2 Earthquake intensity of the M7.9 Wenchuan earthquake in year 2008 by the USA
Figure 4.3 Structure of government affiliation of the two study areas -- Pingwu and Wenchuan
Figure 4.4 Location of Pingwu County
Figure 4.5 Landscape and terrain of Pingwu County
Figure 4.6 Full view of Nanba Township Centre on the right coast of Fu Jiang
Figure 4.7 View of Longmenshan from Group 4, Xinjian Village, Nanba Township
Figure 4.8 Xingping Gully - A view from afar
Figure 4.9 Xingping Gully - A closer look at the source
Figure 4.10 Satellite photo (upper) and Geological map (lower) of the Xingping Gully area
Figure 4.11 Satellite map showing source materials and gullies of Xingping Gully Debris Flow
Figure 4.12 Satellite images of Xinjian Village by Google Maps and USGS
Figure 4.13 Farmlands are precious
Figure 4.14 Many Xinjian villagers plant their farms on steep slopes near their houses. Some raise livestock and poultry for private use or for sale
Figure 4.15 Houses in Shicouzi affected by Xingping Gully Debris Flow in August 2010
Figure 4.16 Debris accumulated at the Settlement Site of Xinjian Village
Figure 4.17 A comparison of the environments of Shicouzi before and after the concrete levee was built
Figure 4.18 A comparison of the environments of the Settlement Site before and after the concrete levee was built
Figure 4.19 View of Xingping Gully’s debris flow mitigation measures from uphill

Figure 4.20 Source materials for debris flow in different locations in Xinjian Village before the conduct of the survey
Figure 4.21 Various places in the downstream of Xingping Gully are still exposed to debris flow risk
Figure 4.22 Some houses in the midstream of the Xingping Gully catchment area, though not next to gullies, are fragile to landslip and debris flow
Figure 4.23 Full view of Pingtong Township Centre
Figure 4.24 Many Niufei villagers relocated from uphill to flatland along the road to avoid geohazard risks induced by the 2008 earthquake
Figure 4.25 Huanglianshu Gully Debris Flow and mitigation measures
Figure 4.26 Source of Huanglianshu Gully Debris Flow
Figure 4.27 Satellite map showing an overview of Niufei Village, surrounding landscape, Huanglianshu Gully Debris Flow, its source materials and affected areas
Figure 4.28 Geotechnical mitigation measures to tackle debris flows along Huanglianshu Gully
Figure 4.29 Farmlands and residences still close to Huanglianshu Gully which might induce geohazard risks
Figure 4.30 Some sediment trap dams along Huanglianshu Gully are almost filled up
Figure 4.31 Zone Map of Geohazard Prevention and Mitigation of Pingwu County
Figure 4.32 Sample of Geohazard Monitoring Notebook of Pingwu County
Figure 4.33 Audio system and speakers readily available at the Niufei Village government office building to provide early warning
Figure 4.34 Geohazard Prevention and Protection Plans 2016 prepared by Pingwu County and Nanba Township governments
Figure 4.35 One Table, Two Cards
Figure 4.36 Pingtong Township Geohazard Emergency Response Plan
Figure 4.37 Training offered by Pingtong Township on geohazard prevention, mitigation and monitoring in 2015 in preparation for the upcoming flooding season; The training kit
Figure 4.38 Drills arranged by Pingtong Township Government
Figure 4.39 Distribution of M8.0 Wenchuan earthquake aftershocks of M4.0 above
Figure 4.40 Geographical location of Wenchuan County and Wolong National Nature Reserve, Gengda and Wolong Townships
Figure 4.41 Location of Gengda Township, Wolong Township and Yingxiu Township, and the distances among them
Figure 4.42 Satellite map showing an overview and landscape of Gengda Township with its three villages
Figure 4.43 Post 2008 earthquake Residential Settlement Plan of Gengda Township
Figure 4.44 Central area of Gengda Township along Provincial Road 303

Figure 4.45 Local people selling souvenirs and food opposite to the main entrance of the Panda Centre
Figure 4.46 Satellite map showing an overview of the Xingfu Village, the debris flow gullies nearby and its adjacent Panda Centre
Figure 4.47 Geotechnical mitigation measures constructed upstream of Xingfu Village
Figure 4.48 The biggest sediment blockage dam in Wolong SAR provides protection for Xingfu Village and the Panda Centre
Figure 4.49 The closeness among Xingfu Village, the Panda Centre and the surrounding gullies
Figure 4.50 Various parts of Xingfu Gully during regular rain
Figure 4.51 Satellite map showing the overview of Longtan Village, its Concentrated Settlement Sites (CSS) and Cangwang Gully
Figure 4.52 Old houses on mid-hill serve as warehouses for farm produce or pigsty
Figure 4.53 Narrow rainwater drainage channels and levees in different parts of Longtan Village adjacent to houses
Figure 4.54 Landslips in Longtan Village area
Figure 4.55 Houses exposed to geohazard and flooding risks in Longtan Village area
Figure 4.56 The three villages under the administrative jurisdiction of Wolong Township
Figure 4.57 Central area of Wolong Township along Provincial Road 303
Figure 4.58 Satellite map showing an overview and landscape of Wolong Township with its three villages
Figure 4.59 Motels along Provincial Road 303 for tourists
Figure 4.60 Entrance of Wolongguan Village on Provincial Road 303
Figure 4.61 Satellite map and photos showing an overview of Wolongguan Village, its four groups, Shaotang River and Provincial Road 303
Figure 4.62 Farming in Wolongguan Village
Figure 4.63 A hotel near the eastern entrance of Wolongguan Village
Figure 4.64 The four groups of Wolongguan Village and the gullies affecting them
Figure 4.65 Satellite map showing the catchment area of Wolongguan Gully
Figure 4.66 Geohazard threats persist around Wolongguan Gully
Figure 4.67 Satellite map showing the catchment area of Xiushui Gully
Figure 4.68 Geoengineering measures imposed on Xiushui Gully
Figure 4.69 Signage showing the debris flow threat and the evacuation route
Figure 4.70 Debris flow outburst in Xiongmao Gully
Figure 4.71 Signage of “Liaojiadadi Debris Flow and Rockfall Geohazard Potential Risk Site”
Figure 4.72 Immediate actions of the monitoring personnel
Figure 4.73 Special roster on a rainy summer day
Figure 4.74 Gengda Xiang Geohazard Prevention and Protection Plans

Figure 4.75 Wolong Township Geohazard Prevention and Protection Plans
Figure 4.76 One Table, Two Cards
Figure 4.77 Understanding Card posted outside a house
Figure 4.78 Handbooks on disaster prevention and protection
Figure 4.79 Wolong Township Geohazard Emergency Response Plans
Figure 4.80 Signs showing the numbers of debris flow threatened population and evacuation routes
Figure 4.81 Dissemination of geohazard risk reduction measures in a public area by posters
Figure 4.82 Disaster Preparedness Warehouse in Wolong Township Government Building

Figure 5.1 The decision of moved / not moved of all Pingwu respondents
Figure 5.2 The decision of moved / not moved of all Wenchuan respondents
Figure 5.3 Perception of existing community debris flow threat in Pingwu
Figure 5.4 Perception of existing community debris flow threat in Wenchuan
Figure 5.5 Anticipated disaster response of Pingwu respondents when see signs of debris flow at home
Figure 5.6 Anticipated disaster response of Wenchuan respondents when see signs of debris flow at home
Figure 5.7 Gender distribution of respondents in the two counties
Figure 5.8 Age distribution of respondents in the two counties
Figure 5.9 Ethnicity distribution of respondents in the two counties
Figure 5.10 Distribution of respondents' educational attainment in the two counties
Figure 5.11 Distribution of respondents' Chinese literacy in the two counties
Figure 5.12 Distribution of respondents' knowledge of Putonghua in the two counties
Figure 5.13 Distribution of respondents' household size in the two counties
Figure 5.14 Distribution of respondents' annual per capita net income in the two counties
Figure 5.15 Distribution of respondents' occupation before the Wenchuan earthquake in the two counties
Figure 5.16 Distribution of respondents' occupation after the Wenchuan earthquake in the two counties
Figure 5.17 Distribution of whether respondents performed any position or role in their villages in the two counties
Figure 5.18 Distribution of respondents' length of stay in the community per year in the two counties
Figure 5.19 Community and personal experience of debris flow
Figure 5.20 Community, home and personal experience of debris flow
Figure 5.21 Perception of substantial debris flow
Figure 5.22 Knowledge of debris flows (Score 0 to 4)
Figure 5.23 Perception of remoteness of communities
Figure 5.24 Perception of remoteness of homes

Figure 5.25 Awareness of geotechnical engineering measures introduced in the communities
Figure 5.26 Awareness of / Accessibility to government disaster preparedness measures
Figure 5.27 Awareness of / Accessibility to government disaster response measures and facilities
Figure 5.28 Perception of existing debris flow threat on homes
Figure 5.29 Relation between Pingwu respondents' ethnicity and their decision to move or not
Figure 5.30 Relation between Pingwu respondents' educational attainment and their decision to move or not
Figure 5.31 Relation between Pingwu respondents' occupation after the Wenchuan earthquake and their decision to move or not
Figure 5.32 Relation between Pingwu respondents' length of stay in the community per year and their moving decision
Figure 5.33 Factors associated with moving decision in Pingwu
Figure 5.34 Relation between Wenchuan respondents' ethnicity and their decision to move or not
Figure 5.35 Factor associated with moving decision in Wenchuan
Figure 5.36 Effect of the five non-demographic constructs on Pingwu and Wenchuan respondents' decision to move or not
Figure 5.37 Relationship between Pingwu respondents' age and their perception of existing community debris flow threat
Figure 5.38 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their age
Figure 5.39 Relationship between Pingwu respondents' ethnicity and their perception of existing community debris flow threat
Figure 5.40 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their ethnicity
Figure 5.41 Relationship between Pingwu respondents' occupation after the Wenchuan earthquake and their perception of existing community debris flow threat
Figure 5.42 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their occupation after Wenchuan earthquake
Figure 5.43 Relationship between village affiliation of Pingwu respondents and their perception of existing community debris flow threat
Figure 5.44 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their village affiliation
Figure 5.45 Relationship between debris flow experience of Pingwu respondents and their perception of existing community debris flow threat
Figure 5.46 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their debris flow experience

Figure 5.47 Relationship between Pingwu respondents' perception of remoteness of their communities and their perception of existing community debris flow threat
Figure 5.48 Boxplot showing distribution of Pingwu respondents' debris flow risk perception in relation to their perception of community remoteness
Figure 5.49 Relationship between Pingwu respondents' awareness of geotechnical engineering measures introduced in community and their perception of existing community debris flow threat
Figure 5.50 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their awareness of geotechnical measures
Figure 5.51 Relationship between Pingwu respondents' awareness of four early warning disaster response measures in the community and their perception of existing community debris flow threat
Figure 5.52 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their awareness of four early warning tools applied in their communities
Figure 5.53 Factors associated with Pingwu respondents' perceptions of existing community debris flow threat (among all other tested but non-associated factors marked in white)
Figure 5.54 Factors associated with Pingwu respondents' perceptions of existing community debris flow threat
Figure 5.55 Relationship between Wenchuan respondents' ethnicity and their perception of existing community debris flow threat
Figure 5.56 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their ethnicity
Figure 5.57 Relationship between village affiliation of Wenchuan respondents and their perception of existing community debris flow threat
Figure 5.58 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their village affiliation
Figure 5.59 Relationship between debris flow experience of Wenchuan respondents and their perception of existing community debris flow threat
Figure 5.60 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their debris flow experience
Figure 5.61 Relationship between whether the Wenchuan respondents had heard of MMMP and their perception of existing community debris flow threat
Figure 5.62 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their awareness of MMMP
Figure 5.63 Relationship between Wenchuan respondents' accessibility to Card or Table and their perception of existing community debris flow threat

Figure 5.64 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their accessibility to the Card or Table
Figure 5.65 Relationship between Wenchuan respondents' awareness of using gong for debris flow early warning in community and their perception of existing community debris flow threat
Figure 5.66 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their awareness of gong
Figure 5.67 Relationship between whether the Wenchuan respondents were monitoring personnel and their perception of existing community debris flow threat
Figure 5.68 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to whether they were monitoring personnel
Figure 5.69 Factors associated with Wenchuan respondents' perceptions of existing community debris flow threat (among all other tested but non-associated factors marked in white)
Figure 5.70 Factors associated with Wenchuan respondents' perceptions of existing community debris flow threat
Figure 5.71 Relations between Pingwu respondents' age and their anticipated disaster responses
Figure 5.72 Relations between Pingwu respondents' role in village and their anticipated disaster responses
Figure 5.73 Relations between Pingwu respondents' awareness of / accessibility to each government disaster preparedness measure and their anticipated disaster responses
Figure 5.74 Relations between Pingwu respondents' accessibility to / awareness of each government disaster response measure or facility and their anticipated disaster responses
Figure 5.75 Factors associated with Pingwu respondents' anticipated behavioural responses when see debris flow signs at home (among all other tested but non-associated factors marked in white)
Figure 5.76 Factors associated with Pingwu respondents' anticipated behavioural responses when see debris flow signs at home
Figure 5.77 Relations between Wenchuan respondents' occupation after Wenchuan earthquake and their anticipated disaster responses
Figure 5.78 Relations between Wenchuan respondents' role in village and their anticipated disaster responses
Figure 5.79 Stacked columns showing three aspects of perceptions of substantial debris flow and their respective relations with anticipated disaster responses when respondents in Wenchuan see debris flow signs at home (N = 363)
Figure 5.80 Relations between Wenchuan respondents' perception of remoteness of home and their anticipated disaster responses

Figure 5.81 Relations between Wenchuan respondents' awareness of government disaster mitigation (engineering) measures and their anticipated disaster responses
Figure 5.82 Relations between Wenchuan respondents' awareness of / accessibility to each government disaster preparedness measure and their anticipated disaster responses
Figure 5.83 Relations between Wenchuan respondents' accessibility to / awareness of each government disaster response measure or facility and their anticipated disaster responses
Figure 5.84 Factors associated with Wenchuan respondents' anticipated behavioural responses when see debris flow signs at home (among all other tested but non-associated factors marked in white)
Figure 5.85 Factors associated with Wenchuan respondents' anticipated behavioural responses when see debris flow signs at home

Figure 6.1 Factors that could affect Pingwu respondents' decision to move or not
Figure 6.2 Factors that could affect Wenchuan respondents' decision to move or not
Figure 6.3 Factors that could affect Pingwu and Wenchuan respondents' decision to move or not
Figure 6.4 Relations among people, place, culture and behaviour
Figure 6.5 Han flags and historical monuments in Nanba Township centre
Figure 6.6 A huge dam uphill of Xingfu village in Wenchuan
Figure 6.7 Artificial step pools along the gully downstream
Figure 6.8 Factors that could affect respondents' existing community debris flow risk perceptions
Figure 6.9 Farmlands on slopes in Pingwu
Figure 6.10 A sediment trap dam filled up with debris flowed from upstream
Figure 6.11 Development and situation of landline and mobile phones penetration rate from 1949 to 2020 in China
Figure 6.12 Factors that could affect anticipated disaster responses when see debris flow signs at home

Figure 7.1 A model on the impacts of government disaster risk reduction measures on rural populations' relocation decisions, risk perceptions and disaster responses
Figure 7.2 Recommendations on how to enhance disaster response capacities of rural residents based on the findings from the two study areas

Acronyms

AAL	Annual Average Loss
CSI	China Seismic Information
CSS	Concentrated Settlement Sites
GDP	Gross Domestic Product
HOP Model	Hazards of Place Model
IPCC	Intergovernmental Panel on Climate Change
JMA	Japan Meteorological Agency
MMMP	Mass Monitoring and Mass Prevention
MLR	Ministry of Land and Resources
NBSC	National Bureau of Statistics of China
NGO	Non-governmental organisation
PAR Model	Pressure And Release Model
PW	Pingwu
PADM	Protective Action Decision Model
RMB	Renminbi
SGIO	Sichuan Geological Investigations Office
UNDRR	United Nations Office for Disaster Risk Reduction
UNISDR	United Nations International Strategy for Disaster Reduction
USD	United States Dollar
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USGS	United States Geological Survey
WC	Wenchuan
WMO	World Meteorological Organization
Wolong SAR	Wolong Special Administrative Region

Chapter 1
Introduction, Research Objectives and Hypotheses

1.1 Introduction

The Wenchuan earthquake occurred in Sichuan, China, on 12 May 2008 ("the 2008 earthquake"). It induced numerous secondary geological hazards, dominated by various forms of landslide. As of 24 June 2008, official records revealed the existence of 12,536 geohazards, including 1,054 debris flows (NPC 2008). An official estimation in September 2008 showed that there were 8,700 potential risk sites after the Wenchuan earthquake (SCIO 2008). The impacts were particularly severe in remote mountainous regions, where many of the rural settlements of Sichuan Province are located.

The 2008 earthquake is described by the former Chinese President Hu Jintao as the most devastating and widespread earthquake disaster since the establishment of the new China (Hu 2008). After the 2008 earthquake, under the leadership and request of the Central Government, all levels of government in Sichuan have invested many resources and efforts in rehabilitation, mitigation and disaster preparedness works with the aim of assisting the affected populations in resuming their normal lives and preparing them for any future earthquake and secondary geohazards such as debris flows that might be triggered.

In view of the damages caused by such secondary geohazards and their huge potential risk of occurrence in the future, the Chinese Central Government has captured the post-disaster policy windows (Kingdon 2011; Solecki and Michaels 1994) to lower vulnerability through mitigation (Alexander 2000, 2002). In the interests of implementing risk avoidance measures to protect the residents, the government has introduced new regulations and new legal requirements, and amended existing laws on rehabilitation site selection.

The State Council (2008a) has promulgated the regulations for the post-Wenchuan earthquake rehabilitation and reconstruction, which addresses the planning and implementation of the reconstruction works. In particular, the regulations stipulate that reconstruction site selection should avoid seismic fault zones and areas with

huge potential disasters, while for those towns and villages which require relocation, seismic fault zones and potential areas of geohazard are to be avoided. This shows the Government's intention of applying legal controls after the 2008 earthquake as risk avoidance measures by ensuring that the sites selected are not affected by potential geohazards and thus preventing damage and losses to the residents.

If the residents resided in relatively unstable geohazard risk sites or with high susceptibility, or if the threat pertained to a small number of people, was difficult to mitigate or required high mitigation costs, the government would arrange relocation. Based on such criteria, only a relatively small number of people have been required to relocate. For instance, in one county, Pingwu, only 15 sites distributed in 11 townships involving 72 people in 24 households fall into this category (SGIO 2015a).

In reality, it is impossible to eliminate all risks and protect the general public from all potential geohazards. For areas where risks are unacceptable, risk avoidance measures like those mentioned above are required. For other areas where risks are tolerable, disaster mitigation, preparedness and response measures aiming at risk reduction are to be performed in order to influence risk perception and behaviour so as to reduce the vulnerability of the populations involved.

Aiming to enhance rural populations' risk awareness towards geohazards, the Government has put much effort in implementation, promotion and education of disaster risk reduction measures on a community level.

According to the Sichuan Geological Investigations Office (SGIO), some of the most common geohazard risk reduction measures include: (a) relocation and risk avoidance, (b) engineering mitigation and management, (c) monitoring and early warning, and (d) risk reduction in emergency situations and normal times (SGIO 2015a). The criteria for imposing and applying different kinds of measures to tackle geohazard risk at a certain site were explicitly listed out, including the scale of the geohazard, risk level, stability of the geohazard, the number of people and properties affected or threatened, concentration of settlements, availability of time, frequency of geohazard triggering factors, cost of mitigation, resources available and impact on the community (SGIO 2015a).

Studies show that government or political influences have crucial impact on other post-earthquake recovery experiences (Alexander 2012a). Similarly, in China, imposition of the above mentioned preventive and mitigation measures, together with disaster preparedness and response training or promotion has been part of the major works of the Chinese authorities after the 2008 earthquake. To date, comprehensive investigations and evaluations of such government disaster risk reduction measures in alleviating vulnerability of the risk affected populations are limited.

In fact, populations, especially those living in remote rural mountainous regions in China where negative impacts of secondary geohazards were particularly serious after earthquakes, have seldom been the targets of academic studies. Even less attention has been given to disaster risk reduction measures specifically adopted to tackle secondary geohazards induced by the Wenchuan earthquake.

1.2 Objectives of the research

The main objective of this thesis, therefore, is to investigate the post-2008 Wenchuan earthquake debris flow risk and subsequent disaster risk reduction measures introduced by the government. This thesis evaluates the effectiveness of government directives, disaster mitigation, preparedness and response measures in two study areas. Whether and to what extent they were effective in reducing rural residents' exposure to secondary geohazard risks by affecting their relocation decisions, as well as influencing risk perceptions and future disaster response behaviour are the foci of this study.

Those governmental disaster mitigation, preparedness and response measures imposed on the remote mountainous areas where earthquake-induced secondary geohazard risks are tolerable but needed to be managed after the 2008 earthquake are of particular interest. Such evaluation involves the testing of whether or how the vulnerability indicators in existing vulnerability models can be applied to the remote mountainous regions of rural China.

Based on field investigations, information and documentations gathered, as well as data collected through a survey on the case study areas, this thesis explores, compares and evaluates the effectiveness of government measures in five villages in two counties with respect to three major aspects of the Chinese context:-

(i). Mitigation directives in terms of rehabilitation site selection and disaster risk reduction efforts designed to avoid potential debris flow risk exposure encountered by the affected populations. This involves the analysis of whether and how different types of vulnerability together with political influences (Alexander 2012a) and other factors had affected residents' post-earthquake relocation decisions.

(ii). After the Wenchuan earthquake, disaster mitigation, preparedness and response measures were imposed by the government to the populations influenced by the earthquake. The effectiveness of such measures and impact of other factors in affecting their debris flow risk perceptions are evaluated.

(iii). By imposing disaster mitigation, preparedness and response measures, the government hoped to shape the disaster response behaviour of the geohazard affected populations. The impact of such government disaster risk reduction measures in the study areas on anticipated behaviour is also evaluated.

It is hoped that the findings of this study can provide recommendations for the Chinese directives and measures in order to encourage their improvement and influence future relocation decisions, to influence the risk perceptions of the populations exposed to earthquake-induced secondary geohazard risks and also to assist their disaster response behaviour in the interests of reducing their vulnerability.

On top of the Government's initiatives, this research seeks to find out what other factors might have affected the relocation decisions, risk perceptions and disaster response behaviour of the populations threatened by debris flows. These evaluations help to analyse and characterise the risk of earthquake-induced secondary geohazards facing the rural populations.

1.3 Hypotheses of the research

The scope of this thesis is defined with three hypotheses. Three hypotheses were set and tested to ascertain whether the government directives and disaster risk reduction measures were effective in affecting relocation decisions, risk perceptions and disaster responses and whether they varied in different case-study areas.

1.3.1 Hypothesis 1

When making relocation decisions after the Wenchuan earthquake, among the rural populations there was a lack of consideration of institutional directives and disaster risk reduction measures.

The driving forces that in combination created this situation of inertia were mainly ethnical, cultural, geographical, in supplement with socioeconomic, personal competency and political. This hypothesis refers to conditions during the eight years that elapsed between the 2008 Wenchuan earthquake and the time of the survey.

1.3.2 Hypothesis 2

The rural populations living in remote mountainous areas have developed perceptions of geological risk that are now generally more advanced than the measures for disaster mitigation, preparedness and response imposed by the government since the earthquake.

There is nevertheless a possible perception gap between intuition and objective reality. Intuition may cause inaccurate picture of the situation while government measures involve expert judgement.

1.3.3 Hypothesis 3

Disaster response behaviour of the rural populations living in remote mountainous regions of Sichuan is affected by their awareness of government disaster risk reduction measures.

The government had imposed a whole range of disaster risk reduction measures tending to influence, change or shape rural residents' future disaster responses.

Human behaviour, however, could be affected by demographic and/or non-demographic factors other than government measures.

Results from the three hypotheses together can give insights to the overall impact of government risk reduction measures on relocation behaviour, risk perceptions and disaster responses.

1.4 Significance of the research

This research is significant to the academic discipline, to the disaster affected populations, and also to the policymakers.

Firstly, with reference to analysing and characterising the earthquake-induced secondary geohazard risk facing the rural populations and the subsequent government directives and disaster risk reduction measures imposed, evaluations of their effectiveness in impacting relocation decisions, risk perceptions and disaster behaviour covered by this thesis can serve as demonstrations of the country's ability to manage potential earthquake-induced debris flow risk and the effectiveness of the measures that it has propounded.

Secondly the exploration of explanations behind the effectiveness of the post-2008 earthquake government disaster risk reduction initiatives in rural remote Sichuan can help the policymakers to understand the characteristics and attitudes of the debris flow affected residents. With such understanding, more suitable and effective risk reduction measures can be tailor-made for the targeted populations.

Thirdly, this thesis investigates whether variations of impacts of such factors in the two study areas have caused different relocation decisions, risk perceptions and anticipated disaster responses. Both study areas lie on the two ends of Yingxiu-Beichuan Fault of Longmenshan Fault Zone which movement had caused the Wenchuan earthquake (Wen 2011) and experienced the highest earthquake intensity (CSI 2008). However, these two counties used for comparison have different socioeconomic characteristics and caught different levels of attention after the quake. Reasons behind the similarities or differences of the relocation decisions, risk perceptions and disaster responses of respondents of the two

counties, such as social, economic, cultural and political influences as well as debris flow history, are explained. The different explanations for any variations in the effectiveness of the government initiatives in the two counties can serve as references for other areas facing similar geohazard risk but with different conditions.

Fourthly, evaluations from the study areas can be referred in more general conditions, i.e. the relocation decisions, debris flow risk perceptions and disaster responses of populations of other remote mountainous regions in Sichuan or even other provinces in western or southwestern China with similar topography and affected by earthquake-induced debris flows, such as Yunnan, Guizhou, Gansu and Shaanxi. The findings can provide references to these provinces on the effectiveness of various debris flow directives, mitigation, preparedness and response measures. By doing so, the geohazard risk management practices in China can be improved. Any lessons learnt from this thesis can also be applied, with appropriate modifications, to other remote mountainous regions outside China affected by earthquake-induced debris flows.

Fifthly, this research utilises existing vulnerability models and analytical frameworks in evaluating the indicators and factors affecting relocation, perception and behaviour. An exploration of relationship between social vulnerability indicators and reconstruction behaviour further allows this thesis to provide an alternative perspective to disaster studies. The findings of this research can help to examine the applicability of these indicators and models to the Chinese context. Through testing the vulnerability indicators both included and excluded in existing vulnerability models, the research results can help refine the models and fill in some empirical and theoretical gaps not covered by existing literatures.

1.5 Theoretical contribution of the research

By studying villages in remote mountainous areas, this research study investigates the effectiveness of the disaster mitigation, preparedness, response measures and directives imposed by the government after the Wenchuan earthquake and the related vulnerability. Existing literatures reveal that this part of knowledge in the disaster risk reduction discipline concerning remote parts of China, or simply China, is so far underexplored. Previous academic research has not accessed the type of

information and data being covered and studied in this research. Vulnerability in relation to earthquake-induced debris flow hazards, and particularly those occurred in rural China, had not yet been tested by the existing models.

Instead of applying any single model which were all developed in the western academic world to explain the vulnerability of communities in post-earthquake rural China, this thesis takes account of existing models and their indicators as inspirations, and evaluates the effectiveness of disaster mitigation, preparedness and response measures. Through case studies, the thesis measures and compares the impacts of such government disaster risk reduction measures on the study areas.

The ultimate goal of this thesis is to develop and create a tailor-made, new model based on the findings in remote mountainous regions of China to explain how people made their relocation decisions, perceived debris flow risk and how they would behave when reacting to future debris flows. How and to what extent the disaster mitigation, preparedness and response measures imposed by the government, and various dimensions of vulnerability such as socioeconomic status etc. might relate to or impact risk perceptions and disaster behaviour are explored. The possible relation between debris flow risk perception and responding behaviour was also evaluated. In addition, whether and to what extent the different dimensions of vulnerability affected the relocation decisions are analysed.

The grounded theory (Glaser and Strauss 1967; Strauss and Corbin 1998) provided inspirations to this thesis as well. This thesis first presents relevant previous theories or models. Based on these, data were collected and analysed, results were given, and an additional theory or model is derived and developed. In this process, the previous theories or models situated the thesis and the empirical work. Some important themes identified are highlighted in the discussion chapter and presented in the conclusions, contribute to theoretical development and can stimulate further research.

In terms of theoretical contribution, hopefully the newly created model which based on Chinese experiences, can be of interest and useful for future studies about debris flow in other mountainous regions, and can be applied to other parts of the

world, especially those with similar physical, social, economic and political characteristics. Ultimately, it is hoped that the new model can contribute to vulnerability study, especially through the study of the means affecting post-disaster relocations, risk perceptions and disaster responses.

From a practical point of view, it is hoped that the purpose of improving the current risk management applied in Sichuan in order to alleviate vulnerability can be achieved.

1.6 Structure of the research thesis

There is a total of seven chapters in this thesis.

Chapter 1 is the Introduction. It gives a brief description of the 2008 Wenchuan earthquake and the secondary geohazards the earthquake induced, and led to the objective and significance of this research project. This is followed by an articulation of the theoretical contribution of this research and how to explore it within the thesis. The three hypotheses are stated.

Literature review is in Chapter 2. Literature review on debris flow in general and in China, and after the Wenchuan earthquake, as well as disaster risk reduction are illustrated. Another section focuses on vulnerability. It includes a discussion of theoretical development of vulnerability research, the concept and the multi-dimensions of vulnerability. Through reviewing existing vulnerability models, which model, or which aspects of the models, are most useful to the field situation of this research is concluded. This involves an explanation of vulnerability indicators application and how advances in theoretical understanding can be achieved.

Chapter 3 describes the methodologies used in data collection and data analysis. This includes a detailed account of the questionnaire survey design used to collect the core part of data in this research, the administering of the questionnaire in the field, and analytical techniques applied to the results.

Chapter 4 introduces the study areas. A thorough description of the selected fieldwork areas which involve five villages from two counties is provided. Both the

geotechnical and non-geotechnical risk reduction measures imposed by the government after the Wenchuan earthquake are introduced and illustrated.

Chapter 5 presents the data analysis results aiming to test the three hypotheses. Descriptive statistics of both the dependent and independent variables of the three hypotheses are first presented. This is followed by the statistical analysis of associations between each independent and dependent variable through Chi-square tests of independence (Chi-square tests), Yates' corrections, T-tests, Mann-Whitney *U* tests and Spearman's *Rs*. Comparisons of the two study areas, Pingwu and Wenchuan, are illustrated.

Discussions take place in Chapter 6. This chapter explores the significance of the results. It revisits the literature and reveals what this study has added to current literatures. Explanations of the statistical results are also given in this chapter.

Chapters 5 and 6 are the core part of the thesis. Hypothesis 1 is tested. It starts by discussing the imposition of mitigation planning in terms of rehabilitation site selection after the Wenchuan earthquake. In order to protect the rural residents, according to the government, residential housing reconstruction site selection and relocation should avoid areas with huge potential disaster risk, including debris flow. Despite all the five villages in this research were affected or threatened by the Wenchuan earthquake, debris flows and other earthquake-induced geohazards, some survey respondents decided to move after the earthquake but some did not. Factors affecting their relocation decisions are identified, evaluated and explained. These involve an examination on whether or to what extent government directives and risk reduction measures regarding rural residential housing site selection were considered and effective.

Hypothesis 2 and 3 are also addressed. Chapters 5 and 6 discuss the various kinds of disaster mitigation, preparedness and response measures carried out by the government to reduce debris flow risk exposure and vulnerability of the rural populations in the study areas through various channels after the 2008 earthquake.

Increasing provision of disaster risk reduction measures, however, does not necessarily imply an alleviation of risk exposure and vulnerability. Therefore,

effectiveness of such measures is examined through the evaluation of risk perceptions and anticipated disaster responses of the rural populations after those measures were imposed. Through testing Hypotheses 2 and 3 on the impact of disaster risk reduction measures on debris flow risk perceptions and anticipated disaster responses of the residents in the study areas, the effectiveness of those measures is revealed.

Comparisons of the two study areas are also made. This research compares the different effectiveness of government disaster risk reduction measures and directives on relocations, risk perceptions and behaviour in the two counties. This is done throughout Chapters 5 and 6.

In addressing Hypothesis 1, this thesis investigates and analyses whether the residents in the two counties affected by the 2008 earthquake on different scales might have different considerations of government directives and disaster risk reduction measures, or they might encounter different obstacles when deciding to move or not.

In addressing Hypotheses 2 and 3, this thesis evaluates whether disaster risk reduction measures have been equally applied and impacted risk perceptions and behaviour in the two counties. On top of the government measures, impacts of different experience and knowledge of debris flows, different geographical connectedness and other factors are also evaluated. In the light of existing models, vulnerability indicators were applied to test the different effects of various types of vulnerability in the two study areas.

Chapter 7 is the concluding chapter. It gives a brief summary of the main findings and their significance. Recommendations are given. Limitations of the study are noted. Finally, what needs to be studied next as revealed by this study is addressed.

Chapter 2
Literature review

This thesis deals with debris flows consequent upon the 2008 earthquake. This chapter reviews the phenomenon and impact of debris flows in China, particularly in post-Wenchuan earthquake Sichuan. It also outlines the literature on vulnerability and disaster risk reduction, aiming to establish what is already known about the research problem, to provide insight in setting the scope of this research on what has not yet been studied, and to contribute to the answers of the research questions. The theoretical contribution of this research to current knowledge is defined later in the thesis.

2.1 Debris flows

The concept of debris movements came to attention in the early 20th century (Stini 1910). The term “debris flow” was coined by Sharpe (1938). For years, there were relatively few works that specifically focused on debris flow. The knowledge about this process and its significance was limited, while the classification and terminology were far from perfect (Scrivenor 1929; Brunsden 1979), leading to problems in interpretation (Innes 1983). For instance, the term “debris flow” was considered to be used to describe other earth movements (Lowe 1979, 1982) while actual debris flows were described using other terminologies (Sharpe 1938; Pierson 1980).

Despite the limitations on clear differentiation, this section, based on literatures, defines and distinguishes debris flow in the overall schema of mass movements.

2.1.1 Characteristics of debris flows and conditions causing debris flows

High density

High density is one of the major characteristics of debris flows. They may consist of more than 80% solids by weight, and the unit weight could reach 2.5 tonnes per metre^3 in individual occasion (Hutchinson 1988). Debris could reach 30 metres in depth when surges occurred (Sheko and Krupoderov 1984).

One distinguishing element among different types of flow is the percentage of coarse fragments. As a mix of rock, soil, clay etc. (Varnes 1978), debris flow contains more coarse fragments than mudflow under Varnes' classification (1958). It composes of less than 50% of relatively fine materials like sand, silt and clay, with high density solid materials as big as boulders constitute to over 60% of the flow (Varnes 1978). Huge rocks with diameter of several meters can be mobilised (Hutchinson 1988; Cruden and Varnes 1996). Hungr *et al.* (2013) further proposed that solid should constitute at least 60% of the flow during the surge peak. During the process, debris mixed with water and flow downslope (Innes 1983).

Heavy water content

Flows involve continuous movements of unconsolidated particles in a moving mass at different wetness and speeds (Varnes 1958, 1978). Debris flow, together with sand or silt flow, are wet flows with the highest water content among all types of flows (Varnes 1958). Innes (1983) suggested that debris flows can be classified according to the nature of the flow which includes the ratio of water and debris, and is closely related to the nature of the source which affects the duration of the flows that can vary from minutes to a few days (Pierson 1980). Hutchinson (1988) specified the water content of debris flow as below 30%.

With heavy water content, debris flows down with material sources from landslides that have occurred upslope (Bailey 1971; Burroughs *et al.* 1976). Water content of debris may change during the flow (Hungr *et al*. 2013) while coarse fronts always occurred (Pierson 1986).

Debris flows are often caused by torrential rainfall associated with heavy runoff flowing along pre-existed stream (Varnes 1958, 1978; Cruden and Varnes 1996). Regolith conditions, undrained loading, high or excess pore pressures and excessive moisture are fundamental to debris flow occurrence, with the latter closely relying on meteorology (Innes 1983; Hutchinson 1988). Excessive moisture can be caused by heavy rainfall intensity and long rainfall duration (Caine 1980; Innes 1983). Eisbacher and Clague (1984) specified three meteorological situations causing debris flow involving rock debris weathered on mountains, including high density rainfall of at least 40 to 60 millimetres in an hour, accumulated rainfall of at least 150 millimetres in a region in one day, and rapid

snowmelt-induced rainstorms.

A sudden accession of water can mobilise debris on slopes (Hutchinson 1988). Water loaded with soil can carry disproportionate energy, and with the supplement of soil on steep slopes and along river banks, especially those without vegetation protection, by caving or erosion as it flows downstream, a debris flow can grow both in size and power and can flow for kilometres until it reaches the valley or mountain bottom (Varnes 1958, 1978; Cruden and Varnes 1996; Hungr *et al.* 2013). The coarser materials usually form levees in flatter areas while the fine-grained materials and fluids would continue to flow down (Varnes 1978; Cruden and Varnes 1996), and travel up to 15 miles on gentle slopes (Sharp and Nobles 1953). Debris flow was labelled as a common and significant mountain hazard along established gullies or drainage channels. It always comes with flood, then spread out when the materials reach debris deposit area (Hungr *et al.* 2013).

Diversion of streams or melting of snow and glaciers can also lead to excess moisture and trigger debris flows (Innes 1983; Wei *et al.* 2018). A mixture of snowmelt and torrential rain (Broscoe and Thompson 1969; Rapp and Stromquist 1979), frozen soil and snow thaw (Varnes 1978) as well as permafrost thawing (Varnes and IAEG 1984) can also induce debris flows.

High speed and velocity

Debris flow is described as a rapid downslope movement (Varnes 1978; Iverson 1997) and even a very to extremely rapid flow of wet debris (Hutchinson 1988). It moves between 3 to 12 metres per second in general and may reach 30 metres in extreme occasions (Campbell 1975).

If vulnerability increases with velocity of a mass movement (Cruden and Varnes 1996), risk of harm of those people and properties affected by debris flow can be relatively higher than those threatened by other slower mass movements. Debris flows are considered as “potentially very destructive” in mountainous regions (Hutchinson 1988). This is particularly important for selecting debris flow as the focus of this thesis which tends to pay attention to the highly vulnerability groups living in areas affected by the Wenchuan earthquake.

Steep slopes

Steep slopes are a fundamental element behind debris flow occurrence, although there is no consensus on the exact range of slope angle (Innes 1983; Brunsden 1979). Innes (1983) plotted the distribution of known debris flows on the world map and found that they were widely spread on Earth and occurred much on alpine, semi-alpine and semiarid places. However, Innes' map had limitations due to imperfect information. For instance, no debris flow was found in China. This thesis can provide some insights into the Chinese situation.

2.1.2 Classification of debris flows

There are various classifications of debris flows with different considerations. Catastrophe level is one of those. As early as the 1930s, Heim (1932) classified debris flows as "catastrophic" if they sourced from heavy rockfalls and rockslides which then flow downhill.

Brunsden (1979) classified debris flows based on: (a) scale, and (b) nature of source area. Innes (1983) initiated a four-tier classification: large scale flows involving >100,000m^3 debris, medium scale flows ranging from 1,000 to 100,000m^3, small scale flows from 1 to 1,000 m^3 and the smallest micro scale flows with <1m^3 debris.

There is no consensus on the frequency of debris flow occurrence. Innes (1983) argued that debris flows do not reactivate but occur in individual basis, while some suggested debris flow can occur as either a single surge or multiple surges (Hubl *et al*. 2009; Hungr *et al*. 2013). This ambiguity also occurred in Sichuan. The great amount of debris flows occurred after the Wenchuan earthquake made it difficult for the authorities to identify which were new and which were reactivated in some situations. What they can do is to tackle them and to impose relevant mitigation measures based on existing conditions.

The impact of debris flows was huge in different aspects in various places (Innes 1983). In northern Scandinavia, debris flows were responsible for almost half of the debris volume involved in rapid mass movements in the 1950s (Rapp 1960). In Japan, almost one-third of life lost under heavy rains were due to debris flows, leading to development of mitigation measures in the 1980s (Takahashi *et al.* 1981).

The United States Geological Survey (USGS 1982) even considered debris flow as one of the most hazardous and threatening types of landslide.

2.2 Mass movements and debris flows in China

2.2.1 Causes of mass movements in China

In China, mass movements were caused by many factors, such as geology, topography, climate and earthquakes. Places frequently affected by fatal mass movements were mainly mountainous, steep and rugged in southwestern and southern China (Duan *et al.* 1993; DGEM 2003), including Chongqing, Sichuan, Yunnan and Hunan (Wen *et al.* 2005). Colluvium, surface residual soils and sedimentary rocks like mudstone and sandstone are particularly fragile (Wen *et al.* 2005).

Most of the 147 fatal landslides in China from 2001 to 2004 occurred in rainy summer from May to September, with 70% triggered by rainfall while the rest induced by a mix of human activities and rainfall (Wen *et al.* 2005). Sichuan is one of the provinces with mountainous areas susceptible to mass movements especially during rainy season.

2.2.2 Classification of mass movements in China

Varnes (1958) classified mass movements into three major types: falls, slides, flows, together with the fourth “complex” type. The classification by the Chinese government is very similar.

Back in the early 1990s, the Chinese government (MGMR 1991) recognised three types of mass movements, namely rockfalls, landsides and mudflows, as common in various parts of the country, especially the mountainous western region. They were labelled as the three most significant geohazards and could occur suddenly in different parts of China and were destructive.

The Ministry of Natural Resources (formerly the Ministry of Land and Resources before 17 March 2018) of China, later classified all geohazards into 12 categories comprising 48 types based on their nature and location of occurrence (MNR 2018). Slope mass movement was one of the 12 geohazard categories, and mainly

include rockfalls, landslides and debris flows, and they are considered as major geohazards and emergent events (Sinoprobe 2012). As using the description of Hungr *et al.* (2013), each of these three classes of mass movement has a concise and comprehensive definition that can be repeated.

Academics in China also tried to classify mass movements. Wen *et al.* (2005) investigated fatal mass movements across China from 2001 to 2004. They applied Varnes (1978) classification and found that the 147 mass movements studied could be categorised into four types: slide, fall, debris flow and slide-debris flow.

2.2.3 Debris flows in China and their impacts

Although “debris flow” was distinguished from “mudflow” in western literatures (Innes 1983; Varnes 1958, 1978), the definition and the use of the term “debris flow” is ambiguous in China where the terms “mudflow”, “mud-rock flow” and “debris flow” are, in many cases, used interchangeably. This classification is similar to that by Hutchinson (1988).

In 1991, the Chinese authorities published a comprehensive record of geological hazards in China (MGMR 1991) which listed out examples of so-called “mudflow”. The term “mudflow” was used as the English translation of “泥石流”, which literally means “mud 泥-rock 石 flow 流” (MGMR 1991). Instead of using the parameters like the coarse and fine materials ratio which can distinguish debris flows from mudflows, the Chinese government mainly described or quantified a flow by using the total volume of solid materials it discharged or accumulated (MGMR 1991).

Subsequently, the Chinese government specified debris flow as a special kind of torrential flow occurs in mountain gullies, caused by water sourced from heavy rain and melting snow, and composed great amount of sticky soil, sand and rock debris (Sinoprobe 2012). Three conditions are required concurrently for its formation: steep landscape and topography to allow the ease of water and material collection, rich and loose materials, as well as huge water sources in a short period of time (Sinoprobe 2012).

In the academia, and even in daily use, the English term “debris flow” is often used as the English translation of the Chinese term “泥石流”. In some cases, “debris flow” were used to describe the flow with low percentage of fine particles as suggested by Varnes (Tang *et al.* 2009). In many other academic articles published after the Wenchuan earthquake (Zhou *et al.* 2013), “debris flow” was used generally to describe rapid downslope movement of a mix of rock, soil and water under gravity caused by torrential rainfall flowing along pre-existed stream and can grow in size and power with the supplement of debris and soil on steep slopes and river banks as it flows downstream, but without specifying the percentage of coarse fragments as done by Varnes (1958, 1978). Again, many of the academic studies focused more on the total volume of solid materials being discharged or accumulated, the velocities of the flows, and the seriousness of rainfall triggering the flows.

In reality, as Varnes (1978) noted, it is unrealistic to follow strict classifications because movements and materials would change through time in the same place and more than one type of movement may occur in one occasion. A possibility that the phenomena is ambiguous and cannot be fully recognised must be admitted.

Since this study focuses on China, it aligns with the Chinese government and most academic research on the study of flows in China. This means that the term “debris flow” is used to cover “debris flow” in Varnes’ narrower definition (1958, 1978) as well as “mudflow” and “”mud-rock flow” in Hutchinson’s broader classification (1988).

Since mudflows (MGMR 1991) and debris flows (Sinoprobe 2012) have been considered as major slope mass movements in China, indicating they are much more influential than other types of flow.

Indeed the Chinese authorities noted the frequency of mudflow (or debris flow) was high (MGMR 1991). It was estimated that more than 60,000 mudflow/debris flow ditches were found in the country, affecting more than 70 counties and cities (MGMR 1991). In the whole nation, a study before the Wenchuan earthquake revealed that about 5% of all fatal slope movements in early 2000s were slide-debris flows (Wen *et al.* 2005).

2.2.4 Causes of mass movements in Sichuan after the Wenchuan earthquake

Earthquake is one of the causes of mass movement and is expected to cause grain displacement and to lower loose sands cohesion (Zaruba and Mencl 1969). With the contribution of earth stress by the 2008 earthquake, the quake regions have also experienced slope movements or exposed to such risks.

The Wenchuan earthquake triggered more than 12,500 geohazards (NPC 2008). Another study even estimated that more than 15,000 secondary geohazards were triggered, most of which consist of various forms of landslide (Yin *et al.* 2009a). Furthermore, the total number of potential geohazards, mainly as landslides and unstable slopes, in regions extremely suffered from the earthquake, tripled after the disaster (Yin *et al*. 2009b).

The impacts of various types of mass movement, as one of the 12 categories of geohazards under the official classification (Sinoprobe 2012), occurred after the 2008 earthquake are mixed. Yin (2009) noted that a great portion of landslides induced by the earthquake involved a fixed process of broken, thrown, crushed and then high speed debris flow. Rockfalls and landslides could provide material sources for subsequent debris flows if the slope movements are nearby ditches or gullies, and in many cases, contributed by heavy rainfall in summer (Huang and Li 2014). The Wenchuan earthquake occurred on 12 May 2008, and the month is at the start of the annual rainy season. A number of serious geohazards occurred during the 2008 summer, and many more were induced in the subsequent rainy seasons. The impacts were particularly severe in remote mountainous regions where many of the rural settlements of Sichuan Province are located.

2.2.5 Classification of mass movements in Sichuan after the Wenchuan earthquake

The earthquake has induced thousands of different slope movements in which many of them are mixed, meaning a single region could be affected by several types of mass movement which might or might not relate to each other (Sichuan Government 2010; LRDSP 2010; SGIO 2015e). In many cases, a small area could have experienced or be threatened by a mixture of different mass movements at

the same time or at different times as the environment changed, and the situation has been more complicated than what can be found in previous classifications. A clear distinction among them in the fields are very often not easy. This echoes the complexity and possible boundless definition of such phenomena as noted by (Terzaghi 1950). Nevertheless, a clear distinction of each mass movement and their mechanisms are helpful to understand field situations. Therefore shortly after May 2008, there were efforts to classify various types of mass movements induced by the Wenchuan earthquake (Xu and Huang 2008; Kong *et al*. 2009; Yin 2009) according to various criteria. Varnes' classifications (1958, 1978) based on "type of movement" and "type of materials" were still highly relevant and offered important insights to geologists and engineers to impose relevant and tailor-made mitigation measures addressing mass movements with known characteristics.

2.2.6 Relevance of mass movement classifications in Sichuan to this research

The Chinese government, which understood that certain areas were threatened by complex and different mass movements or geohazards simultaneously, tended to clearly separate and distinguish one type from another in individual sites in their annual assessments and mitigations (Sichuan Government 2010; LRDSP 2010; SGIO 2015e).

Regarding the Wenchuan earthquake, five geohazards were identified officially. They are landslide, debris flow, rockfall, unstable slope and dangerous rock mass (Sichuan Government 2010; LRDSP 2010; SGIO 2015a, 2015e). Except "unstable slope" and "dangerous rock mass" which are more general terms not having specified criterion for classification like material type, movement or velocity, the other three are actually the three main types of slope movements recognised by the Chinese government in the past decades, and were identified by Ministry of Geology & Mineral Resources (MGMR 1991) and Ministry of Land and Resources (Sinoprobe 2012). Although how and why geohazards were categorised in such a way were not explained, such classification provided a foundation, guidance and framework for Sichuan Province to impose post-earthquake mitigation, disaster preparedness and response measures. For the sake of analysis, this research also takes reference of this simple classification approach of the Chinese government.

This classification is simple and straightforward. One possible reason for adopting is for ease of administration, management, communication, planning (Fleming *et al.* 1979; Varnes and IAEG 1984) and evaluation (Hungr *et al.* 2013). Such pragmatic arrangements allowed local governments to have clear assessment, calculation and record of the population and properties being threatened or affected by each geohazard risk so as to impose relevant and suitable risk reduction measures. Particularly, geohazard risk assessment became a regular annual exercise for all the Wenchuan earthquake affected and threatened local governments. Without clear classification, both the mitigation and administrative efforts would be more difficult, complicated and even confused.

Classification can also facilitate the recognition of mass movements so as to avoid building on hazardous areas, to control or correct it through engineering works (Varnes 1978) under proposed action for the government and the public to reduce hazards (Fleming *et al.* 1979). In Sichuan, such classification could also help achieve risk avoidance, control and correction.

2.2.7 Debris flows in Sichuan after the Wenchuan earthquake

As mentioned, debris flows have several key features, including high density and high percentage of coarse materials, high level of wetness, high speed and velocity, and occur under a number of conditions: unusually heavy precipitation or sudden access of water, and a steep slope environment.

Sichuan, with its mountainous nature and regular rainy season, possesses these characteristics. Serious debris flows existed before the Wenchuan earthquake. Those occurred along Sichuan-Xizang Highway (west of Chengdu), Baoji-Chengdu Railroad and Jinsha River (northeast of Chengdu) were highlighted (MGMR 1991). In particular, a large-scale Liziyida Ravine debris flow destroyed the Chengdu-Kunming railway bridge (east of Chengdu), overturned a moving train in 1981, and took over 300 lives (Wu *et al.* 1993).

After the quake, more debris flows were directly or indirectly triggered in Sichuan and adjacent provinces Shaanxi and Gansu, including some newly-induced (Cui *et al.* 2011) and some reactivated (Zhao *et al.* 2021).

Official record showed that debris flows contributed to a significant portion of all geohazards induced by the 2008 earthquake. Among the 12,536 geohazards triggered, 1,054 were debris flows (NPC 2008).

It has been widely recognised that the Wenchuan earthquake has increased slope instability and has triggered rockfalls and landslides which provide huge amount of destabilised loose and unconsolidated coarse material source for subsequent debris flow on steep mountain slopes in different parts of Sichuan (Tang *et al.* 2009; Cui *et al*. 2011), including the study areas. Earthquake-induced landslides tend to occur near water channels and drainage areas (Fan *et al.* 2019a). If the rockfalls and landslides are nearby gullies, valley-confined or channelized, debris flows would occur with the contribution of heavy summer rainfall (Brunsden 1979; Innes 1983; Hutchinson 1988; Cruden and Varnes 1996). Indeed, debris flow here is part of a specific range of earthquake-related multi-hazards which overlap and cascade with spatial-temporal connections (Gill and Malamud 2014; De Angeli *et al.* 2022).

Rainfall as a crucial factor for debris flow occurrence in Sichuan was made evident in the first two rainy months right after the Wenchuan earthquake. The destructiveness of debris flow was illustrated in one of the most affected areas, Beichuan County, where heavy rainfall in September 2008 had induced 72 debris flows and took 42 lives (Tang *et al.* 2009). Qingping, another site in Sichuan, had houses and infrastructures rebuilt after the quake destroyed by debris flow, which was a more commonly induced geohazard by the quake and subsequent heavy rainfalls than other collapses and landslides (Tian *et al.* 2011).

2.2.8 Significance and long-term impact of the study of debris flows

Debris flow is particularly dangerous and even devastating to residential areas, roads, railways and utility facilities. Its impact on human lives and properties was huge in different aspects in various places (Innes 1983; Hu *et al.* 2012). Unlike other secondary geohazards like rockfall and landslip which were expected to influence earthquake-affected areas for a shorter period of time after a quake, debris flows could become more active and frequent and affect an area for a period of up to 20 years (Cui *et al.* 2009). They could also affect the earthquake area for 20 years following seismic landslides that created lakes (Cui *et al.* 2011).

The Wenchuan earthquake-induced landslides produced a significant amount of loose deposits capable of developing debris flows during future rainstorms (Fan *et al.* 2018). Given the changing slope and environmental conditions, the critical threshold values for a cumulated rainfall and hourly rainfall intensity causing debris flows were lowered by 15-32% when compared to the 2003 data, meaning the earthquake affected areas are more susceptible to debris flows (Tang *et al.* 2009). A smaller rainfall can cause debris flows, which would not have occurred before.

More recent studies revealed that, besides rainfall intensity, the Wenchuan earthquake led to a great decrease in the duration of rainfall needed to trigger debris flows, followed by a gradual recovery (Yu *et al.* 2014; Guo *et al.* 2016, 2017). A comprehensive post-Wenchuan earthquake debris flow database and a rainfall-induced debris flow early warning model showed that the threshold of debris flow initiation, though subject to steady increases, had not yet resumed the pre-2008 earthquake level (Fan *et al.* 2019a). Another study (Fan *et al.* 2019b) revealed that as much as 90% of the earthquake-induced materials still remained on mountain slopes and river basins, indicating sufficient material sources are available for debris flow for decades and even centuries after the quake (SKLGP 2019).

Debris flow is a highly mobile and kinetic form of slope movement which is particularly destructive. The impacts can be especially severe in remote mountainous regions. It is much more worthy, meaningful, necessary and impactful to focus on studying debris flow and its influences on the rural populations in a longer run rather than other types of mass movement. Therefore, five Sichuan villages with settlements nearby or on steep slopes and along gullies located in two remote mountainous counties, namely Pingwu and Wenchuan, affected by earthquake-induced debris flows and having heavy rainfall almost every summer are studied in this research.

By evaluating the effectiveness of debris flow disaster risk reduction measures and directives, this study can shed lights on other remote mountainous regions that experience and influenced by similar debris flow risks, including but not limited to other provinces located in western or southwestern China with similar geology, topography and climate conditions, such as Yunnan, Guizhou, Gansu and Shaanxi.

2.3 Post-disaster relocation, risk perception and disaster response

2.3.1 Disaster loss, recovery, reconstruction and relocation

According to United Nations International Strategy for Disaster Reduction (UNISDR), although China only constitutes to 7% of the total land area on Earth, about 33% of all recorded earthquakes affected the country (UNISDR 2017a). China, categorised as "upper middle income", had an absolute annual average loss (AAL) associated with earthquakes amounted to US$4,001 to 14,000 million, and ranked fourth in the world, just behind Japan, USA and Italy (UNISDR 2017a). In terms of riverine floods, China ranked first in the world in terms of AAL, again amounted to around US$4,001 to 14,000 million (UNISDR 2017a). China has not only adhered to the Sendai Framework for Disaster Risk Reduction, but also set a cap for disaster economic loss at 1.3% of Gross Domestic Product (UNISDR 2017b). Throughout the years, particularly since the 2008 Wenchuan earthquake, different levels of the Chinese government have invested huge amount of resource and manpower in order to reduce disaster risks.

In terms of geohazards, in 2003 the State Council of the People's Republic of China enacted the Regulation on the Prevention and Control of Geologic Disasters, stating that geohazard disasters are categorised into four threat levels or scales based on the number of deaths or amount of properties loss (Table 2.1).

Table 2.1 Four levels/scales of geohazard disaster threat in China

Level	Scale	Deaths caused	People required to relocate	Direct economic loss[1]	Potential economic loss[1]
I	Mega	30 or above	1000 or above	RMB 10 million or above	RMB100 million or above
II	Large	10 to 29	500-999	RMB 5 to <10 million	RMB 50 to <100 million
III	Medium	3 to 9	100-499	RMB 1 to <5 million	RMB 5 to <50 million
IV	Small	<3	<100	< RMB 1 million	RMB <5 million

Source: State Council 2003; MLR 2008b.

Disaster recovery, although there is no consensus on its definition (IFRC 2020), is generally regarded as a restoration or an improvement of livelihoods of an affected community, with an enhancement of various dimensions of its activities and

[1] Direct economic loss and potential economic loss are measured in Chinese currency Renminbi (RMB). Ten RMB equals to about 1.14 British pound according to mid-2017 exchange rate and this applies to the rest of this thesis.

systems (UNDRR 2017). According to this, a successful recovery is sustainable, and involves building back better of a community's socioeconomic, physical, cultural and environmental aspects so future disaster risk could be minimised.

Reconstruction is always an integral part of disaster recovery. A refined conception of social vulnerability is considered as crucial for sustainable construction of a community in a disaster context (Uekusa *et al.* 2024). Previous disaster studies revealed that reconstruction behaviour was closely connected with social vulnerability such as old age (Cutter and Finch 2008) and unemployment (Talbot *et al.* 2022). Socioeconomic vulnerability has inevitable influence on the adoption of various reconstruction plans (Davis 2015) while sociocultural vulnerability negatively affected post-disaster reconstruction (Lin and Lin 2016). Sites available for housing reconstruction for the vulnerable poor and marginalised were found limited (Thomas *et al.* 2013).

People's relocation decisions, on the other hand, are a form of societal choice which could influence much on the loss incurred and subsequent recovery (Alexander 1991a).

Some scholars investigated what factors might relate to people's willingness to undertake various disaster risk reduction efforts, including relocation. An online survey reported that elderly people and women were less willing to pick up disaster reduction skills or trainings in China (Hu *et al.* 2021). Perception of government policies and adaptation cost were found significant in determining people's willingness to adapt to climate change in another study on China (Xue *et al.* 2021).

As for relocation, in a landslide-prone province in Turkey, Mizrak and Turan (2023) noted that those had higher self-efficacy, in a sense that believing they had more knowledge to protect themselves in a landslide, were more willing to relocate. They also showed that those who lacked social support would be more likely to move. Perceived inadequate disaster reduction measures and feared of landslides possibility also increased relocation willingness.

Similarly, in China, a post-Wenchuan earthquake study found a positive association between perceived severity of earthquake occurrence and relocation

willingness (Xu, D. *et al.* 2020). A study on another region in China, the Three Gorges area, revealed that relocation willingness was related to place identity and place dependence, but in a negative direction (Xu *et al.* 2017).

After the Wenchuan earthquake, although the Chinese government has highlighted the importance of avoiding places exposed to geohazard risk during rehabilitation site selection, some residents affected by the quake or the induced secondary geohazards had not relocated elsewhere. These societal choices could be due to factors other than government directives.

Hypothesis 1 therefore tested the respective relations between various vulnerability indicators, economic competencies, sociocultural factors and government influences, on one hand, and respondents' relocation decisions being a form of societal choice during disaster recovery on the other.

Demographic factors

Some scholars showed that disaster recovery was influenced by social vulnerability (Finch *et al.* 2010), while others suggested social vulnerability was commonly affected by several demographic factors, including gender, age, race and socioeconomic status (Cutter *et al.* 2003). Such relations are presented in Figure 2.1. Indeed, there is relatively few studies addressing the qualities, including the social vulnerability ones, shaping recovery. This thesis therefore tends to contribute in filling this gap through referencing existing literatures on vulnerability and risk, as well as investigating what factors, including the demographic ones, might affect relocation as part of the recovery process.

Figure 2.1
Relations among demographic factors, social vulnerability and disaster recovery



Gender

Gender has been widely considered as an important demographic variable affecting disaster recovery. Women were commonly found facing higher disaster

risks and tended to be more vulnerable (Cutter *et al*. 2000, 2003) because of their dependency role (I¸sık *et al.* 2015; Rhodes and Tran 2012; Falk 2012).

Similarly, in China, gender could be a significant source of diversity on experience and behaviour in the context of post-disaster reconstruction. Rapid economic growth in China did not necessarily improve gender equality (Molyneux and Razavi 2005). After the 2008 earthquake, unique family roles and duties were found causing ethnic minority women in Sichuan facing higher risks than men (Wang et *al.* 2017). There were even reports stating that some women staying in temporary houses had a pregnancy loss (Davis and Alexander 2016).

Despite the devastation and distress brought by the quake to women (Hu 2010; Li *et al.* 2011), a study on school teachers found that females yielded higher levels of both post-traumatic stress disorder (PTSD) and post-traumatic growth (PTG) (Hou *et al.* 2014). In Yingxiu Town, the government offered special care to address the needs of women, including pregnant ones, among other vulnerable groups during the post-earthquake emergency stage *(*Sim and Cui 2017), although such aid was insufficient after a debris flow emergency in 2013 (Cui and Sim 2015). Availability of external assistance and resources could enhance rural women's planning and decision-making capability as well as community cohesion during earthquake recovery and the rebuilding process (Sim *et al.* 2019). Yet another study on Yingxiu found no evidence of any significant relation between gender and perception of community resilience (Cui *et al.* 2018).

Nevertheless, with reference to the biological, psychological and social differences of the two genders, and that women are generally more risky and traumatised in disasters, there was advocacy of considering the special needs of women during post-disaster reconstruction, so as to encourage harmonious relations between men and women (Hu 2010).

Age

Age has been considered as an important demographic variable that might relate to and affect vulnerability. For instance, the hazards-of-place model (HOP; Cutter *et al.* 2000, 2003) suggested that people of different ages can have differential access to resources, leading to disparities in vulnerability.

Ethnicity, Racialised inequality and socioeconomic status

Early disaster studies addressing ethnic minorities in recovery was minimal. Bolin and Bolton (1986) referenced a study on Texas tornadoes by Moore (1958) and noted that the blacks, as ethnic minorities, suffered more losses than others, hence external support should be provided to the blacks to help them recover. Similar outcome that the blacks and the poor suffered most was still found in hurricane studies about half a century later (Hartman and Squires 2006; Lavelle 2006). Minorities were also found to be more exposed to hazard risks (Cvetkovich and Earle 1992). Marginalisation of the disadvantaged race or class could link to environmental inequalities and hazard risk exposure (Bolin 2007). Language, isolation and low sensitivity contributed to higher vulnerability in ethnic minority groups (Fothergill *et al.* 1999).

With increasing studies it was found that different races and classes responded and recovered differently towards the same disaster (Elliott and Pais 2006). Different races encountered different levels of difficulty during restoration, leading to variations in vulnerability (Fussell *et al.* 2010; Rhodes and Tran 2012). Many of these studies addressed the racial differentiation between the blacks and the whites, with the former being deprived (Zottarelli 2008) and further marginalised (Peacock and Girard 1997) consistently during recovery after different disasters. The post-disaster needs of Mexican-Americans as racial minorities were also not fully considered (Aptekar 1990). Fothergill *et al.* (1999) quoted Davis (1986) and showed that the culture of the Alaskan were neglected during disaster recovery. In other words, treatment by society and government could induce racialised inequity, hence lead to racialised vulnerability or access to recovery.

In China, ethnicity could also be an important source of diversity on experience and behaviour in the context of Sichuan post-disaster reconstruction. However, the situation in China is different from the above mentioned literatures. According to several studies, after the Wenchuan earthquake, instead of fostering deprivation, Sichuan gave special attention to settlement reconstruction and recovery among marginalised ethnic minorities (CPG 2008a; Wang and Prott 2016; Qiu 2016; Li 2017). An important attempt was to protect intangible cultural heritage of the Qiang ethnic group as part of the heritage recovery plan (Zhang 2018).

Ethnicity could also connect to mobility during post-disaster reconstruction. Sichuan accommodates residents of different ethnic groups, such as the ethnic majority Hans, and the minorities Tibetans and Qiangs. Historically, the Hans are more ready to migrate to another place, and their high mobility means members of a family do not need to live together or nearby, whereas the Qiangs tend to be more cohesive and reside in the same area (Wang et al. 2017).

Ethnicity could also affect post-Wenchuan earthquake recovery and reconstruction in other aspects. For instance, Wang *et al.* (2017) found that the Hans trusted public donations being very useful for their recovery, whereas the Qiang and Tibetans did not. The same study also revealed that household heads of the minority groups had a more significant position in post-quake household recovery.

However, ethnic difference might not be influential in some contexts. For instance, the recovery process of the ethnic majorities and minorities were found similar (Wang *et al.* 2017). A study on Yingxiu showed that relationship between ethnicity and community resilience perception was not evident (Cui *et al.* 2018).

Nevertheless, more study on the possible impact of ethnicity on disaster risk reduction has been called upon. For instance, in an analysis of over a hundred Chinese and English literatures studying social support impact on psychological health of the Wenchuan earthquake-affected during the recovery revealed that the ethnicity element was basically neglected (Cui *et al.* 2023), meaning scholars' attention on this aspect was limited. It was proposed that more research should be done to decide whether to include vulnerability of ethnic minorities in future government disaster risk management policies (Sim and Cui 2017).

Educational attainment

Educational attainment is another demographic factor widely considered to affect people's decision making in terms of how they cope with, adapt and respond to disasters (Fussell *et al.* 2010; Muttarak and Lutz 2014; Hoffmann and Blecha 2020). However, a study of the Wenchuan earthquake's most heavily damaged villages found that the educational attainment of villagers was not associated with disaster recovery in terms of the likelihood of houses rebuilt (Tse *et al.* 2014).

Individual economic competencies

For decades, social scientists have paid much attention to the study of factors that affect disaster recovery. The classic study by Kates and Pijawka (1977) argued that level of economic development and access to recovery funding are crucial. Similarly, Hogg (1980) and Alexander (1989) suggested that availability of financial resources contributed to the success of reconstruction or recovery.

On an individual level, the MOVE framework considered economic dimension as one of the key thematic components of susceptibility, and financial deprivation can be indicated by income level (Vinchon *et al.* 2011). Existing vulnerability models and literatures suggested that individual economic competencies, including financial support from various sources (Birkmann 2013), the availability of funding (Hogg 1980) or economic vulnerability (Alexander 1997) could be considered as individual coping capacity. Impacts of different socioeconomic conditions during difficult times and aid variation were noted (Bolin and Bolton 1986). Economically disadvantaged, a lack of funding or an unequal distribution of financial or economic resources can affect the compliance with risk reduction measures (Arnold 2006). Economic competencies could relate to whether one decides to move after a disaster. In the USA, after Hurricane Katrina, the underprivileged and those enduring greater destruction of their houses were more likely to migrate (Myers *et al.* 2008). In China, research on the Yao'an earthquake suggested that external financial support was important for recovery (Wang, Chen and Li 2012).

After the Wenchuan earthquake, tens of thousands of Sichuanese were displaced. The need for relocation was one of the most urgent items in the disaster recovery process. Funding, economic and financial factors were crucial for relocation and recovery. However, academic studies on economic vulnerability of rural populations affected by the Wenchuan earthquake were limited. One of the few early examples was by Sun *et al.* (2010) who studied agricultural risks and discussed farmer households' vulnerability before and after the earthquake. This research found that the more damage the houses caused by the quake, the poorer and more vulnerable the farmers became. It provided insights for post-earthquake reconstruction but the impact on relocation was not covered.

Sociocultural factors

Culture is in itself a complicated concept. It has numerous definitions (Kroeber and Kluckhohn 1952; Oliver-Smith 2020). The Cambridge Dictionary (2022a) defines culture as "the way of life, especially the general customs and beliefs, of a particular group a people at a particular time". Ethnography views culture as a collection of intangible beliefs, values, knowledge, customs, rituals, language, art and habits (Taylor 1920; UNESCO 2003) as well as tangible crafts (Costin 1998), architecture (Pavlides and Cranz 2011), and more**.** From sociology perspective, culture is comprised of symbolic or nonmaterial elements like ideas, customs and knowledge, and material elements like tools and artifacts (Hall *et al.* 2003; Schaefer 2013)**.**

Culture involves a learning process. Cultural anthropologists suggested that people learn certain ideas and behaviour as their culture to accustom to the environment (Nanda and Warms 2020)**.**

Culture is closely linked with communities and societies, involving a group of people. It is interpreted as shared assumptions learned by a group during problem solving and become the right method to perceive and act (Schein and Schein 2016). Cross-cultural study revealed that culture is a collective mind-set differentiating people of one group from others (Hofstede 1991).

Values and beliefs of a culture are transferred within a group (Rapoport 1987). Culture entails the transmission and inherit of symbolic concepts for knowledge communication and development (Geertz 1973). People reproduce and transmit culture within a generation or from one generation to the next (Patterson 2010), or pass to new group members through socialisation (Van Maanen and Schein 1977). In the disaster context, metamorphosis of inherited and modern cultures could affect recovery (Alexander 2012b).

Culture shapes action and behaviour (Schaefer 2013), including during disaster situations (Swidler 1986). Culture, which embeds beliefs, historical and social elements, can impact post-disaster response and decision making (Oliver-Smith 1996; Zaman 1988). The MOVE Framework suggested that culture is one of the key thematic components of susceptibility (Vinchon *et al.* 2011). Closely linked to

culture and ethnicity is indigenous knowledge. Some scholars illustrated the contribution of indigenous knowledge in disaster risk reduction (Kelman *et al.* 2012).

Community was identified as the foundation of disaster resilience (Dynes 2005). Chamlee-Wright and Storr (2009) referred to the three pillars of the sense of place concept in environmental psychology: place identity (Proshansky 1978), place dependence (Stokols and Shumaker 1981) as well as place attachment (Altman and Low 1992; Milligan 1998), and studied the case of New Orleans, the USA, after Hurricane Katrina attack in 2005. They found that what people believed about the uniqueness of a place, or their sense of place, affected post-disaster behaviour.

The function of civil society, community ties, social capital networks and social cohesion on disaster response and recovery were investigated by various authors (Ersing and Kost 2012; Aldrich and Meyer 2015; Aldrich 2010, 2012a, 2012b). Social, cultural and historical cohesion (Hogg 1980; Nakagawa and Shaw 2004) as well as voluntary public participation (Oliver-Smith 1991) affected effectiveness of reconstruction which aimed to reduce risks. People having networks with a higher percentage of kin could receive more assistance in disaster recovery (Hurlbert *et al.* 2000).

Shepherd and Williams (2014) pointed out the effectiveness of a broader community to mobilise and supply resources to a local community after a disaster. The value of social capital and networks lies in their pragmatic use of providing disaster related assistance from material aid (Beggs *et al.* 1996) to psychological support (Kaniasty and Norris 1993). Social capital could also make the vulnerable stronger (Lovekamp and Arlikatti 2013). In contrary, social marginalisation hinders recovery (Angotti 1977; Alexander 2007).

In China, a study that covered eleven western provinces, cities and autonomous regions found that social capital network of the disaster-affected populations had obvious positive impact on the receipt of aid and post-disaster recovery (Zhao 2007). However, the less advantaged groups relied too much on their strong networks might adversely affect their economic recovery.

After the Wenchuan earthquake, individual sociocultural factors and their potential relations with recovery were explored. The findings echoed previous literatures both outside and within China. For instance, Spring Festival network is a measurement of the social capital and network one has. It counts how many individuals, usually relatives, friends and even acquaintances a household encounters during the Spring Festival (or Chinese New Year) (Bian *et al.* 2005). Study of the Wenchuan earthquake recovery showed that those Sichuan households with bigger Spring Festival social networks gained more assistance to apply for government aid and were offered more housing reconstruction grants, and were then more likely to reconstruct their houses, hence recovered faster and easier (Tse *et al.* 2014; Wei and Han 2018). Another study on the aftermath of the same earthquake found that social networks contributed to rescue, information provision as well as social and mental health support (Zhao 2013). A longitudinal study on changes of social capital conducted shortly after the 2008 earthquake found that social cohesion intensified during disaster recovery (Han 2017).

As for the impact on post-disaster relocation, the more social capital and networks a community has, the cost of leaving the place increase, the people are hence less likely to migrate out (Aldrich 2010, 2012b).

On the other hand, a research on the 1994 Chuetsu earthquake in Japan by Iuchi (2010) found that people who disliked, felt inferior of, or even depressed by their communities in the mountains with disaster risk as well as those who lacked of positive experience with neighbours, had a bigger chance to move elsewhere because of marginalisation, isolation, inconveniences and underdevelopment. The earthquake was a triggering factor for their relocation.

Boen *et al.* (2001) further argued that relocation is not simply a matter of moving people from one place to another, but is relocating a collective way of life, involving not just a social network. He found that villagers relocated elsewhere after the 1992 Flores earthquake and tsunami in Indonesia returned to their native village, though declared as a restricted area, a few years later, because the original place was established by their ancestors.

2.3.2 Risk perception

Studies revealed that risk perception can be associated with many factors, including demographic ones. However, to a great extent, these literatures could not provide a definitive list of demographic factors influencing disaster risk perception across different scenarios.

Gender is one of the demographic factors that gives an inconclusive result. Females were found to perceive risks and disasters differing from males (Cutter *et al.* 1992; Enarson 1998). The influential role of gender on risk perception of different types of disaster was found in America (West and Orr 2007), Europe and Asia (Fernandez *et al.* 2018). Particularly, gender influenced earthquake risk perception in China (Tian *et al*. 2014).

Gender is a key indicator of vulnerability in the hazards-of-place (HOP) model (Cutter *et al.* 2000, 2003). Morrow (1999) quoted census data of the USA and noted that women typically possess fewer resources with economic inequality constraints and have higher risk. With their special family role, women were vulnerable to various hazards (Steady 1993; Armas 2006). However, gender difference in risk perception only existed among the whites but not the non-whites in the USA (Flynn *et al.* 1994). A study on Italy suggested gender did not impact much on landslide risk perception (Salvati *et al.* 2014). A study on China could not find big difference on debris flow risk perception between male and female (Huang *et al.* 2020).

Ethnic minorities were another social phenomenon that was often to involve heightened vulnerability (Birkmann 2013) as they perceived greater disaster risks (West and Orr 2007) or were simply at higher risk and were marginalised (Morrow 1999). These results were consistent with the arguments of some social vulnerability models, such as the HOP model (Cutter and Solecki 1989; Cutter 1996; Cutter *et al.* 2000, 2003).

As noted by Fothergill *et al.* (1999), there is a lack of research on why ethnic minorities in Asia may perceive higher risk. Moreover, although some ethnic minority groups had higher risk perception, others showed no significant difference (Fothergill *et al.* 1999).

The impact of age on disaster risk perception is also inconclusive. A comprehensive national evaluation and survey in Italy revealed that landslide risk perception did not differ much between different age groups (Salvati *et al.* 2014). Conversely, age was found to be commonly related to risk perception, although its impact varied in different studies. For instance, age influenced both earthquake and fire risk perception in Myanmar (Fernandez *et al.* 2018). A study of Yunnan Province of southwestern China echoed the findings in Italy (Miceli *et al.* 2008) and concluded that rural residents aged 19 to 59 were more likely to perceive bigger landslide threat than were elderly persons (Huang *et al.* 2020).

In China, the literature on disaster risk perception is limited, but in recent years it has started to gather pace. Some post-Wenchuan earthquake studies simultaneously revealed an association between age and secondary geohazard risk perception (Cui and Sim 2017; Huang *et al.* 2022).

As for education, a recent post-Wenchuan earthquake study found that secondary geohazard risk perceptions were associated significantly with educational attainment. The primary school educated had the highest disaster risk perceptions (Huang *et al.* 2022). This echoes some research outside China which noted the impact of education on risk perception (Shaw *et al.* 2004; Fernandez *et al.* 2018).

In terms of earthquake risk perception, income was found to be influential in China (Tian *et al*. 2014). A Wolong study revealed that the perceived risk of a future earthquake disaster was negatively associated with income levels (Lo and Cheung 2015). It shed lights on the relationship between financial preparedness for future earthquakes and resilience.

An investigation of the Salween Valley in Yunnan Province found that farmers perceived high debris flow risk (Huang *et al.* 2020). However, all the studied subjects were farmers, meaning there was no comparison of risk perception between farmers and non-farmers.

Risk perception can also relate to non-demographic factors. The impact of disaster experience on risk perception has been widely discussed in disaster studies. Previous literatures consistently found that experience has positive impacts on

disaster risk perception. Weinstein (1989) evaluated 18 natural hazard studies conducted from the 1960s to 1980s and found that the impact of experience on risk perception varies for different types of hazard and scenarios. In about three-quarters of the situations, experience positively affected risk perception. Case studies conducted at different times since the 1990s in different places also illustrated the same. These include cases in the Netherlands (Bezuyen *et al.* 1998), Switzerland (Siegrist and Gutscher 2006) and Italy (Salvati *et al.* 2014), as well as in India (Chaturvedi and Dutt 2015) and Myanmar in Asia (Fernandez *et al.* 2018).

There are exceptions. Japanese literature revealed that although it helped students to know about earthquake disaster, experience was not important in increasing their risk awareness (Shaw *et al.* 2004). In China, disaster experience did not necessarily imply high risk perception (CCOUC 2014). In Taiwan, it was less influential in risk perception than was education (Luo *et al.* 2014). However, a number of other studies in China revealed the positive relationship between disaster experience and risk perception. People from Yunnan Province with disaster experience were more likely to have more acute debris flow risk perceptions than those without (Huang *et al.* 2020).

In Sichuan, several post-Wenchuan earthquake studies consistently showed the positive relationship between disaster experience and risk perception. Perceived likeliness of future earthquake occurrence was positively correlated with intensity of damage experience from previous earthquakes in Wolong (Lo and Cheung 2015). Severity of disaster experience was positively related to perception of severity of disaster occurrence in villages in Beichuan, Pengzhou, Baoxing and Lushan counties (Xu *et al.* 2019). Another study on 12 towns showed that large scale secondary geohazard experience was positively correlated with risk perception (Huang *et al.* 2022).

2.3.3 Disaster response behaviour

When a disaster strikes, different people may react differently. Some chose to evacuate (Drabek and Boggs 1968) but some respond in other ways (Drabek 1969).

Behavioural response during emergencies can be affected by many factors. For instance, a combination of barriers prevented people in Haiti from evacuate during

hurricane attacks but led them to stay at home instead (World Bank 2020). Such barriers include failure in risk communications, risk perception, fear of leaving livestock at home and inaccessible to evacuation resources or emergency shelter. Twigg (2003) highlighted risk perception in particular because it might affect the impact of early warning on disaster response.

In terms of demographic characteristics, gender is commonly considered as affecting disaster preparation (Neal *et al.* 1982) and ability to respond to disaster (Mustafa *et al.* 2015). Females were often found to respond to disaster differing from males (Enarson 1998), although there was exception that evacuation decisions were not influenced by gender (West and Orr 2007). Many studies suggested that women were more disproportionately vulnerable (Rivers 1982; Walker 1994; Enarson and Morrow 1997; Morrow 1999; Padavic and Reskin 2002). They seldom participated in decision making on disaster response (Khondker 1996) or were difficult in disaster response (D'Cunha 1997). Others, however, found that women had special, unique social role and family responsibilities (Abel and Nelson 1990) and dominated in some disaster situations (Neal and Phillips 1990).

In the 1980s and 1990s, studies had already explored the impact of ethnicity on disaster response (Bolin and Bolton 1986). Some concluded that ethnicity influenced behaviour during disasters (Perry and Mushkatel 1986) though might not be directly (Perry and Lindell 1991). Apart from special cultural preferences, ethnic minorities' disaster responses could be affected by their limitations in language proficiency, which is related to their information and knowledge access (Morrow 1999). People of different ethnicities were found different in terms of having evacuation plan (Bethel *et al.* 2013). In particular, perceived race-based and historical inequalities, together with low socioeconomic status or financial limitation were some of the reasons making African Americans chose not to evacuate before hurricane attack (Elder *et al.* 2007).

Age is commonly considered as adversely affecting disaster response (Morrow 1999), with the elderly persons having less help (Friedsam 1961), fewer resources (Phifer 1990) or less access to resources (Tobin and Ollenburger 1992). During Hurricane Katrina attack, young age contributed to evacuation decision (West and Orr 2007).

Besides formal education, informal or public education on disaster preparedness and response should be equally important, especially in hazards-prone areas, because public education can affect disaster response decision (Nielsen and Lidstone 1998; Shaw *et al.* 2011). Dissemination of information regarding government disaster response measures or facilities could be considered as informal or public education. However, people received more disaster risk reduction education and employed more disaster knowledge might not always change their response behaviour, therefore particularly improving the attitudes of knowledge recipients was proposed to narrow the discrepancy between knowledge and behaviour (Nakano and Yamori 2021).

The more capable and informed community leaders were found to be the key players in hazard early warning, including the relay of information between the institutions and local residents (Rahayu *et al*. 2020). They were expected to perform special roles, like communications, in disaster scenarios (Grossman 2020). Sichuan village leaders was the third most important group people would rely on during disaster emergency (Du *et al.* 2016).

Apart from demographic factors, Weinstein (1989) confirmed the effect of disaster experience on disaster response. Risk perception, ability and vulnerability level all affected the taking of protective or evacuation action (Perry and Lindell 1991; Uehara 2018). Geographical proximity also contributed to evacuation decision (West and Orr 2007). Through the 2011 Tohoku earthquake tsunami in Japan, World Bank suggested safe evacuation of people would not rely on a single mitigation, but a combination of structural and non-structural measures (Ishiwatari and Sagara 2012).

As for geohazards, disaster responses are also affected by a mix of factors. A post-Wenchuan earthquake study in Sichuan found that the higher educated and those perceived higher seismic risk were more likely to escape if earthquake hit (Ao *et al.* 2020). This echoes some findings in other places (Alexander and Magni 2013).

A study on landslides revealed that some Indians were not prepared for big landslides because such disasters do not occur frequently (Chaturvedi and Dutt

2015). Another study on debris flow in Taiwan showed that those possessed disaster education, including knowledge of debris flows, participated in trainings and drills, were aware of evacuation route and had disaster experiences, knew best how to react when debris flow strike (Luo *et al*. 2014).

2.4 Development of vulnerability research

This thesis intends to find out what factors affected Sichuan rural populations' relocation decisions, debris flow risk perceptions or disaster responses. This involves an investigation of possible impacts of vulnerability indicators. A detailed understanding of previous literatures on the concept of vulnerability, the development of vulnerability theories and how they are relevant to this thesis is necessary.

2.4.1 The discussion of "naturalness" in disaster research and the relevant prevention and mitigation to alleviate vulnerability

Previous literatures explored the impacts of both the natural physical environments and the humans on disasters, their interaction, and how such interaction could affect vulnerability.

Starting from late 1970s, disaster risk reduction became a new discipline in academia (Birkmann 2013). The domination of physical sciences in disaster study with a "linear" model began to be replaced by social sciences (Alexander 2012b). The "naturalness" of the widely understood "natural disasters" was questioned and revisited by O'Keefe *et al.* (1976) in their key paper published in *Nature*, which argued that socioeconomic factors contributing more to disasters when compared to natural ones. Burton *et al.* (1978, 1993) conducted a pioneer research focused on human response and adjustments as well as their capability in coping with hazards, with analysis from individual, collective to national and international levels. Kates (1976) divided environments into three categories: natural, made and social. Whittow (1979) argued the significance of human systems in environmental hazards, and how human interact with physical forces by distinguishing "natural", "quasi-natural" and "social and man-made" hazards.

Hewitt (1983) noted that treating hazard as natural events can be misleading and the human element must be considered. Through the study of different countries from both the developing and the western world, Hewitt elaborated that calamities can be caused by constraints upon social response, socioeconomic orders and habitat which should be taken into account to alleviate future damages through applying suitable solutions. The theory of marginalisation by Susman *et al.* (1983) further suggested vulnerability is closely connected to underdevelopment caused by exploitation, while underdevelopment and vulnerability are more influential than physical hazards in disasters.

On the other hand, adopting and focusing on technocratic approaches or structural, architectural or engineered solutions for disaster reduction and to alleviate damages caused by hazards have been dominating, even after more than a decade of discussions on non-naturalness or human cause of disasters (UNESCO 1978; Coburn and Spence 1992; Cannon 1994). These include those initiated by the United Nations during the International Decade for Natural Disaster Reduction, such as earthquake-resistant design (United Nations 1988a; Clayton 1994).

Conversely, other literatures questioned the effectiveness of radical land-use change in reducing geohazard risk (Wisner 1978) or counter-argued that technological measures are not the simple answer to disaster risk, especially in developing countries where relevant expertise and resources were unavailable, and may even cause greater vulnerability (Westgate and O'Keefe 1977). Poor hazards-prone countries would rely on mitigations other than sophisticated technology to be ecologically sustainable (Alexander 1991b). Hence, hazard mitigation and reduction measures other than technical and structural ones served as alternatives and gained increasing attention. White and other researchers (1974), through their studies of a wide range of hazards in local, national and global scales, proposed that a mix-mode of adjustments in coping hazards, including technical devices, government policies and social regulations, as well as insurance to land-use adjustments, is to be adopted to alleviate negative impacts of extreme events. Pelling (2001) argued that although distribution of disaster impacts was molded by both physical and human features, physical and social sciences disciplines were competing for financial resources and political impact rather than cooperating to tackle the problem. Ultimately, there was a stagnation in disaster

management and a creation of hazard geopolitics. Cardona (2004) further stated that vulnerability is caused by a combination of physical and socioeconomic fragility as well as lack of resilience and suggested a holistic and interdisciplinary approach of risk assessment and risk management.

The Wenchuan earthquake induced numerous secondary geological hazards in Sichuan, dominated by various forms of mass movements, including debris flows. Their potential impacts on the threatened populations depend, not only on the nature of the hazards themselves, but also on how people deal with them.

In view of the potential future occurrence of mass movements, the Chinese Central Government has captured the post-disaster policy windows (Kingdon 1984, 1995, 2011; Solecki and Michaels 1994) to lower vulnerability through mitigation (Alexander 2000, 2002). A mixed-mode, except insurance (White 1974), and a holistic approach (Cardona 2004) have been adopted. A range of disaster mitigation, preparedness and response measures were imposed on the communities to reduce the risk exposed and to assist the threatened or affected population in coping with debris flow risks.

The government has introduced new regulations and amended existing laws on rehabilitation site selection. For areas where risks are unacceptable, risk avoidance measures are imposed. The law reminds that reconstruction site selection should avoid seismic fault zones and areas with huge potential geohazards risks to prevent damage caused to the residents. Possible human contribution to future disasters are hoped to be eliminated by land-use adjustments.

For other areas where risks are tolerable, the government has imposed geotechnical measures like dams as an upgrading (Alexander 2007) to reduce the risk affecting the populations, hence alleviating their vulnerability. The authorities also considered human and social factors through the promotion and education of community disaster risk reduction measures.

Whether such measures would actually reduce risk exposure and vulnerability depend on their compliance and effectiveness. This is to be evaluated by the rural

residents' relocation decisions, debris flow risk perceptions and anticipated disaster responses.

2.4.2 The concept of vulnerability

The understanding and explanation of the concept of "vulnerability" has kept changing since this terminology was first used in connection with the research of natural hazards and disaster risk reduction. Being inspired by studies of famine and food allocation in the 1970s and 1980s, including the "entitlement approach" (Sen 1981), social elements began to be included in the study of vulnerability (Birkmann 2013).

Since the 1970s, it has been aware that a combination of social, political and economic dimensions to investigate how vulnerability was influenced in changing environments is crucial, implying that flexible measurements of the dynamic vulnerability are needed (Vogel 2001).

Similarly, Cardona (2004) and Birkmann (2013) pointed out that since the 1990s, social, economic, political, cultural and educational factors were explored as the causes of vulnerability across the academic world in different continents. Blaikie *et al.* (1994) and Wisner *et al.* (2004) investigated the combination of factors causing vulnerability in the developing world, and what conditions can make a natural hazard become a disaster. A discussion of different dimensions of vulnerability was opened up.

UNISDR (2009) defined vulnerability as the "characteristics and circumstances" of a community that make it "susceptible" to the damages caused by a hazard. Such characteristics and circumstances can be caused by a wide range of physical, social, economic, and environmental factors.

Internal defencelessness and external stress exposure

The social element of vulnerability in terms of peoples' capacity to absorb and recover from hazard events was considered in the mid-1970s (Westgate and O'Keefe 1976). Chambers (1989) then introduced the concepts of "internal" defencelessness as well as "external" stress exposure and shock with reference to the study of agroecosystem sustainability by Conway (1987). Through eliminating

external stress and shocks by means like disaster preparedness and at the same time enhancing internal and private defence and response ability, vulnerability can be reduced (Chambers and Conway 1992).

In short, vulnerability is an interaction or consequences of human coping capabilities and social assets when exposed to sudden stress (Swift 1989; Chambers 1989; Chambers and Conway 1992; Downing *et al.* 1996; Vogel 2001). Cardona (2004) described vulnerability as susceptibility to damage and reduced capacity.

With reference to these studies, this thesis evaluates whether government's imposition of disaster preparedness measures, i.e. eliminating external and sudden stress, and imposition of disaster response measures aiming to enhance disaster response ability, i.e. enhancing internal defence and coping capacities, can effectively reduce vulnerability. These were done by surveying the relocation decisions, risk perceptions and disaster responses of the populations exposed to debris flow risks.

Vulnerability varies in time and space

The type and extent of vulnerability vary in time and space. For countries with high economic growth and technological advancement, hazards can be created by human occupancy of hazard zones and environmental change (White 1974). “New” hazards were developed with technology or medical advancements (Cutter 1993), especially after World War II (Kates *et al.* 1985) and affected the industrialised nations significantly, while rural populations in developing nations were more affected by hazards originated from the nature (Harris *et al.* 1985).

The relative impacts of different vulnerability aspects also vary in time and space. Blaikie *et al.* (1994) and Wisner *et al.* (2004) highlighted the significance of power relations and political ideologies on vulnerability in developing countries, while Rhyner (2013) suggested environmental and institutional aspects of vulnerability were becoming more crucial.

Variation in the types of hazard can affect the vulnerability of different places (Cutter 1996; UNDP 2004; Birkmann 2013). Even the exposure to the same type of hazard by the same community could vary in time (Colten 1988a, 1988b).

Based on these understandings, the vulnerability dimensions affecting remote rural residents can be different from those influencing urban or less remote populations. Those living in one place can have different vulnerabilities from those residing elsewhere.

2.4.3 Dimensions of vulnerability

Social vulnerability

Variation in social conditions of places and of people might relate to any difference in compliance with and effectiveness of government disaster risk reduction measures.

Poverty and Vulnerability

Social vulnerability can exist on both societal and individual levels. Academic discussion on socioeconomic dimension of vulnerability has started in the 1970s, when O'Keefe *et al.* (1976), who based on global statistics, stated that the poorest countries were most hard hit by disasters while the ability to monitor disasters in developed countries tended to save them from the occurrence of disaster. Poor countries were more vulnerable to earthquake risk (Coburn and Spence 1992). Through marginalisation, the poor populations in the third world were becoming poorer and poorer. Social class is a vulnerability indicator and the underprivileged are in general more vulnerable (Susman *et al.* 1983). The poorer populations were more vulnerable to disasters and suffered disproportionately more, although this might not be fully applied to technological disasters (Bogard 1989). A World Bank study of 52 countries revealed that poor populations were more exposed to droughts and floods in urban areas where land resources are limited, particularly in Africa (Winsemius *et al*. 2015). Poor households living in slums and dilapidated settlements in India were the most vulnerable to floods (Patankar 2015). However, not all literatures agreed the poorer are always the more vulnerable. The United Nations Intergovernmental Panel on Climate Change (IPCC) Report showed that not only the poor and the elderly in the developing countries were more vulnerable

under climate change, those groups in developed countries experienced the same (IPCC 2008).

Poverty can be closely linked with low coping capacity. People of lower socioeconomic status recovered slower (Bolin and Bolton 1986). In terms of relocation, people with lower income were less able to move to another place for new jobs (Morrow 1999). In some cases, populations with the same level of income could experience different impacts from the same disaster (Wisner 1993).

Cannon, Twigg and Rowell (2003) included initial individual's well-being as well as institutional environment and networks as two other elements of social vulnerability. Vulnerability should be reduced by offering disaster protection to the vulnerable (Cannon 2006). Involvement of governments and NGOs on top of individual efforts in enhancing protection and eliminating vulnerability to hazards were called upon (Cannon 1994, 2006).

Demographic distribution

Demographic distribution may also influence social vulnerability of a community. Real world case studies widely established that dependents like elderly persons, children and females are in general more vulnerable in a society (Parasuraman 1995; Olson and Alexander 1996; Birkmann 2013). Elderly persons have higher disaster risk (Friedsam 1960; Morrow 1999). They tend to have fewer resources and support (Friedsam 1961; Bolin and Klenow 1988; Phifer 1990; Tobin and Ollenburger 1992) or take longer time to recover (Phillips 1991).

Ethnic minorities were also considered as more socially vulnerable (Birkmann 2013). They were found marginalised throughout the disaster cycle, as Morrow (1999) cited several studies and argued that the minorities were neglected from disaster preparedness, response, recovery to mitigation.

United Nations Environment Programme (UNEP) found that social discrepancies, inequalities and eventual marginalization caused by gender, ethnicity, social and financial status, or even the residing location, can reduce one's capacity to react when environment changes (Kok and Jäger 2007). Different groups in the society

have different vulnerabilities -- besides the dependents, refugees and displaced populations were also more vulnerable (Kok and Jäger 2007).

Economic vulnerability

Economic vulnerability can be grouped into macroeconomic and microeconomic scales, for instance, low income level, low savings and high debt were some major microeconomic causes of vulnerability in developing countries (Birkmann 2013).

On an individual or household level, occupation, livelihood and assets are all relevant to microeconomic vulnerability to disasters. Households with members inclining to a certain occupation or livelihood may be more vulnerable to disaster attack because they tend to earn their income from one particular industry that disasters might affect (Birkmann 2013).

Geographical/ Biophysical vulnerability

Some literatures investigated the possible relations between geographic location or biophysical environment and vulnerability by referencing case studies exposing to different disaster risks. Alexander (1993) suggested the nearer to a hazard risk source, the more vulnerable one would be. Vulnerability level relies on risk proximity, exposure and location. A study of earthquake exposure in California illustrated the significance of location to vulnerability (Palm and Hodgson 1992). Areas of low latitude such as megadeltas and dry lands were exposed to higher risk (IPCC 2008). A combination of biophysical or geographical elements and social response also affected the understanding and assessment of vulnerability (Weichselgartner 2001).

Environmental vulnerability

Regarding the impact of environment on vulnerability, two problems can be identified. Firstly, whether/how environmental changes in terms of increasing occurrence and experience of debris flows have impacted people's vulnerability.

Secondly, whether/how the subsequent improvements in environment, including imposition of geotechnical mitigation measures to tackle the environmental problem in terms of debris flow risk, and the improvement of human well-being by

introducing disaster preparedness measures, can reduce environmental vulnerability.

For the first problem, previous literatures considered environmental vulnerability as linked closely with both social and economic vulnerability. It is about how a changing environment or natural resources degradation can impact one's disaster risk exposure as well as affect one's livelihood and vulnerability (Birkmann 2013). Environmental vulnerability can be more relevant to rural populations like farmers and fishermen who are more closely connected to natural environment and rely much of their livelihood on the environment and land resources (Santha 2014). Environmental vulnerability in terms of frequent earthquakes, typhoons and floods was noted as influencing China (Paltemaa 2017).

The sustainable livelihoods approach (Chambers and Conway 1992) tended to understand the interrelations between environment and communities at risk and investigated how external impact on livelihoods interacts with internal coping capacity to affect vulnerability.

Mapping was also applied in the study of environmental vulnerability through identifying and comparing highly vulnerable regions affected by environmental degradation and endangerment, and marked the zones with socioeconomic and physical risk and different environmental vulnerability (Kasperson *et al.* 1995).

For the second problem regarding the impact of environmental improvements, UNEP indicated that secure entitlement to environmental assets are crucial for the livelihoods of those heavily relying on natural resources and avoiding them from becoming more vulnerable (Kok and Jäger 2007, 2013). There should be detailed determination of community demand of resources and the provision of such resources by ecosystems to reduce environmental vulnerability with institutional capacity (Renaud 2013).

Liverman (1990) further proposed the implementation of agricultural techniques to impact vulnerability in response to environmental change. Although this literature studied drought, it provided insight on the use of geotechnical mitigation measures in alleviating debris flow vulnerability.

Environmental vulnerability changes in time (Vogel 2001) and space (Kasperson *et al.* 1995). Good ecosystem management is crucial to reduce both disaster risk (PEDRR 2013) and vulnerability in countries suffered from multiple hazards (PEDRR 2014). Maintenance and improvements of human well-being are necessary to reduce not only socioeconomic vulnerability but also environmental ones (Kok and Jäger 2007). From a broader perspective, Vogel (2001) even suggested environmental vulnerability covered a wide scope from geophysical, engineering, technological to physical, economic and social aspects.

Institutional/Political vulnerability

Government or institutional involvements are sometimes used to tackle disaster risk exposure of citizens. In China, historical record showed that the first disaster governing institution was established about 1,000 years ago during the Western Zhou era (Paltemaa 2017). Relocation, resettlement and imposing structural and non-structural measures are some usual forms of adaptation strategy imposed by governments to avoid the communities from exposing to disaster risk. Measures imposed to tackle floods in Mekong Delta is an example, yet such strategies might instead cause mismatch and create vulnerability if the reliance on the local environment, livelihoods and usual practices of the affected populations are not fully considered (Birkmann 2013).

Many other studies revealed the negative impacts of state policies or government strategies in dealing with disaster risks, emergency reliefs and recoveries. The cases of Somalia and Haiti illustrated the incapability of governments in handling drought and earthquake disasters and negatively influenced vulnerability and recovery (Birkmann 2013).

People's trust on government is another important issue. The public typically distrusted governments and officials as risk information source (Poortinga and Pidgeon 2003, 2004; Haynes *et al.* 2008). However, government suggestions were influential to evacuation decision under a hurricane hit scenario if there were effective communications and detailed planning (West and Orr 2007).

Government or political influences have crucial impact on other post-earthquake recovery experiences (Alexander 2012a). A central agency such as the Federal Emergency Management Agency (FEMA) was considered as crucial for disaster management (Moynihan 2013). As for China, the political structure was analysed and a unitary responsiveness or U-form feature and a power-concentrated structure of the Chinese government were considered as underlying the strong disaster response ability but led to a neglect of disaster relief, reduction and prevention (Luo 2014). In other words, institutional, state and political influence may or may not help reduce vulnerability.

The significance of regulations was recognised as early as in the 1970s. Wisner (1978) investigated this from a political economy perspective. It is arguable whether the impacts of institutions and their policies should be merged into the discussions of social, economic and environmental dimensions of vulnerability because they are actually interconnected. Similarly, Cannon (2006) suggested vulnerability is influenced by a set of root causes comprising social, economic and political processes, all combined into “institutional factors”. For practical purpose, Birkmann (2013) proposed institutional vulnerability should be treated as a separate aspect in vulnerability studies in order to produce more detailed assessments focusing specifically on how variations in governance can influence vulnerability.

Cultural vulnerability

It was argued that the study of culture in the discipline of disaster was difficult in getting recognition (Gheradi 1998). Relatively limited studies on culture could be due to a mixture of factors, including its dynamic, complicated and indefinite nature, making culture difficult to quantify (Alexander 2012b). Nevertheless, Turner (1978) showed a cultural approach in his Man-Made Disaster model and Hewitt (1983) highlighted the importance of comparing different cultures to understand how sociocultural or human ecological situations can affect the characteristics of damages caused by hazards.

Alexander (1997) emphasised the significance of culture, and explained how the emic (inherited and special context) and etic (universal and modern) components of culture keep changing through time by cultural metamorphosis, and eventually

affect one's perception, interpretation, attitude, disaster response and community-based disaster reduction efforts (Alexander 2012b). Heijmans (2001) argued vulnerability is basically about perception hence understanding risk perception of the affected populations and their active participation in finding disaster protection and response strategies are crucial in lowering vulnerability. Adaptability of a certain culture may affect its vulnerability and risk exposure (Bankoff 2001).

2.4.4 Multi-dimensions of vulnerability

Many studies showed that vulnerability of communities was the result of a combination of more than one dimension of vulnerability.

Bohle *et al.* (1994), for example, developed a structure in which vulnerability is affected by entitlement, human ecology and political economy, as well as political and social empowerment, endowments and political ecology. This model aims to understand the development of vulnerability through time and space, in order to alleviate risk exposure and enhance future coping capacity. *La Red* in Latin America indicated that vulnerability is caused by a combination of socioeconomic and political factors (Cardona 2004) while Rhyner (2013) argued economic vulnerability did include public-sector fiscal vulnerability.

In a study on reducing disaster risk and risk estimation, the United Nations Development Programme (UNDP 2004) considered the impact of a basket of 24 vulnerability indicators grouped under eight categories of social, economic and environmental variables on risk. In a subsequent study, the United Nations further stated that vulnerability is influenced by a mixture of physical, social, economic and environmental dimensions that contribute to susceptibility of a unit, ranging from an individual, a community, a system to an asset, to damage and loss (UNISDR 2009, 2015, 2017a). It noted the complexity of vulnerability and the difficulties to untangle its factors, therefore rigorous analysis is necessary in unbundling the relations of various dimensions (Vogel 2001). With reference to previous literatures, this research study, instead of just exploring the possible impacts of individual dimension of vulnerability, also takes a multi-dimension approach.

2.5 Theoretical development of vulnerability studies

2.5.1 This research thesis and the need of a general model of vulnerability

In the past few decades, various models of vulnerability have been developed based on testing different circumstances. This section briefly describes and discusses the major existing vulnerability models which mainly considered multi-dimension vulnerability. It explores and concludes which model(s), or which parts of them, are relevant to this research thesis. The theoretical underpinnings of the fieldwork and analysis involved in this thesis are explained.

Understanding how the different dimensions of vulnerability and other factors explain the post-earthquake situations in China is an important task of this thesis. A general model of vulnerability that can explain the Sichuan, or China, situation, is to be developed.

2.5.2 Reviews of the models

The Hazards Of Place (HOP) Model of Vulnerability

This model was proposed by Cutter and Solecki in 1989 in their study of airborne toxic releases when they found diversified definitions and different themes in vulnerability study. The initial HOP model was inspired by Hewitt and Burton's work on hazardousness of place which studied regional ecology of damaging hazards (Hewitt and Burton 1971; Cutter 1993, 1996). Cutter's initial HOP model was applied in some chemical disasters, pesticides studies and technological hazards in rural United States (Solecki 1990; Tiefenbacher 1992; Cutter 1993). Being a geographer like Hewitt and Burton, Cutter (1996) emphasised locality and place and refined the model with reference to new studies.

The model showed the interactions of different elements, including risk, mitigation, hazard potential, geographic context and social fabric, and how they produce and contribute to vulnerability, specifically biophysical and social vulnerability, and then the vulnerability of certain place (called place vulnerability) and the communities. In other words, vulnerability is place and context specific. Such relations among the variables and vulnerability change over time, in response to the changing context; and a feedback loop exists from place vulnerability to risk and mitigation (Cutter 1996).

The study areas in this research are located in different parts of Sichuan and should have different biophysical, social and place vulnerability. The socioeconomic indicators proposed by the HOP model are useful for evaluation. The highlight of place and context specific of vulnerability is also an important reference. However, the HOP model does not emphasise the role of government in influencing vulnerability, therefore this research does not apply the model fully.

The revised HOP model was mostly applied in the United States (Cutter and Morath 2013; Cutter *et al*. 2000). Eight socioeconomic indicators including total population and housing units, number of females, non-white, population under 18 and over 65, house value and mobile homes were used.

Together with a list of factors influencing social vulnerability spotted by Cutter *et al.* (2003), such as education and family structure, valuable references are provided for this research. However, some cannot be directly applied to China. For instance, the number of "non-white" is an indicator in Cutter's study in the US. This is not applicable to Sichuan simply because there is no distinction between white and non-white. Nevertheless, Cutter *et al.* (2003) further developed a Social Vulnerability Index (SoVI) with 11 independent factors, including ethnicity, income, age and occupation. Chen *et al.* (2013) replicated the U.S.-based SoVI in China Yangtze River Delta region. They found that ethnic minorities, i.e. the non-Hans, have higher social vulnerability, a result similar to the finding of non-whites in the USA. Since Sichuan also accommodates different ethnic groups, like Han, Tibet and Qiang, it is sensible to study vulnerability through looking into ethnicity.

By applying Cutter's indicators, such as gender and age, in the questionnaire of this research, whether these socioeconomic factors might be related to vulnerability of the studied residents are evaluated. The outcomes can also tell whether such indicators have different impacts on the US and China contexts.

A Model of Vulnerability Types

David Alexander's Model of Vulnerability Types (2007), built on his earlier work (Alexander 1997, 2000), suggested various types of vulnerability, including total/pristine (i.e. precarious nature of life), economic, deprived, residual, wilful, newly-generated, technological/technocratic and delinquent. Each can lower the

effectiveness of reconstruction process, and a combination of them can affect successfulness of reconstruction and resilience (Alexander 2007).

This model provided fresh ideas about some vulnerability dimensions not addressed in other models. For instance, total/pristine vulnerability means those vulnerability caused by limited experience of hazards when hazards are not yet been reduced and life is precarious. Economic here means particularly the vulnerability of the marginally employed. Newly-generated represents those vulnerabilities arouse from unexperienced hazards. It highlighted the significance of the impact of limited or incomplete knowledge (deprived and wilful). It also touched on the sensitive question of corruption and criminal activity, i.e. delinquent, as well as technological/technocratic aspects. However, these last two vulnerabilities do not fall into the scope of this research.

In the post-Wenchuan earthquake Sichuan, five vulnerability types from Alexander's model are particularly relevant for debris flow risks. The first one is "total/pristine" vulnerability. It is related to the second type of vulnerability in Alexander's model, the "newly-generated" or new vulnerability "caused or exacerbated by deteriorating circumstances" or worsening geological environment in the study areas (Alexander 2007). Therefore unexperienced, or unexperienced scale of, debris flows can be a vulnerability indicator in this thesis.

The third and the fourth vulnerability types in Alexander's model that provides important reference to this research are "deprived" and "wilful". "Deprived" or "residual" means the under-utilise of available knowledge and safety options caused by insufficient upgrading (Alexander 2007) which can be due to isolation, literacy or education level, language barrier, communication and financial limitations. New safety standards are available but lack of determination, political efforts or resources to upgrade (Alexander 1997). "Wilful" means existing knowledge is wilfully or intentionally ignored for political, perception, culture, financial limitation, institutional factors or other reasons (Alexander 2007). Since this research explores the compliance and effectiveness of government disaster risk reduction measures after the Wenchuan earthquake, it is about knowledge dissemination. The importance about knowledge utilisation, i.e. deprived, and ignored of existing knowledge, i.e. wilful, are relevant.

The fifth vulnerability type proposed by Alexander (1997, 2007) is economic vulnerability. It means disaster can, through damaging of production means or business, result in occupation loss. Together with vital impacts of geographical connectedness, different political influence and funding availability on variations in disaster recovery successfulness (Hogg 1980), different extent of compliance (Angotti 1977) with government directives are addressed in this research.

Alexander's risk and vulnerability equations

Alexander (1991a) presented an equation of total risk as Equation 1a below where Rt is the total risk, including casualties and loss; E is the elements at risk, consisting the elements threatened by disaster such as population, environment and economic activities; Rs is the specific risk, that is the expected losses from specific hazards, which is the impact of a given natural hazard in a specific time and place (H) multiplied by vulnerability (V). Total risk is a function of the elements at risk, together with hazard and vulnerability as presented in Equation 1b (Alexander 1991b).

Equation 1a $Rt = E \cdot Rs = E \cdot (H \cdot V)$

Equation 1b

Total risk

= impact of Hazard × elements at Risk × Vulnerability of elements at risk

The impact of natural hazards (H) can depend on either natural trends or humans. The number of elements at risk (E) could be affected by imposition of laws, development and evacuation plans (Alexander 1991b). This means imposition of laws, development and evacuation plans would affect the population, environment and economic activities, hence the total risk.

Alexander also noted disaster risks has been influenced much by cultural-based societal choices which then affect vulnerability management, through citing examples from Italy (Alexander 1991a).

Fothergill (2000) found that culture, institutions, links and interaction were related to knowledge transfer between academic researchers and practitioners in the hazard discipline. Based on this notion, Alexander (2012b) suggested the key resources for disaster risk reduction are knowledge, organisation and communication which are inexpensive and becoming more convenient.

Alexander (1991a, 1991b) proposed total vulnerability to disasters are composed of three elements as shown in Equation 2.

Equation 2

$$\text{Total vulnerability (V)} = \text{Risk amplification measures } (R_A) - \text{Risk mitigation measures } (R_M) \pm \text{Risk perception factors } (R_P)$$

Risk amplification and risk mitigation are the products of bad and good construction practices respectively. Risk perception relies on the collective sense on attitude and behaviour of planners, consultants and developers, and affected by cultural and value systems indirectly (Alexander 1991a). Risk amplification is caused by continued development of past and future disaster areas but can be alleviated by mitigations (Alexander 1991b).

The equation was developed by further defining R_A and R_M as the sum of factors that amplify and mitigate risks resulting from bad and good practices respectively (Alexander 2000, 2012b):

Equation 3

$$\text{Vulnerability (V)} = \text{Risk amplification processes } (R_A) – \text{Risk mitigation processes } (R_M) \pm \text{Risk perception factors } (R_P)$$

Vulnerability can be increased through bad practices and lowered through mitigating hazards (Alexander 2000, 2002). Engineering risk, which is included in R_A and R_M, is relatively easier to calculate (Alexander 2012b). Several criteria can be adopted in evaluating the impact of a mitigation proposal to vulnerability level, including whether the measures may exacerbate existing hazards, create new risks and too expensive (Alexander 2002).

A new social vulnerability model

-- Model of cultural metamorphosis

Perceived risk or public attitudes is a kind of social science risk difficult to measure, assess, interpret and apply appropriately (Purchase and Slovic 1999; Alexander 2012b). However, risk perception can increase or decrease vulnerability depending on the accuracy, and is closely related to cultural factors and influence of ideologies (Alexander 2000, 2012b).

In the context of disasters, decision making involves perception which is influenced by both inherited and modern culture (Alexander 2012b). Through applying a model of cultural metamorphosis using the L'Aquila earthquake in Italy as the case study, Alexander (2012b) proposed a new model in which human socioeconomic vulnerability is affected by a combination of identifiable cultural characteristics, history and physical hazards.

Alexander's consideration on cultural impacts, together with his equations (1991a, 1991b, 2000, 2002, 2012b) on risk and vulnerability, included the key risk elements contributed to vulnerability, could help test the hypotheses and useful for the analysis of this thesis.

Pressure And Release Model (PAR Model)

Blaikie, Cannon, Davies and Wisner developed and presented their disaster PAR model in 1994 (Blaikie *et al.* 1994; Wisner *et al.* 2004). As with Alexander's risk equations (1991a, 1991b, 2000, 2002, 2012b), the PAR model argued that risk (R) is a result of a combined effect of hazard (H) and vulnerability (V) of people to that hazard, i.e. R = H x V.

Disaster is caused by two components: hazard and the processes leading to vulnerability. "Pressure" in the model is caused by vulnerability of the population and the hazard they are exposed to while "Release" is the reduction of vulnerability hence pressure and disaster. Vulnerability can be caused or contributed by hazard itself, or some factors or processes which are not quite related to the hazard.

The PAR model stated that vulnerability is developed through a progression starting from a group of spatially and temporally distant root causes involving

political, economic and demographic processes affected by political and socioeconomic structures, governance, administration as well as culture and ideologies (Wisner *et al.* 2004). These root causes have direct implications on resource allocation.

The second step leading to vulnerability in the PAR model is called “dynamic pressures” in forms of rapid population change, urbanisation, or deforestation etc., through which the impacts of the root causes are translated into various forms of “unsafe conditions” in terms of physical environment, local economy, social and institutional situations, such as prevalence of endemic diseases, for the vulnerable populations (Wisner *et al.* 2004). The sequence of root causes to dynamic pressures to unsafe conditions can lead to spatially and temporally specified vulnerability of a community in face of different hazards. Application of the model in real world situations showed that it should be the specific community defines its own vulnerability and decides how much risk it wants to take (Wisner *et al.* 2004). The PAR model is very comprehensive and emphases both the causes and reductions of vulnerability.

Although many of the dynamic pressures and unsafe conditions mentioned in the PAR model are global trends not directly relevant to Sichuan, making the model not fully adopted as the framework of this research, it comprises elements involved in the “progression of vulnerability” that are relevant. Unsafe conditions such as “low income levels”, “livelihoods at risk” and “special groups at risk” as well as dynamic pressure such as “training” are some of those.

In addition, Wisner (2001) introduced a list of indicators of vulnerability and resilience by phases of the disaster management cycle, i.e. prevention, preparedness, response and recovery, as well as by social actors, i.e. government, private sector, community, locality and individual/household. Isolation, knowledge and experience are some on the list that are relevant to this research.

BBC Conceptual Framework

The BBC Conceptual Framework (BBC) is based on the works of Bogardi and Birkmann (2004) and Cardona (1999) (quoted in Birkmann 2013). The concept of vulnerability in this framework echoes the “three pillars” of sustainability, i.e. social,

economic and environmental elements are the key integrated components. This implies both the socioeconomic aspect of a society and the environment can be vulnerable to hazards (Birkmann 2013). As in the HOP model, the impact of locality and place is noted. The location of human and infrastructure and the extent of their exposures to disaster risk are considered as affecting susceptibility and vulnerability.

BBC identified two temporal scales in which vulnerability can be reduced. This first is before disaster risk occurred and vulnerability reduction is carried out through disaster preparedness measures. The second is after disaster risk occurred and vulnerability reduction is done through post-disaster emergency response and management (Birkmann 2013). BBC focused on the dynamic process and the feedback loop in which vulnerability falls into (Birkmann 2013). The three thematic spheres and the two temporal scales provide a clear and simple umbrella to analyse the factors affecting vulnerability.

The situation of post-Wenchuan earthquake Sichuan being studied in this thesis falls onto both temporal scales described in BBC. On one hand, the place is now at a post-disaster stage and vulnerability reduction has been done through post-disaster response, mitigation and management. On the other hand, disaster preparedness measures have been imposed to reduce vulnerability before the next debris flow strike.

BBC emphasised simultaneously on susceptibility and degree of exposure, coping capacities and the need to adopt potential intervention tools to help reduce vulnerability in the social, economic and environmental spheres (Birkmann 2006, 2013). Impacts of organisation and institutional factors, potential losses and deficiencies are all analysed proactively before disasters hit to reduce vulnerability (Birkmann 2013). The framework was applied in case studies such as tsunami vulnerability in Sri Lanka (Birkmann and Wisner 2006).

The core element of this thesis, namely the impact of government measures, is neither the main focus nor much elaborated by BBC. Therefore BBC is not fully applied in this study. Nonetheless, it provided valuable insights for studying pre- and post-disaster situations.

The elements of exposure, susceptibility, coping capacities and intervention in alleviating vulnerability in BBC are referenced in this thesis. In terms of susceptibility and exposure, “location of residences”, “impact of debris flow on the populations, their homes and their properties”, together with “socioeconomic situation” like “occupation” and “family structure”, are considered. The residents’ “knowledge and experiences of debris flow”, their “family and social networks to tackle debris flow”, “information access” as well as “financial support from various sources” *are marked as coping capacities*. Finally, “relocation”, “imposition of geotechnical mitigation measure”, “early warning”, “training”, “exercise” and “implementation of hazard zone” are applied as intervention tools (Birkmann and Wisner 2006). All these indicators are adopted to study their impacts on the Sichuanese.

MOVE Conceptual Framework

The MOVE Conceptual Framework (MOVE) was the product of a project called “MOVE” (Methods for the Improvement of Vulnerability Assessment in Europe) developed by the collaborative works of 13 European institutions (Vinchon *et al.* 2011). It is a manual using a holistic approach, addressing disaster risk assessment and management from various dimensions, and aimed to develop effective risk management strategies (Vinchon *et al.* 2011).

According to MOVE, vulnerability is the outcome of exposure in spatial and temporal scales, susceptibility and resilience. Similar to Alexander’s risk equation (1991a, 1991b, 2000, 2002, 2012b) and the PAR model (1994, 2004), MOVE proposed when hazards, either natural or socio-natural ones, combined with vulnerability of a society which can be of local, national or international level, risk with socioeconomic and environmental impacts will be triggered (Vinchon *et al.* 2011). Risk level is depended on exposure, susceptibility and resilience.

Similar to the BBC framework, the MOVE framework focused on how exposure, susceptibility, coping capacities and intervention affect vulnerability. MOVE tended to further conceptualise different aspects of vulnerability, including the causes such as exposure, susceptibility, lack of resilience (lack of societal response capacities)

and dimensions, including physical, social, ecological, economic, cultural and institutional (Birkmann *et al.* 2013).

MOVE suggested that disaster risk are managed by planning and governance on both institutional and community levels, and will then be reduced by adaptation through different forms of preventive and preparedness measures as well as risk transfer and mitigations to intervene both hazard and vulnerability. Through this process, exposure and susceptibility will be reduced while resilience can be improved, implying vulnerability can be alleviated, and at the same time, as negative impacts of hazard being reduced, risk will be minimised (Vinchon *et al.* 2011).

MOVE is not simply a generic conceptual framework, but a tool designed for real world practical applications by disaster risk management stakeholders and policymakers (Vinchon *et al.* 2011). It provided a useful pool of indicators to reflect the degree of exposure, susceptibility and resilience (Vinchon *et al.* 2011). However, it is so comprehensive that not every aspect of the MOVE framework can be adopted in this thesis. Moreover, although MOVE was first applied in an Asian country Japan, it was derived and designed based on European needs and experiences, and mainly applied in European places such as Cologne, Barcelona (Birkmann *et al.* 2013), Florence, London, Portugal and South Tyrol with different types of hazard (Birkmann *et al.* 2014). These places are very different from the study areas in China in terms of socioeconomic and institutional dimensions. Nevertheless, MOVE is useful and provided a very good overall framework in structuring the thesis, especially in terms of exposure, susceptibility, coping capacities, together with interaction with interventions in relation to vulnerability. The core methodology adopted by MOVE in measuring vulnerability is to select and develop relevant vulnerability indicators from physical, ecological, social, economic, cultural and institutional dimensions to reflect the degree of exposure, susceptibility and resilience (Vinchon *et al.* 2011). Some of these indicators are applied in this thesis (Birkmann *et al.* 2013).

For instance, disaster can cause unemployment, resulting in financial deprivation and socioeconomic vulnerability (Vinchon *et al.* 2011). “Socioeconomic dimension”

of vulnerability is therefore reflected by “the level of social and financial deprivation” which is indicated by income level in the thesis.

“Exposure” is interpreted as whether the respondents perceived they are staying in places threatened by (or avoiding) geohazards like earthquake and debris flow, that is, the safeness of the place. Topography or landscape of a place is also treated as an indicator of exposure in this thesis.

“Susceptibility” is multi-dimensional and its key thematic components are economic, physical, cultural, environmental and institutional. Susceptibility is indicated by the “expected economic loss to be caused by debris flow attack” in the study areas, “the percentage of people who are...able and willing to evacuate” and "have experience with debris flows”.

“Coping capacity” is indicated by “early warning system”, “in what ways the government provided information regarding debris flow”, and “individual’s knowledge about debris flow”.

2.5.3 Which model, or which aspects of the various models, are most useful to this research

The vulnerability models provided frameworks to understand the possible causes and types of vulnerability, including socioeconomic situations, government and institutional factors, environmental elements and cultural issues. Some models were tested in different countries. The HOP model was mainly tested in the United States. The model of vulnerability types was applied in the study of earthquakes relief in Japan, Turkey and India (Ozerdem and Jacoby 2006). The PAR model was applied to a number of developing and developed countries suffered from different hazards (Wisner *et al.* 2004). However, these models have not been applied and tested in China before, except the replication of the social vulnerability index of the HOP model in the Yangtze River Delta region (Chen *et al.* 2013). No single model of vulnerability can possibly fully explain the situation in the study areas in Sichuan. Nevertheless, some of these models, or some aspects of these models, are relevant and should be useful in explaining the field situation of this thesis and might be applied to other remote mountainous regions in rural China and places with similar characteristics. Therefore a mixture of selected indicators,

factors and dimensions of vulnerability referenced from these models are adopted to evaluate the situations of the study areas.

This research evaluates the post-earthquake compliance with mitigation measures and effectiveness of disaster risk reduction measures imposed by the Chinese government on the rural mountainous areas where debris flow risks are tolerable but need to be managed.

Such compliance and effectiveness are evaluated by analysing affected populations' relocation decision, risk perception and disaster response when exposed to debris flow risk. This is done by investigating whether and to what extent the vulnerability dimensions, particularly the government/institutional ones, of the studied population are related to their decisions, perceptions and behaviour.

Based on the models above, a list of vulnerability indicators relevant to the Sichuan situation are referenced in this thesis. Some indicators are grouped under "intervention tools" (comprised of government disaster mitigation, preparedness and response measures), as well as "exposure", "susceptibility", "culture", "socioeconomic vulnerability", "economic vulnerability" and "coping capacities (individual and institutional)". The three risk components in Alexander's vulnerability equations are also applied. Here below is the selected list of indicators with their sources in brackets:

Exposure

- Physical vulnerability (MOVE)
- Location of residences (BBC)
- Whether the people perceived they are staying in places threatened by earthquake or debris flow (MOVE)
- Impact of debris flow on the populations, their homes and their properties (BBC)
- Topography or landscape of a place (MOVE)

Susceptibility

- Socioeconomic situation (BBC)
- Family structure (BBC)

- Expected loss from debris flow strike (Alexander's equations on total risk; MOVE)
- Willingness to evacuate when debris flow hits (MOVE)
- Total/Pristine vulnerability (Alexander 1997, 2000, 2007)

Culture

- Cultural vulnerability (MOVE)
- Cultural issues (Alexander 1997, R_A in Alexander's equations on vulnerability)
- Cultural-based societal choices (Alexander's equations on total risk)
- Metamorphosis of inherited and modern cultures (Alexander 2012b)
- Family networks to tackle debris flow (BBC)
- Social networks to tackle debris flow (BBC)
- Insufficient land (R_A in Alexander's equations on vulnerability)

Socioeconomic vulnerability (BBC)

- Socioeconomic factors (R_P in Alexander's equations on vulnerability)
- Gender (HOP)
- Age (HOP)
- Ethnicity (HOP)
- Education (Cutter *et al.* 2003)
- Household size (MOVE)
- Income levels (HOP, PAR, MOVE)
- Occupation (HOP, BBC)
- Disaster can result in occupation loss through damaging of production means or business (Alexander 1997)
- Livelihoods at risk (PAR)
- Special groups at risk (PAR)
- Social deprivation (MOVE)
- Mobile homes (HOP)

Economic vulnerability *(MOVE):*

- Funding availability (Hogg 1980) or economic vulnerability (Alexander 1997)
- Financial support from various sources (BBC)
- Financial limitations (R_A in Alexander's equations on vulnerability)
- Financial deprivation, income (MOVE)

Coping capacity (individual)

Non-demographic factors

- Knowledge of debris flows (BBC, MOVE, Wisner 2001)
- Deprivation of available knowledge of debris flows (Alexander 2007)
- Deprivation of available knowledge of debris flows risk reduction measures (Alexander 2007)
- Wilfully ignore of existing knowledge of debris flows (Alexander 2007)
- Wilfully ignore of existing knowledge of debris flows risk reduction measures (Alexander 2007)
- Residual vulnerability (Alexander 1997)
- Experiences of debris flow (BBC, Wisner 2001, considered as “susceptibility” in MOVE)
- Newly-generated or unexperienced debris flows (Alexander 2007)
- New or unexperienced scale of debris flows (Alexander 2007)
- Isolation (Wisner 2001) or remoteness
- Risk perception of existing debris flow on home (R_P in Alexander’s equations on vulnerability)

Coping capacity (Institutional)

- Institutional vulnerability (MOVE)
- Information access (BBC)

Intervention tools *(Birkmann and Wisner 2006)*

- Relocation (BBC) and compliance (Angotti 1977)
- Laws (Alexander’s equations on total risk) on disaster relocation

Government disaster mitigation measures

- Imposition of geotechnical mitigation measures (BBC) or government structural risk mitigation measures (Alexander 1991a, 1991b, R_M in Alexander's equations on vulnerability)

Government disaster preparedness measures

- Hazard zone implementation (BBC)
- In what ways the government provided debris flow information (MOVE)
- Publication channels (R_M in Alexander’s equations on vulnerability)

Government disaster response measures

- Early warning system (BBC), Early warning tools (R_M in Alexander's equations on vulnerability)
- Emergency response facilities, involving evacuation plans and evacuation routes designed by the government (Alexander's equations on total risk, R_M in Alexander's equations on vulnerability)
- Disaster response training (BBC, dynamic pressure in PAR) or government risk reduction trainings (R_M in Alexander's equations on vulnerability)
- Exercise or disaster response drill (BBC) organised by the government (R_M in Alexander's equations on vulnerability)

2.6 Disaster risk reduction measures

The models above mentioned the impact of government intervention on vulnerability. Such intervention, in many cases, involves disaster risk reduction measures. Whether and to what extent the post-earthquake government disaster risk reduction measures affected relocation decisions, risk perceptions or anticipated disaster responses in Sichuan are tested in this research.

In this study, disaster risk reduction measures are comprised of mitigation, preparedness and response measures. Their definitions here adopted or referenced those by the UNISDR (2009). "Mitigation measures" include "engineering techniques and hazard-resistant construction". "Preparedness" means "the knowledge and capacities developed by governments,…communities and individuals to effectively anticipate, respond to and recover" from the impacts of…disasters". Preparedness measures must be supported by "formal institutional, legal and budgetary capacities" so the affected populations are able to respond to disasters in fast and suitable ways (UNISDR 2009). Disaster "response" involves emergency services to save lives and protect properties, such as the provision of temporary housing. Participation of the communities and volunteers is also considered as disaster response measures.

2.6.1 Disaster mitigation measures

There are numerous studies on debris flow mitigation in different places, including China, covering various kinds of slope stabilisation, drainage channel, sediment

blocking or check dams and dredging measures, with some best practices (Wu *et al.* 2016; Liu *et al.* 2013; Banihabib and Forghani 2017) and some failure cases (Wang 2013; Huang *et al.* 2020; Baggio and D'Agostino 2022). These studies basically focused on the technical impact and effectiveness of the engineering measures in reducing debris flow risks.

The Wenchuan earthquake and the induced secondary geohazards have inspired much investigation on their formation, geomorphology, mechanism and distribution (Yin *et al*. 2009a; Yin *et al*. 2009b; Li *et al.* 2010; Zhou *et al.* 2010; Gorum *et al.* 2011; Zhou *et al.* 2013; Ge *et al.* 2014; Wang *et al.* 2014).

In response to such geohazards, the government constructed numerous structural measures in the form of sediment trap dams, drainage channels, artificial step-pools and levees etc. to reduce debris flow risks. A heavy rain incident which seriously hit Wenchuan County in 2019 revealed the debris flow mitigation treatments had performed well and offered residents protection (SKLGP 2019). However, some other measures failed (Wang, Qi and Wang 2012; Chen *et al.* 2015). Such failures of dams, to some extent, were contributed by huge amount of materials carried by more occurrence of post-earthquake debris flows (Tian *et al*. 2022). Reinforcement was required for some of these geotechnical measures.

People's awareness of the imposition of such structural measures, regardless they were properly imposed or failed to perform, could affect disaster risk perception or response behaviour. Those who perceived structural mitigation could reduce flood risk did agree the need to introduce such measure (Starominski-Uehara 2021). In another case, residents who believed they were protected by levees had lowered risk perception but in fact they were exposed to flood risk (Ludy and Kondolf 2012).

2.6.2 Disaster preparedness measures

People's risk perception and disaster response behaviour could also be affected by their awareness of government disaster preparedness measures.

In some countries, local communities are involved in disaster preparedness through setting up neighbourhood disaster groups, led by disaster professional (Ogawa *et al.* 2005). These teams of community members spot and handle hazard

(Lewis 1999), contributing to disaster risk reduction (López-Carresi 2012).

In China, similar community involvement in disaster preparedness takes the form of a collective monitoring system called Mass Monitoring and Mass Prevention (MMMP) or Collective Monitoring Collective Defense, which can be traced back to encountering earthquakes (Zhang *et al.* 2020) since the late 1960s (Fan 2012) initiated by the Chinese government.

The former Ministry of Land and Resources (MLR) noticed the effectiveness of MMMP in preventing geohazard before the Wenchuan earthquake and tried refine the system after the quake (MLR 2008a). Various monitoring methods and different equipment targeting different types of geohazard were listed by the China Geological Survey (CGS 2008). Since 2009, the establishment of geohazard MMMP "Ten-possession counties" commenced (MLR 2009). The Ministry planned to develop most of the focused counties in mountainous and hilly areas into places that possess "organisation, funding, planning, prevention, system, promotion, early warning, monitoring, method and alertness" in geohazard MMMP within five years. The geohazard MMMP system has been upgraded through the years and until 2016, there were a total of more than 290,000 MMMP personnel across China (MLR 2017).

MMMP has been applied nationwide through the years, including the coastal regions. It is so popular that a survey regarding MMMP was openly distributed and collected online by a district government in Fujian Province (Hanjiang Government 2022). Local governments of Yuhang District in Hangzhou City and Panyu District in Guangdong Province had invited experts to provide training for MMMP personnel (Zhou 2013; GZ 2022). In Panyu, for example, apart from inspection, monitoring and early warning, knowledge regarding local geohazard distribution and development with case studies and scientific analysis was offered in training. However, probably because MMMP is a unique system developed by the Chinese government, academic research focusing or addressing it in languages other than Chinese is limited. Many of the Chinese literatures analysed and evaluated MMMP application in various localities (Qi 2008; Feng 2013), including its role in disaster reduction (Zhao 2008; Zhu and Li 2018) and lives saving (Tao and Yi 2010). Some discussed the integration of technology like using participatory sensing to collect

environmental data (Jiang 2018) and application of GIS or even Global Navigation Satellite System (GNSS) into MMMP to enhance risk monitoring effectiveness (Ren *et al.* 2013; Liu *et al.* 2020; Tao *et al.* 2021).

Research, especially the English ones, which specifically analysed the awareness of MMMP and its association with disaster risk perception is limited. A research on the Three Gorges Reservoir area in Chongqing, a city east of Sichuan Province (Xu *et al.* 2016), if not unprecedented, showed that the awareness of MMMP had no impact on rural populations' disaster risk perception. However, another piece of research on Chongqing showed how MMMP had enhanced disaster awareness (Zhao *et al.* 2019). An evaluation of a landslide occurred in a Sichuan village in 2018 also found that the implementation of MMMP contributed to a successful risk avoiding evacuation (Wu *et al.* 2018).

Besides MMMP, various other disaster preparedness measures were also developed in Sichuan. For instance, the government of Mianyang City tended to establish websites as well as radio and television broadcasting platforms to promote disaster reduction and earthquake prevention information, aiming to enhance residents' knowledge (SEA 2019).

The government has also carried out annual assessment on potential debris flow risk and economic loss in each threatened community (Sichuan Government 2010; SGIO 2015a).

Various forms of hazard zonation mapping is another disaster preparedness measure. Outside China, the assessment and measure of vulnerability in terms of vulnerability map showing socioeconomic situations, hazard risk exposure and coping ability was proposed to help reduce hazard loss and damage (Weichselgartner 2001). Attempts were made to develop better hazard maps to improve disaster response (Lindell 2020).

In China, official debris flow and landslide hazard zoning maps on a national scale were published by the Chinese Academy of Sciences in 1991 (Wu *et al.* 2016). Such debris flow hazard zonation tends to classify an area into risk zones of different levels, such as from having extremely high to extremely low risk. This is

closely linked to land-use planning through which the dangerous zones should be prohibited from development. However, hazard zonation in local or community scale is not well-developed in China.

Risk communications, which have drawn attention since 1986 (Lindell and Perry 2004), might also affect risk perception or disaster behaviour. As Slovic (1986) suggested, those in charge of information dissemination could influence people's perception and behaviour. The Protective Action Decision Model (PADM) by Lindell and Perry (2004) highlighted the connection between risk communication and protective behaviour.

In China, the effort of risk communications was reflected in certain projects. For example, a comprehensive training manual on health aspect of disaster preparedness aimed to arouse health risk awareness and to change behaviour of Chinese rural populations was published (Chan *et al.* 2016).

In Sichuan, Zhu *et al.* (2011) conducted a survey on seismic risk communications in Mianzhu, about 50 kilometres away from Wenchuan earthquake epicentre, with quake-affected city dwellers. Risk perception was found greatly affected by the credibility of information. The higher the credibility of word-of-mouth information, the higher the risk perceived.

2.6.3 Disaster response measures

Some countries put many resources in preparing and disseminating information to educate their people how to respond when hit by various disasters, including debris flow (FEMA 2020, 2022; Ready 2022). Some invest in different sorts of early warning systems (Glade and Nadim 2014; Segoni *et al.* 2018; USGS 2016; Allen and Melgar 2019; NWS 2022), including integrated ones (UNISDR 2016) which cover hazard monitoring, prediction, assessment, communication and preparedness.

In China, geohazard response measures or facilities introduced by the government include disaster information booklets and "Understanding Cards" (cards) distributed to residents living in geohazard risk spots (MLR 2008b), various early warning tools, designated risk monitoring personnel, as well as emergency

response facilities like evacuation routes and shelters etc.

Information on appropriate disaster response

In places frequently affected by various threats like Indonesia, information access was relevant for evacuation (Lestari *et al.* 2021). In China, a few studies addressed disaster response measures like the cards (Sim *et al.* 2015) which tells the appropriate disaster response behaviour while individual studies also focused on their awareness rate among the populations (Huang *et al.* 2020).

Early warning systems

Early warning tool is an intervention to alleviate vulnerability in the BBC framework (Birkmann and Wisner 2006). According to the MOVE framework, coping capacity is indicated by performance of early warning system (Vinchon *et al.* 2011).

A World Bank analysis (Hallegatte 2012) estimated that if all developing countries enhance their early warning systems and hydro-meteorological information production to developed-country standards, not only tens of thousands of lives could be saved and billions of dollars of asset loss could be prevented, extra economic benefits could also be incurred.

Recently, a report by the United Nations Office for Disaster Risk Reduction (UNDRR) and World Meteorological Organization (WMO) (UNDRR and WMO 2022) found that 166 million people were protected per year on average from 2015 to 2021 through evacuation before disaster hit following early warnings. Another analysis on hurricane studies also revealed official warnings generally affected evacuation (Huang *et al.* 2016). All these reflected early warnings were effective in promoting evacuation behaviour. However, the UNDRR and WMO global analysis further noted that only half of the countries in the world reported they were protected by multi-hazard early warning systems. China did not report having such system or simply does not have it. In view of this, the UN Secretary General said all people must be protected by early warning by 2027 (UNDRR and WMO 2022).

On a local scale in the Philippines and Dominica, Yore and Faure Walker (2021) found that tropical cyclones evacuation or safety-seeking behaviour was affected by the delayed delivery or lack of understanding of important storm information

from the early warning systems. In the urban setting of Hong Kong, although as many as 90% of the people were aware of the existing landslip early warning system, the most common reaction was inaction (Yik *et al.* 2023). As for landslide early warning, although a significant number of studies focused on it, including some on China (Ju *et al.* 2020; Xu, Q. *et al.* 2020), many of them targeted on technological advancement in monitoring and issuing alerts.

After the Wenchuan earthquake, technological advancement in identifying geohazards (Shi *et al.* 2018; Wang *et al.* 2021), developing real-time geohazard monitoring (Ju *et al.* 2015; Zhao *et al.* 2021) and real-time early warning (Fan *et al.* 2019c; Ju *et al.* 2020) using artificial intelligence technology (Xu, Q. *et al.* 2020) through web platform along main transportation route (Sichuan Government 2016; Chen 2015), have been some major research foci. In rural southwest and northern China, landslide early warnings issued by newly-developed monitoring and alerting systems successfully contributed to timely evacuation, saved properties and even human lives (Fan *et al.* 2019c; Xu, Q. *et al.* 2020). However, only a small amount of research has attended to individual and relatively traditional early warning tools commonly adopted in remote mountainous areas in China (Huang *et al.* 2020), although some researchers incorporated the use of website, mobile phone text messaging, sirens or loudspeakers as part of the landslide early warning system they designed (Ju *et al.* 2015, 2020). Comparison of different early warning systems or tools are also rare, both within and outside China (Corral *et al.* 2019; Cepeda *et al.* 2020; Huang *et al.* 2020). Analysis and comparison of the effectiveness of different early warning tools in affecting disaster response is particularly lack of.

Individual early warning tools

The emergence and development of the mobile phone has provided a new early warning method that can reach people individually. In a tsunami setting in Indonesia, first hand WhatsApp and SMS warning messages were sent by the official city emergency operation centres to a selected group of people responsible for community disaster preparedness, while some schools also adopted SMS or phone calls to share warning alerts to stakeholders (Rahayu *et al.* 2020). The Tohoku earthquake and tsunami stimulated effort in developing a smartphone early warning application to deliver real-time emergency information (Park *et al.* 2015).

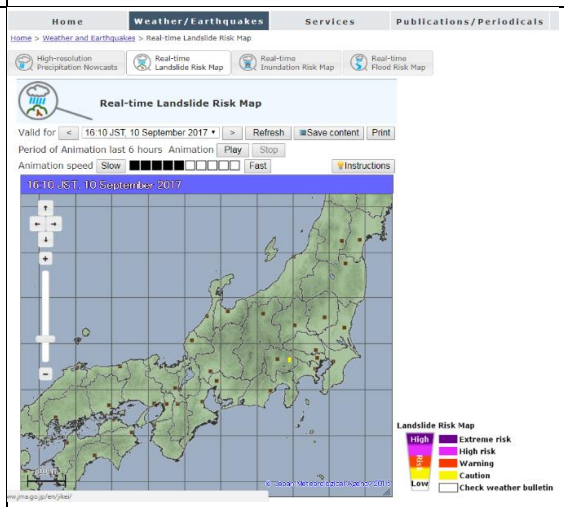
A German experiment using virtual reality technology found that those who received thunderstorm warning messages via a mobile phone application could arrive a safe place faster and more efficiently (Markwart *et al.* 2019). For geohazards, issuing mobile phone short messages to the disaster management personnel was a method to alert people of debris flow arrival in Italy (Arattano and Marchi 2008).

In China, warning information was issued in selected loess landslide sites in Gansu Province, where SMS, WeChat and telephone alarms were sent to the local town and village authorities by the early warning system developer based on real-time monitoring (Xu, Q. *et al.* 2020). Another attempt of using mobile text messaging as part of an early warning system was applied in a debris flow site in Sichuan (Ju *et al.* 2020). These two studies concluded that the comprehensive early warning systems as a whole, including sophisticated monitoring, did collectively improve risk detection and help evacuation. However, they had not investigated the individual impact or effectiveness of phone messaging alone. But they still marked the usefulness of phone as a debris flow early warning tool in rural China.

Siren is also a widely applied early warning tool. For landslide, some proposed to regulate and standardise early warning, including siren sounds (Fathani *et al.* 2016).

A website is another platform to issue geohazard early warning. In the USA, the USGS runs a Landslide Hazards Program in which landslides across the country are monitored continuously in real-time or periodically, with the latest measurements of some sites provided online. Graphs showing the latest information are updated every 15 minutes to 24 hours. Preparedness and safety measures are introduced in the website.

Figure 2.2
Landslide early warning websites in the USA and Japan

Landslide Monitoring hazard map by USGS website	Real-time Landslide Risk Map by JMA website
 *Source: USGS 2017.*	 *Source: JMA 2017b.*

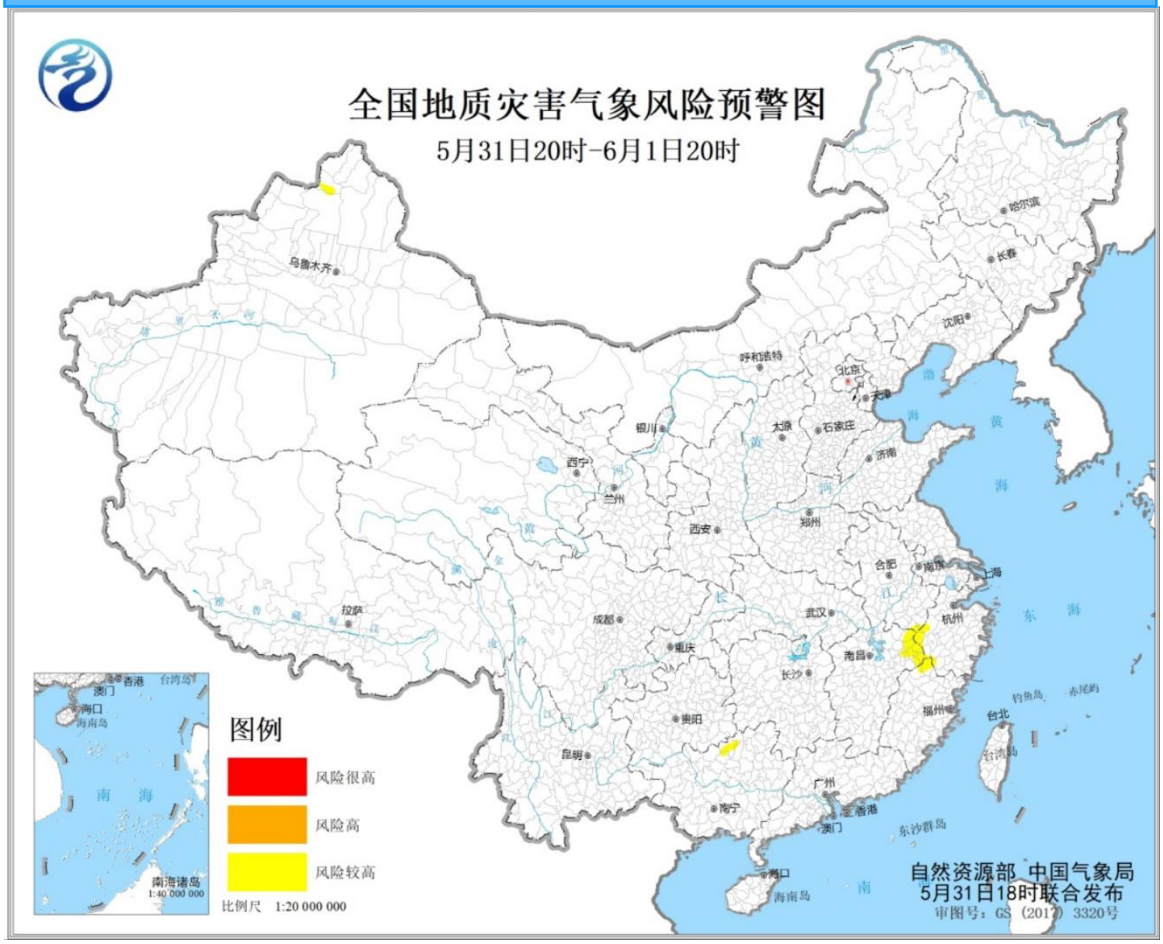
The Japan Meteorological Agency (JMA) provides detailed previous and latest earthquake information of the country on its website (JMA 2017a) and also a real-time landslide risk map. One can enter a date on the webpage and find out which part of the country is exposed to what level of landslide risk on that day. The risk information is provided on the prefecture level but no further information about the exact threatened location within the prefecture is available.

Similarly, in China, geohazard is not only a regional, but a national issue. A national-wide geohazard early warning website prepared by the Ministry of Natural Resources is available for public access (Figure 2.3).

Figure 2.3

Geohazard early warning website by Ministry of Natural Resources, China

National geohazard and meteorological risk early warning map
20:00, 31 May - 20:00 1 June (2022)



Source: MNR and CMA 2022. Accessed on 30 May 2022.

In parallel, as different provinces are affected by different geohazards, individual provinces tend to adopt their own geohazard risk reduction methods based on the general national guidance. Hubei Province, for example, established a geohazard forecast and information release system using advanced web-based technologies. By referring also to rainfall information, they developed their own geohazard warning map and issued timely geohazard forecast (Zheng *et al.* 2008).

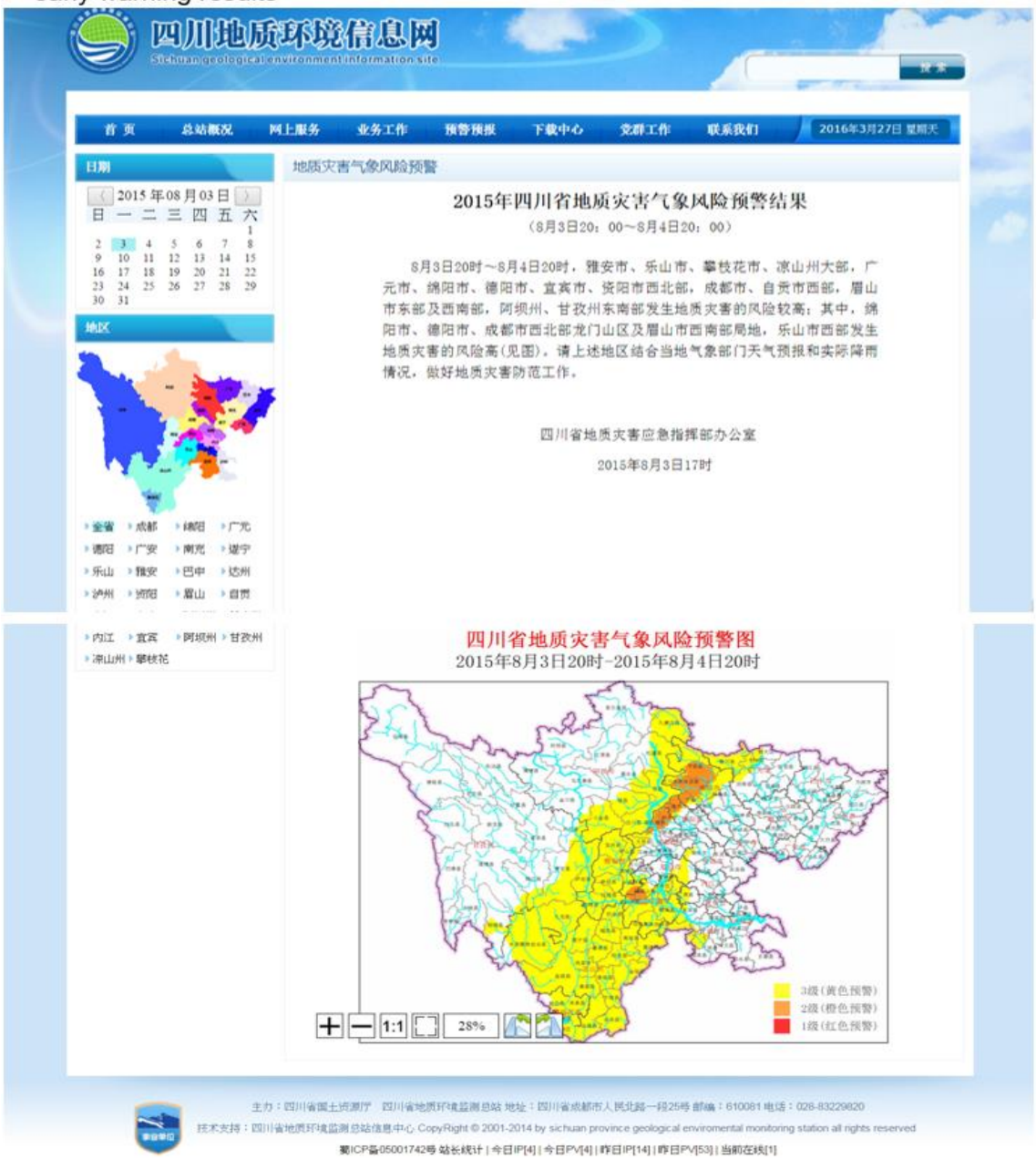
The Sichuan Provincial Government has also developed a “Sichuan geological environment information site” to issue geohazard and meteorological risk early warning (DLRSC 2016) (Figure 2.4). This website updates every 24 hours and spotted any risk on provincial and city levels. Zooming in on the map can reveal any risk in counties and even townships. Website users can select a certain date

and look up the risk. Three risk levels were shown on the map: Level 1 as the highest risk red early warning, followed by Level 2 in orange and Level 3 in yellow. Take 3 August 2015 as an example. Almost one-third of the Sichuan Province was at Level 3 (yellow) geohazard and meteorological risk from 20:00 on the day till the same time next day. By clicking the city name, it can be seen clearly that part of the three counties of Pingwu, Beichuan and An were having Level 2 (orange) early warnings.

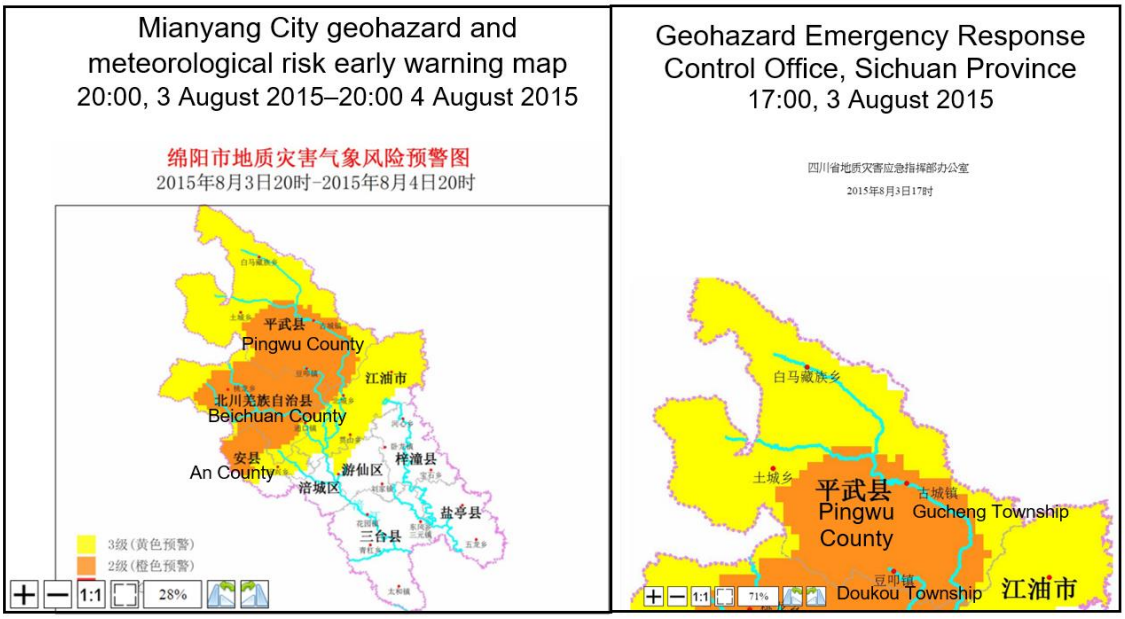
Figure 2.4

Sichuan geological environment information site

a. Provincial level – 2015 Sichuan Province geohazard and meteorological risk early warning results



(Left) b. City level – Part of the three counties of Pingwu, Beichuan and An under Mianyang City were having Level 2 (orange) early warning.
(Right) c. The subordinate township names can be seen clearly when zoom closer.



Source: Sichuan Province Geological Environment Monitoring Station, Department of Land and Resources of Sichuan Province (DLRSC 2016).[2]

Huang *et al.* (2020) provided one of the very few academic studies that have evaluated early warning tools in China. This study on Yunnan Province divided the early warning systems into two categories: automatic and manual. The former is electronic device-based while the latter employed trained local farmers as inspectors. Both had their limitations. The automatic devices were poor in operation and less functional. The manual ones was time and place-restricted. Moreover, the respondents were more aware of the manual early warning systems.

Emergency response facilities

Countries such as Japan and New Zealand spend resources in developing emergency response facilities, like evacuation routes or emergency shelters (MLIT 2023; Harris *et al*. 2021). Government evacuation order also contributed to evacuate decision in the USA (West and Orr 2007). However, not all places have adequate evacuation instructions (Kawasaki *et al.* 2017). Nevertheless, the introduction and awareness of these measures or facilities may affect people's disaster response.

[2] After the replacement of DLRSC by Department of Natural Resources of Sichuan Province, the information site has been transferred to http://dnr.sc.gov.cn/scdnr/scdzyj/iframe.shtml. As accessed on 31 May 2022, the date selection function is no longer available. A total of four levels of response are listed out: from Level 4 (Blue), Level 3 (Yellow), Level 2 (Orange) to Level 1 (Red). Actions to be taken in each level are stated (DNRSC 2022).

Emergency response dissemination

Although it was almost always ignored in the past (Willison and Gaillard 2012), community involvement in emergency management has been gaining traction. Emergency response dissemination with community involvement has become more common. In the USA, Turkey and India, disaster trainings were given to citizens and community-based emergency response teams were established so that they can contribute during emergencies and help save lives (López-Carresi 2012; Ogra *et al.* 2021). Drills are another major means to reduce vulnerability of the disaster-affected populations and are encouraged to be held regularly (Ranghieri and Ishiwatari 2014). Those who participated in tsunami drills before the Tohoku earthquake and tsunami were more likely to evacuate (Nakaya *et al.* 2018). In China, certain local governments in Sichuan stressed the need to carry out different drills or emphasised disaster reduction education (SEA 2019). However, academic literature studying how the awareness of such measures influences risk perception or disaster response in China is limited.

2.7 Conclusions of literature review

Through the research findings, advances in theoretical understanding can be achieved in two dimensions: (1). whether the vulnerability indicators and factors mentioned in existing models can explain the post-Wenchuan earthquake debris flow situation, and (2). are there any other extra factors or indicators related to vulnerability in this research can provide insights to future studies. A general model of vulnerability that can explain the Sichuan, or China, situation, is to be developed through this research.

In practice, it is hoped that the research findings can provide insights on the compliance with and effectiveness of government disaster risk reduction measures imposed after the Wenchuan earthquake. Recommendations are to be provided on how the Chinese measures can be improved to shape the risk perception of populations exposed to earthquake induced debris flow risks and to reduce their vulnerability through changing behavioural pattern in the light of the new model under development.

Chapter 3
Methodology

3.1 Data collection

A combination of various methodologies has been adopted to collect the information and data required for this thesis. This includes three common methods used in disaster studies: field research, sometimes known as field studies or qualitative case study, documentary research and survey research (Stallings 2007), together with interpretation and application of satellite images and air photos as well as literature review.

The geographical distribution of debris flow and other geohazard risks incurred by the Wenchuan earthquake was established and interpreted through satellite images and maps, together with the aid of literature review and post-earthquake secondary geohazard risk assessment performed by the government. For background geological information, geological maps and references from governments have been adopted. Study of geological history of the selected sites were done for an overview of geological situation in both pre- and post-earthquake periods. Together with a questionnaire survey in the field, effectiveness of government measures and directives on debris flow-affected populations' relocation decisions, risk perceptions and disaster responses are evaluated.

3.1.1 Documentary research, desk study of background information and literature review

To measure and evaluate the effectiveness of government rehabilitation sites selection directives and disaster risk reduction measures on relocation decisions, pre- and post-2008 earthquake government requirements on residential site selection were compared through documentary research. Distribution of rehabilitation sites in the study areas were acquired through the collection of government documents and information, together with field studies and interviews with local leaders. Comparisons of such post-earthquake rehabilitation sites distribution with geographical distribution of debris flow risks are made.

Information regarding the various kinds of disaster preparedness and response measures imposed by the government after the Wenchuan earthquake through

promotional and educational means is also collected through documentary research.

Documents and official information issued by the governments are valuable sources of post-Wenchuan earthquake geohazard risk and mitigations. Websites of various levels of the Chinese government, from the State Council of the Central Government, Ministry of Land and Resources (currently the Ministry of Natural Resources), to provincial level Sichuan Government and county level, all offered useful and comprehensive geohazard and risk reduction information.

Some annual geohazard risk inspection and assessment results of Sichuan Province were also available and some lists of geohazard risk sites were released. For instance, a comprehensive list of geohazard risk sites of the whole Sichuan Province announced after an inspection (Sichuan Government 2010) is referred as an important foundation for studying the geohazard risks across all the selected study areas after the Wenchuan earthquake in this research. Details about the list of villages and the debris flows affecting those villages were shown on official government website. However, earlier geohazard risk sites information of such comprehensiveness was unavailable or fragmented due to a mix of reasons according to the officials, including limited resources to perform such an inspection before year 2010 because most of the efforts were devoted to tackling all sorts of geohazards developed right after the 2008 earthquake. Priority of governments of various levels during the first couple of years after the mega disaster was to settle the affected populations across the province. Moreover, some earlier records of geohazard risks were lost or destroyed in geohazards attack.

Such official information on risk sites inspection, however, were not without limitations. Sichuan Province is the fifth largest province of China and covers a total area of 486,000km^2 (Sichuan Government 2017e). Given the vast size of the province, with a huge part of it are mountainous regions, together with the thousands of geohazards of various types the government had to dealt with after the Wenchuan earthquake, as well as limited experiences and manpower in tacking or investigating geohazards, official inspection might not be able to cover all risk zones in full scale at any one point of time. This was reinforced by the fact that geohazards can develop over time, that is, they might not appear immediately

after the quake, not to say to be found threatening to humans shortly after the disaster. Under such circumstances, what the government decided to do is to conduct annual inspection and to publish a list of geohazard risk sites annually or whenever necessary.

An unexpected landslide occurred on 24 June 2017 is an example. The geohazard risk in Xinmo Village in Mao County was not found to threaten nearby residents and was therefore not included as a geohazard risk site until 2016, and even since the site was then included in the list, the origin of this disaster high up in the mountain was not monitored (Sichuan Government 2017b). This geohazard risk was difficult to discover because the source of the rapid long runout was on a steep slope just too high up in no man's land in the Fugui Mountain at 3,400 metres, which is 1,250 metres higher than the village downhill in terms of elevation, and therefore out of the scope of regular geohazard risk site inspection and monitoring mainly conducted by human (Sichuan Government 2017b). Moreover, as the slope was well covered by thick vegetation, changing shape of the slopes might not be filmed even by high technology means like high precision remote sensing satellite (Sichuan Government 2017b).

Based on the information available, the best the author can do in this research to capture the latest situation and changes of the study areas is to refer to the 2015/2016 list of geohazard risk sites, on top of the 2010 list. The 2015/2016 list served as an important update reference for finalizing the questions to be asked to the people of the study areas during the survey done in summer 2016. The 2015/2016 list also provides a very good comparison on how the geohazard risks threatening the villages had changed over the years, which could have implications on the relocation decisions, risk perceptions and anticipated disaster responses of the survey respondents.

Rehabilitation supporting parties such as Hong Kong Special Administrative Region Government and Hong Kong Jockey Club also provide useful information and reports online regarding the projects they financed in Sichuan. Together with the information and experiences sharing provided by the local governments, official information is a very important and crucial source of reference for this research.

In certain occasions where no official document or information is available, media reports are referred to. Although some media reports might not be fully accurate (Scanlon 2007), critically selected news articles could be an important information source in disaster studies, especially if they cover emergency situations that were not studied or not yet studied by academics. In this paper, only those media with government background and media reports adopted on government websites are referenced.

Furthermore, a general understanding of the practice of disaster risk reduction measures on debris flow risk both within and outside China was studied through a review of literature. More information about various aspects of literature review is illustrated in the literature review chapter.

3.1.2 Analysis of satellite imagery

This research adopts satellite images and maps to collect data on natural terrain, topography and local landscapes. Satellite photos and images were searched, accessed, collected and analysed. These tools not only gave a close look of the hazard exposure zones, but they helped identify the extent of debris flow risk faced by the rural population in the study areas. They also helped evaluate the various forms of geohazards and their relations with the debris flows affecting the study sites. With limited images accessible to scholars and the public, Google Maps and Google Earth were found to be the best available sources. This research makes use of these Google resources to the limits of their effectiveness to visualize the location, scale and impacts of the debris flows affecting the sites. Satellite maps offered by the USGS and appeared in official documents were adopted as supplements.

Google Maps and Google Earth had their limitations and uncertainties. No pre-2008 earthquake images of the study areas could be found in Google despite numerous trials in searching. Therefore it could not be proved by comparing pre- and post-2008 earthquake satellite images that certain geohazard was directly caused by the 2008 earthquake. However, since the earthquake was of such a mega-scale, it is justifiable that the geohazards found in the region should be, to a certain extent, triggered or induced by the quake, no matter whether it was pre-existed before 2008. Another problem of Google Earth is that images of different

dates are sometimes very similar, making it unclear if the so-called “imagery dates” listed are accurate. The Google Earth system is also unstable and does not always have continuous coverage – sometimes it shows images of a certain place at a certain time but not at another time. Nevertheless, Google Maps and Google Earth provide a very good source of clear images of the places studied by this research.

Based on cross referencing the information collected during the Sichuan visits in which on-site inspection of each of the case study area were carried out, together with information gathered from literature review, as well as comparing and evaluating the satellite images available, an objective idea of the actual geohazard risks induced by the 2008 earthquake was identified, analysed and mapped out.

3.1.3 Field studies and interviews

The author carried out a total of five field studies to Sichuan from late 2014 to mid-2016. The first three took place in December 2014, May 2015 and January 2016, with the major purpose of exploring study sites for this research from a range of potential sites. The fourth field trip was held in early July 2016, mainly to finalise and confirm the study sites, as well as to prepare for the conduct of survey. A survey research was conducted during the fifth field trip from mid-July to August.

In those 21 months, field research to collect field data on geology and morphology, discussions with officials and local leaders, and a total of 631 questionnaires on villagers were successfully done in five villages in two counties. Risk assessment, analysis and estimation for the field trips were conducted and approved by the primary supervisor.

The first Sichuan field visit was to get in contact with the academics in Sichuan and to learn from them the latest study on the Wenchuan earthquake from geological, geotechnical engineering and mitigation aspects. This trip allowed the author to observe directly on site and learn that debris flow is the major secondary geohazard that was expected to affect the province for the next couple of decades or more, and established the focus of this research on debris flow.

During the second field study, potential research sites in Pingwu were visited. The trips to the villages together with official information provided an overview on the

effects of geohazards on the County after the Wenchuan earthquake. Important information on post-2008 geohazard risk assessment, recommendations and mitigation measures done by the government were collected. More geological information and in-depth information on the post-earthquake debris flow risk reduction measures imposed by the government were gathered.

Until 2015-16, the populations of Pingwu County and Wenchuan County were still threatened by numerous debris flow risks (SGIO 2015a; Wolong Township Government 2016a, 2016b). Material sources of many of these debris flows has been coming from landslides and rockfalls in the surrounding areas.

Following such clues, the author paid visits to Pingwu County and Wenchuan County subsequently to get an initial idea of their landscapes, as well as the impact of the Wenchuan earthquake and secondary geohazards on the remote villages, in particular the destruction of previous debris flows and subsequent mitigations there. Detailed information on non-geotechnical disaster preparedness and response measures introduced by the government after the earthquake to the study areas was also collected. Although the author visited many sites that were eventually not included in the thesis, such efforts have provided a well-rounded perspective on the field sites that were ultimately adopted for study.

During the field visits, meeting with and interviewing local officials helped the author to learn more geological background and the latest situations of the study areas, particularly its geohazard risks. Official information and data of various forms on geohazards or the 2008 earthquake were collected from counties, townships and villages. Their experiences in tackling debris flow were also learnt. All these provided valuable resources for background analysis of this research and offered a significant foundation for the questionnaire design.

3.1.4 Questionnaire surveys

By referring to the dimensions, indicators and models of vulnerability, survey questions were designed to test whether and how different vulnerability types are related to relocation decision, debris flow risk perception and response behaviour.

Apart from the existing vulnerability models which provided valuable and potential frameworks for testing the hypotheses, a full set of vulnerability indicators applied in this thesis for evaluating the effectiveness of government measures are structured, designed and refined according to the information collected in the field and from the government.

After confirming the case study areas, empirical data of the indicators were collected through survey questionnaires conducted with rural residents in the five selected villages in remote parts of Sichuan. The different vulnerabilities of various social groups to debris flow risk were identified and assessed. A total of 631 questionnaire-based interviews were carried out. More than 100 people were successfully interviewed in each village.

In particular, data on relocation decisions, risk perceptions and anticipated disaster responses regarding earthquake-induced debris flows with reference to the measures imposed by the government was collected. Information and data collected from the study areas are compared among themselves and with practices found in other places noted in literatures. Section 3.2 provides more information about the survey.

By analysing the data collected, not only the applicability of the selected indicators of the existing models in the study areas is explored, but an all-rounded understanding of which governmental or non-governmental factors affecting relocation decisions, debris flow risk perceptions and anticipated disaster responses is revealed. Regularities are discovered and relations among the variables are explored.

3.2 Questionnaire survey design

3.2.1 Planning

A pilot survey was planned to ensure the main survey be conducted efficiently and done within a certain time frame. The main purpose of the pilot survey is to interview local residents of one selected village to collect data and information on post-earthquake risk reduction measures imposed by the government and their effectiveness. It could help the author to ensure the questions asked were relevant,

sensible and understandable to the local villagers. More accurate data could therefore be collected and more precise measurement, evaluation and comparison could be made. The design of the pilot survey was finished in early 2016. Regarding ethics, approval was granted by chair of the IRDR ethics committee of the institution in January 2016.

In the next few months, further exploration on study areas selection was made. Additional literature review was done to ensure the questionnaire was suitable and meaningful for the rural residents.

During the course of preparing the questionnaire, continuous consultation and advices from the author's primary supervisor Professor Alexander was received. In July 2016, the survey design was finalized. Most of the questions are specific and close-ended. Details of the conduct of both the pilot and final surveys are presented in Section 3.5.2.

3.2.2 Contents of the survey

The survey started by asking demographic and socioeconomic information. The core of the survey consists of two major parts.

Survey Part 1 – To evaluate the compliance with and effectiveness of government mitigation directives and disaster risk reduction measures in influencing relocation decisions of the earthquake-affected populations

After the Wenchuan earthquake, the Chinese government introduced new regulations and has amended existing laws on rehabilitation site selection in the interests of implementing risk avoidance measures to protect the residents.

Accordingly, reconstruction site selection should avoid seismic fault zones and areas with huge potential risks; while for those towns and villages which require relocation, seismic fault zones as well as potential areas of landslide are to be avoided during the selection of new sites.

The first major part of the survey and this study therefore aim at evaluating the compliance with and effectiveness of government directives and measures on relocation decisions by looking into A and B below.

(A). Consideration of government directives and measures on residential housing site selection

This involves an examination on whether or to what extent political influences (Alexander 2012a) in the form of non-structural (Alexander 2002) mitigation directives and disaster risk reduction measures regarding rural residential housing sites were considered. This is reflected by whether the respondents moved or not moved after the quake.

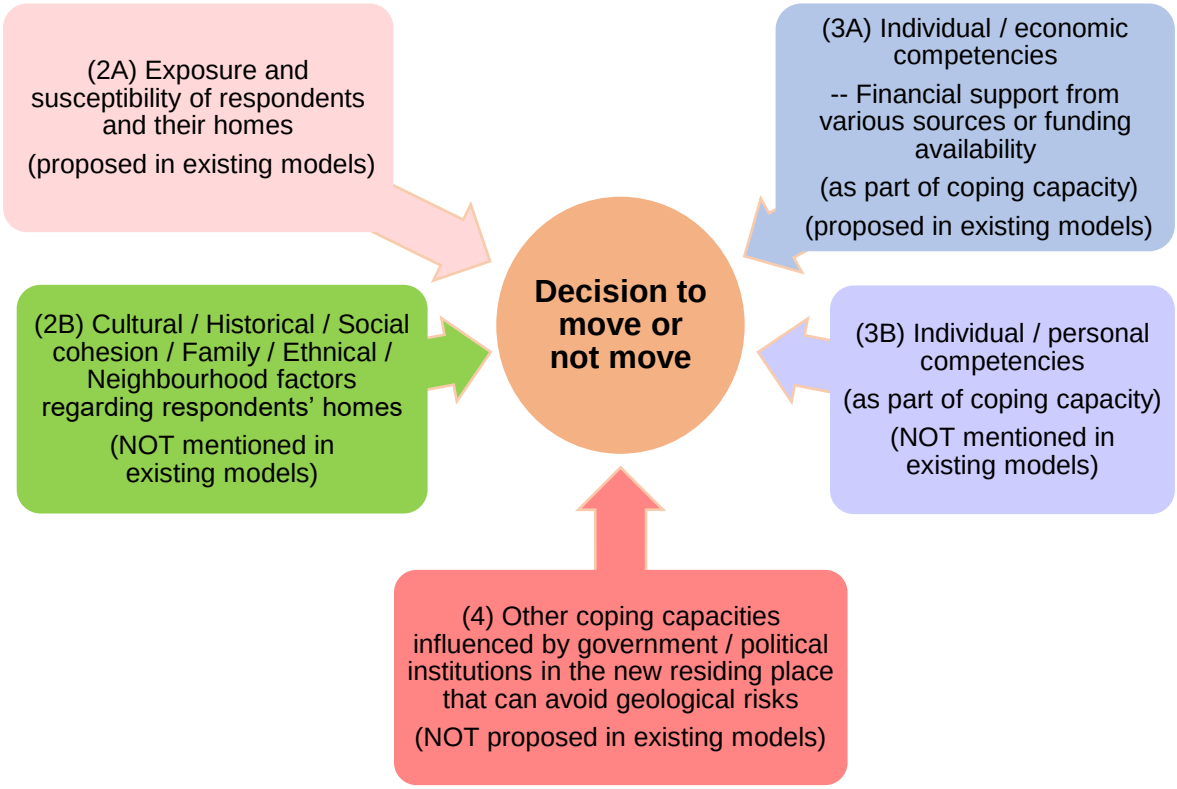
(B). Whether and how different types of vulnerability could have affected relocation decisions

The survey questions were designed to test whether and how different types of vulnerability could affect relocation decisions involving rehabilitation site selection.

Whether the vulnerability indicators in various vulnerability models can, or to what extent they can, explain the post-2008 earthquake relocation decisions in rural remote mountainous Sichuan is tested. Residents from different study areas were interviewed to determine if variations of impacts of such factors in different places could have caused different relocation decisions.

In testing Hypothesis 1, demographic factors were put under “Group 1”. The respondents were further given 25 statements evaluating their possible consideration when deciding whether to move to reside in another place after the quake on a 5-point Likert-type rating scale. The 25 items were put into five groups: 2A, 2B, 3A, 3B and 4 as shown in Figure 3.1.

Figure 3.1 The five constructs composed of 25 Likert items that might affect the decision to move or not



Group 2 - Factors regarding the exposure and susceptibility of survey respondents and their current homes

In Pingwu County, 31 and 89 geohazard risk sites were inspected in Pingtong and Nanba Township areas in 2010 respectively, including four affecting Niufei Village and six affecting Xinjian Village (Sichuan Government 2010). A great portion of the Xinjian villagers were affected or threatened by various types of earthquake induced geohazards, threatening properties amounted to over RMB 24 million (Sichuan Government 2010).

Wolong Region in Wenchuan County is composed of Gengda and Wolong townships, which are two of the few township centres nearest to the 2008 earthquake epicentre. With its proximity to the epicentre, the Region was devastated by the quake with numerous aftershocks and exposed to geohazards concentrated nearby, including the three villages studied in this thesis: Xingfu and Longtan in Gengda Township and Wolongguan in Wolong Township.

Group 2A - Factors regarding the exposure and susceptibility of survey respondents and their homes proposed in existing models

The concept of exposure in BBC is reflected in the location of residences. Alexander (1997, 2000, 2007) introduced total or pristine vulnerability caused by limited experience of hazards when hazards are not yet been reduced and life is precarious. This is similar to whether the respondents perceived they are staying in houses or places threatened by (or avoiding) geohazards, that is, the idea of exposure in MOVE. These can be reflected in the safeness of the place perceived by the respondents, including whether the place is affected by earthquake and debris flow risk, topography or landscape. Risk perception (Alexander 1991a, 1991b, 2000, 2012b) is an important factor that might related to moving decision.

Based on these models, five sub-variables were tested under Group 2A in this research. These include three sub-variables regarding the new residing place and were revealed through three survey questions:

(i). Whether the new place will be affected by earthquake (MOVE)
(ii). Whether the new place will be affected by debris flow (MOVE)
(iii). The topography and landscape of the new place (MOVE).

Another two sub-variables regarding survey respondents' perception of exposure and susceptibility as reflected by safeness of the place were asked through another two questions:
(iv). Whether the places the respondents originally lived were safe
(v). Respondents' current home location made them feel safer than the location before the Wenchuan earthquake.

Group 2B - Other factors regarding survey respondents' homes NOT mentioned in existing models
-- Cultural / Historical / Social cohesion / Family / Ethnical / Neighbourhood factors

Pingwu inhabits 20 ethnic groups (Pingwu Government 2017) with Tibetans, Qiangs and Hans as majorities (SGIO 2015a). For instance, most residents in Nanba Township where Xinjian Village is located are Hans, Qiangs, Hui and Tibetans (SGIO 2015b). Wolong is part of Aba Zang and Qiang Autonomous

Prefecture where many Tibetans and Qiangs resided, although some residents are of other ethnicities.

Therefore cultural, ethnical and other related factors might affect the villagers' moving decisions. Such data was collected by seven survey questions:

(i). Social cohesion and sense of belonging, e.g. whether the respondents liked the place they originally lived and their sense of belongings

(ii). Historical concerns, e.g. whether the respondents' ancestors lived in the same original place

(iii). Social cohesion, e.g. whether the respondents liked their neighbours of their original homes

(iv). Family concern, e.g. whether the respondents' children studied nearby the place they originally lived

(v). Whether the land in the new residing place was big enough to accommodate family members of the respondents

(vi). Ethical concerns, e.g. whether the respondents' neighbours of their original homes were of the same ethnic group

(vii). Whether the neighbours of the new residing place were of the same ethnic group.

Group 3 - Factors regarding individual competencies (as coping capacity)

Some indicators of individual's competencies were grouped under coping capacity in BBC and MOVE frameworks. In China, evaluation of post-earthquake rural populations' relocation decisions can be more accurate and detail if "individual competencies" are separated from "other coping capacities" in which the latter can be influenced by institutions and external factors other than the respondents themselves.

Group 3A - Factors regarding individual / economic competencies (as part of coping capacity) proposed in existing models

Financial situations of the respondents may relate to their moving decisions. Financial support from various sources (BBC) or funding availability are also important (Hogg 1980). Therefore the following were asked in the questionnaire:

(i). Availability of money for relocation

(ii). Availability of money for building new homes in another location

(iii). Financial support from other sources for relocation.

Economic vulnerability is also mentioned in existing models (Alexander 1997). This means disasters can lead to unemployment or destroy the means of production or commerce. Most villagers studied in this thesis were farmers and their livelihood relied much on agricultural produce which could be farmed on natural mountain slopes. The situation got worst after the 2008 earthquake because most of the lands were destructed or covered by debris. Many villagers in the mountains also earn their living by raising cattle. Therefore asking questions about land availability for production and employment is important:

(iv). Availability of land, i.e. whether moving to the new place required the giving up of the current farmland

(v). Accessibility to one's farmland, i.e. proximity of respondents' farmlands to the new places for home.

Group 3B - Factors regarding individual / personal competencies (as part of coping capacity) NOT mentioned in existing models

Some other factors regarding individual competencies might also relate to relocation decision. Such factors were not proposed in existing models but were included in the survey:

(i). Whether the respondents were afraid of moving to a new place

(ii). Whether the moving process was too complicated for the respondents and their families and could be handled

(iii). Respondents' evaluation of one's capability to tackle debris flow risk.

Some additional factors related to government influence were also asked:

(iv). Trust, meaning respondents' perception about whether the government would take care of them, including the provision of accommodation when they would be affected by debris flow

(v). Whether the respondents perceived the government would provide training for them to tackle debris flow.

Group 4 - Factors regarding other coping capacities influenced by government or political institutions regarding the new residing place that can avoid geological risks NOT mentioned in existing models

Another group of factors regarding the avoidance of geological risks in the new residing place in particular, which were influenced by government and impacting respondents' coping capacities are included in the survey. They were not mentioned in existing models:

(i). The government said whether the new residing place is safe

(ii). Whether the government had introduced effective geotechnical engineering measures, including sediment trap dam, to the new residing place

(iii). Whether the government had introduced effective disaster preparedness measures, including risk notifications, early warnings and disaster response, to the new residing place.

This Group 4 is particularly important because respondents' answers to this set of questions directly reflected whether they had considered "institutional directives and disaster risk reduction measures when making relocation decisions" after the Wenchuan earthquake as stated in Hypothesis 1.

Survey Part 2 – To evaluate the effectiveness of government disaster risk reduction measures or facilities in affecting rural populations' debris flow risk perceptions and anticipated disaster response behaviour

The government has imposed various disaster risk reduction measures and facilities after the 2008 earthquake. However, these provisions did not necessarily imply a reduction of risk exposure or vulnerability. Therefore, effectiveness of such measures and facilities is examined in this thesis through evaluating their impacts on risk perceptions and anticipated behaviour of the rural populations in places where debris flow risks were tolerable or in some cases unacceptable hence needed to be managed. This is done through the study of association between respondents' awareness of or accessibility to such measures or facilities on one hand and their risk perceptions and anticipated response behaviour on the other.

Part 2 of the survey, therefore, began by understanding respondents' perceptions of existing debris flow risk in the place they were living, followed by their anticipated behaviour when they see signs of debris flow at home.

The questions then tend to find out the effectiveness of government disaster risk reduction efforts on community after the 2008 earthquake in influencing risk perceptions and behaviour in terms of:
(1). structural debris flow mitigation measures,
(2). non-structural debris flow disaster preparedness measures, and
(3). non-structural debris flow disaster response measures and facilities.

Through examining and evaluating whether the public awareness of these three types of measures were associated with and worked best in influencing risk perceptions and anticipated disaster responses, the actual ability of the rural residents to tackle debris flow risks and hence reduce their risk exposure and vulnerability was explored.

In addition, the survey respondents were asked for their debris flow risk experiences, perception of community and home remoteness, perception of substantial debris flow and knowledge of debris flows by referencing previous literatures (Tuladhar *et al*. 2015). Villagers' responses can reflect how much information, experience and knowledge they grasped about the past, present and even future debris flows threatening or affecting their places (UNEP 2008). Together with the collection of demographic data, including age, gender, ethnicity, education, household size, income, occupation, role in village and length of stay in the community per year, with reference to vulnerability indicators adopted in previous studies, a comprehensive and all-rounded analysis of what factors or what combination of factors could have affected debris flow risk perceptions and anticipated disaster response behaviour has been conducted.

Factors that could affect risk perceptions of rural populations

There are two parts of factors identification.

Firstly, possible associations between debris flow risk perception and awareness of the imposition of various disaster risk reduction measures introduced by the government after the 2008 earthquake are examined.

Secondly, possible associations between debris flow risk perception and another set of factors unrelated to government disaster risk reduction measures, including demography and socioeconomic situations, village affiliation, debris flow experiences, perception of substantial debris flow, knowledge of debris flows and perception of remoteness are tested.

A total of 46 selected sub-variables grouped under nine independent factors (I to IX in Figure 3.2) were tested. Among them, three are government-related disaster risk reduction measures (VII, VIII and IX).

Government disaster risk reduction measures

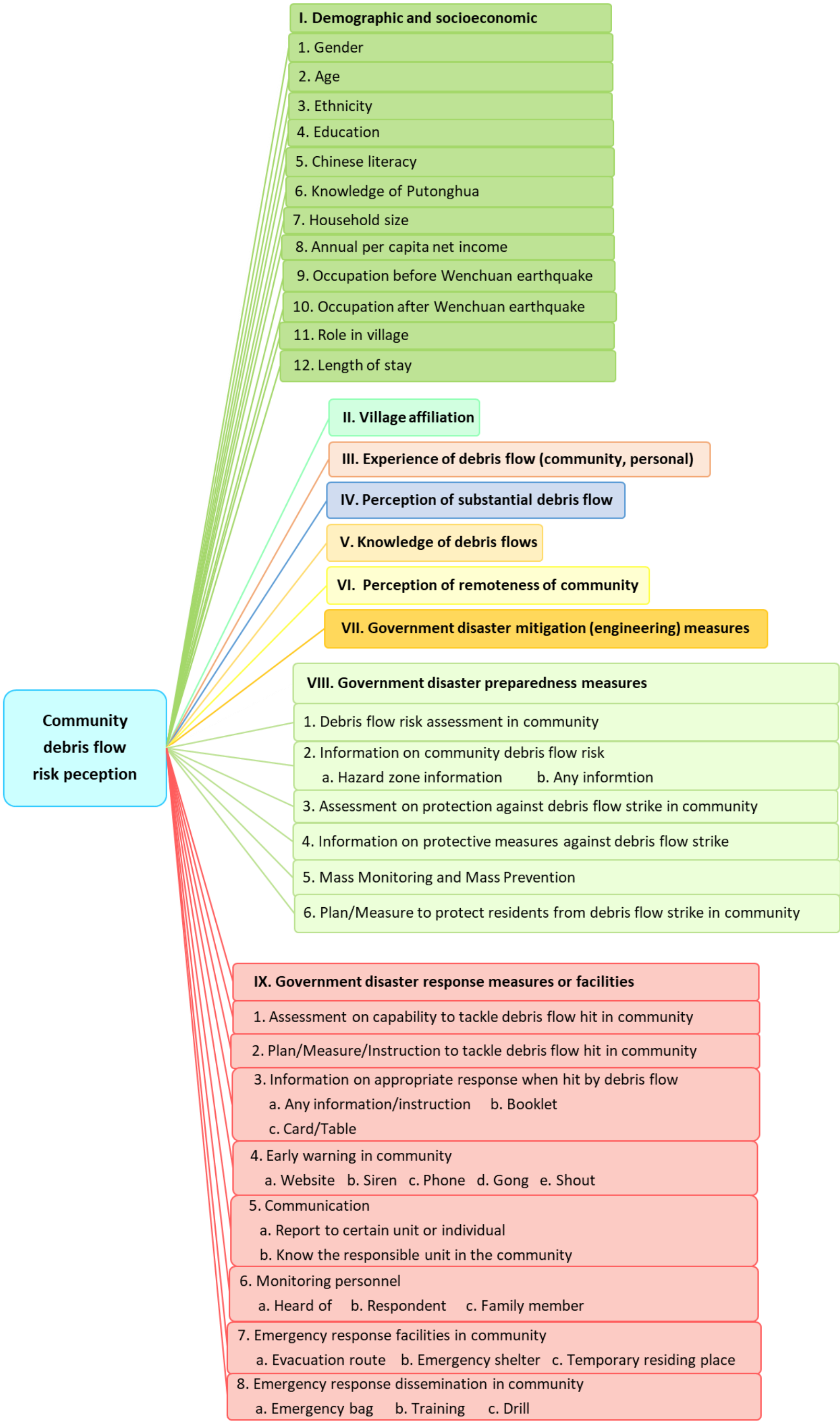
The first part of independent variables, respondents' awareness of the imposition of debris flow risk reduction measures, are considered as political or institutional factors because they reflected the effectiveness of government promotion of such measures in the two counties from the respondents' perspective. Some of such government measures were imposed to all threatened households and individuals in all five villages while some were only applied selectively. Whether the respondents' awareness of the imposition of these measures had any and how much effect on their debris flow risk perceptions were examined. Some of the measures involved were proposed in existing vulnerability models as stated in the literature review chapter.

There are three major categories of government measures presented as a total of 29 sub-variables:

- Geotechnical disaster mitigation (engineering) measures
- Non-geotechnical disaster preparedness measures
- Disaster response measures and facilities

Figure 3.2

Possible factors associated with perception of existing community debris flow risk



- **Geotechnical disaster mitigation measures**

Sichuan government has introduced a series of geotechnical mitigation measures, basically in the form of sediment trap dams, drainage channels, artificial step-pools, and others such as levees after the quake to reduce risk. Empirical data on respondents' awareness of the introduction of such measures in their communities were collected.

- **Non-geotechnical disaster preparedness measures**

Disaster risks can be effectively reduced by enhancing public awareness through information dissemination via various means, such as education, community or participation actions, and governments' advocacy (UNISDR 2009).

The Sichuan government has introduced or enhanced a series of non-geotechnical disaster preparedness measures in local communities after the quake to reduce risk and vulnerability. Seven questions were asked to collect data regarding respondents' awareness of or accessibility to such measures:

1. Debris flow risk assessment in community
2. Information regarding debris flow risk
   a. hazard zone information on community
   b. any information on community
3. Assessment on protection against debris flow strike in community
4. Any information on protective measures against general debris flow strike
5. Mass Monitoring and Mass Prevention
6. Plan/Measure imposed to protect residents from debris flow strike in community.

- **Disaster response measures and facilities**

The Sichuan government also imposed or enhanced a series of non-geotechnical disaster response measures in the communities, including capability assessment, plan or measure to tackle debris flows, dissemination of information regarding appropriate debris flow response, application of various early warning tools, enhancement of risk communications, as well as introduction or strengthening of the practice of monitoring personnel. Emergency response dissemination or emergency response facilities were introduced in some places or for certain

community members. The detailed list of such measures or facilities covered in the questionnaire is as below.

1. Assessment on capability to tackle debris flow strike in community
2. Plan/Measure/Instruction to tackle debris flow strike in community
3. Information on appropriate response when debris flows strike.
   This means in what ways the government provided debris flow information
   a. Any information/instruction
   b. Booklet
   c. Card/Table
4. Early warning tools in community
   a. Website
   b. Siren
   c. Phone
   d. Gong
   e. Shout
5. Communication channels
   a. General
   b. Community unit
6. Monitoring personnel in community
   a. Heard of
   b. Respondent
   c. Family member
7. Emergency response facilities in community
   a. Evacuation route
   b. Emergency shelter
   c. Temporary residing place
8. Emergency response dissemination in community
   a. Emergency bag
   b. Training
   c. Drill

Factors other than government disaster risk reduction measures

Relations between debris flow risk perception and another set of factors not related to government disaster risk reduction measures are investigated as well:

- Demography and socioeconomic factors (with 12 sub-variables, including some of the vulnerability indicators tested in Hypothesis 1)
- Village affiliation
- Experience of debris flow (community, personal)
- Perception of substantial debris flow
- Knowledge of debris flows
- Perception of remoteness of community

The possible impact of each independent variable on the dependent variable, debris flow risk perception measured by a 5-level Likert scale, are explored one-by-one in the results chapter. Through such analysis, this study tells which measure or factor, and what combination of the measures and/or factors, can yield maximum and minimum debris flow risk perceptions. Profiles of villagers with high and low risk perceptions are developed. Any differences between Pingwu and Wenchuan are also investigated.

The reasons and explanations behind such regularities or differences between the two counties are further explored in the discussion chapter. An all-rounded understanding of the effectiveness of government disaster risk reduction measures and other factors on debris flow risk perception is revealed.

Factors that could affect disaster response behaviour of rural populations

In testing Hypothesis 3, survey questions were asked to collect empirical data on respondents' awareness of the three major categories of government disaster risk reduction measures tested in Hypothesis 2 as well. Their relations with and possible effects on anticipated disaster responses are examined:

- Geotechnical disaster mitigation (engineering) measures
- Non-geotechnical disaster preparedness measures
- Disaster response measures and facilities

Apart from these three categories of government measures (VII, VIII and IX in Figure 3.3), another set of factors not related to government was also investigated (I to VI in Figure 3.3). These other factors are also tested in Hypothesis 2.

- Demography and socioeconomic factors (with 12 sub-variables)
- Village affiliation
- Experience of debris flow
- Perception of substantial debris flow
- Knowledge of debris flows
- Perception of remoteness of home

One exception here in Hypothesis 3 is that, perception of remoteness is focused on “home” rather than “community” as in Hypothesis 2, because Hypothesis 3 tends to investigate disaster response at “home” whereas Hypothesis 2 aimed at understanding “community” debris flow risk perception. For the same reason, awareness of assessment on home debris flow risk and protection, accessibility to any information on debris flow risk on home, and also awareness of plan/measure imposed on home to protect respondents’ family members from debris flow strike are also explored.

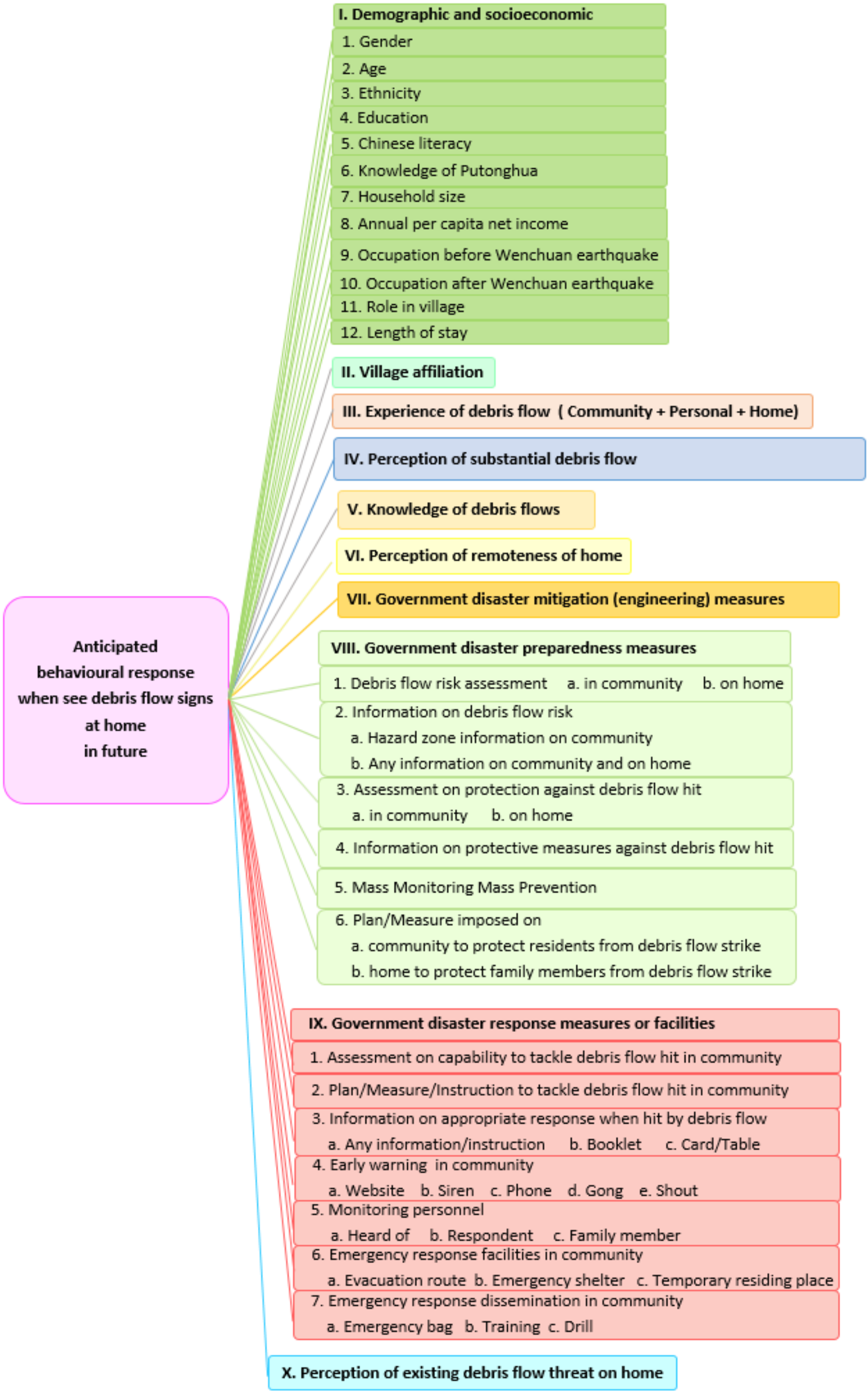
In addition, any impact of perception of existing debris flow threat on home (X in Figure 3.3) on anticipated disaster response is also tested.

As a result, in Hypothesis 3, the potential associations between a total of ten independent factors categorised as I to X with 54 sub-variables or indicators on one hand and anticipated disaster response behaviour on the other are tested one-by-one.

Based on the empirical data analysed, a profile of behaviour, meaning which categories of the respondents were more likely to have certain disaster response when they see debris flow signs are developed. In particular, respondents with what kind of profile would behave proactively and reactively to debris flow hit are revealed in the results chapter. The similarities or differences of the behaviour of respondents from the two counties are also investigated. The reasons and explanations behind such regularities or differences are explored in the discussion chapter.

Figure 3.3

Possible factors associated with anticipated behavioural response when see debris flow signs at home



Based on such analysis, Hypothesis 2 and 3 regarding whether risk perceptions and anticipated disaster response behaviour of the rural populations living in remote mountainous regions could be affected by government disaster risk reduction measures after the Wenchuan earthquake are tested.

Moreover, since different villages are threatened or affected by debris flows at different levels, whether the impact of such measures on respondents' risk perception and anticipated behaviour varied between the two study areas are evaluated. Whether the variations of risk perception and behaviour were caused by differences in demographic, socioeconomic influences, experiences or knowledge of debris flows in the different study areas are also addressed.

With the survey results, this thesis can provide insights on how the Chinese disaster risk reduction measures can be improved, and which demographic and characterised group are to be targeted, in order to influence risk perceptions and anticipated behaviour of populations exposed to earthquake-induced debris flow risks. Their disaster risks and vulnerability can be reduced.

The survey instrument is provided in Appendix 1.

3.3 Study areas

The targeted population of this research is the vulnerable population residing along the Yingxiu-Beichuan Fault of the Longmenshan Fault Zone which experienced the highest Scale XI earthquake intensity during the Wenchuan earthquake. Those living in remote places with lower accessibility and fewer support from county centres were of particular interest.

Wenchuan and Pingwu are the two counties selected for comparison because both lie on the two ends of the Yingxiu-Beichuan Fault. Being part of the Longmenshan Fault Zone, the 400 kilometres long Yingxiu-Beichuan Fault started in Wenchuan County near Yingxiu Township and ended in Pingwu County near Shikanzi Village of Nanba Township (Zhou *et al.* 2010; SGIO 2015b). Both counties were categorized as the ten "Counties of Extreme Severe Hazard" (Wei 2010) and

experienced the highest earthquake intensity at a scale of XI according to China Seismic Information (CSI 2008).

As elaborated in the upcoming chapter on the study areas, Wolong Township and Gengda Township under Wenchuan County, as well as Pingtong Township and Nanba Township under Pingwu County, lie on the two ends of the Yingxiu-Beichuan Fault. These four townships were heavily affected and threatened by debris flows and other geohazards. They were also remote and away from the centres of Wenchuan County and Pingwu County respectively. Given these characteristics, the four townships under the jurisdiction of the two counties can well serve as study areas in this research.

Despite the similarities of Wenchuan and Pingwu, the two counties are different in certain aspects.

Pingwu County was seriously hit by the earthquake but received much less attention and disaster mitigation resources from the academics, the public, the government and the media when compared with other seriously hit places.

As part of Wenchuan County, Gengda Township and Wolong Township are under direct administration of the Wolong Administrative Authority. Wolong Special Administrative Region (Wolong SAR) is China's best-known panda conservation and research area. Wolong SAR has long been benefitted from the giant pandas there which made the place an important and world-renowned tourist site. With the development of tourism, Wolong SAR has more connections to the outside world and better off than Pingwu County.

Through studying the two counties with the above similarities and differences, comparisons are made on the effectiveness of government disaster risk reduction measures and directives in the two groups of rural populations. The factors behind are explored.

3.4 Target population, sampling and the selected villages

As shown in Table 3.1, the four townships in Pingwu and Wenchuan administered 47 villages with a total population of 35,221 in year 2015-2016.

Table 3.1

The number of village, population and occupied areas of the four townships under Pingwu and Wenchuan counties

	Pingwu County		Wenchuan County		
Township	**Nanba**	**Pingtong**	**Gengda**	**Wolong**	**Total**
Number of village	26	15	3	3	47
Population	20505	9981	2669	2066	35,221
Occupied areas	321.73 km^2	146.20 km^2	855.61 km^2	819.09 km^2	2142.63 km^2

Sources: SGIO 2015b; Sichuan Government 2010; Pingwu Government 2012b; Gengda Township Government 2016a; Wolong Township Government 2016a.

The four townships occupy a total area of over 2000 km^2 in remote regions. Many of their villages are scattered, located high up in the mountains and not easily accessible. Travelling is time consuming. It is not uncommon that travelling from one village to another takes half an hour or more. The more villages were to be included in the study, the more time would be needed to spend on travelling and searching for respondents in different unfamiliar places.

Given the large target population scattered in a huge geographical mountain area comprising 47 villages, it would be time consuming and costly to collect data from each individual (Draugalis *et al.* 2008). Simple random sampling which needs to identify all individuals in a large population was not feasible and not practical. Under the circumstances with limited time, budget and resources, cluster random sampling or cluster sampling, which identifies the samples systematically and is commonly used in disasters studies (Hlady *et al.* 1994; Stratton 2019), was adopted in this research.

In this study, the target population was divided into multiple clusters. Each village, being a “naturally occurring grouping” (Henry 1990), formed a cluster. Each cluster was affected or threatened by existing or future debris flow or other geohazard risk. The clusters were similar or externally homogeneous but internally heterogeneous with different internal composition. Each cluster can represent the target population.

Five clusters, or villages, which contained the targeted population, were identified randomly. Two were from Pingwu and three were from Wenchuan. Villagers who lived in these five clusters were potential interviewees. Since a two-stage sampling in which simple random sampling is to be further applied within each cluster to select study subjects would yield a smaller sample size in each cluster, a one-stage sampling (or single-stage cluster sampling) in which all individuals in a cluster are sampled was adopted in this research. It is also not feasible to do a two-stage sampling in this research and post-disaster setting because a large percentage of target population were not reachable due to practical reasons. A sample was formed by random selection of the clusters and data was collected from the sample in the selected clusters. Being a probability sampling method, the survey findings from the samples identified by cluster sampling can be generalised to and inferred by the target population (Draugalis *et al.* 2008; Stratton 2019).

3.4.1 Sample size

In one-stage cluster sampling, the sample includes all individuals of the identified clusters. By referring to the sample selection approaches proposed by Henry (1990), the sample size of this research was determined.

As noted, the total population of the four selected townships in 2015/16 was 35,221. Since about 50% of the villagers did not live there for most of the year, the target population is determined at 17,611 to reflect the reality and ensure the sample does represent the target population. With the target population grouped into 47 clusters (villages), the average cluster size is 17,611 / 47 =375. Five clusters were randomly chosen. As all individuals in the identified clusters were included, the sample size is 375 x 5 =1,875. The overall probability of selection is 1,875 / 17,611 =0.11.

3.4.2 The selected villages

This research focuses on a total of five villages in the two counties of Pingwu and Wenchuan. All five villages are remote but some are more remote than others in terms of their concrete distances from the provincial capital Chengdu.

In Pingwu, Niufei Village is 212 km from Chengdu and Xinjian Village is 255 km away from it, whereas the three Wenchuan villages: Xingfu, Longtan and

Wolongguan are relatively closer to Chengdu with distances of 113 km, 116 km and 140 km respectively (Google Maps 2015). Here are their brief descriptions:

Niufei Village, Pingwu County

Original residents of this village were clustered into different groups scattered from hill top to adjacent to the provincial road, with some vague boundaries before the Wenchuan earthquake. However, disruption of houses after the quake had forced many households to move away from their original locations. The relocation had reshuffled the populations. Since then, residences of different groups of the Village were mixed up geographically. Therefore survey respondents were basically originated from different groups.

Xinjian Village, Pingwu County

More than half of the Xinjian villagers lived or worked outside for most of the year. For Group 1 to Group 4, about 50% of the populations resided outside. Group 5 and Group 6 got one-third living outside. For Group 7 and Group 9, the three most remote groups located high up near the mountain top, basically all residents had been living outside most of the time. Under such circumstances, the survey team could only reach the villagers of Group 1 to Group 6 for survey.

Xingfu Village, Wenchuan County

Residents of three groups of the Village were threatened by debris flows. Group 1 was basically located on the other side of the Provincial Road and not affected by debris flows at the time of interview.

Longtan Village, Wenchuan County

Longtan Village has a total of seven groups. Basically all villagers of Groups 1, 2, 4, and 6, as well as a small portion from Group 3, 5 and 7 were living along or threatened by the gullies. The majority of populations from Group 3, 5 and 7 were residing along the Shaotang River and threatened more by flooding rather than debris flows. A small portion of them moved to the Concentrated Settlement Sites after the 2008 earthquake and threatened by debris flow risk.

Wolongguan Village, Wenchuan County

This village is comprised of four groups having quite clear boundaries. All four groups have gullies and were threatened by debris flows.

Villagers in Pingwu were more positive and welcoming in accepting interview invitation of the author's survey team while those in Wenchuan, in particular those in Xingfu Village, were relatively more reluctant to answer questionnaires. This might be explained by the fact that, according to the locals, almost all Pingwu respondents had never been interviewed by academic interested in how their surrounding geohazard risk affected them, and in such in-depth. Therefore they were very willing to share their views in detail with the team which they believed were, and actually were, caring about them. Hence, although the percentage of villagers actually residing in the villages was much lower in Pingwu, response rates of the two Pingwu villages were higher.

3.5 Administering the questionnaire in the field

3.5.1 Consent from respondents

To ensure all invited villagers joined the survey voluntarily, the survey team members comprised of university student helpers had told each potential respondent that the survey was to be joined on a voluntary basis, and the interviewees could terminate the interview anytime during the course of interview. All the questionnaires done are treated in strictest confidence and the analysis in this research based on the survey results would not disclose the identity of any of the respondents. All respondents were clearly informed about the nature of the research and the use of data collected. A consent form with all this information was read out by the survey team members explicitly to each invited respondent to facilitate both the illiterate and literate individuals. Each respondent had to sign a printed consent form to confirm that he/she understood such details. For the illiterate respondents, a circle was adopted as their signatures. The usual procedures were followed regarding respondents' consent. Ethical approval was sought from the author's institution.

3.5.2 Conduct of the survey

The survey was conducted with the employment of 15 local university students from Sichuan. Local students were employed for the sake of effective communications, because many Sichuan people do not speak Putonghua at all and Sichuan dialect is the major language used in Sichuan, especially in the rural mountainous areas where this research is focused on. Employing local students speaking Sichuan dialect was crucial for the conduct of the survey.

Structured interviews were carried out by local university student helpers having summer holidays being recruited as interviewers. Prior to the conduct of survey, they were trained, particularly through piloting, to ask questions and record answers in standardised ways so that error due to interviewers' variability could be reduced and the answers could be aggregated (Bryman 2012). They were required to read out each question exactly the same as what was printed in the survey and in the same sequence.

In July 2016, the survey team visited the first selected village, Niufei, where a pilot survey with a sample of 16 respondents was conducted. Each respondent was interviewed by a pair of survey team members simultaneously, and a total of 32 surveys were collected. Convenience sampling is adopted for this pilot data collection. After gathering feedbacks from both the interviewees and survey team members, some questions were refined. For example, a question regarding communication skills asked whether the respondents know Putonghua, the official Chinese language, the original choices of answer were simply "Yes" and "No". However, quite a number of respondents replied "understand but cannot speak", because many villagers learnt to understand Putonghua through various channels like television but they never needed to speak Putonghua because the major language for daily communications in Sichuan is Sichuan dialect. Therefore, the third answer "understand but cannot speak" was added to the choices of answer. Meanwhile, some questions were deleted because the respondents viewed them as repetitive or redundant. The pilot survey is provided in Appendix 1.

After refining the questions, the survey team visited the five villages one by one from 27 July to 9 August 2016 and conducted the main survey. Two to three days

were spent in each village. Each survey lasted for about one hour. Debriefing sessions were held every evening to ensure everything was on the right track.

Upon arriving a village, the survey team members had to walk and search for the residents scattered in their remote houses or farmlands. Repeated contacts and appearance were found to significantly increase survey response rates. Since this thesis is interested in individual respondents in the study areas, in order to capture as many individuals in the selected villages as possible, the survey team revisited every village, group or community, and went from door-to-door for at least twice. The team sometimes have to visit the same household for two to three times before a villager could be reached and an interview could be conducted and those who might have missed during the team's first visit could be captured. By doing so, there could be multiple respondents from the same household, giving a good diversity across age groups, gender, and even linguistic or cultural groups.

As noted, the survey team members had told each respondent that the survey was to be joined voluntarily, and the interviewees could terminate the interview anytime during the course of interview. Although the researcher tended to eliminate sensitive questions that might trigger traumatic stress in the survey, certain residents were reluctant to recall the disaster experiences and declined the interview invitation from the beginning. In individual situations where the respondents felt distress arising from memories coming out of the interview, the interviewers paused the conversation until the respondents felt comfortable to continue. In a few cases, the surveys were terminated as the respondents considered not suitable to continue.

As a result, a total of 652 residents from the five villages could be reached and invited to participate in the survey. Among them, 631 responded and completed the questionnaire of this research. The response rate is 96.78%.

3.5.3 Limitations and implications

Like many other remote parts of China, a great portion of young males and some young females in the study areas left their hometowns and work in cities for most of the year. According to the government, approximately 50% of the population of all the five villages worked outside, and the proportion was even higher in Xinjian

Village of Pingwu County, the most remote village among the five being selected. This means as a whole, only about half or less than half of the villagers actually resided in the five villages for most of the year. Such phenomena was reinforced after the Wenchuan earthquake as some of those villagers who worked outside had relocated with their families to the cities, towns or county centres where they earned their living but their old houses might still remain in the mountains.

Indeed, this research interviewed people present in the villages during summer when the survey was conducted. It could be expected that most of the respondents were elderlies, women, farmers, housewives and students taking their summer holidays. These groups of villagers were more vulnerable than young working adults who were absent from the villages. This can be a bias or limitation of this survey because there might be an overrepresentation of certain demographic groups and underrepresentation of others. If the survey was carried out at a different time of the year, a different sample of interviewees might have been generated, hence could have changed the results. For instance, respondents' answers regarding their length of stay per year in their communities may vary according to the time of year the interviews took place. However, the ultimate responding group could reflect the demographic reality or the actual demographic distribution of the population in rural mountainous areas in China for most of the year. This is important because when this group of respondents encounter debris flow, they need to rely on themselves rather than their young and usually more educated family members. Learning the perception and behaviour of this group of respondents is particularly crucial to reduce the risk of the vulnerable.

In addition, the survey was conducted during summer time which is also the rainy season when debris flows are particularly active in mountainous regions. The results collected should better represent the populations who would actually encounter debris flows in future summers. Details of the demographic composition of the respondents is presented in the results chapter.

Owing to safety concerns, the surveys were basically conducted during day-time. Many villagers though residing in the villages for most of the year, might have leave their homes during day-time for work, farm or shopping etc. Some villagers simply left home when the survey team approached, making them unreachable. In post-

disaster settings like the two counties in this study, certain residents did not want to talk about the geohazard topic or to recall the earthquake and/or debris flow experiences, hence declined the interview invitation. Some potential interviewees were too old or not in good health condition and hence unable to participate in the survey. All these limitations affected the number and percentage of population the survey team could reach successfully and could complete the survey interview.

3.6 Data analysis

Data collected by the survey is analysed by various techniques including descriptive statistics and different forms of statistical analysis. Statistical software SPSS version 25 is used as the primary analytical tool, with Excel as a supplement.

3.6.1 Descriptive statistics

The first step of analysis is to describe and provide summaries of the basic features and characteristics of the samples and data collected from the survey in the results chapter. Frequencies, percentages, means, standard deviations, standard errors and medians are some major identifications of basic features of the dataset. Histograms, pie charts and 100% stacked bars are used to display the data distributions. Such descriptive statistics on both the independent and dependent variables provide a solid foundation for the subsequent statistical analysis.

3.6.2 Test of hypotheses

The second step of analysis is to find any correlations and casual relations among the variables studied in each of the three hypotheses of this research.

Given the nature and characteristics of the data set, in which the observations are independent and not normally distributed, non-parametric tests were basically applied. Most of the variables were measured on ordinal or nominal scales. Mann-Whitney *U* tests and Chi-square tests are the most used. In occasions where both the independent and dependent variables are binary, Yates' continuity corrections are used. In cases where more than 20% of the expected count is less than five, Fisher's exact tests instead of Chi-square tests were adopted to obtain more exact results. When the two tested variables are of ordinal, interval or dichotomous types, non-parametric correlations were also used (Bryman 2012). Multivariate analyses

were also applied. In certain occasions where dealing with continuous data and comparing the means of data of two groups of respondents, *t*-Tests were adopted.

The alpha level of statistical significance, *p*-value, of this research is set at .05. Correlations having *p*-value .01 are specified. The *p*-values are supplemented with Chi-square values, Fisher's exact test values, Mann-Whitney *U* values and *t*-values in order to give a more comprehensive view of the statistical findings. When measuring the strength of the relation between two variables, effect sizes are presented. Depending on the types of the paired variables, effect sizes are presented by Cramer's *V*, Phi, Spearman's *R* or Hedge's *g*.

For Hypothesis 1, Chi-square tests and *t*-Tests were conducted to examine any significant relationship between the decision to move to a new place after the 2008 earthquake and the independent variables being considered during the decision processes. Cramer's *V*, Phi and Hedge's *g* were used to find out the effect size of such casual relations.

For Hypothesis 2, risk perception of existing debris flow in the communities is the dependent variable and is evaluated in a Likert-scale. To find out the variables contributing to respondents' debris flow risk perceptions, statistical analysis, including Mann-Whitney *U* test, Spearman's rank correlation and Chi-square test are adopted, depending on the types of variable. Mann-Whitney *U* tests with mean ranks and *U*-values were mainly used. Effect sizes of such relations were basically presented by Spearman's rho. If over 20% of the expected counts of the samples were less than five, a Fisher's exact test instead of a Chi-square test was performed. In addition, histograms are used to illustrate frequency distribution of risk perception in relation to each independent variable, while boxplot diagrams are adopted to show the median, skewness and quartiles of risk perception.

In testing Hypothesis 3, Chi-square tests were run to find the relationships between each independent variable and the dependent variable. Again, if more than 20% of the cells have expected count less than five, a Fisher's exact test would be applied to explore what factors would influence respondents' anticipated disaster response behaviour. Cramer's *V* was conducted to further determine the effect sizes of such relationships.

3.7 Problems encounter, limitations of this research and possible solutions

In China, as in many other places, basically only authorized units can conduct field research and achieve access to information regarding the physical environment (e.g. geohazards risk of different places) and the people involved (e.g. local leaders and villagers). Hence, this study can only be based on official inspection results. Such information, however, may have its own limitation, including the area being covered. In addition, as this study commenced a few years after the Wenchuan earthquake, the author have to rely on information provided by the authorities on what they had done since 2008 on mitigating debris flow risks and disseminating risk reduction messages based on their records, photos and sharing because personally the author was not residing in the study areas. Yet the implementation and effectiveness of such measures could be evaluated by observations during field trips and through the survey on the affected and threatened villagers.

The second limitation is about the comprehensiveness of the information acquired from official sources. Before the Wenchuan earthquake, geohazards only had minimal impact on Sichuan. Records and information of geohazards and related official action before 2008 were limited. In addition, as told by many officials, even though some information did exist before the quake, many documents were destroyed or lost during the quake or the geohazards it induced, hence could not be retrieved. The direct impact on this study is that in many cases, geohazard risk reduction efforts by the government before and after the Wenchuan earthquake could not be compared. In such situations, recalls of the authorities and findings from the survey served as a clue to such questions. In practice, comparison before and after the Wenchuan earthquake is eliminated in this research.

After the Wenchuan earthquake, many resources and efforts poured into mitigating geohazard risks and related disaster preparedness works. However, many official information, data and documents were not openly accessible. In some cases, the information acquired for this research may not be comprehensive enough. There is a possibility that the governments of different levels might have studied the geohazards and have mitigated from different aspects which might not be fully acquired by this research. Owing to such limitation, this research only compares the five villages under study based on the information equally acquired from all of

them. Only by doing so, a fair comparison about the efforts the local governments paid in mitigating geohazards and their respective effectiveness could be given.

In terms of acquiring data, a social survey is adopted for this thesis. Given the resources and manpower available, conducting a survey was the best appropriate and feasible method to collect data from over 600 respondents in the remote mountainous sites. Indeed, it is foreseeable that the inflexibility nature and lack of depth of survey could bring limitations in collecting and interpreting results (DeCarlo 2018). Therefore further research opportunities, such as conducting qualitative research like interviews and focus groups, could be considered to explore the topics this thesis covered if resources allowed in the future.

Relocation after the 2008 earthquake has mixed up some residents in terms of their community affiliations. For instance, a certain household originally belonged to a certain group of a certain village, might belonged to another group after relocation. Some others might not have their group affiliation changed, but might now be living with people from another group of the same village. Although the survey team had asked the respondents which group they belonged to, in a few cases some respondents were not sure about the answer and it is possible that some might provide a wrong answer. We simply could not double check their actual group affiliation because the identity and personnel information of the respondents should not be disclosed and cross-checked with the officials. In addition, the respondents were mobile. Residents of one group might be relatives or friends of another group, and when we interviewed them, some were visiting others and were not staying in their own place at all, making us unable to confirm their actual address and group affiliation. Therefore the author have to trust the group affiliation information provided by the residents. Sometimes, student helpers might simply record the respondents' group information based on where they met. Despite these limitations, the survey analysis was not affected much because this research basically focus on comparing two counties but not among different local groups.

Since both the earthquake-induced geohazards and risk reduction measures develop and change from time to time, it is difficult to track the continued changes during the course of writing this thesis. Instead the time frame of this thesis is set from 2008 to 2016. Only two events that occurred outside this duration were

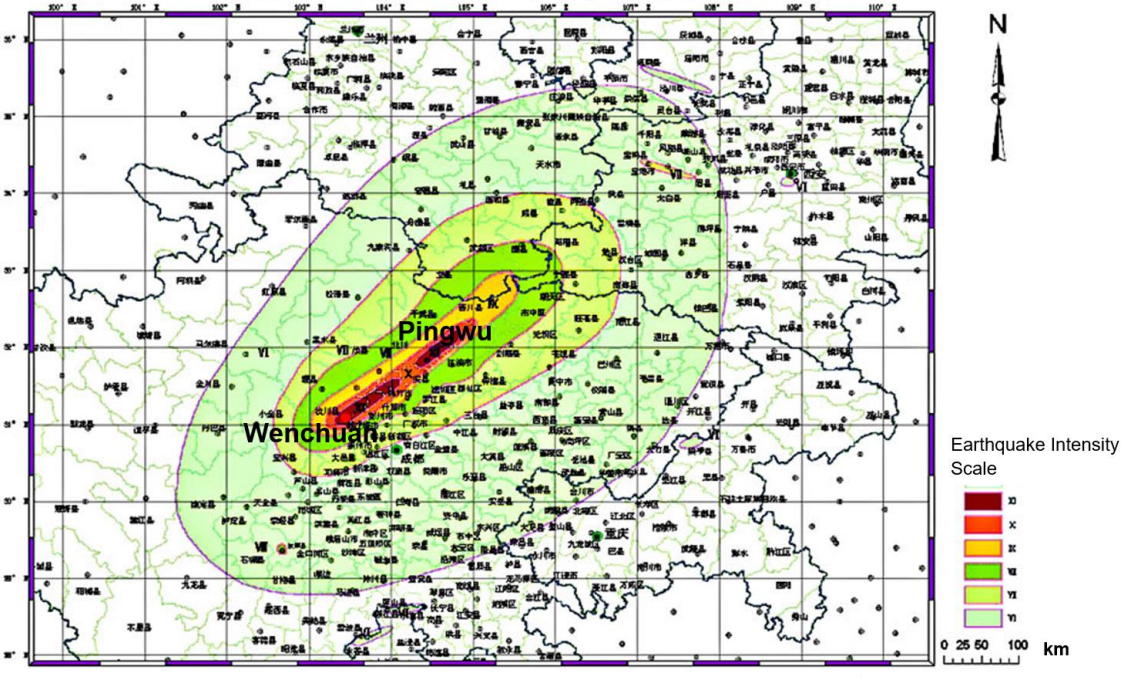
mentioned in this thesis because these two incidents shed light on the discussion and analysis. The first one is the landslide occurred on 24 June 2017 in Xinmo Village in Mao County mentioned earlier in this chapter. The second incident is the outburst of huge floodings and debris flows in Gengda started in late August till early September 2019, and is mentioned in the chapter on case study areas.

Chapter 4
Case study areas

Both study areas in this research, Pingwu and Wenchuan, are located in rural remote mountainous regions with rugged topography and steep slopes, and associate with gullies and ditches. They are selected for comparison as they lie on the two ends of Yingxiu-Beichuan Fault of Longmenshan Fault Zone which movement had caused the Wenchuan earthquake (Wen 2011), while both were categorized as the ten “counties of extreme hazard” (Wei 2010) and experienced the highest earthquake intensity at a scale of XI according to China Seismic Information (CSI) (Figure 4.1). Wenchuan County in particular, experienced earthquake intensity ranges from Level VIII to XI.

The 400 kilometres long Yingxiu-Beichuan Fault started in Wenchuan County near Yingxiu Township and ended in Pingwu County near Shikanzi Village of Nanba Township (Zhou *et al.* 2010; SGIO 2015b).

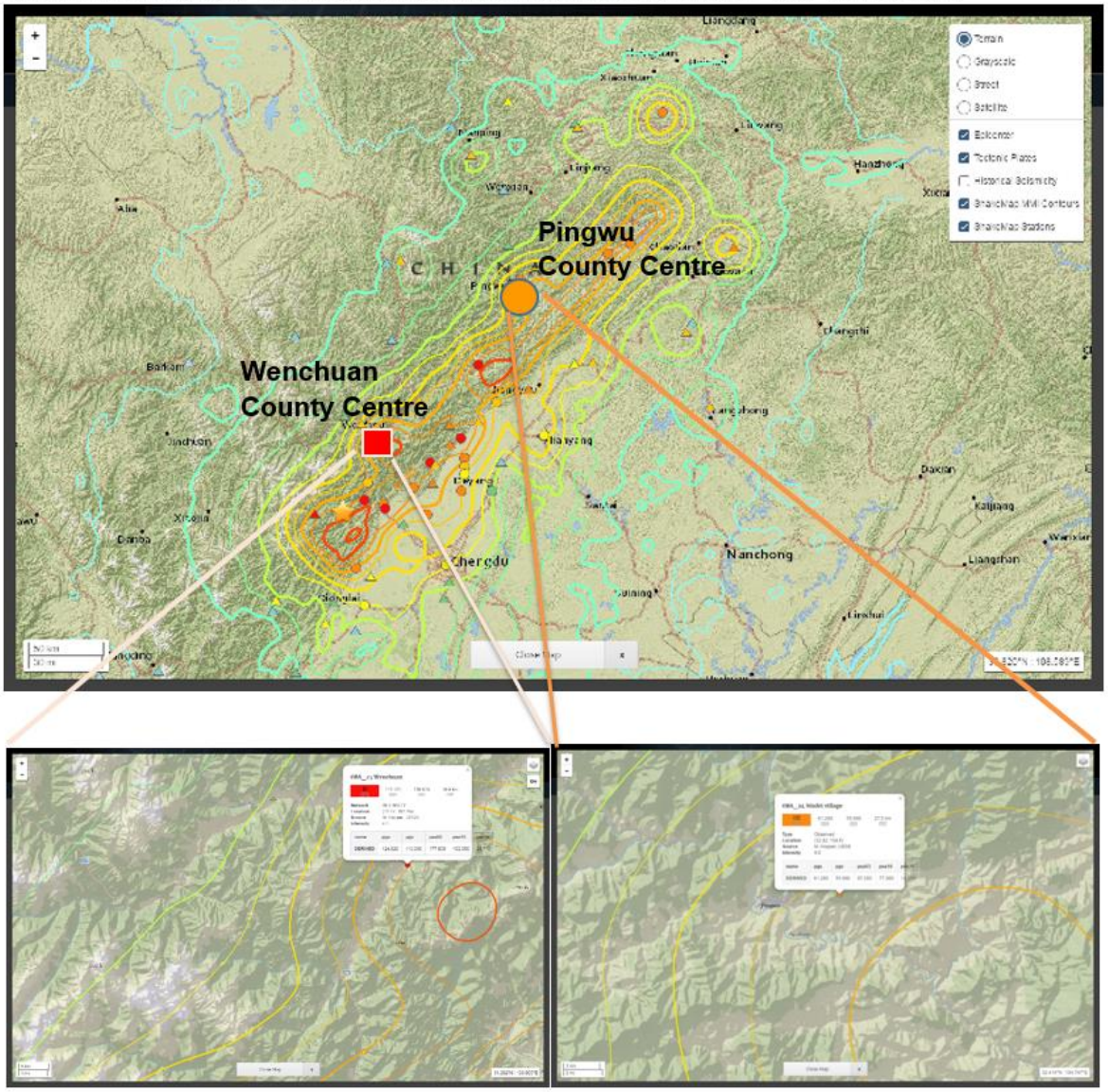
Figure 4.1
Earthquake intensity of the M8.0 Wenchuan earthquake in year 2008 by China



Source: CSIW (China Seismic Information Website) 2015 (in Chinese).

According to USGS, the magnitude of Wenchuan earthquake is 7.9, rather than 8.0 by the Chinese authority, with an origin at the depth of 19 kilometres (USGS 2008). The earthquake intensities experienced by Wenchuan and Pingwu were slightly different (Figure 4.2).

Figure 4.2
Earthquake intensity of the M7.9 Wenchuan earthquake in year 2008 by the USA



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

Source: USGS 2008.

Since Wenchuan County is the site of the epicentre of the 2008 earthquake, Yingxiu, it was more intensely affected than Pingwu. Pingwu fell between VI to VIII instrumental intensity with strong to severe perceived shaking and light to heavy potential damage while Wenchuan fell between V and IX instrumental intensity with moderate to violent perceived shaking and very light to heavy potential damage (Figure 4.2).

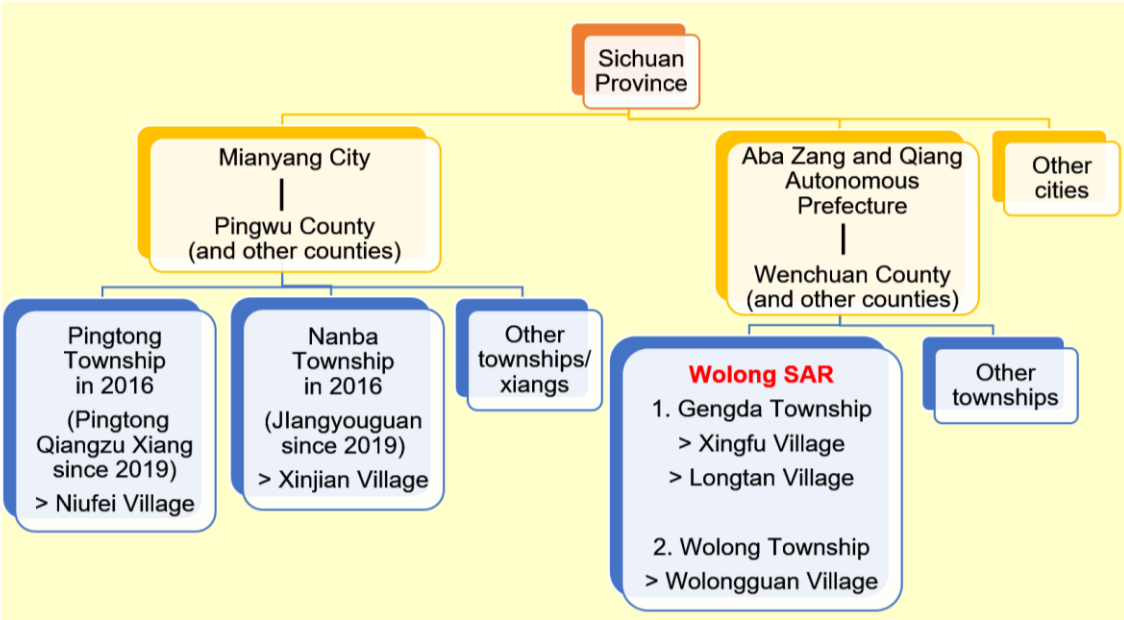
The Literature Review chapter shows that the mass movements in the Wenchuan earthquake affected areas were basically caused by a combination of topography, geology, the 2008 earthquake itself and subsequent heavy rainfalls. In fact, all the

five villages in this research were seriously affected by torrential rainfalls after the earthquake, many of which involved sudden precipitation, causing high levels of antecedent moisture and leading to the occurrence of high-velocity debris flows.

According to the Sichuan Government (2010), Pingtong Township and Nanba Township under Pingwu County, as well as Wolong Township and Gengda Township under Wenchuan County, were heavily affected by debris flows. Specifically, debris flows constituted to 32% of all geohazards risk directly affecting local residences in Wolong Township, 15% in Gengda Township, 10% in Pingtong Township and 3% in Nanba Township. In terms of number, Wolong Township were threatened by 14 debris flow risks (3 mega and 1 large scale), 17 in Gengda Township (1 mega and 3 large scale), while Pingtong and Nanba townships were both threatened by 3 debris flow risks, among which Xingping Gully Debris Flow in Nanba has been threatening as much as three villages with thousands of residents. Post-earthquake debris flows had further destructed dams, protections walls, houses and even resettlements. Up till 2015-16, populations of Pingwu and Wenchuan were still threatened by numerous debris flow risks (SGIO 2015a; Wolong Township Government 2016a, 2016b).

Two of the studied villages are under the jurisdiction of Pingwu County. The other three belong to Wolong Special Administrative Region (SAR) which is affiliated to Wenchuan County (Figure 4.3). Wolong SAR is quite autonomous in terms of administration, i.e. what is characterised in or imposed on Wolong may not be applied in Wenchuan. Wolong may not totally represent Wenchuan. The two are not identical. However, comparing sites in one county (i.e. Pingwu) with sites in another (i.e. Wenchuan) with administrative differences could make the comparison more worthwhile. It can be ascertained whether there are differences in the light of the study aims.

Figure 4.3
Structure of government affiliation of the two study areas -- Pingwu and Wenchuan



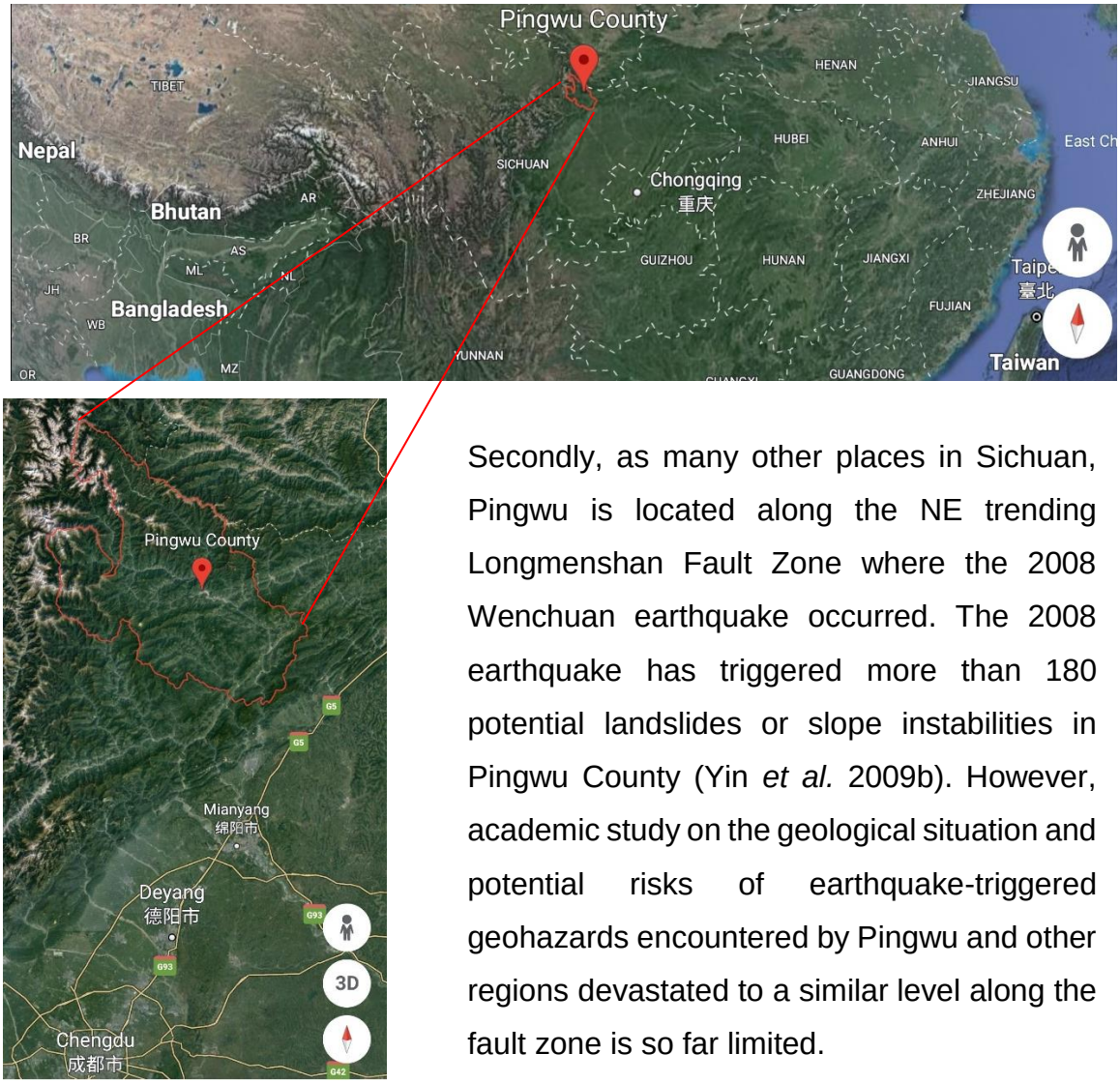
4.1 Case study area 1 -- Pingwu County

After the Wenchuan earthquake, although huge resources and efforts have been put into mitigation measures all over the earthquake-affected areas, the focus always remains on the most seriously affected regions like Wenchuan and Beichuan, particularly their town centres. Similarly, notable academic studies on various aspects of the 2008 earthquake have been carried out since May 2008 but most of them focused mainly on the most seriously affected localities (Cui *et al.* 2011). Instead of concentrates in studying the regions like Wenchuan that have already caught the attention of other researches, this thesis also focuses on a remote county -- Pingwu, as one of the two case studies for comparison.

Pingwu County is a typical rural area in Sichuan. Firstly, it is located next to the Aba Zang and Qiang Autonomous Prefecture where the 2008 earthquake hypocentral location is situated. Although Pingwu is seriously hit and affected by the Wenchuan earthquake, as reflected in its earthquake intensity fell between VII and XI according to CSI (Figure 4.1), it received much less attention and disaster mitigation resources from the public, the government and the media when compared with other seriously hit places.

Figure 4.4

Location of Pingwu County



Adopted from Google Maps 2016.

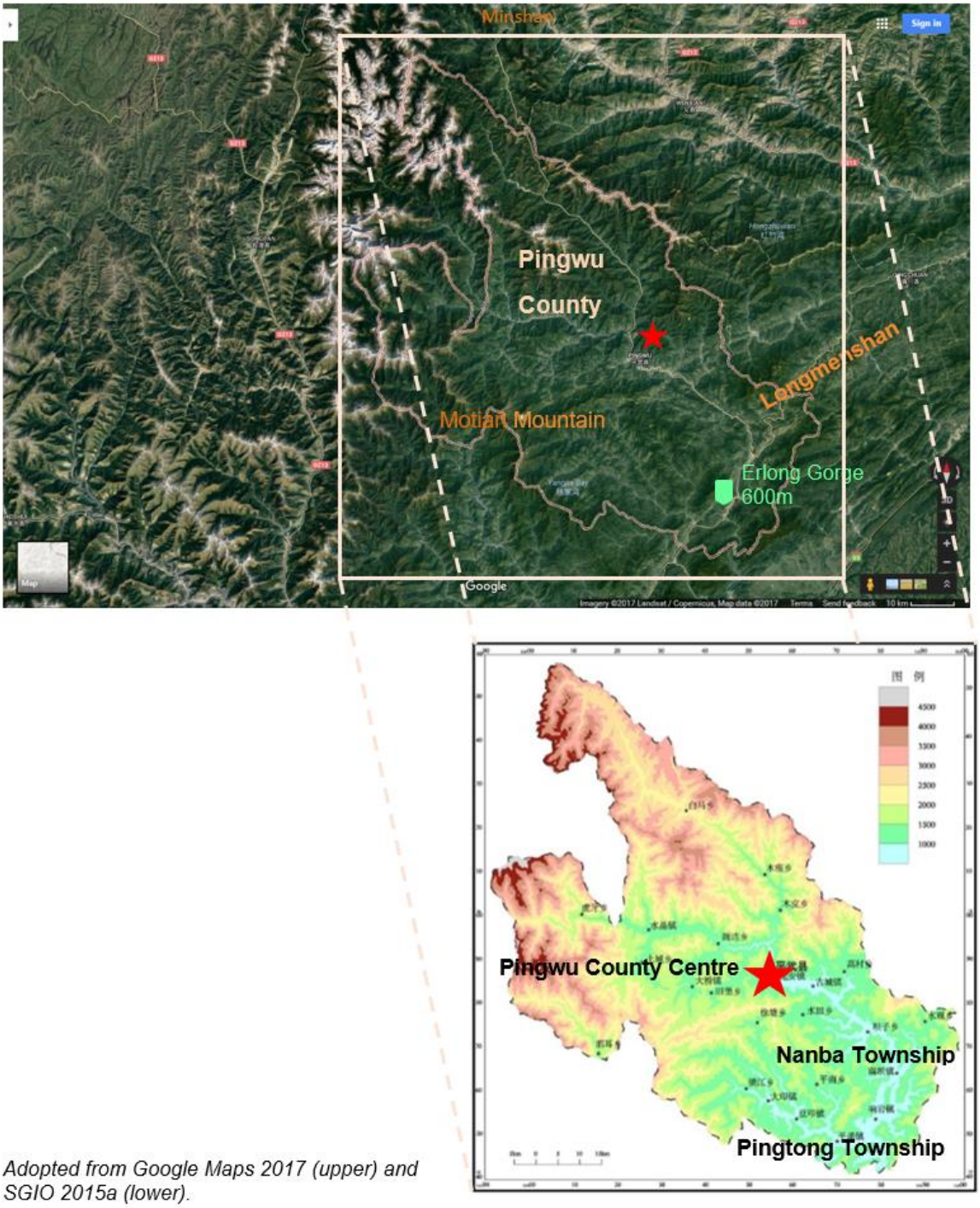
Secondly, as many other places in Sichuan, Pingwu is located along the NE trending Longmenshan Fault Zone where the 2008 Wenchuan earthquake occurred. The 2008 earthquake has triggered more than 180 potential landslides or slope instabilities in Pingwu County (Yin *et al.* 2009b). However, academic study on the geological situation and potential risks of earthquake-triggered geohazards encountered by Pingwu and other regions devastated to a similar level along the fault zone is so far limited.

Thirdly, Pingwu is dominated by rural populations. A great portion of the Pingwu population affected by the 2008 earthquake was from the rural mountainous areas – a topographical situation similar to many other places along the Longmenshan Fault Zone and even other remote areas in China. Pingwu County is located along the margin of mountain ranges with topography varies from west to east (Figure 4.5).

Being dominated by mountains and a lack of flat land, the county is sparsely populated with 187,532 people by the end of 2014 (SGIO 2015a), settling in a total area of 5,974 square kilometres (Wei 2010).

Figure 4.5

Landscape and terrain of Pingwu County



Adopted from Google Maps 2017 (upper) and SGIO 2015a (lower).

About 80% of rural households in Pingwu have been affected by the 2008 earthquake (Mianyang Government 2011). The rural populations are in general living in remote regions, making them more vulnerable to debris flow risks.

This research studies two villages under the jurisdiction of Nanba and Pingtong townships respectively. They were the third and fourth most densely populated townships in Pingwu County, behind the County Centre Longan Township

(population density of 194.22 per km^2) and the adjacent Gucheng Township (population density of 81.91 per km^2) (SGIO 2015a). Their low population densities at 63.73 and 68.27 persons per km^2 respectively (Table 4.1) confirms their rural nature which is the intended target of this research.

Table 4.1
Areas and populations of the two townships in Pingwu County

Township	Area (km^2)	Population	Population density (per km^2)
Nanba Township	321.73	20,505	63.73
Pingtong Township	146.20	9,981	68.27
Pingwu County Total	**5974.00**	**187,532**	**31.39**

Source: SGIO 2015a.

Vulnerability of the Pingwu rural settlers are deepened by their relatively low per-capita income. The county is relatively backward economically. GDP per capita was RMB 16,685, much lower than the Chinese average RMB 53,053.03 (equivalent to USD7,683.5) in 2014, and was close to the “lower middle income” category (World Bank 2014). The average disposable income per rural village resident was RMB10,202 in 2016, which was just 39% of the urban populations (Mianyang Government 2017).

4.1.1 Pingwu County -- Nanba Township

Nanba Township is located at the southeast of Pingwu County (Figure 4.5). A total of 26 villages, one social community residential committee, and the Nanba Township Centre itself of 2.2 km^2 with 7000 plus populations, were under its jurisdiction. Most residents are farmers and are Hans, Qiangs, Hui and Tibetans in ethnicity (SGIO 2015b). Nanba Township and the nearby Shuiguanxiang were rescinded in year 2019 and a township named Jiangyouguan was established (Mianyang Government 2019).

Figure 4.6

Full view of Nanba Township Centre on the right coast of Fu Jiang

It locates at the intersection of Fu Jiang and Shikan River.

Adopted from SGIO 2015b.



4.1.2 Pingwu County -- Nanba Township -- Xingping Gully Debris Flow

The Longmenshan thrust belt located in the eastern boundary of Tibetan Plateau, which produced the reverse slip in 2008, caused the Wenchuan earthquake (USGS 2008) which then induced numerous secondary geohazards.

Xingping Gully Debris Flow located at a transitional zone from Sichuan Basin to Qinghai-Tibet Plateau is the biggest debris flow triggered by the Wenchuan earthquake in Pingwu County (SSGEC 2011) which affected three villages. During the site visit in Xinjian Village, Longmenshan was clearly seen on the other side of Xingping Gully.

Figure 4.7

View of Longmenshan from Group 4, Xinjian Village, Nanba Township

Photo by Rhea Leung, July 2016.



Figure 4.8 Xingping Gully - A view from afar



Source: SSGEC 2011.

Figure 4.9 Xingping Gully - A closer look at the source



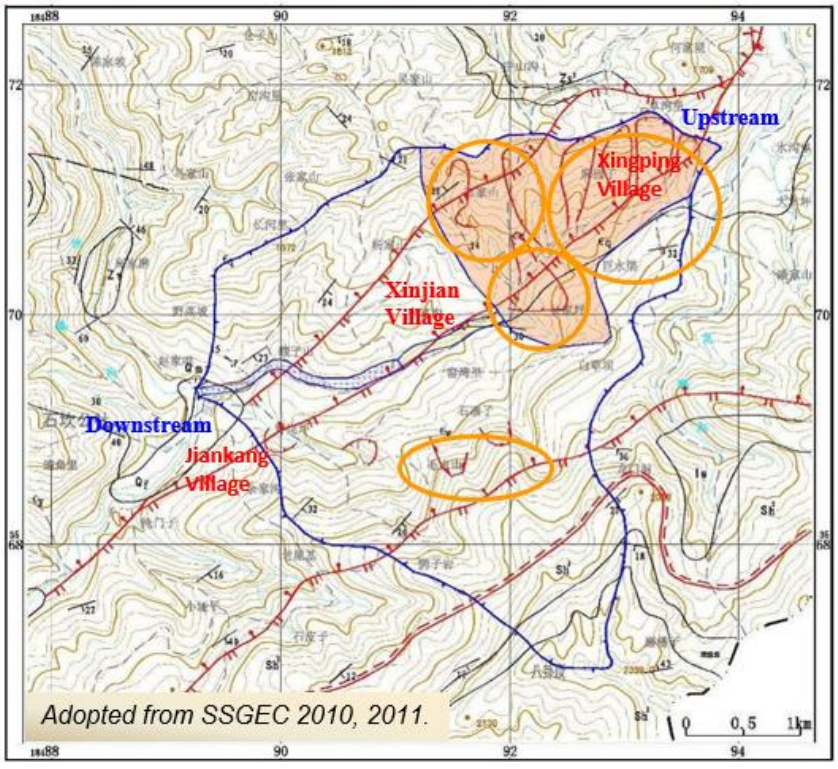
Source: Rhea Leung, December 2014.

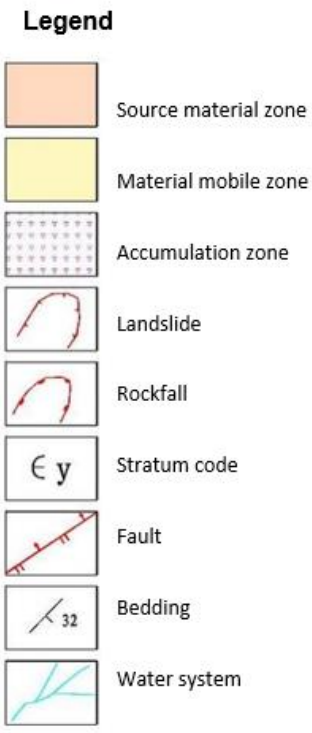
Xingping Gully Debris Flow was considered as totally "new" and no monitoring information had ever been recorded (SSGEC 2010, 2011). It "was triggered" by the Wenchuan earthquake, or at least had not affected the nearby three villages "in the past 20 years" before the Wenchuan earthquake (SSGEC 2010). Local officials and local villagers also indicated that Xingping Gully Debris Flow had been first caused by the Wenchuan earthquake.

The mountains of the Nanba Township area is cut across by the Longmenshan fault zone and therefore the 2008 earthquake has induced very mature geohazards like landslips, rockfalls and unstable slopes which produced huge volume of debris flow source materials in Xingping Gully (SSGEC 2011), including those circled in orange in Figure 4.10. On top of the original deposits and slope eroded materials, source materials of debris flow have been accumulated directly in the 5,330 meters long main gully or entered the main gully via numerous tributaries (SSGEC 2010, 2011) (Figure 4.11).

Figure 4.10 Satellite photo (upper) and Geological map (lower) of the Xingping Gully area





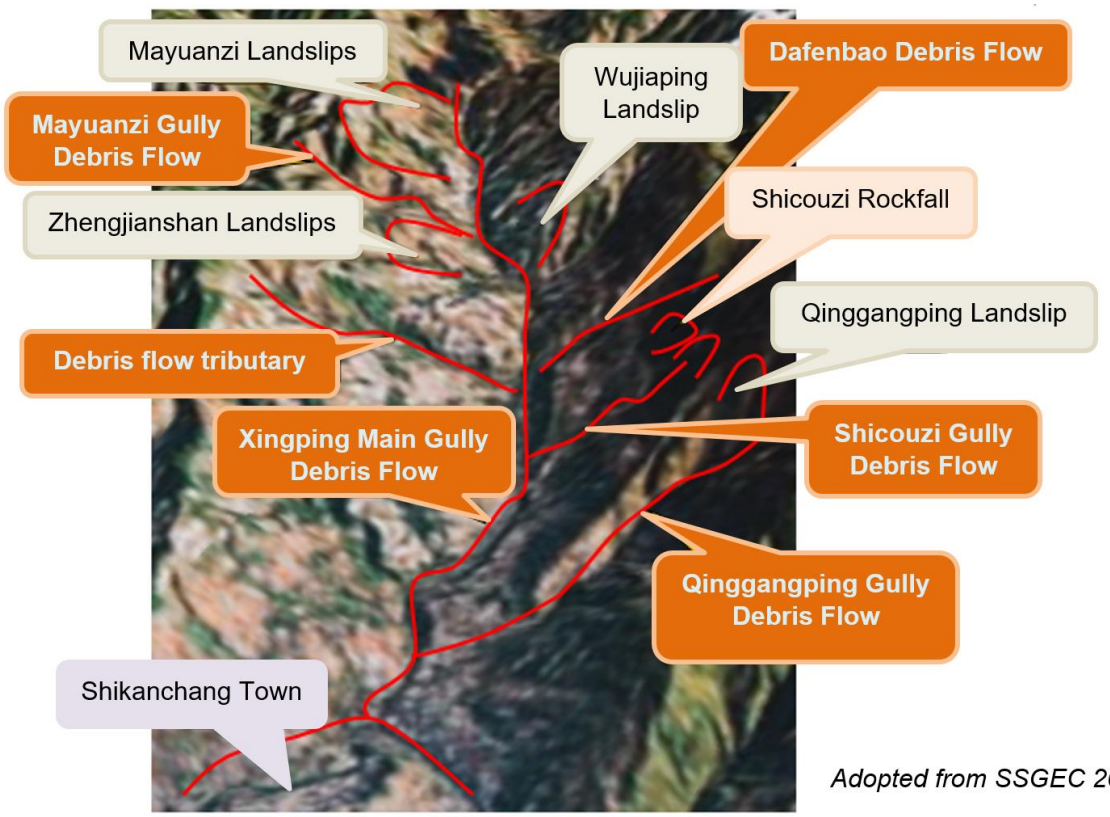


On 24 September 2008, four months after the Wenchuan earthquake, and on 14 July 2009, two 50-year return period torrential rainfalls caused two destructive debris flows carrying surface runoffs downstream filled with soil and mud from highland to lowland. They affected three villages all along the gully (SSGEC 2010, 2011) from Mayuanzi uphill to Shikanchang Township.

Xingping Gully basin therefore can be divided into three zones: Source Material Zone spreading from Mayuanzi of Xingping Village upstream, Material Mobile Zone along Xinjian Village midstream, to Accumulation Zone at Jiankang Village and Shikanchang Township downstream (SSGEC 2010, 2011) (Figure 4.10).

Figure 4.11

Satellite map showing source materials and gullies of Xingping Gully Debris Flow



Adopted from SSGEC 2011.

4.1.3 Pingwu County -- Nanba Township -- Xingping Gully Debris Flow affecting Xinjian Village

Xinjian Village, located at the midstream of Xingping Gully is a typical village in Pingwu and Nanba: mountainous, sparsely populated, less accessible, and with average income lower than the townships.

Landscape and accessibility

Households of Xinjian Village are scattered on the mountains surrounding the midstream of Xingping Gully, with some communities located at an elevation from 900 to 1300 metres. Xinjian is a remote village approximately 252 kilometres northeast of the provincial capital Chengdu (Google Maps 2015) and required more

than four hours' drive to reach. The centre of Pingwu County capital is about 60 kilometres in the northwest (Google Maps 2015). Sometimes it might take longer to travel from Xinjian Village to places outside due to poor road conditions especially after rainfalls, floodings or geohazards that might block the only road.

Demography and economy

Xinjian Village is composed of a nine groups of villagers. The total population is 704 in 2015 (Table 4.2) but only about 40% to 50% regularly resided in the village. The rest worked outside and just returned to their village annually during the Chinese New Year which usually falls on January or February. No detailed breakdown of the age distribution was available but as observed during the field trips, it was similar to many remote mountainous regions in China, where mainly the children, women and elderlies stayed in the village for most of the year and most adults were farmers. According to local village leaders, most villagers in the three groups located highest uphill had moved out in recent years.

Table 4.2

Nine groups of Xinjian Village and their household numbers

Name of the groups	Number of households	Number of threatened households residing in the group	Population
Shicouzi	58	11	NA
Fuzishan	38	8	NA
Maoerdong	23	2	NA
Lijiashan	34	3	NA
Yangjiashan	26	--	NA
Taopingshan	20	6	NA
Wujiashan	10	3	NA
Goulaogua	14	1	NA
Zhangjiashan	9	--	NA
Total	**232**	**34**	**704**

Source: Nanba Township Government 2015.

Figure 4.12

Satellite images of Xinjian Village by Google Maps (left) and USGS (right)



Source: Google Maps 2017.



Source: USGS 2017.

Xinjian Village is a typical poor village with an average annual income per capital of just RMB 6,000 (about USD 877 as in May 2017). The villagers' livelihood relied much on agricultural produce farmed on mountain slopes given the natural environment. The situation became worst after 2008 earthquake because most of the lands were destructed or covered by debris. Many villagers also earn their livings by raising cattle.

Figure 4.13

Farmlands are precious

Xinjian villagers could only farm on barren land or on hillslopes, especially after the 2008 earthquake.

Photo by Rhea Leung 2015-2016.



Figure 4.14

Many Xinjian villagers plant their farms on steep slopes near their houses. Some raise livestock and poultry for private use or for sale.



Photos by Rhea Leung, July to August 2016.

Debris flow risks threatened Xinjian Village – Year 2010 inspection and risk reduction measures imposed

Xinjian Village is located nearby areas filled with debris flow source materials and has been exposed to various geohazards risks. According to a government inspection in 2010, a total of three groups of Xinjian villagers were affected by the Xingping Gully Debris Flow system, including Shicouzi Rockfall which contributed to the debris flows. Mitigating construction of sediment trap dam downhill was done to change the route of flooding waters and debris flow, hence greatly lowered the threats. Still, river bed of Xingping main gully had risen with debris accumulation through the years. Flows of debris and flooding waters still covered up some house foundations in Shicouzi (Group 1), causing direct threats to local populations (Figure 4.15). At least two households therefore planned to relocate elsewhere in the village (SSGEC 2011).

Figure 4.15



Houses in Shicouzi affected by Xingping Gully Debris Flow in August 2010.

Source: SSGEC 2011.

Besides Shicouzi, Xingping Gully Debris Flow had inundated some houses in the Settlement Site located near the entrance of Xinjian Village. The Site was newly built after the 2008 earthquake at the lower stream of the Gully with mud and debris accumulated up to one metre high in 2010. Residents in the Site were directly threatened by floods and debris flows (SSGEC 2011).

Figure 4.16



Debris accumulated at the Settlement Site of Xinjian Village

Source: SSGEC 2011.

In view of such risks, one of the levees in the geotechnical mitigation plan was soon completed to protect 90 Shicouzi villagers (SSGEC 2011). Another levee was also built next to the Settlement Site to protect 12 households (SSGEC 2011).

Figure 4.17

A comparison of the environments of Shicouzi before and after the concrete levee was built



(Left) Houses in Shicouzi affected by Xingping Gully Debris Flow in August 2010. *Source: SSGEC 2011.*

(Right) Photo taken almost from the same angle in 2015 showing a concrete levee built to protect the households. *Source: Pingwu County Government 2015.*

Figure 4.18

A comparison of the environments of the Settlement Site before and after the concrete levee was built



(Left) Debris accumulation at the Settlement Site of Xinjian Village in 2011.
Source: SSGEC 2011.
(Right) Photo taken from a different angle but of the same place in 2015 shows a concrete levee constructed to protect the same group of houses.
Source: Pingwu County Government 2015.

Review of debris flow threats after imposing geotechnical measures

The geotechnical mitigations measures imposed by the government to tackle Xingping Gully Debris Flow and other geohazards contributing to this risk had been revised and upgraded since 2008 in response to the changing geomorphology which was unprecedented not only to local officials and residents but also to higher levels of government. Imposition of the major sediment trap dams and levees to tackle Xingping Gully Debris Flow in 2011 (SSGEC 2011) seemed able to stabilized the risk.

In late 2014, the author visited the upstream of Xingping Gully at Xingping Village and saw the impact of sediment trap dams and levees in blocking surrounding debris flow source materials falling into the main gully (Figure 4.19). Local officials noted that a major follow-up work was to keep monitoring the level of source materials accumulation and keep dredging as appropriate.

Figure 4.19
View of Xingping Gully's debris flow mitigation measures from uphill

– A huge structural mitigation measure, including sediment trap dams constructed up in the mountain at the source of Xingping Gully Debris Flow after the Wenchuan earthquake, to prevent future disasters and to protect villages downstream is far away from the nearby villages.



Photo by Rhea Leung, 17 December 2014.

Although the Xingping main gully debris flow risk was mitigated, a geohazard risk mitigation review in late 2015 showed that the engineering mitigation on Xingping Gully Debris Flow were "effective" but "not safe" (SGIO 2015a, 2015d). Owing to different scales of debris flows occurred in previous years, the sediment trap dams were full and the river bed was rising too high while the sediment trap dam upstream was damaged. Further dredging and additional levee, relocation and settlement were recommended, while another four geohazard risk sites in Xinjian Village as in late 2015 were considered as "safe" (SGIO 2015d). No further geoengineering mitigation was proposed for Xingping Gully area (SGIO 2015a).

Despite all the mitigation efforts, Xingping Gully Debris Flow was still threatening 106 Xinjian villagers in the Settlement Site, while Taopingshan (Group 6) exposed to Landslip Behind-The-House since August 2010 was still threatening 29 villagers (Table 4.3).

The annual assessment in 2016 further revealed that Xingping Gully Debris Flow and the Taopingshan landslip were still putting Xinjian Village's Settlement Site and Taopingshan Group at risk (CCPCO and PG 2016).

Table 4.3

Basic situations of geohazard risk sites affecting Xinjian Village in 2015 *Source: SGIO 2015e.*

Name of risk site	Type of geohazard	New site?	Administrative location -- Community/ Group	Time of occurrence	Scale		Disaster situation			Major triggering cause	Stability judgement		Threatened object				Risk level	Urgency level of prevention and mitigation	Name of monitoring personnel	Phone number	Remarks
					Volume (0,000 m^3)	Level	Death toll	Casualty	Property lost (RMB 10,000)		Current situation (as at late 2015)	Trend	Type of threatened object	Number of household	Number of persons	Threatened properties					
Xingping Gully Debris Flow	Debris flow	No	Machangdi Group (Settlement Site)	2013.7	8	Medium	0	0	0	Rain	Easy to occur	NA	Settlement Site	28	106	400	Big	Relatively urgent	Personnel PX12	Yes	Engineering mitigation completed
Taopingshan Landslip Behind-The-House	Landslip	No	Taopingshan Group	2010.8	2.5	Small	0	0	0	Earthquake, Rain	Relatively stable	Unstable	Scattered farming households	6	29	80	Medium	Relatively urgent	Personnel PX13	Yes	NA

Latest situation observed before the survey

Various places of Xinjian Village were still under debris flow threat as source materials could be found in many locations (Figure 4.20, 4.21, 4.22).

Figure 4.20
Source materials for debris flow in different locations in Xinjian Village before the conduct of the survey

Landslips (left) and debris flows in tributaries of Xingping Gully (right).





Some houses are still adjacent to tributaries of Xingping Gully with lots of debris flowing from upstream caused by rockfalls, landslips or unstable slopes.

Photos by Rhea Leung, 2016.

Figure 4.21
Various places in the downstream of Xingping Gully are still exposed to debris flow risk

Debris accumulated from previous debris flows are left behind at the village entrance outside the Settlement Site.

A wooden warning signage reminding drivers to be aware of sinking road foundation in multiple sites.





The Settlement Site accommodates about 20 households but some houses are vacant.
Although these houses are newer, better facilitated and more convenient, some villagers prefer to stay in their old houses uphill after the debris flow hits.

The two-storey Village Office, Villagers Committee and Health Clinic near the Settlement Site.



Photos by Rhea Leung, mid-2015 (upper) and mid-2016 (middle and lower).

Figure 4.22

Some houses in the midstream of the Xingping Gully catchment area, though not next to gullies, are fragile to landslip and debris flow

Rocks and slopes with debris in Group 4 provide source materials for landslip and hence debris flow.





Fragile rooftop and foundation expose the houses in Group 3 to higher debris flow risks.





Photos by Rhea Leung, 2016.

4.1.4 Pingwu County -- Pingtong Township

The “South Gate” of Pingwu County, Pingtong Township, is located at the southwestern tip of Pingwu County (Figure 4.5), with a total area of 146 km^2 (Pingwu Government 2012b). Human settlements and economic activities in Pingtong Township has been developed along river valleys (SGIO 2015b). The township centre occupies a flatland area of 2.23 km^2 along the major water system in the township, Qingyi Jiang (SGIO 2015b).

Figure 4.23
Full view of Pingtong Township Centre



Source: SGIO 2015b.

A total of 15 administrative village, one social community residential committee and 82 villager groups were under Pingtong’s jurisdiction in 2015. Over 90% of its population were Qiangs, with the rest from Han and Hui ethnic groups (Pingwu Government 2012b). Pingtong Township and the nearby Pingnan Qiangzu Xiang were rescinded in year 2019 and Pingtong Qiangzu Xiang was established (Mianyang Government 2019).

Pingtong Township falls on the northwestern part of Yingxiu-Beichuan Fault which cut across the river valley of Qingyi Jiang (SGIO 2015a). The 2008 earthquake had caused 352 deaths, 60 missing, 5,300 casualties and a direct economic loss of RMB 3.3 billion (about USD 482 million) in Pingtong (Pingwu Government 2012b). After the quake, Pingtong Township housed 11,000 regular residing residents from 3,406 households, with 2,402 residential houses rebuilt and 760 reinforced, in which about 90% were in rural regions (Pingwu Government 2012b). The average annual net income per capita was RMB3,995 (approximately USD584), lower than the county average (Pingwu Government 2012b).

4.1.5 Pingwu County -- Pingtong Township – Niufei Village

Landscape and accessibility

Niufei Village is under the jurisdiction of Pingtong Township and is located at the southern tip of Pingwu County. The elevation of Niufei Village is about 600 to 800 metres and is situated on flatter landscape (Google Maps 2015). The Village is located just adjacent to Provincial Road S205, hence more accessible than Xinjian Village and many other parts of the County. It is relatively close to the provincial capital Chengdu with a distance of approximately 209.6 kilometres, and is about 80 kilometres from the capital of Pingwu County (Google Maps 2015). Its residences were quite concentrated and clustered along the river and the provincial road. As its population density is higher, negative impact of any debris flow can be more severe.

As many other villages in Sichuan, Niufei Village is divided into groups and each group occupied a particular site with clear boundaries before the 2008 earthquake. After the quake and various geohazards attacks, including Huanglianshu Gully Debris Flow, a significant portion of the villagers relocated downhill to safer and more easily accessible places. Residents from different groups are then mixed in terms of the location of their houses. The population of Niufei in 2015 was about 700, similar to that of Xinjian Village. A great portion resided along the two sides of the main road in the Village (Figure 4.24).

Figure 4.24

Many Niufei villagers relocated from uphill to flatland along the road to avoid geohazard risks induced by the 2008 earthquake



Photo by Rhea Leung, December 2014.

Geohazard risks threatened Niufei Village – Year 2010 inspection

Impacts of geohazards induced by the 2008 earthquake on Niufei Village were less complicated than Xinjian Village. The 2010 government inspection revealed that two landslips and two debris flows threatened Niufei Village that year (Table 4.4). As in Xinjian Village, the personnel responsible for disaster prevention was the head of the Township, indicating the government was treating geohazard prevention seriously.

Table 4.4

Potential threats of secondary geohazard risks in Niufei Village and disaster prevention/preparedness measures imposed by the government in 2010

Name of risk site	Scale ($10^4 m^3$)	Threatened population	Threatened properties (RMB10,000)	Establishment of Disaster Prevention and Preparedness Plan	Distribution of Two Cards	Establishment of Mass Monitoring and Mass Prevention System	Personnel responsible for disaster prevention		Personnel responsible for monitoring		Mass Monitoring and Mass Prevention personnel	
							Name	Unit/ Responsibility	Name	Phone number available	Name	Phone number available
Gongqiao Landslip	NA	12	36	Yes	Yes	Yes	Personnel PN1	Head of Pingtong Township	Personnel PN2	Yes	Personnel PN2	Yes
Huanglianshu Gully Debris Flow	N/A	17	60	Yes	Yes	Yes	Personnel PN1	Head of Pingtong Township	Personnel PN3	Yes	Personnel PN3	Yes
Liangshang Landslip	NA	NA	240	Yes	Yes	Yes	Personnel PN1	Head of Pingtong Township	Personnel PN3	Yes	Personnel PN3	Yes
Qiaotoushang Debris Flow	N/A	17	36	Yes	Yes	Yes	Personnel PN1	Head of Pingtong Township	Personnel PN4	Yes	Personnel PN4	Yes

Source: Extracted from the overall list of geohazard risk sites in Sichuan Province in year 2010 (Sichuan Government 2010).

4.1.6 Pingwu County -- Pingtong Township – Niufei Village -- Huanglianshu Gully Debris Flow

According to the local officials, Huanglianshu Gully Debris Flow was the second largest debris flow in Pingwu County triggered by the Wenchuan earthquake, following Xingping Gully Debris Flow. It cut across Niufei Village after the Wenchuan earthquake and was tackled by the government through assessing risk and imposing geotechnical mitigation measures. During the author's visit, the mouth of Huanglianshu Gully, where nearby the centre of the Niufei Village and just adjacent to village houses, was already channelised (Figure 4.25).

Figure 4.25

Huanglianshu Gully Debris Flow (left) and mitigation measures (right)

The routing of Huanglianshu Gully Debris Flow was clearly indicated in an investigation report with geotechnical mitigation proposed.

Geo-engineering measures in the form of levees have been imposed on the two sides of the downstream of the ditch where Niufei Village is located.

Source:
(Left) Adopted from HTSMGEB 2010.
(Right) Photo by Rhea Leung, 18 December 2014.



The source of Huanglianshu Gully in Pingtong Township is Baojia Mountain located at the boundary of Pingwu County and Beichuan County in the south which was severely affected by the Wenchuan earthquake, with an elevation of 1,899 metres (HTSMGEB 2010). The length of the main stream is 2.768 kilometres with 35º to 40º slope steepness and a watershed area is 4.99km^2 (HTSMGEB 2010). Huanglianshu Gully Debris Flow is cut across by Nanba Fault, which also belongs to Longmenshan Fault Zone (HTSMGEB 2010).

Figure 4.26



Source of Huanglianshu Gully Debris Flow

The author walked all the way to the source of Huanglianshu Gully Debris Flow uphill where the landslip provided source materials for Huanglianshu Gully Debris Flow could be seen clearly.

The tree at the back of the author is the "Huanglianshu" named by the locals – literally, "shu" is "tree" in Chinese and "Huanglian" is the species of the tree.

Photo by Rhea Leung, May 2015.

The history of this debris flow is confused. An official document stated explicitly that it was "newly triggered" by the Wenchuan earthquake, yet the same document also indicated there were "very few" debris flow occurred in this gully before (HTSMGEB 2010).

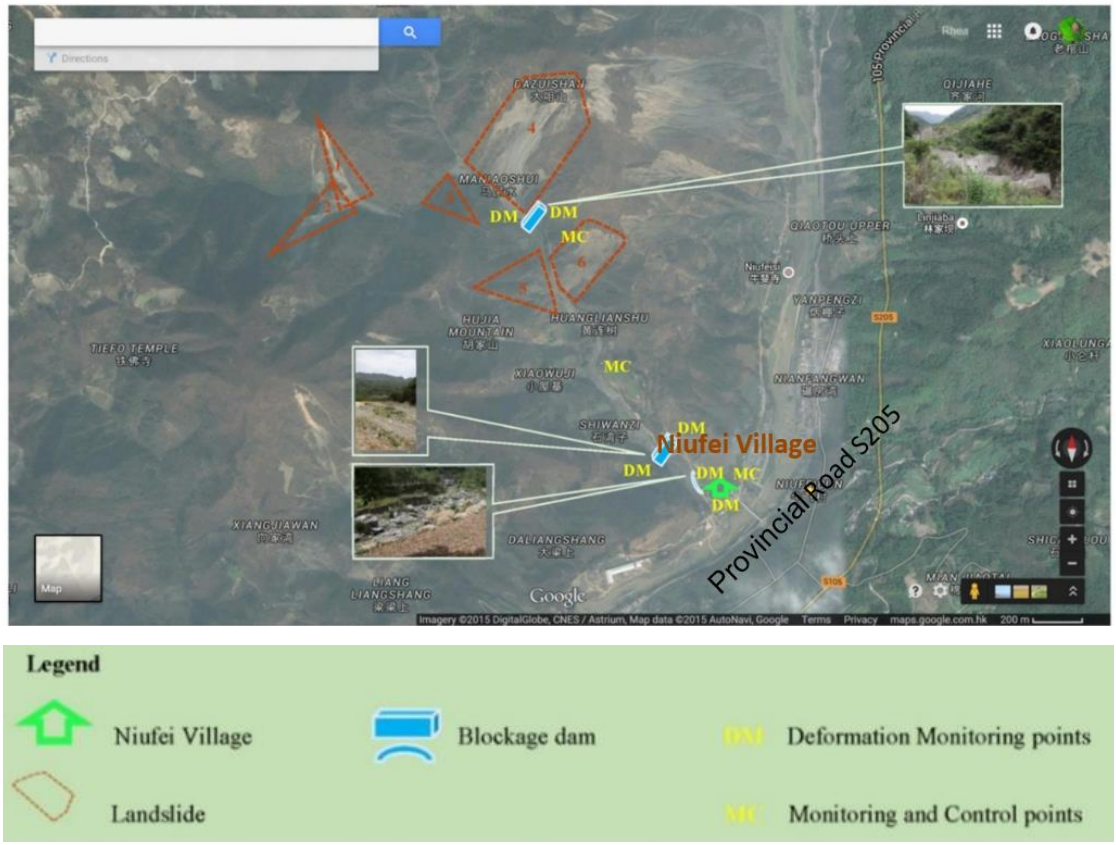
Official investigation (HTSMGEB 2010) found that the Wenchuan earthquake had caused rockfalls and landslides in the area, together with an obvious increase in loose solid materials, inducing higher risk of debris flow occurrence. It was estimated that within 50 years after the quake, there is a possibility of five occurrences of debris flow with solid materials discharge up to $6.81 \times 10^4 m^3$.

Huanglianshu Gully Debris Flow affecting Niufei Village

A debris flow occurred on 24 September 2008 had affected midstream of the ditch and destroyed three houses in the Xiaowuji and Shiwanzi area (Figure 4.27) and had not affected Niufei Village centre much (HTSMGEB 2010).

Another debris flow on 14 July 2009, which was caused by a 20-year occurrence rainfall, had discharged more debris and most of the loose debris has accumulated in the midstream and downstream of Huanglianshu Gully and around Niufei Village (HTSMGEB 2010). The scale and risk level of this debris flow were both medium and had covered five houses by 0.5 to 1 meter (HTSMGEB 2010).

Figure 4.27
Satellite map showing an overview of Niufei Village, surrounding landscape, Huanglianshu Gully Debris Flow, its source materials and affected areas



Adopted from Google Maps 2015.

Debris flow risk threatened Niufei Village -- Year 2010 inspection and risk reduction measures imposed

According to a detailed consultant report done in June 2010, Huanglianshu Gully Debris Flow had affected 108 people from 25 households with, with RMB 3 million assets under threat and potential economic loss over RMB 10 million (HTSMGEB 2010), more than the threatened population and properties estimated during the 2010 inspection (Table 4.4).

To eliminate debris flow risk, engineering mitigation through construction of check dam, sediment trap dam, together with single-sided protection embankment, trough, bridge and culvert base management, were imposed after the Wenchuan earthquake (HTSMGEB 2010), as shown in the photos below. A temporary dam built in 2008 after the quake was broken, then two more sediment trap dams were built after the largest debris flow occurred in 2009.

Figure 4.28



Photos by Rhea Leung, May 2015 (upper left and right, bottom left) and July 2016 (bottom right).

Geotechnical mitigation measures to tackle debris flows along Huanglianshu Gully imposed after risk assessment and evaluation, including cement debris trap dams both upstream and downstream (upper left and bottom left), gravel sand trap dam midstream (upper right) and embankments downstream (bottom left and right).

Review of debris flow threats after imposing geotechnical measures

After the imposition of geotechnical measures suggested in the 2010 report, no further geoengineering mitigation was proposed for the Huanglianshu Gully area (SGIO 2015a). In 2014, Huanglianshu Gully Debris Flow was categorised as “medium scale”, threatening a total of 25 people from six households and properties amounted to RMB 600,000. It was no longer considered as threatening to Niufei residents since 2015 and was removed from the list of geohazard risk sites (CCPCO and PG 2016). The two other engineering mitigation measures imposed on Niufei Village earlier were in good condition and relatively effective, no additional measures was required (Table 4.5).

Table 4.5 Investigation, examination, design of engineering mitigation and management imposed (for emergency risk reduction) on geohazards in Niufei Village and effectiveness review

Recording and reporting time	Location	Type of disaster	Name of engineering mitigation	Type of engineering mitigation	Overview of the engineering mitigation	Status of completion		Appearance of the engineering mitigation	Effectiveness	Current safeness	Proposed next step		Estimated additional expenses
						Completion time	First and final check				Additional engineering mitigation and management measures	Additional risk avoidance and relocating settlement	
2015.10.7	Niufei Group, Niufei Village, Pingtong Township	Debris flow	Engineering mitigation and management of Huanglianshu Debris Flow	Investigation and examination, Design, Engineering mitigation and management	Gravel sand trap dam	2009	NA	In good condition	Relatively good	Basically safe	NA	NA	NA
2015.10.7	Qiaotoushang Group, Niufei Village, Pingtong Township	Landslip	Engineering mitigation and management of Fenlinliangshang Landslip	Investigation and examination, Design, Engineering mitigation and management	Gravel sand trap dam	2009	NA	In good condition	Relatively good	Basically safe	NA	NA	NA

Source: Compiled from SGIO 2015a, 2015c, 2015d.

Latest situation observed before the survey

Although various disaster risk reduction measures were imposed, making Huanglianshu Gully Debris Flow no longer included in the geohazard risk site list, debris flow risks still existed as observed before the conduct of the survey (Figure 4.29).

Figure 4.29

Farmlands and residences still close to Huanglianshu Gully which might induce geohazard risks



At the source of Huanglianshu Gully, landslip risk is obvious and is affecting the farmland just several meters away.



Some farm houses located next to the downstream of Huanglianshu Gully are exposed to debris flow risks.

Photos by Rhea Leung, May 2015.

In addition, although sediment trap dams had protected residents in the first few years after imposition, while dredging had been done from time to time, there were signs of debris overflow or close to overflow in some dams. These imposed threats to households nearby or downstream.

Figure 4.30

Some sediment trap dams along Huanglianshu Gully are almost filled up



Photos by Rhea Leung, May 2015 (left and middle) and August 2016 (right).

4.1.7 Non-geotechnical preparedness and response measures in Nanba and Pingtong under Pingwu County

According to local officials, geohazards seldom occurred in Pingwu before 2008, hence with limited record. Even they occurred, the scale was small and had limited impact. Geohazard risk reduction measures were seldom imposed and some records were destroyed during the 2008 earthquake.

Since the Wenchuan earthquake, Pingwu County had further imposed a series of preparedness and response measures besides the mentioned geoengineering mitigations, including:

(1). conduct of annual geohazard risk inspection and follow up mitigation measures;

(2). establishment of geohazard susceptibility, risk levels and prevention/ mitigation zonation to eliminate the negative impacts of potential disasters;

(3). enhancement of monitoring and early warning system;

(4). enhancement of risk prevention as well as both internal and external risk communications; and

(5). promotion and implementation of emergency response plan including documentation, training and drill.

(1). Risk assessment: Annual geohazard risk inspection and follow up mitigation measures

Since the 2008 earthquake, the government carried out geohazard risk site inspection annually (SGIO 2015a), usually before the flooding season starting from May to September. By around April, a list of geohazard risk sites would be prepared. The list varies from year to year. Table 4.6 summarises the inspection results of year 2010 and 2016.

Table 4.6

Total number of geohazard risk sites on different levels of jurisdiction in year 2010 and 2016 respectively

Level of government	Total number of geohazard risk sites	
	Year 2010	Year 2016
Sichuan Province	28390	NA
Pingwu County	315	366
Nanba Township	89	27
Xinjian Village	6	2
Pingtong Township	31	8
Niufei Village	4	0

Source: Sichuan Government 2010, CCPCO and PG 2016.

Xinjian had six geohazards in 2010 and decreased to two in 2016. Xingping Gully Debris Flow had not threatened the Village directly in early 2010, but after the debris flow hit that summer, it became a threat to Shicouzi Group and the Settlement Site, hence was included in the subsequent list.

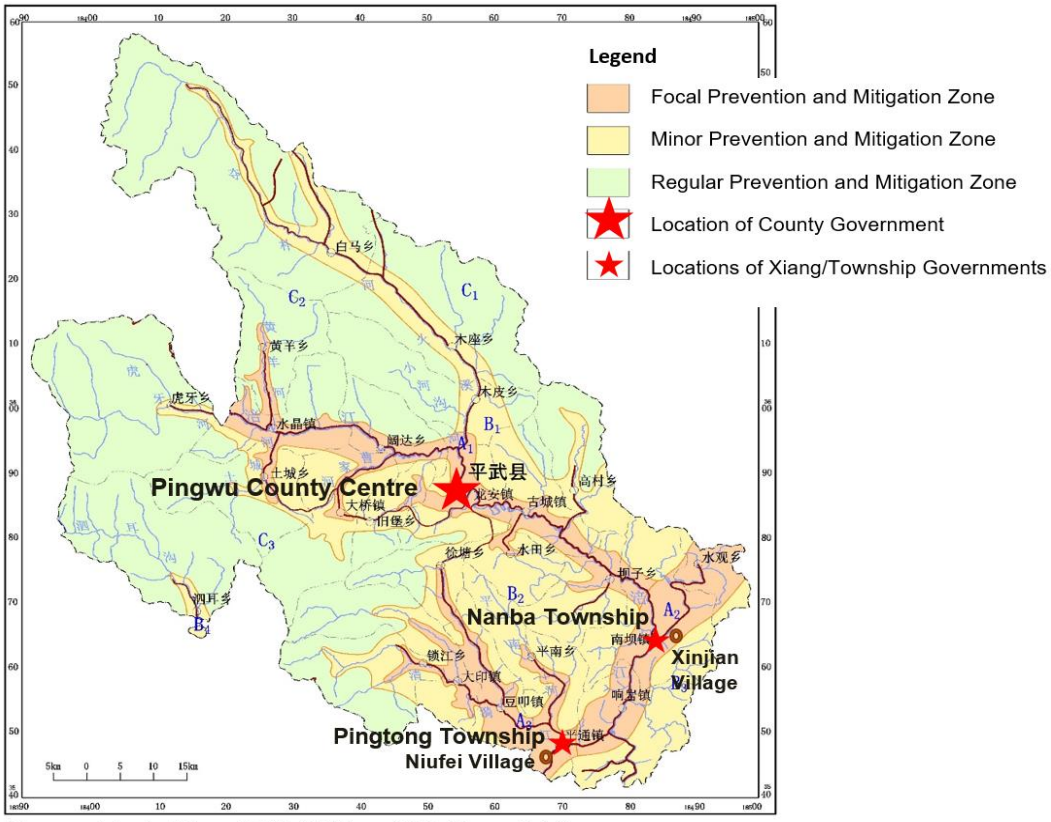
Niufei Village had four geohazards in 2010, decreased to zero in 2016. Huangliangshu Gully Debris Flow in particular, was removed from the list since the risk mitigation measures were completed and the gully was no longer considered a risk site.

(2). Hazard zonation

Detail zonation on geohazard susceptibility, risk levels, as well as prevention and mitigation had been done for some years in Pingwu (Figure 4.31), yet basically on a county level and was later extended to the subordinate township level but not on a village level (SGIO 2015a, 2015b). However, Figure 4.31 revealed both villages of Xinjian and Niufei fell into Geohazard Highly Susceptible Zone, High Risk Zone, and Focal Prevention and Mitigation Zone.

Figure 4.31

Zone Map of Geohazard Prevention and Mitigation of Pingwu County



Source: Adopted from SGIO 2015a, p.265, Figure 7.4-1

(3). Monitoring and early warning

In Pingwu County, after the Wenchuan earthquake, four major kinds of geohazard preventive and mitigation measures have been imposed on different geohazard risk sites with reference to local situations. They are: relocation and risk avoidance, emergency risk reduction measures, engineering mitigation and management, as well as monitoring and early warning (SGIO 2015a).

Among all the 406 geohazard risk sites found in Pingwu County in 2014 until late 2015, it was proposed that 283 should apply “Monitoring and Early Warning” (Table 4.7).

Table 4.7

Proposed preventive and mitigation measures for all geohazards risk sites in Pingwu County in 2014

Preventive and Mitigation Measures	Landslip	Debris Flow	Unstable Slope	Rockfall	Total
Monitor and Early warning	206	35	24	18	283 (69.7%)
Engineering management	22	15	5	4	46 (11.3%)
Risk reduction	23	15	1	23	62 (15.3%)
Relocation	11	1	1	2	15 (3.7%)
Total	**262 (64.5%)**	**66 (16.3%)**	**31 (7.6%)**	**47 (11.6%)**	**406 (100%)**

Source: SGIO 2015a.

Among these sites, 21 were from Nanba Township, including two threatening Xinjian Village (Table 4.8) (SGIO 2015a) which were mentioned above.

Table 4.8

Geohazard risk sites threatening Xinjian Village in 2015/16 and the disaster monitor and prevention measures proposed and imposed by the government

Name of disaster/risk site	*Risk	Location	*Threatened population	*Proposed Disaster Prevention and Mitigation Measures	*Cost of Prevention and Mitigation	*Monitoring System	Communicate with leadership of xiang, township and county	Personnel responsible for disaster prevention			Personnel responsible for monitoring		Mass Monitoring and Mass Prevention personnel	
								Name	Unit/ Responsibility	Phone number available	Name	Phone number available	Name	Phone number available
Xingping Gully Debris Flow	Big	Machangdi Group (Settlement Site), Xinjian Village	Settlement site	Monitoring and Early warning	RMB 20,000	City level	Personnel PX8	Personnel PX9 and PX10	Party Secretary of Nanba County, Head of Nanba County	Yes	Personnel PX11	Yes	Personnel PX12	Yes
Taopingshan Landslip Behind-The-House	Medium	Taopingshan Group, Xinjian Village	Scattered farming households	Monitoring and Early warning	RMB 20,000	City level	Personnel PX8	Personnel PX9 and PX10	Party Secretary of Nanba County, Head of Nanba County	Yes	Personnel PX11	Yes	Personnel PX13	Yes

*Source: *SGIO 2015a, SGIO 2015e, CCPCO and PG 2016.*

Monitoring personnel

Teams of monitoring personnel comprised of local villagers are established in geohazard-threatened rural regions in China. SGIO had listed out the criteria of a monitoring personnel and the work he or she needs to fulfil, while monitoring methods were also described in a detailed geohazard investigation report on Pingwu (SGIO 2015a).

Mass Monitoring and Mass Prevention (MMMP)

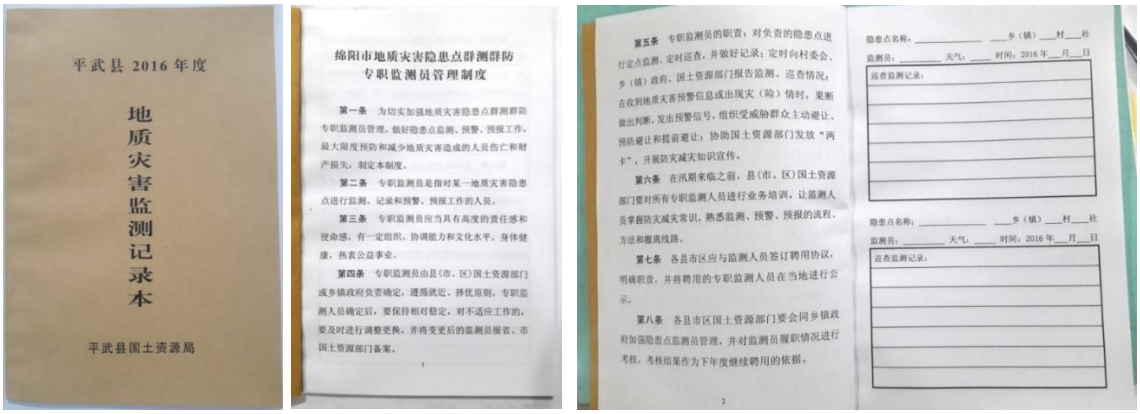
MMMP is highly recommended in rural areas like Pingwu. This government policy encourages residents of a geohazard-threatened community to arrange a mass monitoring system in which community members can prevent geohazard together.

Out of the 406 geohazard risk sites in 2015, 381 were threatening schools, townships, settlement sites and scattered farming households, and they were all included in the MMMP system (SGIO 2015a), including the two sites affecting Xinjian Village: Xingping Gully Debris Flow and Taopingshang Landslip (Table 4.8). Individuals responsible for debris flow risk monitoring would be given a notebook annually (Figure 4.32).

Figure 4.32

Sample of Geohazard Monitoring Notebook of Pingwu County

This notebook by the Land and Resources Bureau in 2016 specifies the role of monitoring personnel who were required to record every single inspection and monitoring of the risk sites assigned.



Source: Nanba Township Government 2016. Photos taken by Rhea Leung, August 2016.

Early warning disaster response measure

In terms of geohazard early warning methods, website, phone message alerts, audio announcement, gongs and even shouts are some of the major ones used in Pingwu and many other parts of Sichuan.

- **Website**

Sichuan government has introduced a website to provide alerts from the provincial down to the county level. This is a relatively high-technology tool among all the early warning methods studied in this research.

- **Siren**

Although Huanglianshu Gully Debris Flow was no longer on the list of geohazard risk sites when the survey of this research was conducted, an audio system was still ready to perform the role of siren to give geohazard early warning (Figure 4.33).

Figure 4.33

Audio system and speakers readily available at the Niufei Village government office building to provide early warning



Photo by Rhea Leung, August 2016.

- **Phone system**

The government has introduced a phone system to issue geohazard early warning in some places. This can be particularly useful and effective if the phone penetration rate in a community is high.

- **Gong**

Using gong to issue early warning is a relatively traditional method applied in Chinese villages. Villagers who see geohazard threats would use the gongs hanged in designated locations to issue early warning to alert other villagers to flee or to respond.

➢ **Shout**

Alerting neighbourhood about geohazard attack by simply shouting is another traditional and the most economic early warning method used in villages in China, especially when other methods are unavailable.

(4). Risk prevention and communications

In Pingwu County, as in other parts of Sichuan, efforts put in risk prevention were enhanced in response to occurrence of more geohazards. Risk communications were also strengthened.

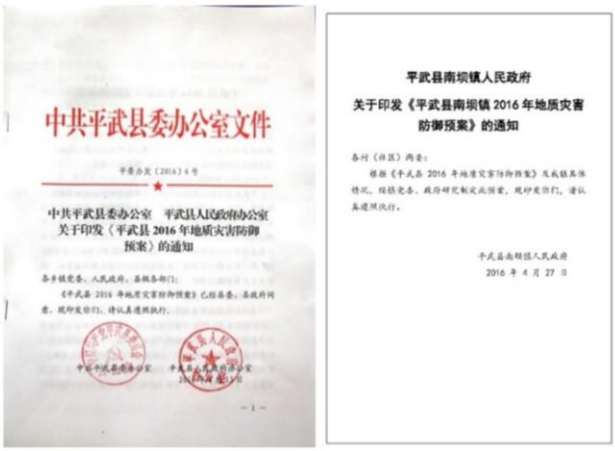
Annual Geohazard Prevention and Protection Plan

Every year, before the rainy and flooding season in summer, Pingwu County Government would prepare a "Pingwu County Geohazard Prevention and Protection Plan" for all its departments and affiliated local governments. Information of the geohazard risk sites were attached (CCPCO and PG 2016; NTG 2016). The townships, including Nanba and Pingtong, would adopt it to prepare their own versions with very similar framework consisting township level information and data for distributing to its affiliated villages (Figure 4.34) (NTG 2016).

Figure 4.34

Geohazard Prevention and Protection Plans 2016 prepared by Pingwu County (left) and Nanba Township (right) governments

Sources:
Pingwu County Government (left) and Nanba Township Government (right), 2016.



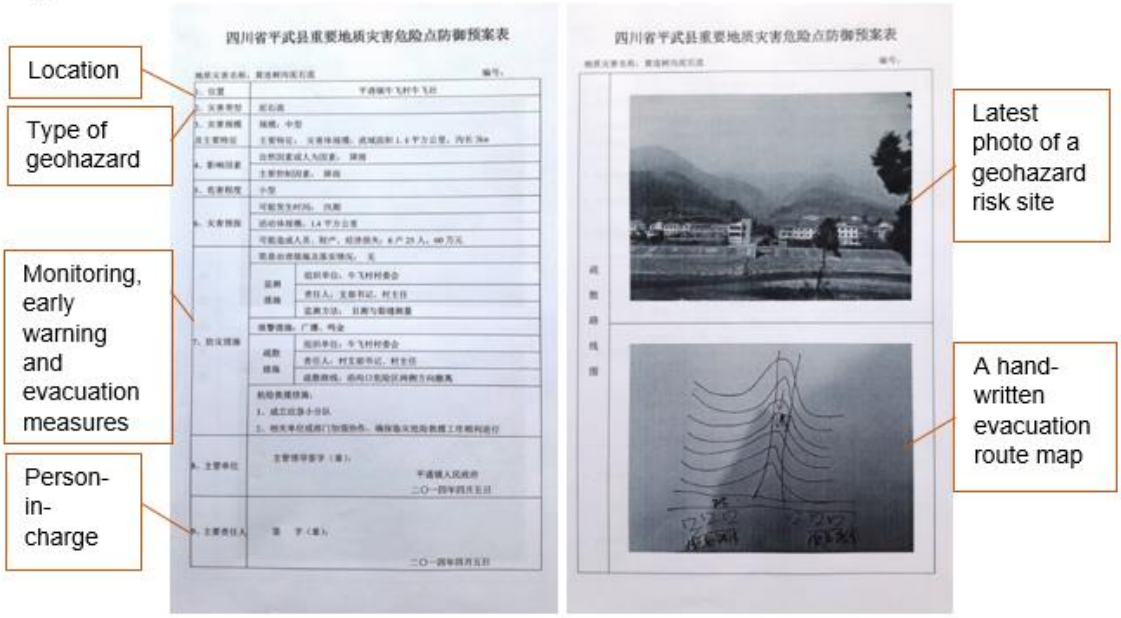
Annual disaster risk prevention documents for internal and external communications

A set of "One Table, Two Cards" (Figure 4.35) is the key communication tool prepared by the government for internal official record and external distribution to geohazard-threatened villagers for enhancing risk awareness. The local

governments prepare and update these three documents annually before the flooding season based on the latest geohazard risks.

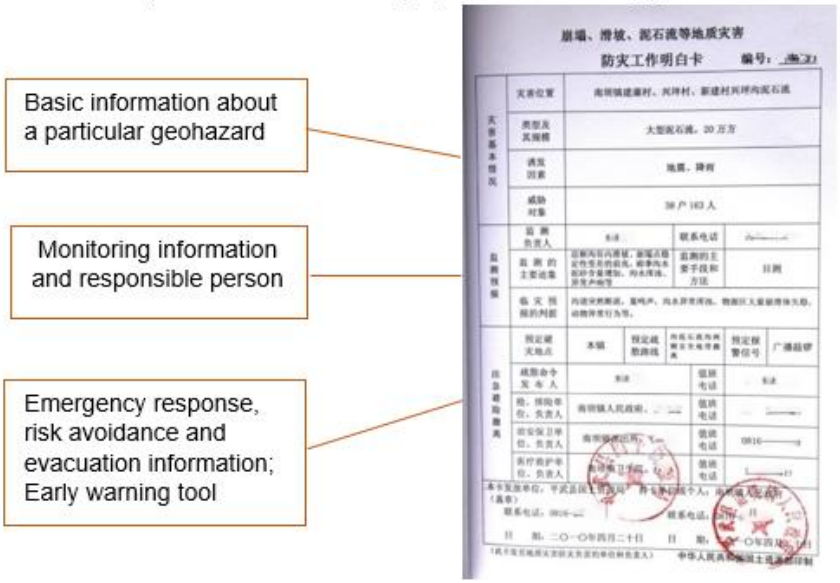
Figure 4.35

One Table, Two Cards (with personal data blurred)
Table of Significant Geohazard Risk Sites Prevention and Protection Plan (2014)
This is basically kept for internal official record, containing information of a geohazard risk site.



Source: Pingtong Township Government 2014. Photos taken by Rhea Leung, August 2016.

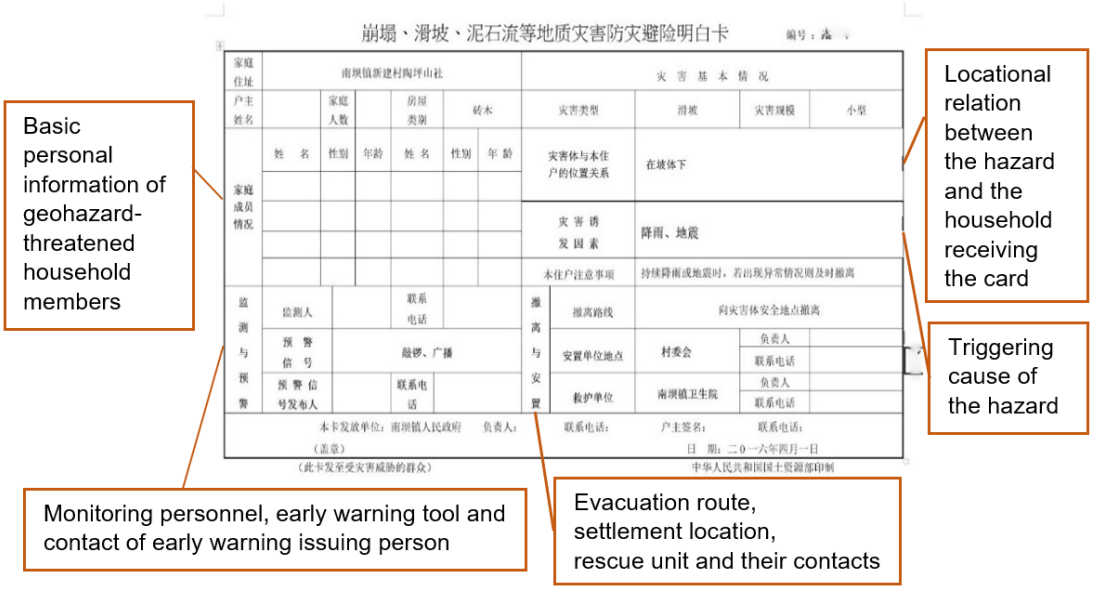
Geohazard Disaster Prevention Work Understanding Card (2010)
This is also mainly kept for internal official record. According to field observations and local authorities, this card is also displayed in or nearby geohazard risk sites.



Source: Nanba Township Government 2015. Photo taken by Rhea Leung, May 2015.

Card of Understanding on Disaster Prevention and Risk Avoidance of Geohazards including Rockfall, Landslip, Debris flow, etc.

This is specially designed for and distributed directly to each geohazard-threatened household as a potential disaster information notification. Each Card is unique and tailor-made. The distribution list of this Card is updated annually before the flooding season based on the latest geohazard risk.



Source: Pingwu County Government 2016.

(5). Emergency response plan

Documentation

An emergency response plan is an important government disaster risk reduction measure. For instance, Pingtong Township prepared two Emergency Response Plans on geohazard and flooding respectively. Both stated the measures and division of labour for tackling the hazards.

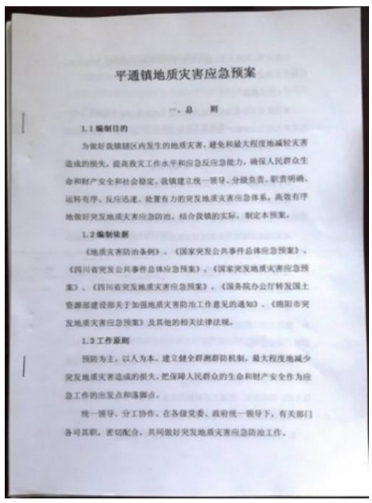
- **Geohazard Emergency Response Plan**

This plan aimed to avoid and minimized the loss caused by hazards, to enhance the standard of disaster relief work and emergency response ability, and to ensure the safety of peoples' lives and properties as well as social stability (Figure 4.36).

Figure 4.36

Pingtong Township Geohazard Emergency Response Plan

This 2015 Plan involves a geohazard emergency response system which considers the actual situation of the township with reference to relevant laws and regulations.


平通镇地质灾害应急预案

一、总　则

1.1 编制目的

为做好我镇辖区内发生的地质灾害，避免和最大程度地减轻灾害造成的损失，提高救灾工作水平和应急反应能力，确保人民群众生命和财产安全和社会稳定，我镇建立统一领导、分级负责、职责明确、运转有序、反应迅速、处置有力的突发地质灾害应急体系，高效有序地做好突发地质灾害应急防治，结合我镇的实际，制定本预案。

1.2 编制依据

《地质灾害防治条例》、《国家突发公共事件总体应急预案》、《四川省突发公共事件总体应急预案》、《国家突发地质灾害应急预案》、《四川省突发地质灾害应急预案》、《国务院办公厅转发国土资源部建设部关于加强地质灾害防治工作意见的通知》、《绵阳市突发地质灾害应急预案》及其他的相关法律法规。

1.3 工作原则

预防为主，以人为本，建立健全群测群防机制，最大程度地减少突发地质灾害造成的损失，把保障人民群众的生命和财产安全作为应急工作的出发点和落脚点。

统一领导、分工协作，在各级党委、政府统一领导下，有关部门各司其职，密切配合，共同做好突发地质灾害应急防治工作。

Source: Pingtong Township Government 2015b.
Photo taken by Rhea Leung in August 2016.

➢ **Emergency Response Plan on Tackling Flooding Risk**

The 2016 version of this plan was issued by the Pingtong Township Government to all its subsidary villages and departments, highlighting the key sites to be monitored. Measures for preventing floods and related emergency response were explained.

✧ **Training**

Many township governments under Pingwu County had organized disaster response trainings to enhance geohazard knowledge and local awareness in geohazard-affected areas. The trainings were basically designed for township, village and xiang leaders, local officials and villagers assigned to monitor geohazard risks and issue early warning.

Figure 4.37

(Left) Training offered by Pingtong Township on geohazard prevention, mitigation and monitoring in 2015 in preparation for the upcoming flooding season; (Right) The training kit



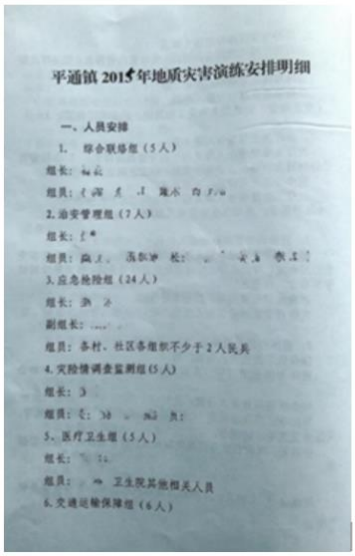
Source: Pingwu County Government 2015.

✧ **Drill**

A drill is another major government measure to prepare disaster response capability of the communities. For instance, Pingtong Township has published a *Geohazard Drill Plan* for a drill to be conducted in May 2014 (Pingtong Township Government 2014). It described the aim, task and principles of the drill, followed by introducing a scenario based on an existing geohazard risk in a village. Detailed division of labour, locations involved and sequence of the exercise were included. It also described various scenarios and the actions ought to be taken. Subsequently, a *Pingtong Township Geohazard Drill Detailed Arrangements 2015* (Pingtong Township Government 2015c) was published with elaborations on manpower arrangements, equipment and props, together with invited units and budget (Figure 4.38).

Figure 4.38

Drills arranged by Pingtong Township Government


平通鎮 2015 年地質災害演練安排明細

一、人員安排

1. 綜合聯絡組（5人）

組長：

組員：

2. 治安管理組（7人）

組長：

組員：

3. 应急抢险组（24人）

组长：

副组长：

组员：各村、社区各组织不少于2人民兵

4. 灾险情调查监测组（5人）

组长：

组员：

5、医疗卫生组（3人）

组长：

组员：　　卫生院其他相关人员

6. 交通运输保障组（6人）

(Left) A detailed script with conversations among the parties hosting the drill is included in the *Detailed Arrangements 2015.*

(Below) Based on the *Pingtong Township Geohazard Drill Plan*, local leaders and some villagers participate in drills in Pingtong Township Centre and some selected villages.





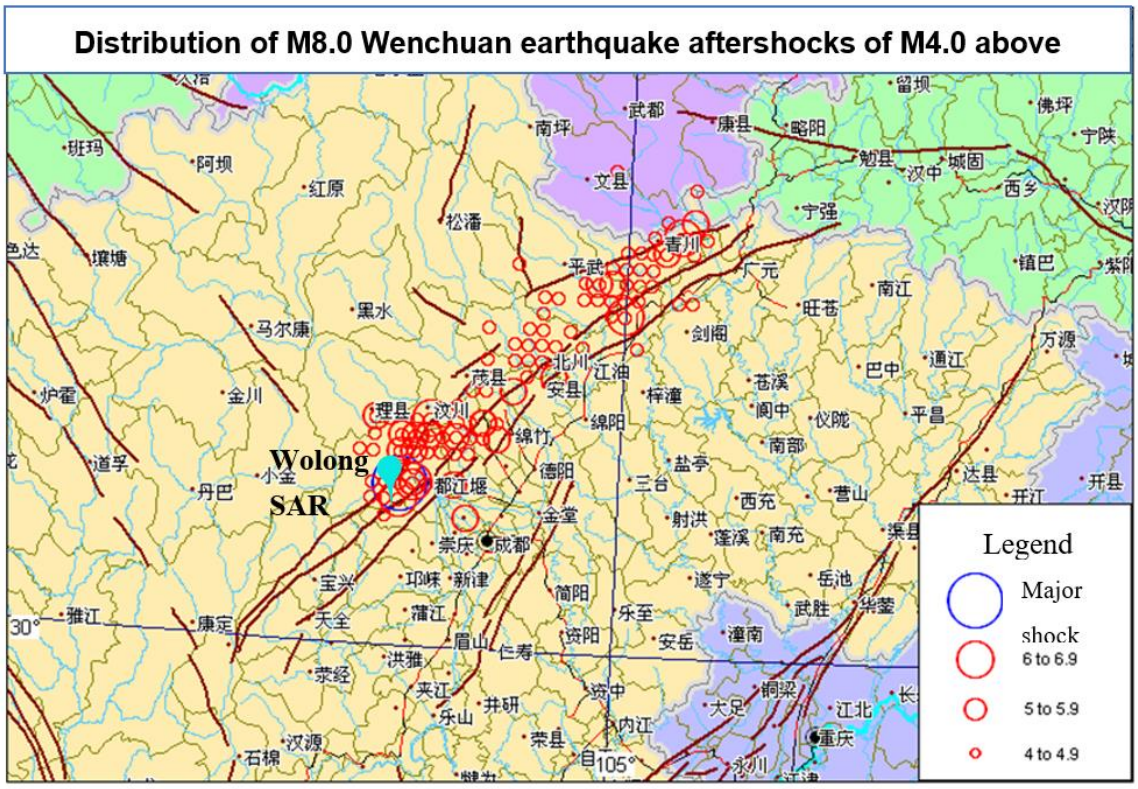
Source: Pingtong Township Government in 2016.
Photos taken by Rhea Leung in August 2016.

4.2 Case study area 2 -- Wenchuan County

Wenchuan County is one of the most seriously hit counties in the 2008 earthquake. It is the home of the epicentre of the quake, Yingxiu (orange star in Figure 4.2). The earthquake of 2008 is therefore called Wenchuan earthquake.

According to the China Earthquake Administration (CEA 2008a), among the 281 aftershocks of M4.0 or above recorded in the region till 2 December 2008, 63 occurred in Wenchuan County (Figure 4.39).

Figure 4.39



Source: CEA 2008b.

Jurisdiction and administration

Wenchuan is one of the 12 counties under Aba Zang and Qiang Autonomous Prefecture (NEAC 2022a), and one of the seven major habitations for ethnic groups in Sichuan Province (Sichuan Government 2017e).

Wenchuan is composed of eight townships and four xiangs (Wenchuan County Government 2015), among which two townships are administered by Wolong

Special Administrative Region (Wolong SAR), the administrative body of Wolong National Nature Reserve established in 1963. Wolong SAR occupies 20 hectares of land (Wolong National Nature Reserve 2015) and is under the jurisdiction of Wolong Administrative Authority, which is under the administration of Wenchuan County (Figure 4.3).

Social and economic situation of Wenchuan and Wolong SAR

Wenchuan is relatively wealthy among the Sichuan counties, partly because it housed a number of renowned tourist areas. The average disposable income of Wenchuan rural populations was RMB11,118 in 2016 (Wenchuan County Government 2017).

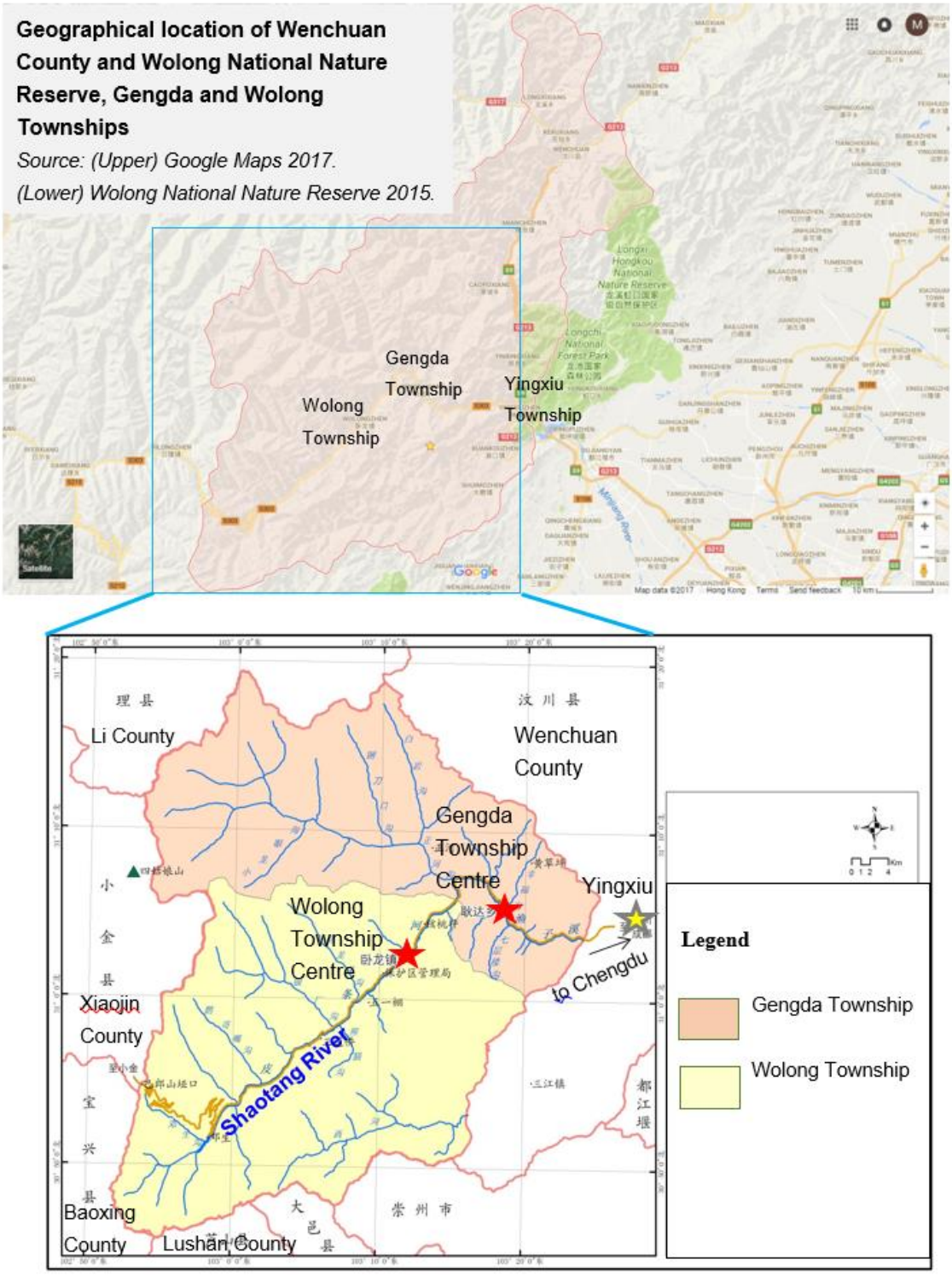
Wolong is China's best-known panda conservation and research area. Wolong SAR has long been benefitted from the national treasures of China there which made the place an important and world-renowned tourist site. With the development of tourism, populations in Wolong SAR is better-off than those in Pingwu.

The two townships of Wolong SAR

Wolong SAR is composed of two townships – one is Gengda and the other one with the same name Wolong (Figure 4.40). Together with Yingxiu and Xuankou, the four township centres all fall within a radius of 20 kilometres around and are the nearest to the 2008 earthquake epicentre, Yingxiu (yellow star in Figure 4.40).

With its proximity to the epicentre, Wolong SAR was devastated by the 2008 earthquake with many aftershocks (Figure 4.39). Numerous houses and buildings were destructed, including the Wolong SAR Government head office in Wolong Township and staff facilities in Gengda Township, which were rebuilt with a cost of over RMB104 million (HKJC 2014).

Figure 4.40



Geographical location of Wenchuan County and Wolong National Nature Reserve, Gengda and Wolong Townships

Source: (Upper) Google Maps 2017.

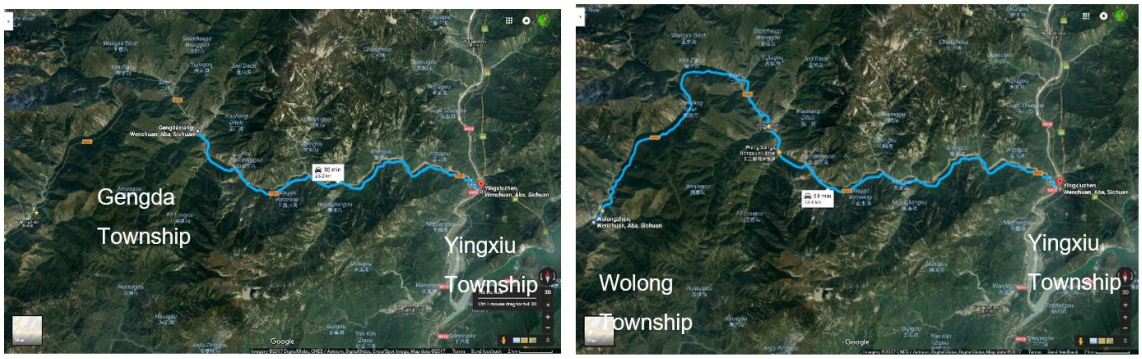
(Lower) Wolong National Nature Reserve 2015.

Accessibility

Provincial Road 303 is the major road connecting both Gengda and Wolong townships to Chengdu and the outside world via Yingxiu Township. The road distance from Gengda to Yingxiu is just 23.2 kilometres, while Wolong Township is slightly more remote, and is 43.4 kilometres away from Yingxiu (Figure 4.41).

Figure 4.41

Location of Gengda Township (left), Wolong Township (right) and Yingxiu Township, and the distances among them



Source: Google Maps 2017.

Meteorology, Torrents and Floods

Both Gengda and Wolong townships lie along Shaotang River (locals called it Pitiao River) with tributaries flowing from the two sides making them threatened by torrents during rainy summer (Figure 4.37). Floodings are particularly impactful because Provincial Road 303 runs almost parallel with Shaotang River. Any flooding or debris flow occurred in Shaotang River would affect the transportation lifeline of Wolong SAR instantly.

Major geohazard prevention and mitigation measures

Sichuan Government conducted assessments annually to spot geohazard risk. The geohazards are categorized as debris flow, landslip, rockfall, slope instability and cracks. The assessment of year 2010 revealed that the whole province had a total of more than 28,000 geohazard risk sites (Table 4.6), among which 110 were in Gengda and 44 were in Wolong.

4.2.1 Wenchuan County – Gengda Township

Gengda Township has a total area of 843.5km^2, comprising of three villages: Xingfu, Longtan and Gengda which is located at the township centre (Gengda Township Government 2016a) (Figure 4.42).

Figure 4.42
Satellite map showing an overview and landscape of Gengda Township with its three villages

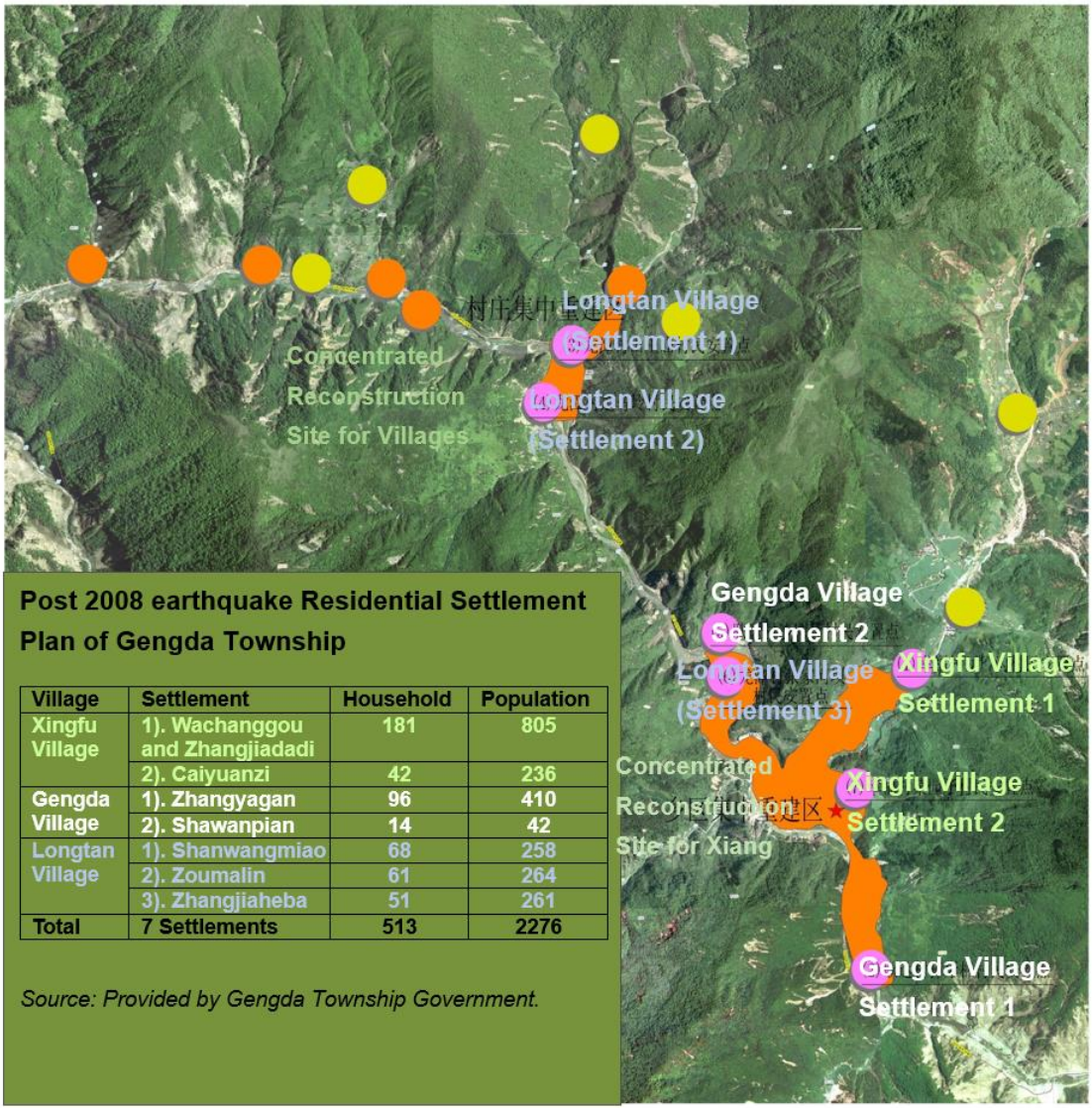


Source: Google Maps 2016.

Resettlement Plan in response to 2008 Wenchuan earthquake

Shortly after the 2008 earthquake, the government proposed a resettlement plan which became an important foundation of the current population distribution of the Township (Figure 4.43). The government built clusters of houses to relocate many villagers to more convenient locations near the original village sites and along Provincial Road 303 (Gengda Township Government 2016a). These locations, however, are still near to debris flow risks.

Figure 4.43



Post 2008 earthquake Residential Settlement Plan of Gengda Township

Village	Settlement	Household	Population
Xingfu Village	1). Wachanggou and Zhangjiadadi	181	805
	2). Caiyuanzi	42	236
Gengda Village	1). Zhangyagan	96	410
	2). Shawanpian	14	42
Longtan Village	1). Shanwangmiao	68	258
	2). Zoumalin	61	264
	3). Zhangjiaheba	51	261
Total	7 Settlements	513	2276

Source: Provided by Gengda Township Government.

Although seven new residential concentrated settlement communities were built downhill to accommodate the originally scattered populations up in the mountains, some villagers still stayed in their scattered houses uphill when the survey was conducted. Even for those moved downhill to safer places to avoid geohazard risks, their farmlands were still high up in the mountains. To facilitate their farming activities and ensure their produces farmed uphill could be transported to the markets in good time, the government had built smaller village roads for the residents (Gengda Township Government 2016a).

Demography and economy

The three villages in Gengda had 17 groups collectively with a total population of about 2,700 in year 2016 mostly composed of Tibetans, Hans and Qiangs (Gengda Township Government 2016a).

Figure 4.44



Central area of Gengda Township along Provincial Road 303

Photo by Rhea Leung, August 2016.

Before the 2008 earthquake, a great portion of the Gengda population earned their livelihood by farming, Chinese medicine and working outside the town (Gengda Township Government 2016a). After the earthquake reconstruction, more residents shifted to the tourist industry, used their houses to provide summer resort accommodation, farming experience or restaurants, or utilised the eco-environment and favourable weather to provide eco-tourism services. The new Shenshuping base of the China Conservation and Research Centre for the Giant Panda (Panda Centre) there also offered many job opportunities for the local people, especially after the full connection of Provincial Road 303 between Yingxiu and Wolong (Gengda Township Government 2016a).

Figure 4.45

Local people selling souvenirs and food opposite to the main entrance of the Panda Centre



Photo by Rhea Leung, August 2016.

4.2.2 Wenchuan County – Gengda Township – Xingfu Village

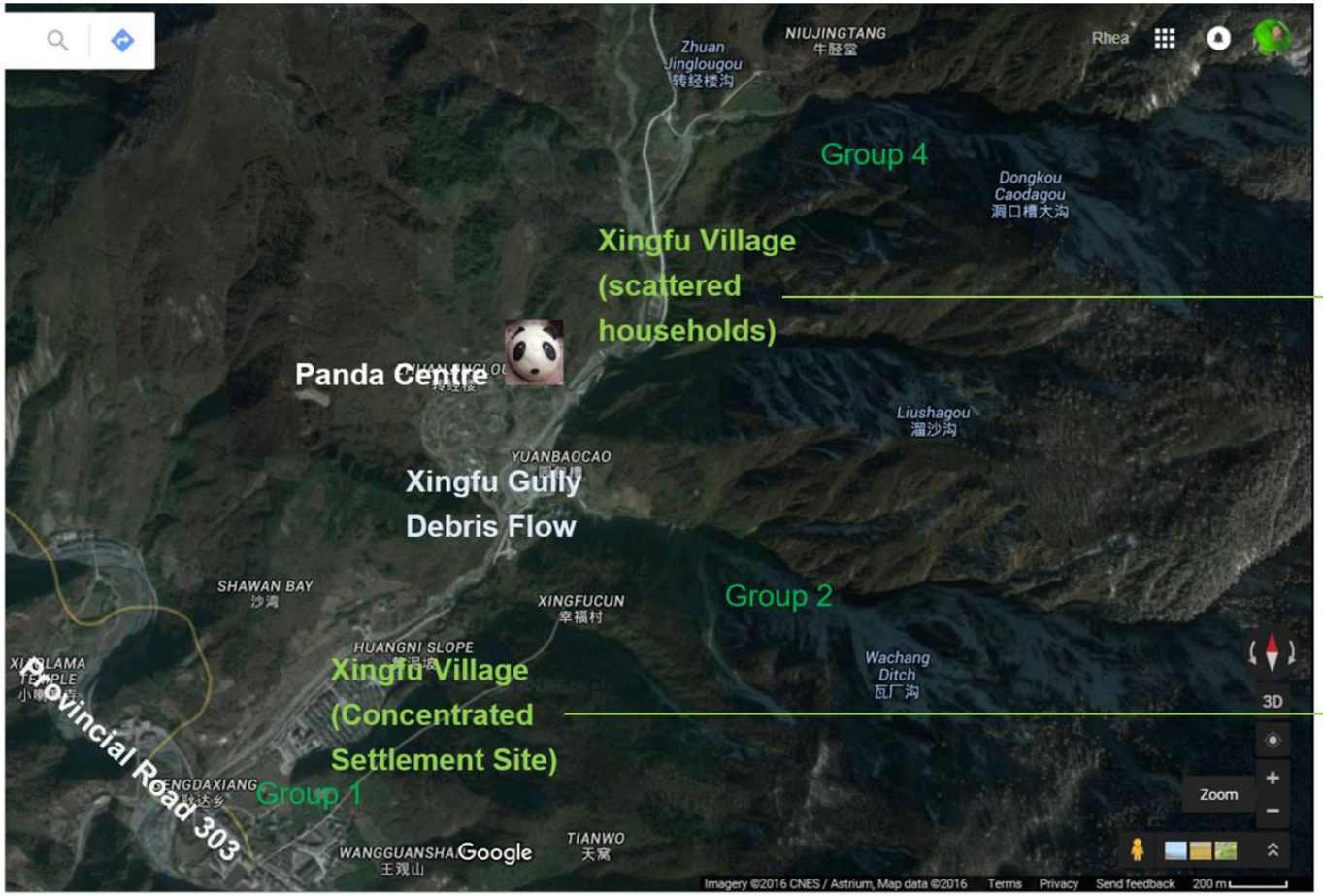
Similar to the two Pingwu sites, Xingfu Village had imposed geotechnical engineering measures to tackle debris flow risks. The major difference is that nearly the whole site was newly built after the 2008 earthquake as part of the recovery to relocate the earthquake-affected population as well as to open up the place for the Panda Centre. To protect this Centre, a series of sophisticated and high-quality sediment trap dams and geotechnical engineering measures were built.

Landscape and accessibility

Xingfu Village is located at the eastern side of Gengda Township and is nearest to the provincial capital Chengdu among all villages in Wolong SAR. Before the 2008 earthquake, many ho-0seholds scattered on mountain slopes nearby while some resided along Provincial Road 303. A Concentrated Settlement Site (CSS) with more clustered houses was built just uphill of Provincial Road 303 after the earthquake to accommodate most of the originally scattered population, while some villagers were still staying in a few individual older houses scattered uphill near the gullies (Figure 4.46).

Figure 4.46

Satellite map showing an overview of the Xingfu Village, the debris flow gullies nearby and its adjacent Panda Centre



Source: Google Maps 2016.



Scattered households near the gullies uphill.



Concentrated Settlement Site near Provincial Road 303.

Photos by Rhea Leung, July and August 2016.

Demography and economy

Xingfu Village is composed of four groups with more than 300 households and around 1,200 villagers (Table 4.9). It is the biggest among the five villages studied in this research.

Table 4.9

Household number and population of Xingfu Village in 2015/16

Group	Household	Population	Manpower		
			Male	Female	Sub-total
1	68	260	83	88	171
2	89	340	107	108	215
3	109	403	140	130	270
4	58	237	73	67	140
Total (by the end of 2015)	**324**	**1,240**	**403**	**393**	**796**
Total (June 2016)*	**NA**	**1,149**	**NA**	**NA**	**NA**

*Source: Provided by Gengda Township Government and *Wolong Special Administrative Authority respectively in mid-2016.*

Debris flow risks threatened Xingfu Village – Year 2010 inspection

Xingfu Village had a total of seven debris flow risk sites in year 2010, ranging from a mega scale debris flow risk caused by Xingfu Gully which threatened 1,176 residents, to a medium scale Hetaoping Number 2 Gully Debris Flow which threatened nine villagers (Table 4.10).

Table 4.10

Potential threats of debris flows in Xingfu Village in 2010

Name of risk site	Scale ($10^4 m^3$)	Threatened population	Threatened properties (RMB 10,000)
Xingfu Gully Debris Flow	Mega	1176	3000
Sujia Gully Debris Flow	Large	37	60
Dongkoucao Gully Debris Flow	Large	108	85
Wachang Gully Debris Flow	Medium	N/A	50
Jiangjia Gully Debris Flow	Medium	N/A	4
Hetaoping Number 1 Gully Debris Flow	Medium	32	25
Hetaoping Number 2 Gully Debris Flow	Medium	9	10

Source: Extracted from the overall list of geohazard risk sites in Sichuan Province in year 2010 (Sichuan Government 2010).

Geotechnical engineering measures imposed to tackle debris flow threats after Wenchuan earthquake

A series of geotechnical mitigation measures were built by the Wenchuan County Government after the quake, aiming to protecting Xingfu Village located downstream of the gullies from geohazards (Figure 4.47). Particularly, a wide drainage channel was constructed to ensure rain water and debris from uphill could be carried away quickly and effectively. According to local people, the primary reason of building such geotechnical measures along the gullies in the area was indeed due to the need of establishing the Panda Centre.

Figure 4.47

Geotechnical mitigation measures constructed upstream of Xingfu Village




Blockage dams




Levees



Drainage channels

Photos by Rhea Leung, August 2016.

The biggest and probably the most expensive sediment trap dam was located further down the hill in the midstream area. It is the closest to the residences and farmlands of Xingfu Village, particularly those scattering on the hill. About one kilometre away from this dam is the new home of the giant pandas (Figure 4.48).

Figure 4.48

The biggest sediment blockage dam in Wolong SAR provides protection for Xingfu Village and the Panda Centre





(Left) The view of the dam from different distances. Houses are very close to it.

(Right) A puzzling giant panda sitting at the new home facing a gully with debris flow risk mitigated by the dam.

Photos by Rhea Leung, August 2016.



The new Panda Centre was built to replace the original Hetaoping Centre in Wolong badly damaged in the earthquake to give home to the displaced pandas (HKSAR 2016c). It occupied an area of 19,844 m² in eastern Gengda (HKSAR 2016c). It is the world's largest giant panda rearing, breeding and research base and the only centre for reintroducing pandas to the wild. With huge investment, its construction was completed by the end of 2014. It was built along Xingfu Gully and at the downstream of several gullies in Gengda Township (Figure 4.49).

Figure 4.49

The closeness among Xingfu Village, the Panda Centre and the surrounding gullies

Houses at the highest elevation in the village are adjacent to the Science Education Centre.



Baby Giant Panda Nurturing Centre is adjacent to village houses.



Aerial view of the Panda Centre and the surrounding gullies with the village houses nearby on the top right corner. Xingfu Gully is on the left - it is well protected by high quality levees.

Source: HKSAR 2016c.

Review of debris flow threats after imposing geotechnical measures – Year 2016 inspection

After imposing the geotechnical measures, Xingfu Village was still threatened by 14 geohazard risks, including eight debris flows (Table 4.11). Hundreds of residents were affected and all 14 sites were assigned with one responsible personnel (Personnel GD 1, and was the same person for Longtan Village).

Table 4.11 Basic situations of geohazard risk sites affecting Xingfu Village in 2016

Name of risk site	Location	Risk level	Affected area	Contact person	Fax	Contact mobile phone number
Sujia Gully Debris Flow	Group 1	Relatively big	Compact residential site with 42 persons	Personnel GD1	Yes	Yes
Zhangjia Gully Debris Flow	Group 2	Big	Settlement site with 500 persons	Personnel GD1	Yes	Yes
Huangjia Gully Debris Flow	Group 2	Relatively big	Scattered households with 17 persons	Personnel GD1	Yes	Yes
Jiangjia Gully Debris Flow	Group 2	Ordinary	Village road	Personnel GD1	Yes	Yes
Wachang Gully Debris Flow	Group 2	Ordinary	NA	Personnel GD1	Yes	Yes
Xingfu Gully Debris Flow	Group 2	Ordinary	NA	Personnel GD1	Yes	Yes
Lijia Gully Debris Flow	Group 3	Relatively big	Panda base	Personnel GD1	Yes	Yes
Dongkoucao Gully Debris Flow	Group 4	Ordinary	NA	Personnel GD1	Yes	Yes
Zhujiabao Landslip	Group 1	Relatively big	Provincial Road 303	Personnel GD1	Yes	Yes
Zhangjia Gully Landslip (also marked as debris flow)	Group 2	Big	Settlement site with 500 persons	Personnel GD1	Yes	Yes
Rockfall in the mountain at the back of Gengda Township Centre	Group 1	Relatively big	Township Centre with 30 persons	Personnel GD1	Yes	Yes
Rockfall on the two sides of Songguoshan Bridgehead	Between Xingfu Village Group 1 and Gengda Village Group 4	Relatively big	Provincial Road 303	Personnel GD1	Yes	Yes
Ruanjiagang Rockfall	Group 2	Ordinary	Village road	Personnel GD1	Yes	Yes
Shijiadi Unstable Slope (also marked as debris flow)	Group 2	Relatively big	Scattered households with 25 persons	Personnel GD1	Yes	Yes

Source: Gengda Township Government 2016b.

Table 4.12 compares the 2010 and 2016 information. Among the eight debris flows in 2016, five had already existed in 2010 while 3 were new or re-existed. The two in Hetaoping Gully found in 2010 were no longer on the 2016 list. Although no direct comparison of "scale" and "risk level" of the debris flows in the two inspections can be done, such information can still give an idea of the possible changes of debris flow impact on Xingfu.

Among the four sites threatened by ordinary debris flow risks in 2016, the two in Xingfu Gully and Dongkoucao Gully were of mega and large scale respectively back then in 2010, indicating they might be mitigated by the geotechnical measures successfully. Another three on the 2016 list but not found in 2010 can illustrate the lead-lag effect of post-earthquake geohazards.

Table 4.12

Debris flows found in Xingfu Village in year 2010 and 2016 respectively

Name of risk site	2010 (scale)*	2016 (Risk level)#
Xingfu Gully Debris Flow	✓ (mega)	✓ (Ordinary)
Sujia Gully Debris Flow (Group 1)	✓ (large)	✓ (Relatively big)
Dongkoucao Gully Debris Flow (Group 4)	✓ (large)	✓ (Ordinary)
Wachang Gully Debris Flow (Group 2)	✓ (medium)	✓ (Ordinary)
Jiangjia Gully Debris Flow (Group 2)	✓ (medium)	✓ (Ordinary)
Hetaoping Number 1 Gully Debris Flow (Group 4)	✓ (medium)	×
Hetaoping Number 2 Gully Debris Flow (Group 4)	✓ (medium)	×
Zhangjia Gully Debris Flow	×	✓ (Big)
Huangjia Gully Debris Flow	×	✓ (Relatively big)
Lijia Gully Debris Flow	×	✓ (Relatively big)

*Source: Compiled from *Sichuan Government 2010, #Gengda Township Government 2016b.*

Latest situation observed before the survey

During the summer rainy season in July 2016 right before the conduct of the survey, the author observed the actual impact of regular rains on Xingfu Village. Various parts of Xingfu Gully were filled with muddy water flew from uphill carrying loose materials and in some cases carrying stones that might cause debris flow under torrential rain (Figure 4.50).

Figure 4.50

Various parts of Xingfu Gully during regular rain

Most parts of the Gully are well-protected by dams or levees. Some are less protected.



Source: Google Maps 2016; Photos by Rhea Leung, July 2016.

Despite these potential threats, an initial impression given by the Xingfu villagers was that they perceived their place very safe because of the huge investments on the geotechnical measures in reducing debris flow risk there.

4.2.3 Wenchuan County – Gengda Township -- Longtan Village

The major characteristic of this village is that it does not have any sediment trap dam. Although the houses of this village spread from upstream to downstream adjacent to a network of gullies, the households were only protected by levees built a few metres next to their houses.

Landscape and accessibility

Longtan Village is located at the western end of Gengda Township and is nearer to Wolong Township in the further west when compared to the two other Gengda villages.

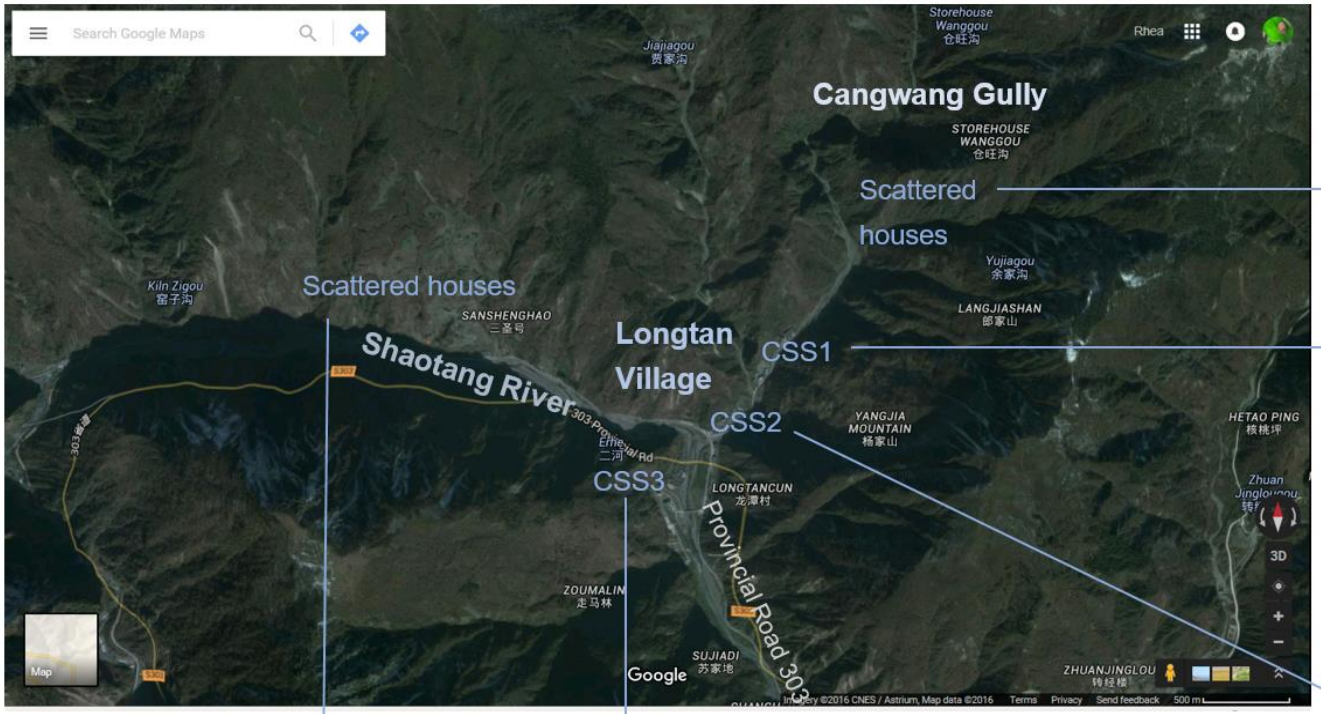
Similar to Xingfu Village, before the 2008 earthquake, many of the households scattered on mountain slopes nearby or along gullies while some resided along Provincial Road 303 and Shaotang River, the major river flowing parallel to Provincial Road 303 and cut across the whole Wolong SAR.

After the earthquake, Concentrated Settlement Sites (CSS) were built to accommodate most of the originally scattered population (Figure 4.51). Besides uphill of Provincial Road 303 (CSS1 and CSS2), another site is also constructed on the other side of the Shaotang River (CSS3), while some villagers were still staying in scattered houses uphill near the gullies or along Shaotang River. Longtan Village therefore is composed of a mixture of old houses built before the earthquake and new houses reconstructed or constructed after it. Houses in this village are more scattered than those in Xingfu Village.

Figure 4.51

Satellite map showing the overview of Longtan Village, its Concentrated Settlement Sites (CSS) and Cangwang Gully

Cangwang Gully is one of the major gullies imposing debris flow risk to Longtan Village.



Source: Google Maps 2016.











The other side of Provincial Road 303, along Shaotang River

Photos by Rhea Leung, July 2016.

Demography and economy

Longtan Village is composed of seven groups, with over 800 residents from 225 households (Table 4.13). Most villagers were farmers in mid-2016. Some of their farmlands, warehouses or pigsties were located along or near the threatening gullies (Figure 4.52).

Table 4.13

Household number and population of Longtan Village in 2016

Group	Household	Population	Male	Female	Manpower
1	62	237	116	121	149
2	26	84	46	38	43
3	14	43	24	19	25
4	23	84	42	42	50
5	44	169	86	83	120
6	32	119	60	59	66
7	24	111	57	54	70
Total	**225**	**847**	**431**	**416**	**523**

Source: Longtan Village Government, August 2016.

Figure 4.52

Old houses on mid-hill serve as warehouses for farm produce or pigsty



Photo by Rhea Leung, August 2016.

Debris flow risks threatened Longtan Village – Year 2010 inspection

Similar to Xingfu Village, Longtan Village was threatened by several, though smaller scale and lower risk, debris flows, together with some landslips and rockfalls from time to time.

According to the 2010 inspection, the whole village was threatened by four debris flows, all in medium scale (Table 4.14). No resident was at risk yet RMB 8.8 million of properties were threatened.

Table 4.14

Potential threats of debris flows in Longtan Village in 2010

Name of risk site	Scale (10^4m^3)	Threatened population	Threatened properties (RMB10,000)
Huangjia Gully Debris Flow	Medium	Nil	50
Cangwang Gully Debris Flow	Medium	Nil	500
Yinhan Gully Debris Flow	Medium	Nil	170
Youzhuping Big Bridge Head Debris Flow in Group 1	Medium	Nil	160

Source: Extracted from the overall list of geohazard risk sites in Sichuan Province in year 2010 (Sichuan Government 2010).

Geotechnical engineering measures imposed to tackle debris flow threats after Wenchuan earthquake

The 2008 earthquake destroyed or damaged many houses in Longtan. Under government arrangement many households were relocated. Such relocation avoided risk of various geohazards, including debris flow. However, at least 100 households were still living adjacent to the four debris flows in Longtan Village in which certain geotechnical measures were imposed or planned (Gengda Township Government 2016b).

Until the conduct of the survey, according to both the local government and field observations, no sediment trap dam was specially built to mitigate debris flow risk in Longtan. Only narrow rainwater drainage channels and levees aiming to protect the village against flooding were built or improved after the quake (Figure 4.53). However, the proximity of gullies to the residences, the limited protection by the narrow drainage channels which collects water and debris during rainy seasons and the fragility of simple levees on Shaotang River did raise the worry about safety of Longtan villagers and their properties.

Figure 4.53
Narrow rainwater drainage channels and levees in different parts of Longtan Village adjacent to houses

to protect concentrated settlements uphill



to protect scattered houses uphill



Photos by Rhea Leung, August 2016.

to protect concentrated settlements downhill



to protect settlements along Shaotang River



Photos by Rhea Leung, July 2016.

Review of debris flow risk and threats after imposition of geotechnical measures – Year 2016 inspection

Longtan Village was threatened by a total of 47 geohazard risks in 2016, including seven debris flows (Table 4.15). Hundreds of residents were affected and all 47 sites were assigned with one responsible personnel (Personnel GD 1, the same person for Xingfu Village).

As in Xingfu Village, no direct comparison of “scale” and “risk level” of various debris flows in Longtan Village can be done but such “scale” and “risk level” information can provide an idea of the possible changes of debris flow impact on the Village.

Table 4.15

Basic situations of geohazard risk sites affecting Longtan Village in 2016

Name of risk site	Location	Risk level	Affected area	Contact person	Fax	Contact mobile phone number
Cangwang Gully Debris Flow	Group 1	Relatively big	Compact residential site with 250 persons	Personnel GD1	Yes	Yes
Jiajia Gully Debris Flow	Group 1	Relatively big	Scattered farmer households with 18 persons	Personnel GD1	Yes	Yes
Huangjia Gully Debris Flow	Group 5	Relatively big	Scattered households with 20 persons	Personnel GD1	Yes	Yes
Wuguibao Gully Debris Flow	Group 5	Relatively big	Scattered households with 105 persons	Personnel GD1	Yes	Yes
Centre Bridge Downstream Left Coast 1# Debris Flow	Group 7	Ordinary	Provincial Road 303	Personnel GD1	Yes	Yes
Fengtongcao Debris Flow	Group 7	Relatively big	Scattered households with 21 persons	Personnel GD1	Yes	Yes
Yaozi Gully Debris Flow	Group 7	Relatively big	Compact residential site with 41 persons	Personnel GD1	Yes	Yes
12 Landslips sites	Three in Group 1, One in Group 2, One in Group 4, One in Group 6, Six in Group 7	8 Ordinary, 3 Relatively big, 1 Not specified	2 Compact residential sites with 140 and 40 persons respectively, 1 Concentrated residential site with 300 persons, 1 Scattered households with 35 persons, 3 along Provincial Road 303, 5 not specified	Personnel GD1	Yes	Yes
19 Rockfalls sites	1 in Group 2 18 in Group 7	1 Relatively big (Group 2), 18 Ordinary (Group 7)	1 Compact residential site with 121 persons (Group 2), 1 Scattered households with 20 persons, 13 along Provincial Road 303, 4 not specified (Group 7)	Personnel GD1	Yes	Yes
9 Unstable slopes sites	7 in Group 1, 1 in Group 5, 1 in Group 7	7 Relatively big (5 in Group 1, 1 in Group 5, 1 in Group 7); 2 Ordinary (Group 1)	1 Concentrated residential site with 123 persons (Group 1), 1 Settlement site with 96 persons (Group 1), 1 Scattered farmer households with 14 persons (Group 1), 4 Compact residential sites including: Two with 96 and 105 persons respectively (Group1), One with 50 persons (Group 5), One with 41 persons (Group 7), 2 not specified	Personnel GD1	Yes	Yes

Source: Gengda Township Government 2016b.

Among the seven debris flows spotted in 2016, only two still existed in the 2010 list (Table 4.16). They were both of “medium” scale in 2010 and their risk level was “relatively big” in 2016. Two other “medium” scale debris flows risk sites in 2010 were no longer on the 2016 list. Meanwhile, there were five new or re-exist risk sites in 2016, again illustrate the lead-lag effect of post-earthquake geohazards. It is noteworthy that in 2010, all four debris flows did not threaten any residents, but in 2016, six out of seven debris flow threatened a total of 455 villagers, all with “relatively big” risk.

Table 4.16

Debris flows found in Longtan Village in year 2010 and 2016 respectively

Name of risk site	2010 (Scale)*	2010 Threatened population	2016 (Risk level)#	2016 Affected area
Huangjia Gully Debris Flow (Group 5)	✓ (Medium)	Nil	✓ (Relatively big)	Scattered households with 20 persons
Cangwang Gully Debris Flow (Group 1)	✓ (Medium)	Nil	✓ (Relatively big)	Compact residential site with 250 persons
Yinhan Gully Debris Flow	✓ (Medium)	Nil	×	×
Youzhuping Big Bridge Head Debris Flow in Group 1	✓ (Medium)	Nil	×	×
Jiajia Gully Debris Flow (Group 1)	×	×	✓ (Relatively big)	Scattered peasant households with 18 persons
Wuguibao Gully Debris Flow (Group 5)	×	×	✓ (Relatively big)	Scattered households with 105 persons
Fengtongcao Debris Flow (Group 7)	×	×	✓ (Relatively big)	Scattered households with 21 persons
Yaozi Gully Debris Flow (Group 7)	×	×	✓ (Relatively big)	Compact residential site with 41 persons
Centre Bridge Downstream Left Coast 1# Debris Flow (Group 7)	×	×	✓ (Ordinary)	Provincial Road 303

*Source: Compiled from *Sichuan Government 2010, #Gengda Township Government 2016b.*

Latest situation observed before the survey

Apart from debris flows, 12 landslips together with some rockfalls and unstable slopes were also on the 2016 geohazard risk sites list (Table 4.15). During the field visits in mid of the same year, landslides occurred occasionally in different parts of Longtan Village and could provide additional source materials to any debris flow occurring nearby. Although some mitigations seemed to have imposed, more attention might be required as they were just adjacent to residences and the main road (Figure 4.54).

Figure 4.54

Landslips in Longtan Village area

(Left) Landslip and mitigation at the back of a house
(Right) Landslip and mitigation along Provincial Road 303



Photos by Rhea Leung, July 2016.

Moreover, although houses located downhill on flatlands near the transportation network seemed to have lower risk exposure, some houses were still exposed to hazard risks (Figure 4.55).

Figure 4.55

Houses exposed to geohazard and flooding risks in Longtan Village area

Houses situated along Shaotang River and adjacent to hillslopes are exposed to both geohazard and flooding risks which are sometimes fed with materials brought down from the slopes.



Photo by Rhea Leung, July 2016.

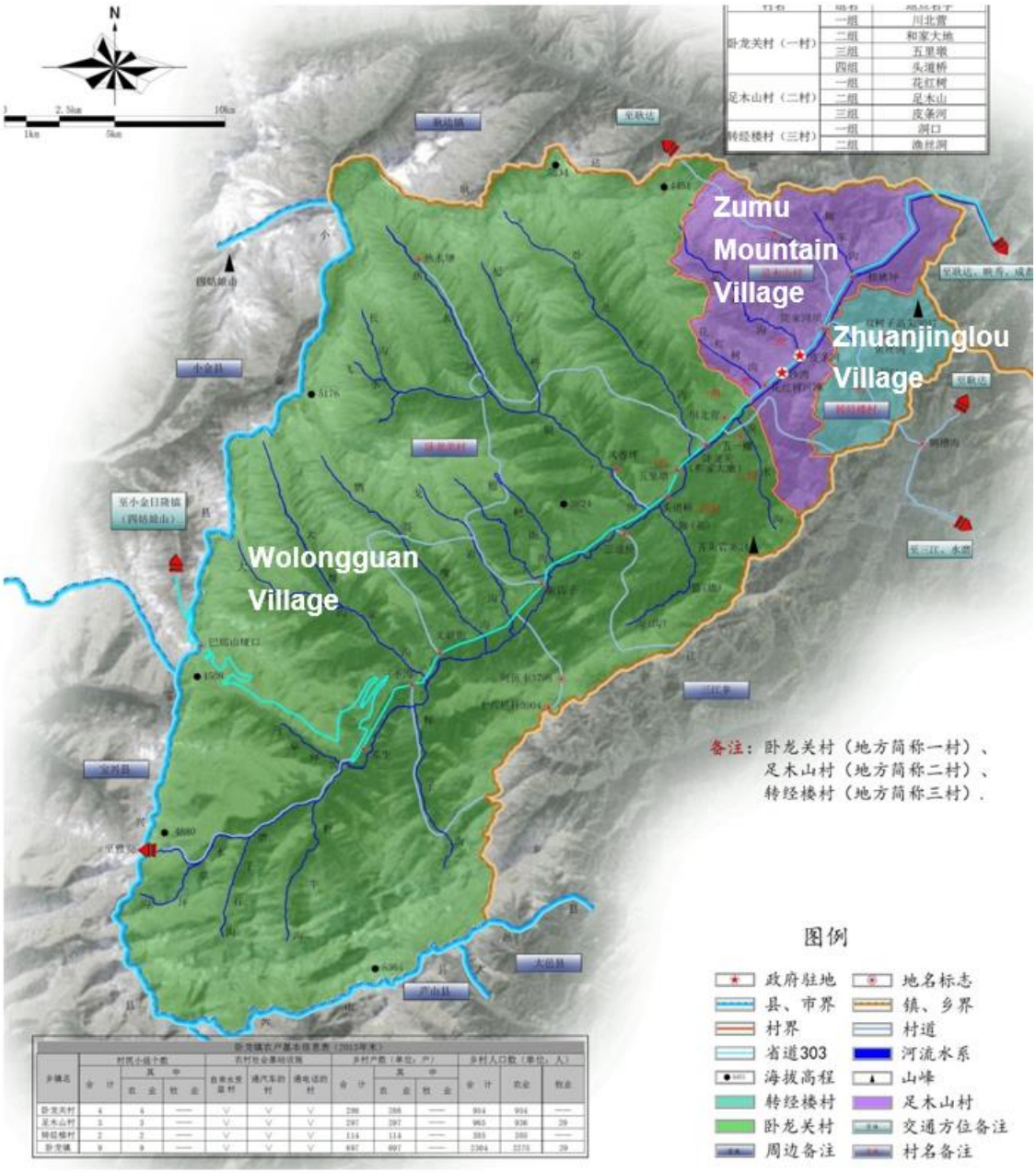
4.2.4 Wenchuan County – Wolong Township

Landscape and accessibility

Wolong Township is comprised of Wolong Township Centre and three villages: Wolongguan Village (also named as Village 1 locally), Zumu Mountain Village (Village 2) where the Township Centre and government are located, and Zhuanjinglou Village (Village 3) (Figure 4.56).

Figure 4.56

The three villages under the administrative jurisdiction of Wolong Township



Source: Wolong Township Government 2014.

Adopted from Overall Plan of Wolong Township, Wenchuan County (2014-2030) in 2014.

Demography and economy

As in Gengda Township, most of the households scattered uphill in Wolong Township in the past. Shortly after the 2008 earthquake, most of the villagers were resettled along Provincial Road 303 for safer environment, better accessibility and easy management (Figure 4.57) (Wolong Township Government 2016b).

Figure 4.57

Central area of Wolong Township along Provincial Road 303



Photo by Rhea Leung, August 2016.

Wolong Township had a total population of about 2,000 from over 700 households in 2016, residing in nine residential groups of three villages (Figure 4.58). Another some 800 people registered as city residents also resided in Wolong Township (Wolong Township Government 2016a).

Figure 4.58

Satellite map showing an overview and landscape of Wolong Township with its three villages *Source: Google Maps 2016.*



Before the 2008 earthquake, most villagers of Wolong Township were farmers and retailers of souvenirs (Wolong Township Government 2016b). After the quake, the government have made good use of its 98% vegetation cover of land area and 56% forestation rate (HKSAR 2016c), greatly developed its farming industry and encouraged the farming of produces with high economic value unique from Sichuan. Some other villagers have engaged in tourist industry involving restaurants, farm resorts and souvenir shops (Figure 4.59).

Figure 4.59

Motels along Provincial Road 303 for tourists



Photo by Rhea Leung, August 2016.

4.2.5 Wenchuan County – Wolong Township – Wolongguan Village

Landscape and accessbility

The third site in Wenchuan County studied in this research is Wolongguan Village of Wolong Township. Among the three villages of Wolong Township, Wolongguan Village is the most sparsely populated, the most widely-spread with an altitude of about 2,000 to 4,300 metres, and the most remote. It is the farthest from the township centre and the provincial capital Chengdu.

The four groups of this village were threatened by three separate gullies. Particularly, a relatively small and quiet gully situated at Group 4, Xiongmao Gully, had outburst in July 2016, just before the survey of this research was conducted there.

Figure 4.60

Entrance of Wolongguan Village on Provincial Road 303

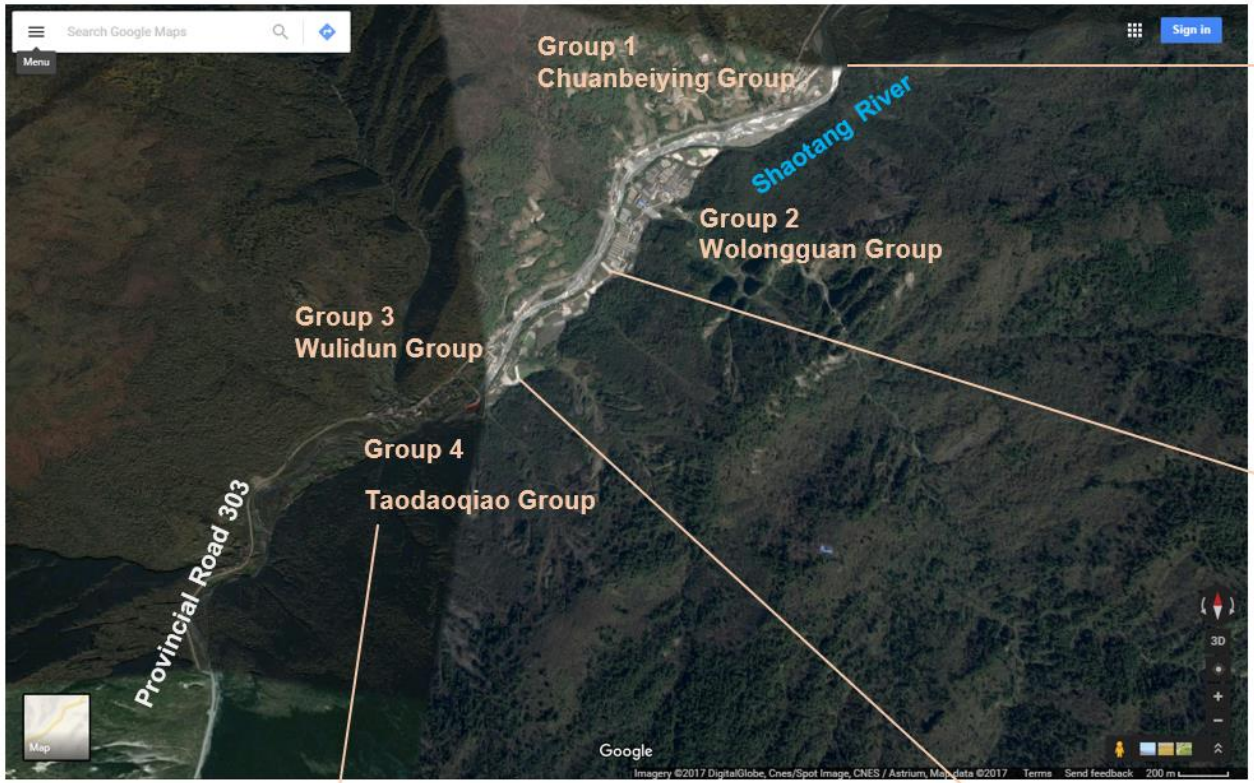


Photo by Rhea Leung, August 2016.

Before the 2008 earthquake, many Wolongguan Village households scattered on mountain slopes nearby while some villagers resided along Provincial Road 303. After the quake, the majority moved and settled along the Provincial Road 303 which runs almost parallel with the Shaotang River with various gullies joining it (Figure 4.61).

Figure 4.61

Satellite map and photos showing an overview of Wolongguan Village, its four groups, Shaotang River and Provincial Road 303



Group 1 -- Concentrated Settlement Site facing Shaotang River



Group 2 - Compact residential site along Shaotang River





(Left) Group 4 - Scattered households along Provincial Road 303 (Right) Group 3 – Concentrated Settlement Site near Provincial Road 303



Adopted from Google Maps 2017.
Photos of Group 1, 2 and 4 by Rhea Leung, August 2016;
Photo of Group 3 by HKSAR 2016c.

Demography and economy

Wolongguan Village is composed of four residential groups (Figure 4.61). Two concentrated settlement sites, including one in Group 1 and another in Group 3 called the Old Street, were built along Provincial Road 303 after the 2008 earthquake. The Old Street revitalized ethnic culture by accommodating 160 villagers originally scattered on the mountain areas nearby (HKSAR 2016c). Group 2 and 4 constituted of other residents staying mainly in residential sites along Shaotang River and Provincial Highway 303, with some other houses located slightly away. This means Wolongguan Village, similar to Longtan, is composed of a mixture of old houses built before the quake and new houses reconstructed or constructed after the quake.

Before the conduct of the survey, breakdown of the population of Wolongguan Village was available for year 2013. Around 1,000 villagers were quite evenly distributed among the four groups (Table 4.17).

Table 4.17

Household number and population of Wolongguan Village in 2013

Group	Households	Population
Group 1 (Chuanbeiying Group)	87	255
Group 2 (Wolongguan Group, also known as Hejiadadi)	78	276
Group 3 (Wulidun Group)	68	241
Group 4 (Toudaoqiao Group)	53	183
Total	**286**	**955**

Source: Wolong Township Government 2016c.

Many Wolongguan villagers were farmers. Since land is limited, many farm produces were grown on narrow scripts of land along the roads or on hillslopes. Some farmers grew mushrooms in greenhouses for sale (Figure 4.62).

Figure 4.62 Farming in Wolongguan Village

Group 2 villagers grow vegetables on hillslopes on the other side of Shaotang River (left) and mushrooms in greenhouses (right)



Corns and vegetables grow on road sides in Group 1 (left) and Group 4 (right).



Photos by Rhea Leung, August 2016.

With the encouragement of local government, Wolongguan Village has also started to diversify its economy by developing tourism (Figure 4.63).

Figure 4.63

A hotel near the eastern entrance of Wolongguan Village



Photo by Rhea Leung, August 2016.

Debris flow risks threatened Wolongguan Village – Year 2010 inspection

Wolongguan Village was threatened by a total of four debris flow in year 2010, all of medium scale. Over 350 residents and RMB 4 million properties were threatened (Table 4.18).

Table 4.18

Potential threats of debris flows in Wolongguan Village in 2010

Name of risk site	Scale ($10^4 m^3$)	Threatened population	Threatened properties (RMB10,000)
Wulidun Debris Flow	Medium	60	72
Wolongguan Gully Debris Flow	Medium	160	180
Gan Gully Debris Flow	Medium	40	60
Xiushui Gully Debris Flow	Medium	94	90

Source: Extracted from the overall list of geohazard risk sites in Sichuan Province in year 2010 (Sichuan Government 2010).

Since then, some gullies became less threatening to the nearby residences due to different reasons. Conversely, some previously small and non-threatening gullies have developed over time and led to increasing risk to some places. According to

the Overall Plan (2014-2030) for Wolong Township, six medium scale and one large scale debris flow risk sites previously recorded in 2010 were no longer influential (Figure 4.64).

Figure 4.64



The four groups of Wolongguan Village and the gullies affecting them

Wolongguan Village had 14 gullies in 2014. All were tributaries of the Shaotang River which flows from the west to the east into a major river in Sichuan, Min Jiang. Three are particularly close to the communities and imposed risks to the residents. Others gullies were located at very remote areas with no villagers and not considered as risk sites.

Source: Wolong Township Government 2014.

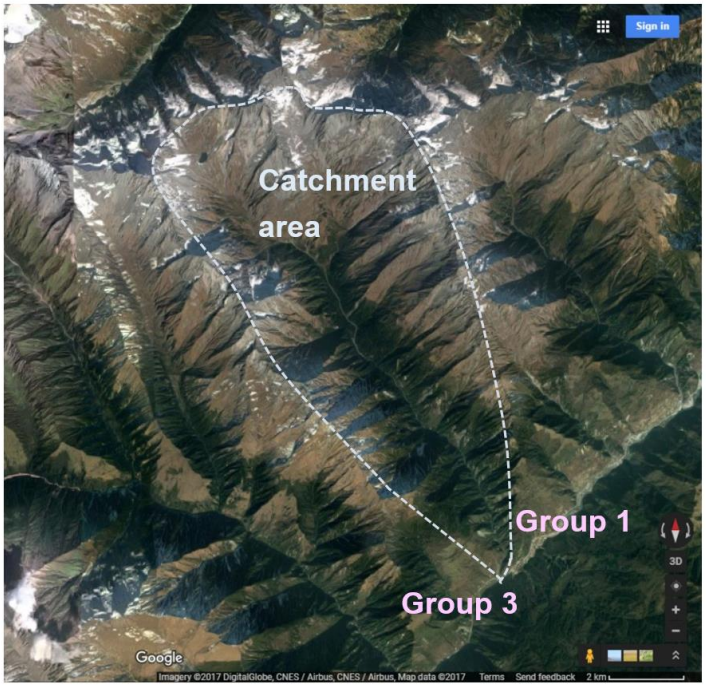
Group number and name	Gully nearby	Upstream/Downstream of the group
Group 1 (Chuanbeiying Group)	Wolongguan Gully	Upstream
Group 2 (Wolongguan Group)	Xiushui Gully	Cutting across the community
Group 3 (Wulidun Group)	Wolongguan Gully	Downstream
Group 4 (Toudaoqiao Group)	Xiongmao Gully	Upstream

Indeed, after the Wenchuan earthquake, geotechnical and/or non-geotechnical risk reduction measures were imposed on some threatening gullies in the village to enhance residents' capability in resisting geohazards and reduce debris flow risk.

Wolongguan Gully threatening Group 1 and 3

Wolongguan Gully flows from approximately 4,800 metres in elevation uphill to joining Shaotang River at around 2,000 metres, with a catchment area of about 30 km^2 (Figure 4.65).

Figure 4.65



Satellite map showing the catchment area of Wolongguan Gully

It is situated in between Group 1 and Group 3, and directly threatening Group 3.

Adopted from Google Maps 2017.

In Group 3, 46 out of about 70 households needed to relocate to newly built settlements while another six households needed to reconstruct their houses in the same location after the Wenchuan earthquake (Wolong Township Government 2016a). Although most residences of Group 1 and Group 3 had been relocated to concentrated settlement sites, and levees were built to protect each group in Wolong Township, threats still persisted (Figure 4.66).

Figure 4.66

Geohazard threats persist around Wolongguan Gully



Scattered houses and most farmlands remains up on the hill near Wolongguan Gully.

Photos by Rhea Leung, August 2016.



Debris flow along Shaotang River near Group 1 could contribute to flooding and more debris flow risks during rainy season.

Xiushui Gully threatening Group 2

Xiushui Gully simply cut across Group 2 and the geohazard risk it caused directly affected the group (Figure 4.67). Although small scale debris flow(s) occurred here before the 2008 earthquake, no big scale debris flow strike after the quake but flooding occurred occasionally (Wolong Township Government 2016c).

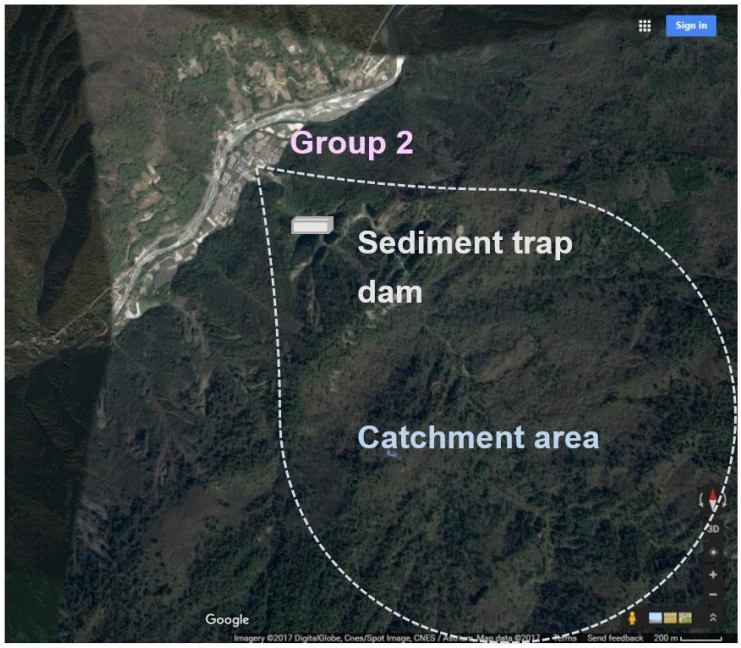


Figure 4.67
Satellite map showing the catchment area of Xiushui Gully

The catchment area is approximately 4 km^2 at an elevation from about 2,000 to 2,900 metres.

Adopted from Google Maps 2017.

Geotechnical measures were imposed on 2011, included mainly a dam and embankment (Figure 4.68).

Figure 4.68
Geoengineering measures imposed on Xiushui Gully



(From left) Dam in midstream; Solar panels for water conservancy project on dam; Dam and embankment on midstream just next to a farm; Embankment along downstream.
Photos by Rhea Leung, August 2016.

Since Xiushui Gully cut across the residences and farms of Group 2, a big red signage was posted at a prominent location downstream of the Gully showing information of the debris flow risk (Figure 4.69).

Figure 4.69

Signage showing the debris flow threat and the evacuation route



Photo by Rhea Leung, July to August 2016.

Xiongmao Gully threatening Group 4

Xiongmao Gully is one of the many tributaries of Shaotang River, situated in the western end of Group 4. "Xiongmao" literally means "panda" in Chinese. It had for long been relatively stable and quiet (Wolong Township Government 2016c). Although it was categorized as a zone susceptible to geohazard in 2009 (Wolong Township Government 2009a), it had neither appeared in the 2010 geohazard risk site list (Sichuan Government 2010) nor counted as debris flow risk sites in 2016. No geotechnical measures were imposed before 2016. However, it became more active and caused risks to Group 4 located immediately downstream of it.

- **Latest situation observed before the survey**

An unexpected debris flow broke out there on 26 July 2016, causing great disruption (Figure 4.70). Residents nearby were evacuated and had to stay in temporary shelters (Wolong Township Government 2016c). Luckily no one was hurt according to reports. Such a debris flow from a non-listed gully site should

have alerted the local government to reveal their inspection and risk prevention practices.

Figure 4.70

Debris flow outburst in Xiongmao Gully

(Middle) Mouth of Xiongmao Gully upstream of Wolongguan Village joins Shaotang River after the debris flow hit.
(Left and right) Accumulation of debris along the nearby sections of Shaotang River. Part of the Provincial Road 303 and houses are disrupted.



Photos by Rhea Leung, July 2016.

Apart from Xiongmao Gully, along the Provincial Road 303 where Group 4 is located, a geohazard red signage was posted next to a house indicating the existence of debris flow and rockfall risks (Figure 4.71).

Figure 4.71

Signage of "Liaojiadadi Debris Flow and Rockfall Geohazard Potential Risk Site"

"Liaojiadadi Rockfall" is in the 2016 geohazard risk site list but not "Liaojiadadi Debris Flow". Therefore the debris flow risk should be detected afterwards.



Photo by Rhea Leung, July to August 2016.

Review of debris flow risk and threats after imposition of geotechnical measures – Year 2016 inspection

Wolongguan Village had a total of 32 geohazard risk sites in 2016, including six debris flows. Hundreds of residents were threatened in 19 geohazard risk sites while another 13 were putting hydroelectric facilities or public roads at risk (Table 4.19).

Table 4.19

Basic situations of geohazard risk sites affecting Wolongguan Village in 2016

Name of risk site	Location	Threatened object	Threatened		Personnel responsible for disaster prevention			Personnel responsible for monitoring		Mass Monitor and Mass Prevention personnel	
			household	population	Name	Unit and Responsibility	Mobile phone number available	Name	Mobile phone number available	Name	Mobile phone number available
Songpanying (Shishuming) Rockfall	Group 1	Scattered peasant households	5	22	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Yang Jiyou Behind the House Rockfall	Group 1	Compact residential site	5	23	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Bachaheba Back Hill (Yang Jiyou) Unstable Slope	Group 1	Compact residential site	8	34	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Songpanying (Previously Chuanbeiying) Landslip	Group 1	Scattered peasant households	2	9	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes

Wolongguan Yin Mountain Rockfall	Group 2	Scattered peasant households	5	13	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Jiuchang Rockfall (Previously Wolongguan Village Rockfall)	Group 2	Compact residential site	92	400	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Yang Youfu Back Hill Landslip	Group 2	Scattered peasant households	4	25	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Longnaoke Unstable Slope	Group 2	Compact residential site	55	238	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Xiushui Gully Debris Flow	Group 2	Compact residential site	11	49	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Longnaoke Rockfall	Group 2	Compact residential site	8	34	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Wulidun Debris Flow	Group 3	Scattered peasant households	8	29	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Wulidun Yin Mountain Unstable Slope	Group 3	Scattered peasant households	1	5	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Wolongguan Gully Debris Flow	Group 3	Compact residential site	35	148	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes

Liu Puliangjia back of house Unstable Slope	Group 3	Compact residential site	10	56	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Chen Guangrong back of house Rockfall	Group 4	Scattered peasant households	1	5	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Fan Fuming back of house Rockfall	Group 4	Scattered peasant households	6	25	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Wang Bo front of house Rockfall	Group 4	Scattered peasant households	1	4	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Liaojiandadi Rockfall	Group 4	Settlement site	17	71	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Liujiadadi Unstable Slope	Group 4	Compact residential site	28	107	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Guanyinyan downstream slope Debris Flow (Previously Guanyinyan Downstream Unstable Slope)	Group 1	Hydroelectric facilities	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Gan Gully Debris Flow	Group 2	Hydroelectric facilities	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Yinchang Gully Debris Flow	Group 4	Hydroelectric facilities	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes

Guanyinyan Upstream Unstable Slope	Group 1	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Chenyaoyan Rockfall	Group 1	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Gongbao Unstable Slope	Group 3	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Lower Wulidun Moving Silt Unstable Slope	Group 3	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Upper Wulidun Moving Silt Slope Rockfall	Group 3	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Cibajia Rockfall	Group 4	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Guiyanwo Rockfall	Group 4	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Transfer Station Unstable Slope	Group 4	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes
Yinchang Gully Lower Mouth Unstable Slope	Group 4	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes

Erdao Bridge in front of Zhangbo Old House Unstable Slope	Group 4	Public road	NA	NA	Personnel WLG1	Head of Wolong Township	Yes	Personnel WLG2 (Village Committee Officer)	Yes	Personnel WLG	Yes

Source: Wolong Township Government 2016a, 2016b.

All 32 sites were assigned with the head of Wolong Township for disaster prevention. A Village Committee Officer was responsible for monitoring. Selected villagers living near the geohazard sites would participate in Mass Monitoring and Mass Prevention.

In terms of debris flow, all four found in 2010 remained on the 2016 list, while two extra debris flows were added in 2016 (Table 4.20). Yet, risk level information of each debris flow in 2016 is unavailable.

Table 4.20

Debris flows found in Wolongguan Village in year 2010 and 2016 respectively

Name of risk site	2010 (scale)*	2016 (Risk level)#
Wulidun Debris Flow	✓ (medium)	✓ (NA)
Wolongguan Gully Debris Flow	✓ (medium)	✓ (NA)
Gan Gully Debris Flow	✓ (medium)	✓ (NA)
Xiushui Gully Debris Flow	✓ (medium)	✓ (NA)
Guanyinyan slope at downstream Debris Flow (previously Guanyinyan downstream unstable slope)	×	✓ (NA)
Yinchang Gully Debris Flow	×	✓ (NA)

*Source: Compiled from *Sichuan Government 2010; #Wolong Township Government 2016b.*

4.2.6 Non-geotechnical preparedness and response measures in Gengda and Wolong under Wenchuan County

As in Pingwu, Wenchuan had also imposed a series of preparedness and response measures after the Wenchuan earthquake. The details might be different but the framework is basically the same, as in point (1) to (5) below.

(1). Risk assessment: Annual geohazard risk inspection and follow up mitigation measures

Wolong Administrative Authority carried out geohazard risk site inspection, or assessment, from time to time in Gengda and Wolong townships and the affiliated villages, followed with mitigation measures. The 2010 annual inspection found that the whole Wolong SAR had 154 geohazard risk sites and increased to 201 five years later (Table 4.21).

Gengda Township alone had 113 geohazard risk sites in 2016, slightly increased from 110 in 2010. Wolong Township had 88 in 2016, doubled than that of 2010.

Table 4.21

Total number of geohazard risk sites on different levels of jurisdiction in year 2010 and 2016 respectively

Level of government	Total number of geohazard risk sites	
	Year 2010*	Year 2016#
Sichuan Province	28390	NA
Wolong Special Administrative Region	154	201
Gengda Township	110	113
Xingfu Village	9	14
Longtan Village	27	47
Wolong Township	44	88
Wolongguan Village	8	32

*Source: *Sichuan Government 2010;*

#Gengda Township Government 2016b and Wolong Township Government 2016b.

(2). Hazard zonation

Pingwu County has prepared the zonation of townships' Geohazard Susceptibility, Risk Levels, as well as Prevention and Mitigation. The governments of Gengda and Wolong under Wenchuan County have also prepared similar information although presented in less comprehensive formats.

Before the start of the rainy and flooding season, which extends from May to September in Sichuan, the governments of Gengda and Wolong prepare their prevention and protection plans to tackle geohazard risks of their affiliated villages.

Gengda's 2008 document issued before the Wenchuan earthquake had already noted the pre-existed Xingfu Gully debris flow and specified its direct threats to the safety and properties of villagers residing along the Gully and in the alluvial fan (Gengda Xiang Government 2008).

As for Longtan, this document noted that Group 7 of the village (Laofangzi Group) had experienced torrent-caused debris flow, which directly threatened the safety and properties of over 70 people from 20 households and induced risk to an electricity station nearby before the 2008 earthquake (Gengda Xiang Government 2008).

In Wolong Township, the 3-page Geohazard Prevention Plan (Figure 4.75) prepared in 2009 spotted the zones and sites susceptible to geohazards that spread across all three villages which required prevention and protection. The 2016 version provided similar yet updated information.

(3). Monitoring and early warning

The monitoring and early warning system in Wenchuan, as in Pingwu, was composed of several elements.

Every summer, Gengda Township Government deployed individual personnel to monitor debris flow and other geohazard risks. In Xingfu Village, the MMMP System was established in all seven debris flow risk sites. One to two personnel, mostly residents of the threatened villages was/were allocated in each site to monitor. In Longtan Village, however, only two out of four sites had such monitoring personnel in 2010.

In Wolong Township, the MMMP System was also established in each debris flow risk site in Wolongguan Village. Similar to Xingfu Village, personnel in Wolongguan were deployed to monitor all sites in year 2010.

Gengda Township

In 2016, all geohazard risk sites in Xingfu and Longtan adopted the same set of major prevention and mitigation measures, including MMMP, monitor, watch, listen, gong, shout and issue early warning (Gengda Township Government 2016b). This is quite different from the arrangements in Pingwu County where different sites were early warned by different methods fitting individual situations and capacity. Both Pingwu and Wenchuan, however, relied much on MMMP.

During the field trips in July and August 2016, the author came across two occasions where an official from Gengda Land and Resources Department and a MMMP personnel received notifications about suspected disaster attacks. Both of them responded swiftly and went to the respective geohazard risk site once they received the notification.

Figure 4.72

Immediate actions of the monitoring personnel

This monitoring personnel communicates with relevant parties through walkie-talkie right after receiving suspected geohazard reports.

Photo by Rhea Leung, July to August 2016.



Wolong Township

As in Pingwu, there is a special roster for government officials in rainy summer. During a field trip in July 2016, the author's observed how the Land and Resources township officials worked on a rainy day (Figure 4.73).

Figure 4.73

Special roster on a rainy summer day

(Left) Government duty officers make phone calls to monitoring personnel living nearby to ensure each site is safe. Advice and assistance in dealing with emergency situations or potential disasters are offered, including deploying a team to the site with equipment to assist.
(Middle) A government mobile team driving a car to carry out geohazard risks site inspection around the Township hoping to respond quickly to emergency situations.
(Right) Official record written by a duty officer on what had happened on a rainy day in chronological order.



(Left and middle) Photos by Rhea Leung, July 2016.
(Right) Source: Wolong Township Government 2016b. Photo by Rhea Leung, July 2016.

(4). Risk prevention and communications

As in other parts of Sichuan, efforts and resources put in geohazard risk prevention in the two townships of Gengda and Wolong have enhanced since the 2008 earthquake. Risk communications were further developed.

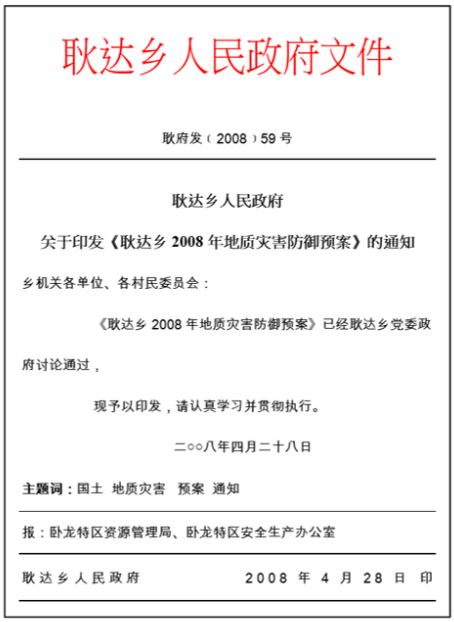
Annual Geohazard Prevention and Protection Plan

When Gengda was still a xiang (lower level than township) prior to 2008, it had already published the *Geohazard Prevention and Protection Plan of Gengda Xiang 2008* in late April 2008 (Gengda Xiang Government 2008) which listed out generally how to conduct risk site inspection, emergency response management and emergency risk reduction. The practice of issuing such a plan continues after the 2008 earthquake, and an emergency plan has been included in the subsequent version (Figure 4.74).

Figure 4.74

Gengda Xiang Geohazard Prevention and Protection Plans

Gengda Xiang Geohazard Prevention and Protection Plan 2008



耿达乡人民政府文件

耿府发〔2008〕59号

耿达乡人民政府

关于印发《耿达乡2008年地质灾害防御预案》的通知

乡机关各单位、各村民委员会：

《耿达乡2008年地质灾害防御预案》已经耿达乡党委政府讨论通过，

现予以印发，请认真学习并贯彻执行。

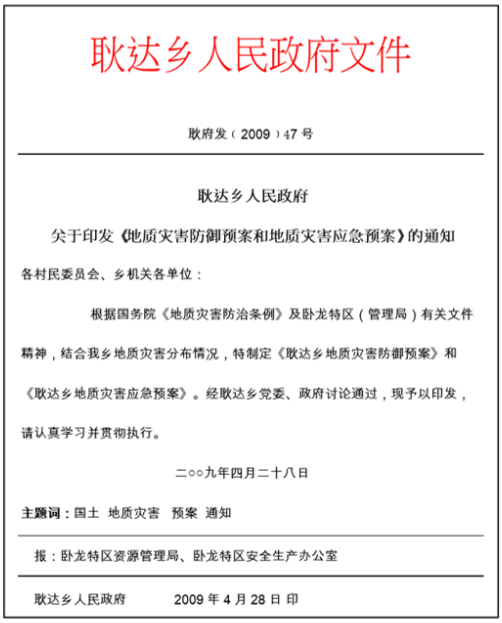
二〇〇八年四月二十八日

主题词：国土 地质灾害 预案 通知

报：卧龙特区资源管理局、卧龙特区安全生产办公室

耿达乡人民政府 2008年4月28日印

Gengda Xiang Geohazard Prevention and Protection Plan cum Geohazard Emergency Response



耿达乡人民政府文件

耿府发〔2009〕47号

耿达乡人民政府

关于印发《地质灾害防御预案和地质灾害应急预案》的通知

各村民委员会、乡机关各单位：

根据国务院《地质灾害防治条例》及卧龙特区（管理局）有关文件精神，结合我乡地质灾害分布情况，特制定《耿达乡地质灾害防御预案》和《耿达乡地质灾害应急预案》。经耿达乡党委、政府讨论通过，现予以印发，请认真学习并贯彻执行。

二〇〇九年四月二十八日

主题词：国土 地质灾害 预案 通知

报：卧龙特区资源管理局、卧龙特区安全生产办公室

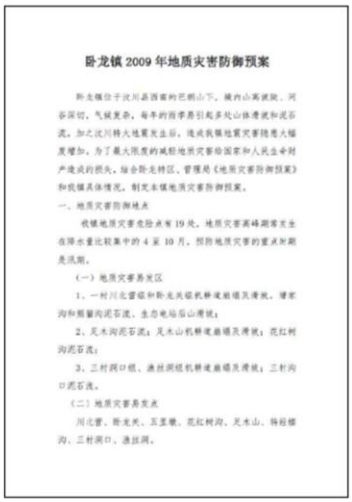
耿达乡人民政府 2009年4月28日印

Source: (left) Gengda Xiang Government 2008; (right) Gengda Xiang Government 2009.

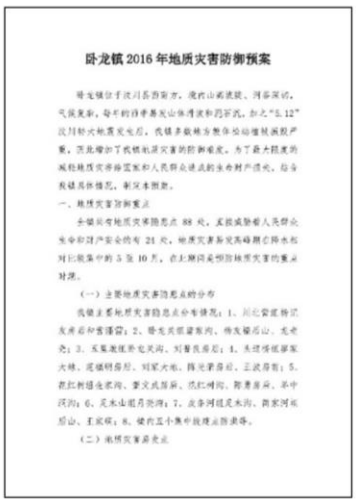
The Plan by Wolong Township emphasized the importance of both publicity and inspection works (Figure 4.75). It stated the need to establish practical risk avoidance measures, suitable relocation and settlement for risk zones, and detailed design of routing, timing, location and early warning for evacuation, so as to minimise hazard loss. The 2016 version was more detailed with the evacuation route and the locations for shelter of 31 sites included.

Figure 4.75

Wolong Township Geohazard Prevention and Protection Plans



卧龙镇2009年地质灾害防御预案



卧龙镇2016年地质灾害防御预案

2009 **2016**

Source: Wolong Township Government 2009a, 2016d.

Another Wolong Township Government annual document is *Geohazard Emergency Response Plan.* The 2016 Plan specifies that during mega, big or medium geohazard hits, the Township has to acquire the SAR or even the County Government to deploy expert teams to further inspect and analyse the cause of the geohazard and the development trend to impose emergency response measure and to avoid further geohazard spread (Wolong Township Government 2016e).

Annual disaster risk prevention documents for internal and external communications

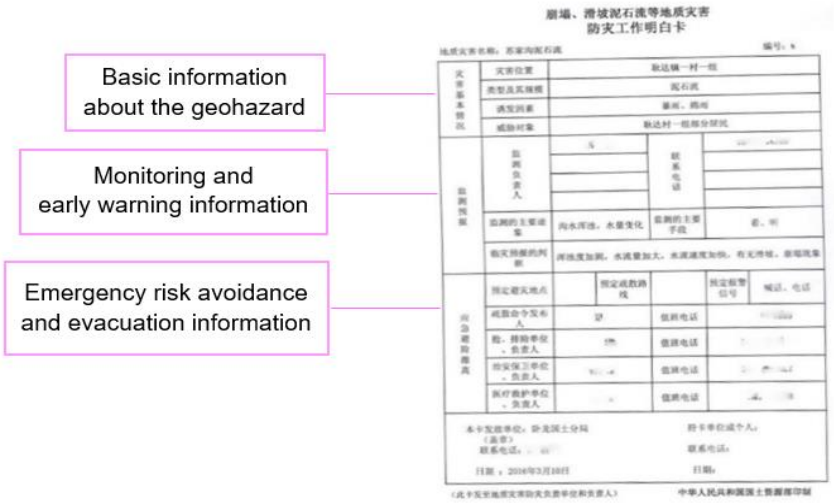
As in Pingwu, Gengda and Wolong Township governments prepared memos and notices for official record and distributed to villagers to enhance their awareness of latest threatening geohazard risk before the rainy season. The contents of these document were basically the same as those issued in Pingwu (Figure 4.76).

Figure 4.76

One Table, Two Cards (with personal data blurred)

✧ **Gengda Township**

Disaster Prevention Work Understanding Card 2016



Card of Understanding on Disaster Prevention and Risk Avoidance of Torrent Hazards, Wolong SAR, Wenchuan, Sichuan Province



Source: Gengda Township Government 2016b.

✧ **Wolong Township**



市（地、州）主要地质灾害危险点防御预案表

地质灾害名称：	WCWL001
1、位置：	
2、灾害类型	
3、灾害规模及主要特征	
4、影响因素	自然因素或人为因素： 自然 主要控制因素，暴雨季
5、危害程度	小型
6、灾害预报	可能发生时间： 活动体现情：
7、防灾措施	简易识别措施及落实情况：
	监测措施：组织单位： 卧龙关村委 责任人： 监测方法： 听、看 报警措施： 喊话
	避险措施：组织单位：卧龙关村委 责任人： 避险线路：两侧避险
	抢险救援措施：组织抢险队，卫生院负责救助指导
8、主管单位	主管领导签字（章）： 二〇一六年 月 日
9、主要责任人	签字（章）： 二〇一六年 月 日



崩塌、滑坡、泥石流等地质灾害

防灾工作明白卡

编号：WCWL001

地质灾害名称：川北管理所

灾害基本情况	灾害位置	卧龙镇一村一组
	灾型及其规模	滑坡，小型
	威胁对象	群众，地震
监测预报	监测负责人	联系电话
	监测的主要手段和方法	看、听
应急避险撤离	预定避灾地点	预定避险线路 / 预警信号 / 喊话
	group command issuer	值班电话
	抢、排险单位，负责人	卧龙镇人民政府 负责人： 值班电话
	治安保卫单位，负责人	卧龙镇派出所 负责人： 值班电话
	医疗救护单位，负责人	卧龙镇卫生院 负责人： 值班电话

本卡发放单位：汶川县至土管理局卧龙分局 持卡单位或个人：

（盖章） 联系电话：

联系电话：

日 期：2016 年 月 日 日 期：2016 年 月 日

（此卡发放地质灾害防灾负责单位和负责人） 中华人民共和国国土资源部印制



2 崩塌、滑坡、泥石流等地质灾害防灾避险明白卡 编号：WCWL002-001

户主姓名		家庭人数		房屋类型		灾害基本情况	
家庭住址						灾害类型	灾害规模
家庭成员情况	姓名	性别	年龄	姓名	性别	年龄	灾害体与本住户位置关系
							灾害诱发因素
							本住户注意事项
监测与预警	监测人			联系电话			撤离路线
	预警信号		喊话				撤离与安置 安置单位地点 负责人
	预警信号发布人			联系电话			保护单位 负责人
							联系电话

本卡发放单位：（盖章） 负责人： 联系电话： 户主签名： 联系电话：

日 期：2016 年 月 日

（此卡发放受灾害威胁的群众） 中华人民共和国国土资源部印制

Table of Significant Geohazard Risk Sites Prevention and Protection Plan 2016;	**Geohazards like rockfall, landslip and debris flow: Disaster Prevention Work Understanding Card 2016;**	**Geohazards like rockfall, landslip and debris flow Disaster Prevention and Risk Avoidance Understanding Card 2016**

Source: Wolong Township Government 2016b.

Although the governments said they did distribute the two cards in the villages, observations in summer 2016 in Wenchuan, as in Pingwu, revealed that many people said they had never heard of or had never seen such documents. Only a very small proportion of them could show the government notices they received (Figure 4.77).

Figure 4.77

Understanding Card posted outside a house



One of the few Longtan Village households post the 2016 Card of Understanding on Disaster Prevention and Risk Avoidance of Torrent Hazard at its entrance as an alert.

Photo by Rhea Leung, August 2016.

Disaster prevention and protection handbooks

Government of different levels have published several handbooks on emergency response, geohazard prevention and mitigation, mountain torrent hazard prevention and protection, and public emergency response for distributing to the public to disseminate disasters risk prevention and reduction knowledge (Figure 4.78).

Figure 4.78

Handbooks on disaster prevention and protection

These handbooks are published by Aba Prefecture and its affiliated governments, including Wolong SAR and Gengda Township.





Source: Provided by township governments of Gengda and Wolong.
Photos by Rhea Leung, 2016.

(5). Emergency response plan

Documentation

Geohazard Emergency Response Plans were prepared annually after the 2008 earthquake by Wolong Township Government (Figure 4.79).

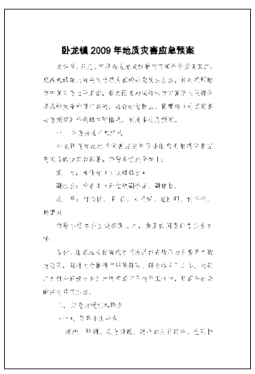
- **Geohazard Emergency Response Plan**

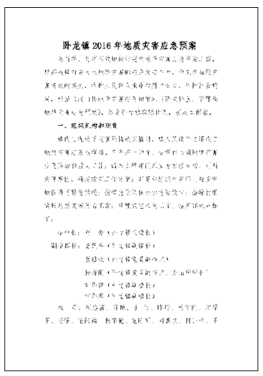
The 2009 version of this Plan stated explicitly that once a geohazard report is received, the Emergency Response Team members should be deployed to the site as soon as possible, to relocate the threatened populations according to the evacuation route and shelter location listed in the Two Cards. Forced evacuation could be enforced whenever necessary. The 2016 edition was elaborated to maintain social stability. It also covers topics on Preventive and Early Warning System and Emergency Response Action.

Figure 4.79

Wolong Township Geohazard Emergency Response Plans

Source: Wolong Township Government 2009b, 2016e.


卧龙镇2009年地质灾害应急预案


卧龙镇2016年地质灾害应急预案

2009 **2016**

Signage

Big red signs could be found at prominent locations along many gullies with debris flow risk in Wolong Township to alert the geohazard risk nearby and the proper disaster response action (Figure 4.80).

Figure 4.80



Signs showing the numbers of debris flow threatened population and evacuation routes

Other information displayed:
- Types and names of the geohazards
- Numbers of threatened household
- Names and contact numbers of monitoring and hazard prevention personnel
- Government duty office and higher level county government emergency phone numbers

Photos by Rhea Leung, July-August 2016.

Posters

In order to reach the residents more direct, big posters to disseminate appropriate geohazard response and the list of monitoring personnel were showcased in a prominient public area (Figure 4.81).

Figure 4.81

Dissemination of geohazard risk reduction measures in a public area by posters



"What to do to save oneself when facing geohazards", together with photos and captions illustrating the works performed in Wolong Township to prevent flooding and disasters in year 2015, are showcased on the street of Group 4, Wolongguan Village, adjacent to residences.

A full list of personnel responsible for monitoring the various potential geohazard areas in year 2015.

Photos by Rhea Leung, August 2016.

Disaster Preparedness Warehouse

Wolong Township got the resources in setting up a flood prevention relief material warehouse which occupied a room of about 20m^2 in the government office building located at the township centre.



Figure 4.82

Disaster Preparedness Warehouse in Wolong Township Government Building

A variety of emergency and relief materials, such as emergency horn, helmet, torches, raincoat, canvas and even generators, are stored for use during emergencies.

Photo by Rhea Leung, July 2016.

4.3 Conclusions of the case study areas

Despite all the efforts and resources invested in both structural and non-structural debris flow risk reduction measures by the Pingwu and Wenchuan governments on their villages, the impacts of the 2008 earthquake on inducing secondary geohazard, though eliminated, still persist through the years. The survey results of this research will disclose how such government measures and other factors would indeed affect relocation decisions (Hypothesis 1), risk perceptions (Hypothesis 2) and disaster responses (Hypothesis 3) of the respondents of the two counties.

Chapter 5
Results

In order to test the three hypotheses of this research, 631 individual rural residents living in five villages of the two study areas were interviewed. This chapter presents the survey results on two levels. Section 5.1 gives an overview of the descriptive statistical findings of the dependent variables of the three respective hypotheses, followed by those of the independent variables. Frequency distribution and percentages of each variable are presented and described. For individual variables, the mean, standard deviation and standard error are presented. Census and official data are referenced whenever relevant. Sections 5.2, 5.3 and 5.4 illustrate the correlations and cause-effect relations of the dependent and independent variables of the three hypotheses respectively. Various statistical methods are applied depending on the type of variable involved.

5.1 Descriptive statistics

5.1.1 Dependent variables

Hypothesis 1: Moving decision

The villages in the study areas of this research were all affected or threatened by earthquake-induced debris flow risks to various extents. Reckoning it was impossible to eliminate risk exposures entirely, the government devised different measures based on local situations. For areas where risks were unacceptable with highly susceptible residents, only a smaller number of people were threatened, or it was difficult or costly to mitigate, risk avoidance measures like relocation were applied. Where geohazard risks were tolerable and manageable, disaster risk reduction measures were used. Not all residents followed the avoidance measures and relocate while some moved due to other reasons.

It is therefore hypothesised that there was “a lack of consideration with institutional directives and disaster risk reduction measures when making relocation decisions”. Hypothesis 1 is to determine what factors contributed to the moving decisions. Survey respondents were asked the question:

“Have you moved after the 2008 earthquake?”

The answer to this question is used as the dependent variable of Hypothesis 1. An answer “Yes” was coded as 1, and “No” was coded as 2. “Not Applicable”, “Don’t know” “I forget” and non-answers were counted as missing values.

Results of dependent variable

Among all 268 Pingwu respondents, the positive and negative answers to this question were 57.84% and 42.16% respectively (Figure 5.1). For the 363 Wenchuan respondents, the positive and negative answers are respectively 71.90% and 26.17%, with 1.93% non-respondents (Figure 5.2). The percentages of those having active behaviour of moving after the quake were bigger than those with passive behaviour of not moving in both counties, and was particularly obvious in Wenchuan.

Figure 5.1 The decision of moved / not moved of all Pingwu respondents (N = 268)

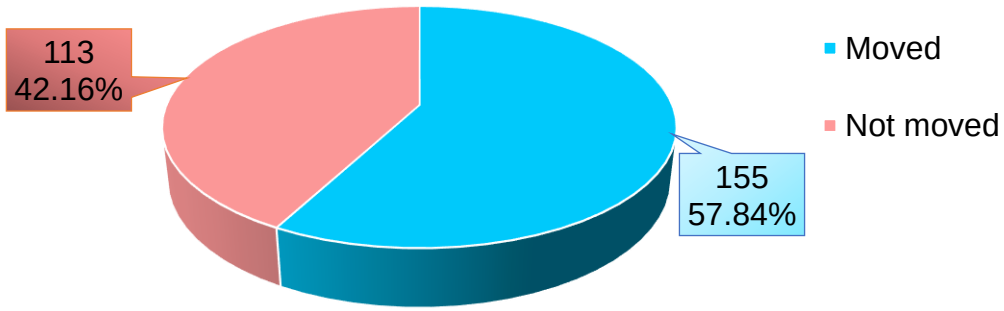
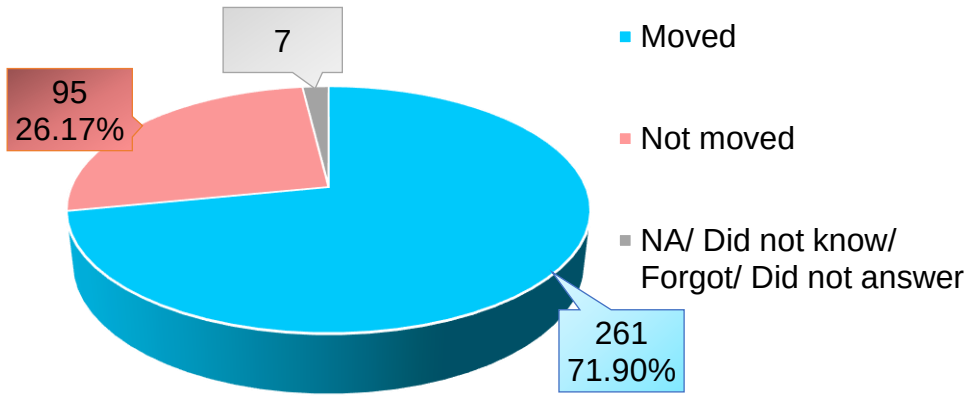


Figure 5.2 The decision of moved / not moved of all Wenchuan respondents (N = 363)



Hypothesis 2: Debris flow risk perception

Hypothesis 2 is constructed to determine the factors governing the risk perceptions of the residents. All survey respondents were asked:

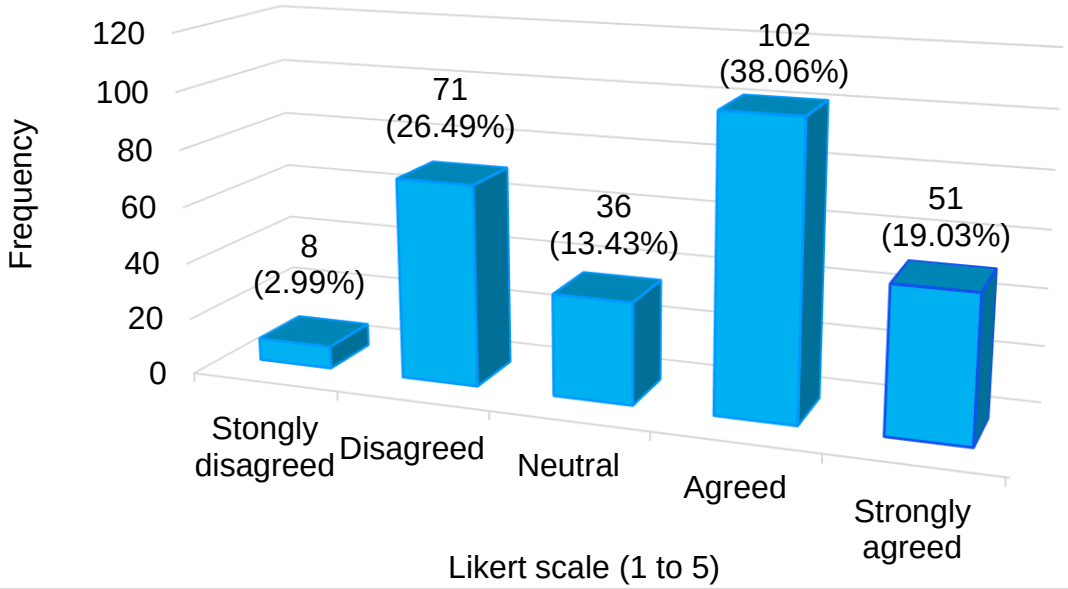
"Is your group/community currently threatened by debris flow?"

The answer to this question, measured by an ordinal 5-level Likert scale from "Strongly agreed (5)" to "Strongly disagreed (1)", is used as dependent variable.

Results of dependent variable

As shown in Figure 5.3, more than half of the Pingwu respondents either strongly agreed (19.03%) or agreed (38.06%) that their communities were at risk. This is almost doubled of those who either strongly disagreed (2.99%) or disagreed (26.49%).

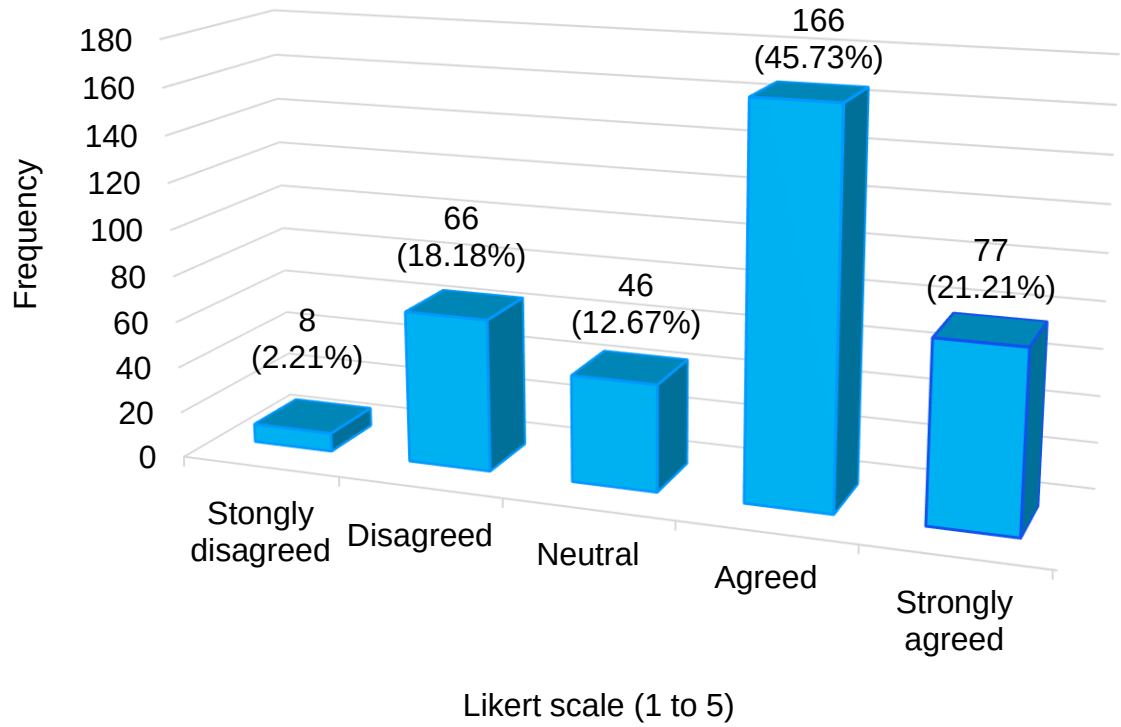
Figure 5.3 Perception of existing community debris flow threat in Pingwu (N = 268)



The distribution of debris flow risk perception in Wenchuan is similar to that in Pingwu. However, there was even a higher portion of Wenchuan respondents perceived existing debris flow threat in their communities.

More than two-third of all Wenchuan respondents strongly agreed (21.21%) or agreed (45.73%) they were at risk. The proportion was more than triple than those who either strongly disagreed (2.21%) or disagreed (18.18%) (Figure 5.4).

Figure 5.4 Perception of existing community debris flow threat in Wenchuan (N = 363)



Hypothesis 3: Anticipated disaster response behaviour at home

Hypothesis 3 was designed to evaluate factors that could affect the respondents' anticipated behavioural responses when they see signs of debris flow at home. The dependent variable is interpreted from the answers to an open question:

"In the future, what will you do in the first place when you are at home and see signs of debris flow?"

The answers gathered from the survey interviews were categorised and coded into four big groups as follows:

(1). Run; Escape; Evacuate;
(2). Stay or take refuge at home; Take care of home; Impose risk reduction preparedness or protective measures such as drain, move stuff or property; Observe;
(3). Inform/Call/Contact family members, authorities or others to run/evacuate by shouting; Evacuate the villagers or public;
(4). Others / Don't know / Did not answer.

Results of dependent variable

As shown in Figures 5.5 and 5.6, the distribution of the answers to this question by the respondents of the two counties are very similar. Very close proportions of 66.79% and 68.60% respectively in Pingwu and Wenchuan chose to “run or escape or evacuate”, followed by 16.42% and 18.73% respectively to “inform family members, authorities or others”, and 10.82% and 7.99% respectively to “stay or take refuge at home, take care of home, impose risk reduction measures or observe”. The rest accounted for 5.97% and 4.68% respectively for Pingwu and Wenchuan.

Figure 5.5 Anticipated disaster response of Pingwu respondents when see signs of debris flow at home (N = 268)

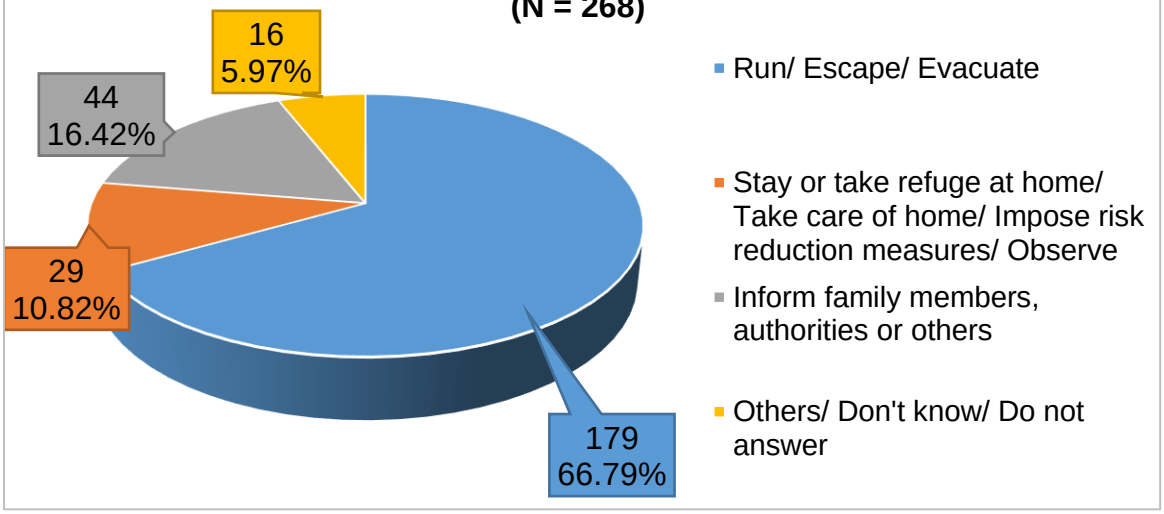
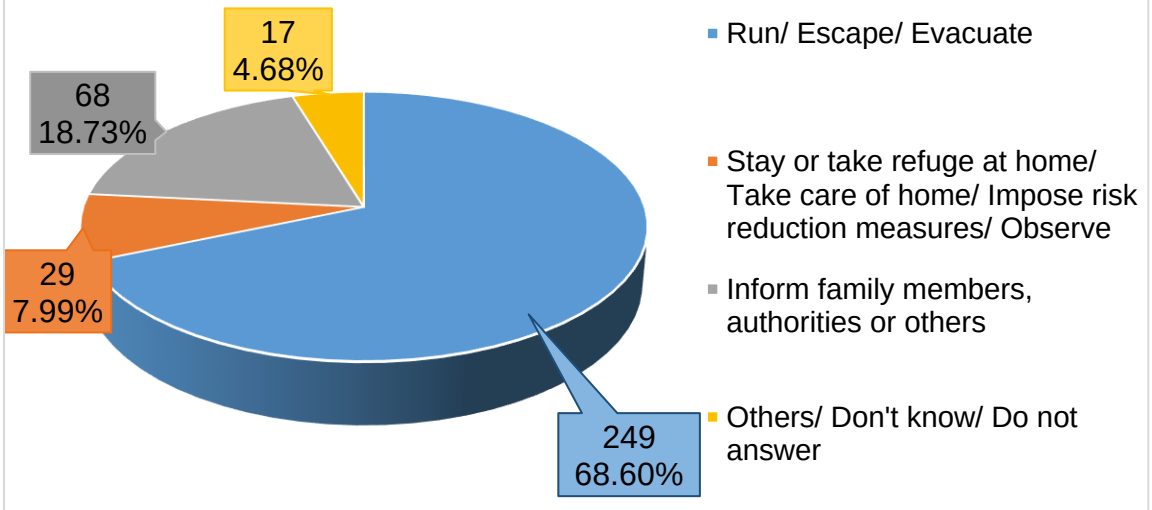


Figure 5.6 Anticipated disaster response of Wenchuan respondents when see signs of debris flow at home (N = 363)



5.1.2 Independent variables

This section presents the descriptive statistics of the independent variables. The first set comprised of twelve demographic and socioeconomic variables which are applicable to all three hypotheses. Other variables, such as experience or knowledge of debris flows, are pertained to particular hypotheses. Various institutional factors are also applied in different hypotheses.

Demographic factors

A total of twelve demographic factors are considered when testing the three hypotheses. Nine were mentioned in existing vulnerability models as shown in brackets and three were not (in *Italic*).

1 Gender (HOP)

2 Age (HOP)

3 Ethnicity (HOP)

4 Education (Cutter *et al.* 2003)

5 Chinese literacy - less literate people might be less accessible to information regarding government mitigation measures simply because they cannot read.

6 Knowledge of Putonghua – this relates to the difference between native language and dialect. Putonghua is the official spoken language in China. However, many provinces, including Sichuan, have their own dialects. Rural populations in particular, very often use their own dialects in daily lives and many elderly persons and less literate residents might not know or might not be fluent in Putonghua. Some can understand Putonghua but do not know how to speak. They might be less communicated in terms of government disaster risk reduction measures disseminated through Putonghua.

7 Household size (MOVE), reflecting the family structure (BBC)

8 Annual per capita net income, reflecting the income levels (HOP, PAR, MOVE)

9 Occupation (HOP, BBC) before the Wenchuan earthquake

10 Occupation after (HOP, BBC, Alexander 1997, PAR, MOVE) the Wenchuan earthquake

11 Role in village - in rural China, some individuals served special position or role in the village they reside, e.g. village head, secretary, officer or geohazard

monitoring personnel. These village leaders are supposed to get the most access to government information, including disaster-related information, and have better knowledge about any debris flow risk and risk reduction measures in their villages.
12 Length of stay per year in the community - referencing mobile homes (HOP) of the rural residents who work outside or within their hometown.

Table 5.1 below provides the summary statistics describing the samples. It highlights the key similarities and differences of the 12 demographic variables between Pingwu and Wenchuan. As noted in earlier chapters, although both counties were categorized as the ten “Counties of Extreme Severe Hazard” (Wei 2010) and experienced the highest earthquake intensity during the Wenchuan earthquake (CSI 2008), hence heavily affected and threatened by debris flows and other geohazards, they are different in certain aspects.

Apart from different socioeconomic backgrounds and varied in the degree of connections with the outside world, the two counties also caught different levels of attention and received different amount of disaster mitigation resources after the quake. Reasons behind the similarities or differences of the relocation decisions, risk perceptions and anticipated disaster responses of respondents of the two counties are the main interest of this research. The different explanations for any variations in the effectiveness of government disaster risk reduction initiatives in the two counties can serve as references for other areas facing similar geohazard risk but with different conditions. Therefore, instead of viewing the complete dataset as a combined, single population, or having other intended lines of comparison, this thesis focuses on comparing and analysing the similarities and differences of the two separate selected counties.

Generally speaking, survey results reveal that the two counties have similar demographic and socioeconomic conditions, with some differences in ethnical composition, educational attainment levels and respondents’ occupation.

Table 5.1
Summary statistics of the 12 demographic variables in the two study areas

Demographic variable	Category	Pingwu	Wenchuan
Gender	Male	120 (44.78%)	144 (39.67%)
	Female	148 (55.22%)	219 (60.33%)
Age	18 to 64	186 (69.40%)	281 (77.41%)
	65 or above	82 (30.60%)	82 (22.59%)
Ethnicity	Han	140 (54.26%)	108 (29.75%)
	Qiang	118 (45.74%)	29 (7.99%)
	Tibetan	0 (0.00%)	224 (61.71%)
	Hui	0 (0.00%)	2 (0.55%)
Education	Uneducated or No schooling	80 (29.85%)	88 (24.38%)
	Primary educated	119 (44.40%)	120 (33.24%)
	Secondary educated or above	69 (25.75%)	153 (42.38%)
Chinese literacy	Yes or Partial	174 (64.93%)	269 (75.35%)
	No	94 (35.07%)	88 (24.65%)
Knowledge of Putonghua	Yes, I know	91 (33.96%)	149 (41.62%)
	Able to understand but don't know how to speak	122 (45.52%)	138 (38.55%)
	No, I don't know	55 (20.52%)	71 (19.83%)
Household size	1 to 3 persons	57 (21.27%)	58 (15.98%)
	4 or more persons	211 (78.73%)	305 (84.02%)
Annual per capita net income	RMB 2855 or below	124 (57.94%)	172 (53.92%)
	RMB 2856 to RMB 10771	78 (36.45%)	125 (39.18%)
	RMB 10772 and above	12 (5.61%)	22 (6.90%)
Occupation before the Wenchuan earthquake	Farmers	201 (75.00%)	217 (59.78%)
	Non-farmers	67 (25.00%)	146 (40.22%)
Occupation after the Wenchuan earthquake	Farmers	184 (68.66%)	180 (49.86%)
	Non-farmers	84 (31.34%)	181 (50.14%)
Role in village	Yes	20 (7.46%)	19 (5.23%)
	Do not serve / Don't know / Forget	248 (92.54%)	344 (94.77%)
Length of stay per year in the community	Stay for whole year	218 (81.34%)	284 (78.24%)
	Not stay for whole year / Don't know / Not sure / NA	50 (18.66%)	79 (21.76%)

The summary statistics in Table 5.1 are further elaborated below. In particular, available official demographic data in year 2015 and/or 2016 when the survey was conducted is referenced.

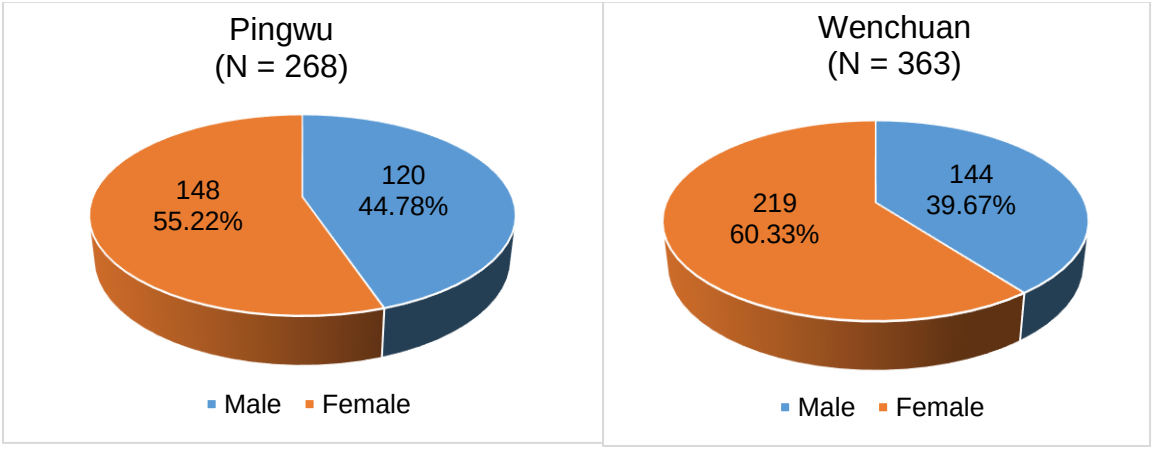
Gender

According to official Chinese record, the country has been dominated by male since the establishment of People's Republic of China in 1949 (NBSC 2017; State Council 2021a). In 2015 and 2016, 51.22% and 51.21% of the national population were male respectively (NBSC 2016, 2017).

Similar for Sichuan, the Population Sample Survey in 2015 showed that male and female constituted to 50.22% and 49.78% of the provincial population respectively.

The male-female ratios are consistently high at the level of cities, townships and villages in Sichuan (SC and NBSC 2010), and is particularly higher in villages at 104.02:100.00. However, due to development and urbanisation in the past decades, many rural populations seek jobs in urban areas. They live in places other than their household registration location and are called the floating population (State Council 2021a). Many of them are males, leaving behind their dependents, including their wives. This may have bearing on the actual gender ratio in rural villages, including those in Pingwu and Wenchuan. In addition, since most of the survey interviews were conducted during day time, some males, even if they stayed in their village, might have left home to go to work. Therefore, majority of the respondents in both places were female, indicating a possibility of over-representation of female in this research.

Figure 5.7 Gender distribution of respondents in the two counties



The variable gender is divided into two groups: “Male” was coded as 0 and “Female” as 1. Survey results show that female respondents dominated in both Pingwu (55.22%) and Wenchuan (60.33%), with a slightly higher ratio of male respondents in Pingwu (Figure 5.7).

Age

In China, National Bureau of Statistics (NBSC) divided the population into three big categories in terms of age: (1) Under working age: 14 or below; (2) Working age: 15 to 64; and (3) Over working age: 65 or above.

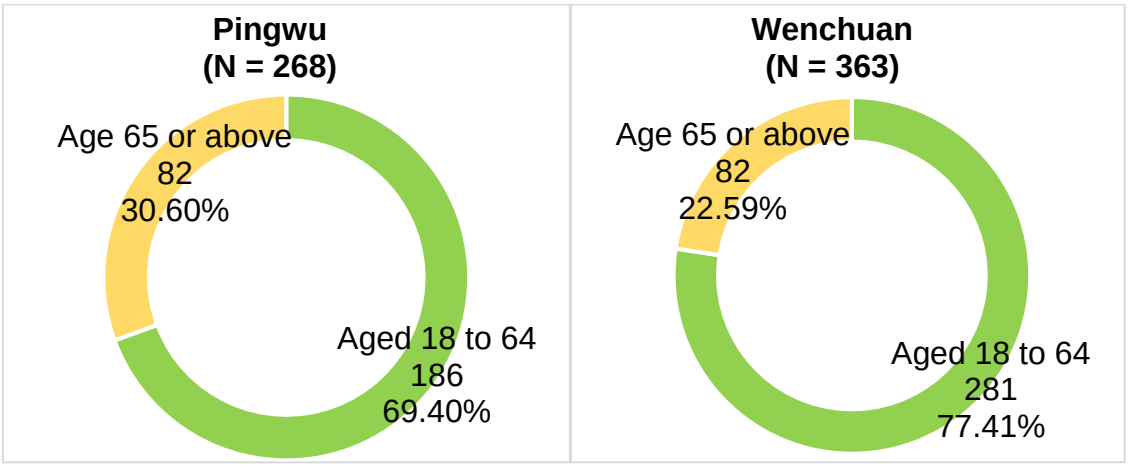
In 2015, 1.00361 billion people in China were in category (2) and 143.86 million were in category (3), constituted to 73.00% and 10.50% of the country’s population respectively (NBSC 2016). The ratio of the two groups was around 7:1. In 2016, the population in category (2) slightly dropped and those in category (3) slightly rose (NBSC 2017). The ratio changed to 6.68:1.

In Sichuan, Category (2) and (3) constituted to 71.18% and 12.94% of the provincial population in 2015 respectively (NBSC 2016). The ratio of the two groups was 5.50:1. Due to aging, the ratio changed to 5.14:1 in 2016 (NBSC 2017). In particular, according to the 2010 Census, the ratio was 5.61:1 on village level, comparing to 8.31:1 in townships and 8.82:1 in cities (SC and NBSC 2010).

Since this study selected adults aged 18 or above as respondents, the data of those aged 15 to 17 was unavailable. With reference to the official categorisation, the respondents were divided into two groups: those aged 18 to 64 were coded as 0 and those 65 or above as 1.

Survey reveals that most respondents were in their working age between 18 and 64 in both counties (69.40% in Pingwu and 77.41% in Wenchuan) (Figure 5.8).

Figure 5.8 Age distribution of respondents in the two counties



The ratio of the sample numbers of the working age group to the elderly group was 2.27:1 in Pingwu and 3.43:1 in Wenchuan. Both were markedly lower than the national ratios of 7:1 (year 2015) and 6.68:1 (year 2016), as well as the Sichuan ratios of 5.50:1 (year 2015) and 5.14:1 (year 2016). The ratios obtained in this study were also lower than the ratio of 5.61:1 for rural Sichuan in 2010.

In terms of mean age, respondents of the two study areas were much older than the national and provincial average (NBSC 2001; State Council 2021a), although the Wenchuan respondents was about six years younger than the Pingwu counterparts (Table 5.2).

Table 5.2 Mean age, standard deviation and standard error of Pingwu and Wenchuan respondents

	Pingwu	Wenchuan
Mean age	**54.55**	**48.07**
Standard deviation (SD)	**16.42**	**18.27**
Standard error (SE)	**1.00**	**0.96**

These indicate an over-representation of elderly persons in this survey compared to rural Sichuan, Sichuan Province and the nation.

Similar to gender, the bias towards a greater fraction of elderlies in the villages is attributable to the floating population that severely affects the age structure in rural areas. Like many other rural remote mountainous regions in China, many middle-aged residents in the two study areas leave their rural homeland and worked outside for most of the year and were not present in the villages during the interview, while their children and elder persons have been left at home (NBSC 2001).

Therefore, the sample probably involved some under-representation of the working middle-aged.

Moreover, since this study only selected adults aged 18 or above as respondents, children under 18 were not interviewed, resulting in an under-representation of children.

Owing to the difference in age categorisation and limits in collecting data from non-adults and the working middle-aged, as well as an inevitable consideration of the practical need to interview whoever could be reached and to solicit willing respondents to answer the long questionnaire in the remote areas, the age distribution of the samples of this study might not be fully comparable with the rural Sichuan, provincial and national census data. Nevertheless, since the samples being surveyed essentially represent the usual population residing in the study areas for most of the year, the subsequent analysis of their responses are meaningful and pertinent for the government in implementing policies.

Ethnicity

Sichuan is the home of different ethnic groups. By 2020, the permanent resident population of the province was 83.675 million, among which 5.688 million (about 6.80%) were ethnic minorities (Sichuan Government 2022). The 631 survey respondents came from four ethnic groups, namely Hans, Qiangs, Tibetans and Huis.

Han is the biggest ethnic group in China, Sichuan Province and Sichuan rural areas, constituted to over 90% of the population in all three levels (SC and NBSC 2010) (Table 5.3).

Hui was the third most populous ethnic group in China but only the sixth in Sichuan. Less than one percent of all Huis in China resided in Sichuan.

Tibetan was the ninth most populous ethnic group in China. They mainly resided in high mountain areas (CPG 2006). Apart from Tibet, Sichuan is the home of most Tibetans (23.82%) in China.

Qiang is a much smaller ethnic group. Only 0.02% of the nation's population (309,576 people) were Qiangs. However, an overwhelming majority of Qiangs (95.92%) lived in Sichuan in 2010. The second most populous province for Qiang was Guangdong, with only 1,886 of them resided.

If only consider the four ethnic groups covered in this study, in both the Sichuan rural areas and the two study areas, Han is the biggest ethnic group, followed by Tibetan, Qiang and then Hui.

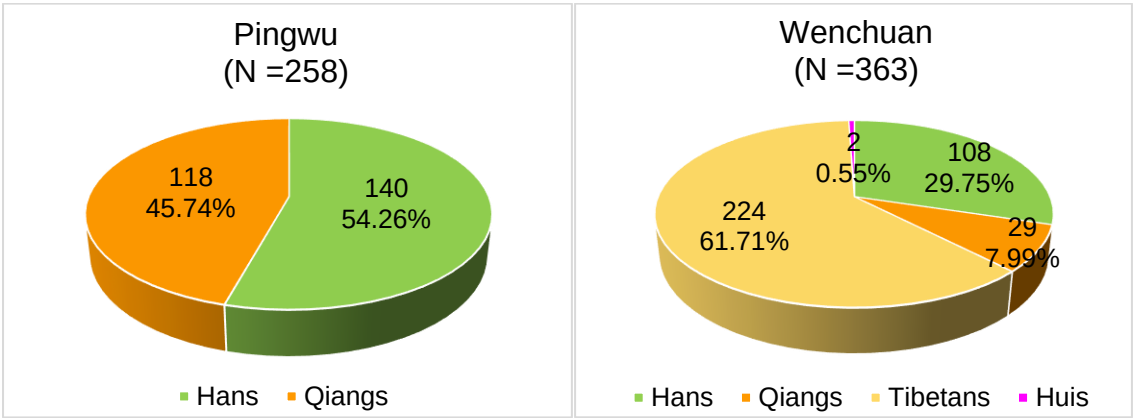
Table 5.3 Population and distribution of selected ethnic groups in China and Sichuan

	All	Hans	Qiangs	Tibetans	Huis
China[i]	1,332,810,869 (100.00%)	1,220,844,520 (91.60%)	309,576 (0.02%)	6,282,187 (0.47%)	10,586,087 (0.79%)
Sichuan Total[ii]	80,417,528 (100.00%) (6.03%)	75,509,724 (93.90%) <6.19%>	296,931 (0.37%) <95.92%>	1,496,524 (1.86%) <23.82%>	104,544 (0.13%) <0.99%>
Sichuan (Villages)[ii]	48,073,100 (100.00%)	43,980,463 (91.49%)	210,732 (0.44%)	1,246,908 (2.59%)	36,524 (0.08%)

Figures in () are % of national, provincial or Sichuan rural total.
Figures in < > are % of the ethnic group.
Sources: [i]SBS 2011, [ii]SC and NBSC 2010.
N.B. Population Census of China 2020 only released the figures of "Han ethnic group" and "Ethnic minorities" as a whole without breakdown, hence the 2020 data is not presented in this table.

In the two Pingwu villages, Han and Qiang are the two major ethnic groups. The independent variable, ethnicity, is divided into two categorical, independent groups: Hans were coded as 1 and Qiangs were coded as 0.

Figure 5.9 Ethnicity distribution of respondents in the two counties



Ten respondents in Pingwu did not declare their ethnicity and were treated as missing values. In the left pie chart of Figure 5.9, Pingwu was dominated by Han respondents (54.26%). The Qiang was the second and the only other responding

ethnic group, constituted to 45.74% of all samples. There was no Tibetan or Hui respondent in Pingwu.

The ethnic composition in Wenchuan is different. The 363 Wenchuan respondents came from four ethnic groups. Unlike in Pingwu where the Hans and the Qiangs were dominating, Wenchuan comprised of a great proportion of Tibetans and a small number of Huis. The right pie chart above shows that 61.71% of the Wenchuan respondents were Tibetans. Only 29.75% were Hans, and an even smaller portion (7.99%) were Qiangs. The other two (0.55%) were Huis.

Education

In China, official data on educational attainment covers those aged 6 and above. In 2015 and 2016, among all Chinese population aged 6 and above, only less than 6% had never attended school. About a quarter and two-third attained primary and secondary school education or above respectively (Table 5.4).

As for the Sichuan population in the same age groups, at least 8% had never attended school, and about one-third received primary education. Both proportions are higher than the national figures. However, only slightly more than half of the Sichuan population attained secondary school education or above, and this is lower than the national percentage.

Table 5.4 Educational attainment of population in China and Sichuan (aged 6 and above)

	Year	Population aged 6 and above	No schooling	Primary	Secondary or above
China	**2015**	19,833,471 (100%)	1,128,946 (5.69%)	5,199,574 (26.22%)	13,504,951 (68.09%)
	2016	1077323 (100%)	61448 (5.704%)	275,939 (25.613%)	739,936 (68.683%)
Sichuan	**2015**	1,200,274 (100%)	97,796 (8.15%)	399,659 (33.30%)	702,819 (58.55%)
	2016	65,259 (100%)	5,508 (8.44%)	21,287 (32.62%)	38,464 (58.94%)

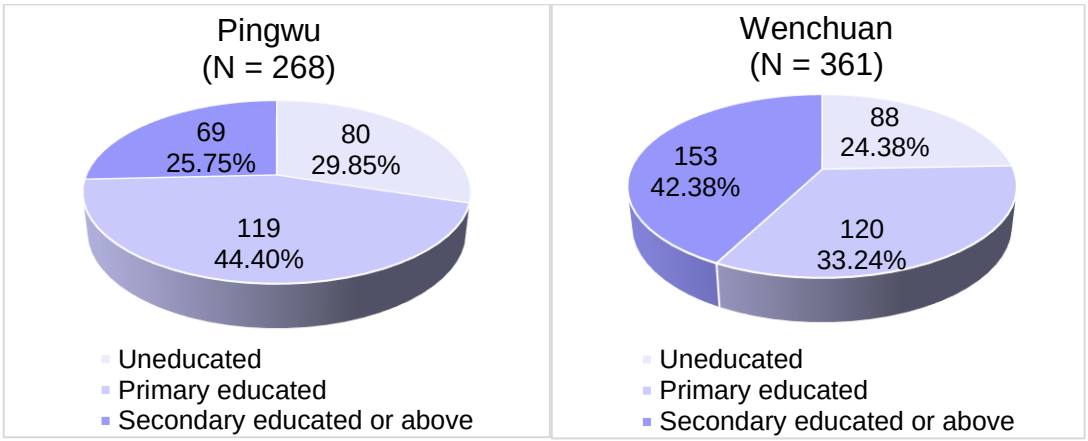
Sources: NBSC 2016, 2017.

In this research, the variable “education” is divided into three categories: (1) Uneducated or No schooling, (2) Primary educated, and (3) Secondary educated or above.

In Pingwu, many respondents were relatively short of educational attainment (Figure 5.10). The uneducated constituted to 29.85%, far more than both the national and provincial percentages. The greatest portion (44.40%) received primary education. Only 25.75% received secondary education or above, much lower than the national and provincial figures.

In Wenchuan, apart from two respondents who did not tell their education levels, 24.38% were uneducated. About one-third (33.24%) received primary education. The greatest portion (42.38%) received secondary education or above, within which 39 attained at least tertiary education, constituted to 10.80% of all Wenchuan respondents.

Figure 5.10 Distribution of respondents' educational attainment in the two counties



Pingwu respondents were generally less educated than their Wenchuan counterparts. Pingwu has a slightly higher proportion of uneducated and a much lower percentage of secondary educated respondents.

When compared with the provincial and national percentages, the proportions of uneducated population of both counties were higher, and the portions of those attained secondary education or above were smaller.

Chinese literacy

In mainland China, including Sichuan, people all use "simplified" Chinese. This written kind is the same for all survey respondents.

The overall Chinese illiteracy rate in China in 2020 was 2.67%, while in Sichuan the rate was higher at 3.98% (State Council 2021a).

If only those aged 15 and above were considered, the illiteracy rates were higher. This is reasonable because elderly persons were more illiterate than the younger generation. In year 2015 (NBSC 2016) and 2016 (NBSC 2017), 5.42% and 5.28% of the national population were illiterate respectively, while the percentages of Sichuan were higher at 8.14% and at 8.22%.

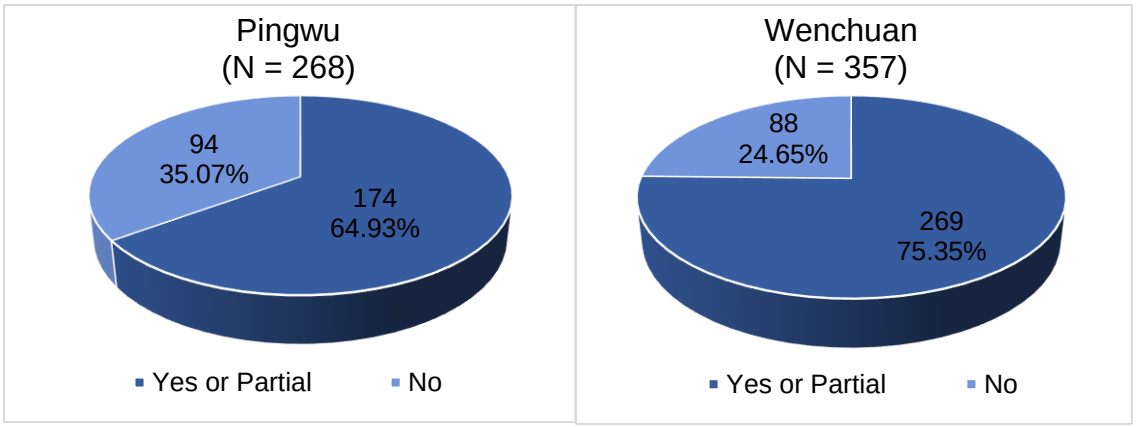
Since majority of the Pingwu and Wenchuan respondents were uneducated or only primary educated, it can be expected that a certain portion of them might not be able to read Chinese.

Chinese literacy might affect a person's ability to receive and understand information on debris flow risk, mitigation, preparedness and response, and in turn might influence their relocation decision, risk perception or disaster response.

Therefore, a question "Can you read Chinese?" was asked. Answers "Yes" or "Partially" were coded as 1 and "No" as 0.

Figure 5.11 shows that 64.93% of the Pingwu respondents replied they could read Chinese or at least could read some of it while 35.07% could not. In Wenchuan, apart from six respondents who did not answer the question, 75.35% replied they could read Chinese or at least could read some of it while 24.65% could not.

Figure 5.11 Distribution of respondents' Chinese literacy in the two counties



The Chinese literacy rate in Wenchuan was higher than that in Pingwu. This echoes the finding that Wenchuan respondents were generally more educated than their Pingwu counterparts. However, although the Chinese illiteracy rates in Pingwu and Wenchuan were different, both rates were much higher than the national and provincial figures.

Knowledge of Putonghua

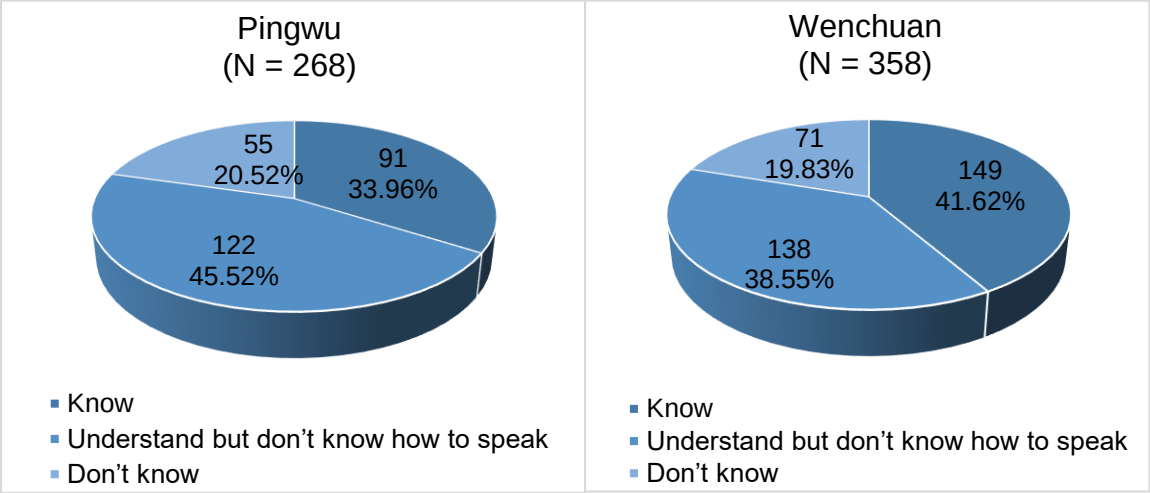
Putonghua is the official Chinese spoken language. Many educational messages and information disseminated by the government are delivered in Putonghua through television, radio, online and other channels. Knowledge of Putonghua might affect the receipt of official messages regarding disaster risk, mitigation, preparedness and response, and might in turn affect relocation decision, risk perception or disaster response.

The survey respondents were asked whether they knew Putonghua. Three answers were provided for selection: (1) Yes, I know; (2) Able to understand but don't know how to speak; (3) No, I don't know. The second choice was provided because many rural Sichuanese speak their own dialect in their daily lives and did not know how to speak Putonghua. But since many official communications use Putonghua, some residents were able to understand.

Apart from five Wenchuan respondents who did not answer the question, more than one-third (33.96%) and the greatest portion (41.62%) of all Pingwu and Wenchuan respondents respectively said they knew Putonghua (Figure 5.12).

Conversely, the greatest portion (45.52%) of Pingwu and more than one-third (38.55%) of Wenchuan respondents understood Putonghua but did not know how to speak. About one-fifth of both Pingwu (20.52%) and Wenchuan (19.83%) respondents said they did not know Putonghua at all.

Figure 5.12 Distribution of respondents' knowledge of Putonghua in the two counties



Respondents in Wenchuan was slightly more knowledgeable in Putonghua than those in Pingwu. This echoes the findings that Wenchuan respondents were generally more educated and more Chinese literate than their Pingwu counterparts.

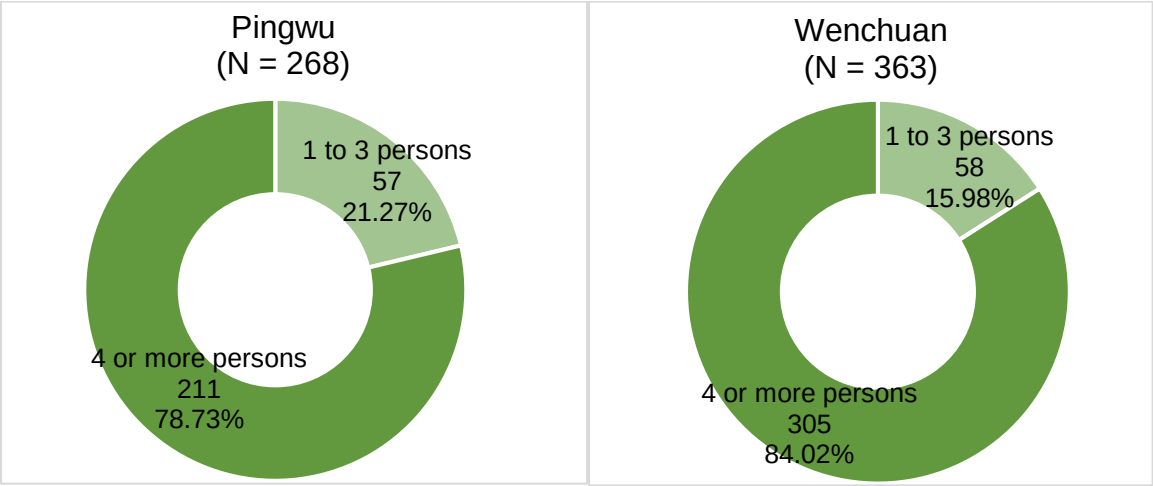
Household size

According to the Chinese official definition, a family household means a dwelling comprised of people mainly with relations of family members living together (State Council 2021b). The average family household sizes in China in 2015 and 2016 were 3.10 and 3.11 persons respectively while those in Sichuan were 3.02 persons in both years (NBSC 2016, 2017). Data analysis in this research take reference of this official Sichuan figure. By doing so, the possible relations between respondents' household sizes and the dependent variables in the hypotheses can be evaluated in a provincial context.

Based on the official definition, all survey respondents were asked for their household sizes through this question: "How many household members, apart from you, live in the same house here in this village?" The answers were divided into two groups: below the provincial average 3.02 persons and above. The answers with one to three persons were coded as 0 while those with four or more as 1.

In both counties, majority of the respondents (Pingwu 78.73% and Wenchuan 84.02%) came from bigger households with four or more persons (Figure 5.13). Only a minority of 21.27% in Pingwu and 15.98% in Wenchuan got small families with three or fewer members.

Figure 5.13 Distribution of respondents' household size in the two counties



When considering average household size, both counties yielded similar figures, with 4.93 and 4.98 persons in Pingwu and Wenchuan respectively (Table 5.5). Both were much bigger than the national and provincial averages.

Table 5.5 Mean household size, standard deviation and standard error of respondents in the two counties

	Pingwu	Wenchuan
Mean household size	**4.93**	**4.98**
Standard deviation (SD)	**2.01**	**1.74**
Standard error (SE)	**0.12**	**0.09**

Annual per capita net income

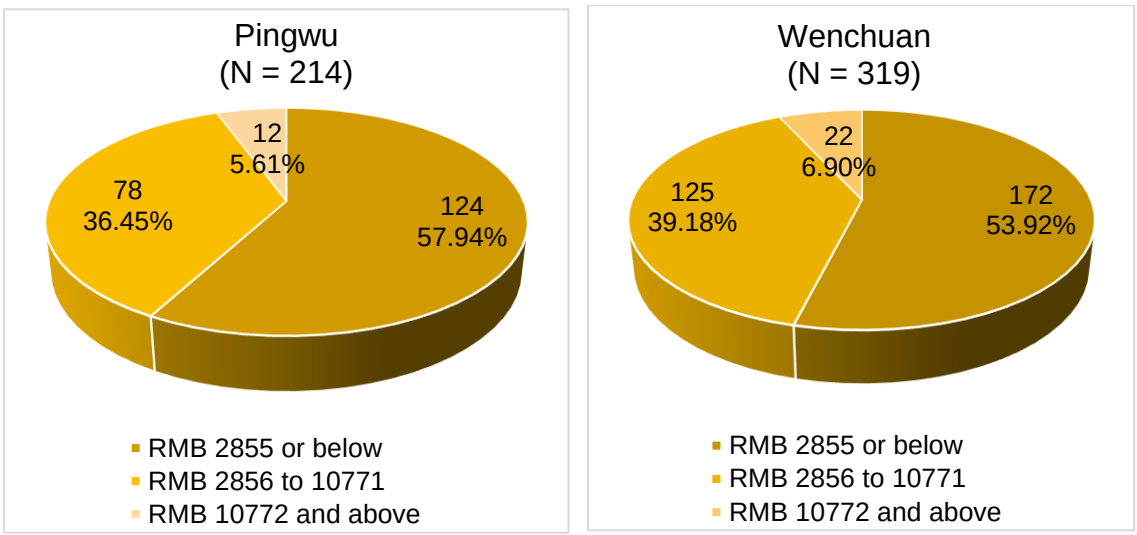
In 2015, annual per capita net income of rural populations in China was Renminbi (RMB) 10772 (NBSC 2016) while the poverty line was set at RMB2855 by The State Council (PDOE 2017).

Household income is widely recognised as an important indicator of living standards (UNDTCD 1989). In this research, the survey respondents were asked directly for their annual household income in RMB in total so as to reflect their living levels precisely. An open-ended question is applied as it is easier to respond to and can avoid misclassification, compared with a question using income bands (Kuhn 2019). By dividing the annual household income with the household size, annual per capita net income of each respondent was found. The answers were divided and coded into three groups: (1) RMB 2855 or below, i.e. on or below the poverty line; (2) RMB 2856 to RMB 10771, i.e. above the poverty line to below

annual rural per capita net income; and (3) RMB 10772 and above, i.e. annual rural per capita net income and above.

Among all 268 Pingwu and 363 Wenchuan respondents, 54 and 44 respectively did not know or did not want to disclose their household income and were counted as missing values.

Figure 5.14 Distribution of respondents' annual per capita net income in the two counties



Results show that income distributions of the respondents from the two counties were similar (Figure 5.14). Over half of both Pingwu (57.94%) and Wenchuan (53.92%) respondents earned an annual per capita net income on or below the poverty line RMB 2855. More than one-third (Pingwu 36.45% and Wenchuan 39.18%) lived with an income above the poverty line but below the national rural average. The rest and the smallest portion of only 5.61% in Pingwu and 6.90% in Wenchuan earned an income at the national rural average RMB 10772 or above.

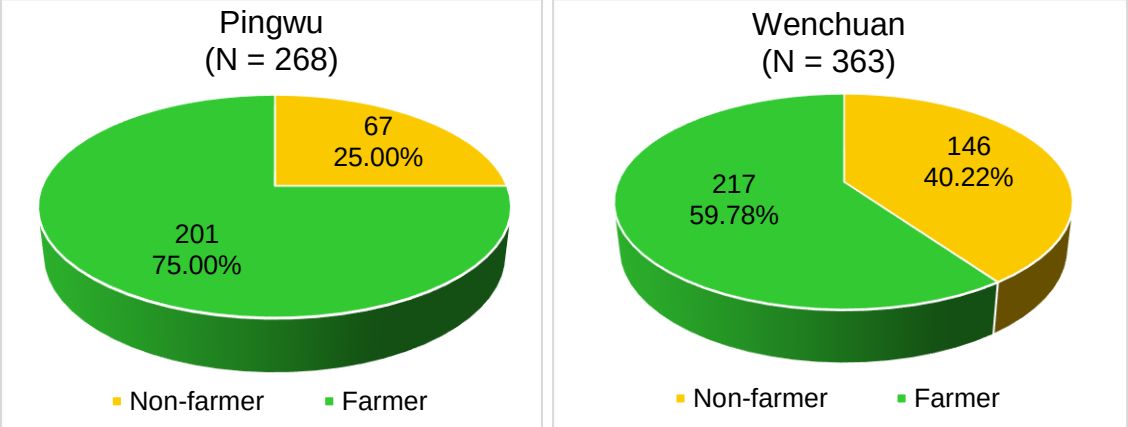
Occupation before the Wenchuan earthquake

Occupation of a person can be tied to his or her social class, which would presumably be likely to affect understanding of debris flows, relocation decision, risk perception and even disaster response.

The survey respondents were asked for their occupations both before and after the Wenchuan earthquake. Answers to both questions were divided into two categorical, independent groups: farmers were coded as 1 and non-farmers

(including businessmen, workers, students, people of other occupations and even the unemployed) as 0.

Figure 5.15 Distribution of respondents' occupation before the Wenchuan earthquake in the two counties



Occupations before the Wenchuan earthquake of respondents from Pingwu and Wenchuan were quite different (Figure 5.15). Although most respondents in both places were farmers, the proportion in Pingwu (75.00%) was much higher than that in Wenchuan (59.78%).

As for non-farmers, the proportion was 25.00% and 40.22% in Pingwu and Wenchuan respectively.

Occupation after the Wenchuan earthquake

China is an agricultural nation. The agricultural registered permanent residence population constituted to 70.86% and 73.19% of China and Sichuan total population respectively in year 2010 (SC and NBSC 2010). The proportions in village levels were even as high as 95.68% in China and 96.22% in Sichuan (Table 5.6).

Table 5.6 Distribution of agricultural and non-agricultural registered permanent residence population in China and Sichuan

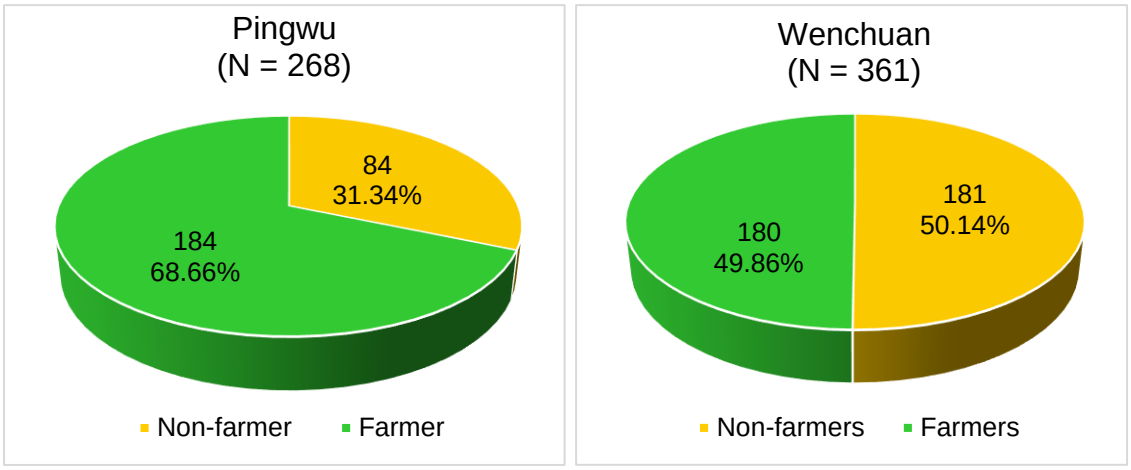
	Total population	Population of registered permanent residence	
		agricultural	non-agricultural
China	1,319,046,434 (100.00%)	934,707,073 (70.86%)	384,339,361 (29.14%)
Villages	653,343,884 (100.00%)	625,121,595 (95.68%)	28,222,289 (4.32%)
Sichuan	79,651,160 (100.00%)	58,295,744 (73.19%)	21,355,416 (26.81%)
Villages	47,432,745 (100.00%)	45,641,278 (96.22%)	1,791,467 (3.78%)

Source: SC and NBSC 2010.

Survey results show that in Pingwu, a majority of 68.66% of all respondents replied they were farmers after the quake and only 31.34% were non-farmers (Figure 5.16).

In Wenchuan, apart from two respondents who did not answer the question, slightly less than half (49.86%) said that they were farmers while slightly more than half (50.14%) were non-farmers.

Figure 5.16 Distribution of respondents' occupation after the Wenchuan earthquake in the two counties



When compared to the pre-earthquake period, the proportion of farmers after the Wenchuan earthquake dropped in both Pingwu (from 75.00% to 68.66%) and Wenchuan (from 59.78% to 49.86%). More respondents became non-farmers. But still, Pingwu had a higher proportion of farmers than Wenchuan.

When compared to the overall villages in Sichuan (96.22%) and China (95.68%), the proportion of farmers in both Pingwu (68.66%) and Wenchuan (49.86%) were much lower. This might due to the rapid economic development in China which turns many farmers in individual rural places like Pingwu and Wenchuan into non-farmers although they are still registered as agricultural permanent residents in government record. This could also due to the Wenchuan earthquake which destroyed farmlands and forced the Pingwu and Wenchuan residents to give up their original farming occupation.

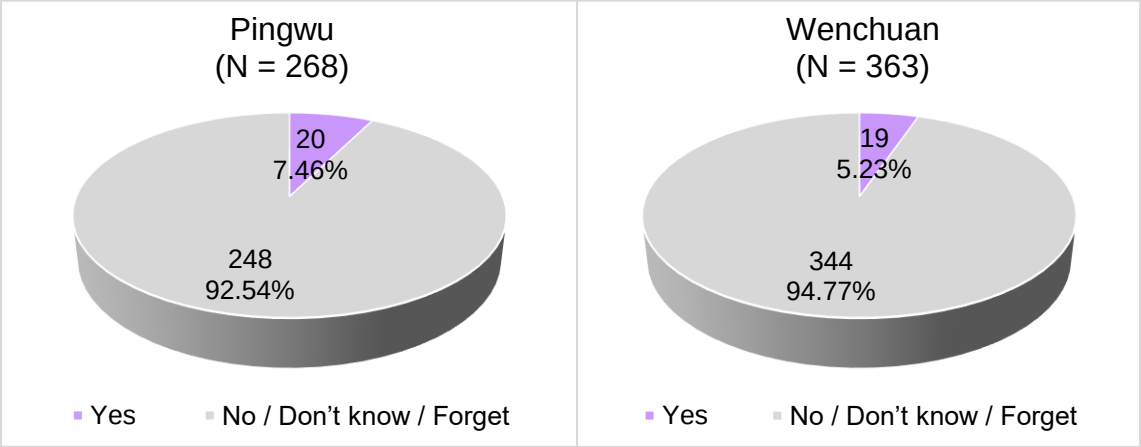
Role in Village

In rural China, some individuals serve as village leaders. These leaders are supposed to access more government information, including disaster-related

information, and have better knowledge of any debris flow risk and risk reduction measures in their villages.

Survey respondents were asked whether they performed any position or role in their villages, such as village head, secretary, village officer or geohazard monitoring personnel etc. Answers "yes" were coded as 1. Answers including "do not serve", "don't know" and "forget" were coded as 0. This variable is different from "occupation" which simply distinguishes "farmers" and "non-farmers".

Figure 5.17 Distribution of whether respondents performed any position or role in their villages in the two counties



Results show that only a small percentage of respondents in Pingwu (7.46%) and an even lower portion in Wenchuan (5.23%) did serve certain village roles (Figure 5.17). An overwhelming majority in both Pingwu (92.54%) and Wenchuan (94.77%) gave other answers.

Length of Stay

Respondents' length of stay in their communities per year might affect their understanding of the place, and might therefore influence their moving decisions, risk perceptions or disaster responses.

Like many other remote regions in China, some Pingwu and Wenchuan residents stay in their communities for the whole year but some floating populations work or study in cities or elsewhere outside the village hence might not live in their communities for part of the year or even the whole year.

The respondents were asked to state how long they stayed in their communities per year and were divided into two groups. Answers of those who stayed for full year were coded as 1. All others answers, including stayed shorter, did not live in their communities at all, did not know, not sure or inappropriate to answer were all coded as 0.

Figure 5.18 Distribution of respondents' length of stay in the community per year in the two counties

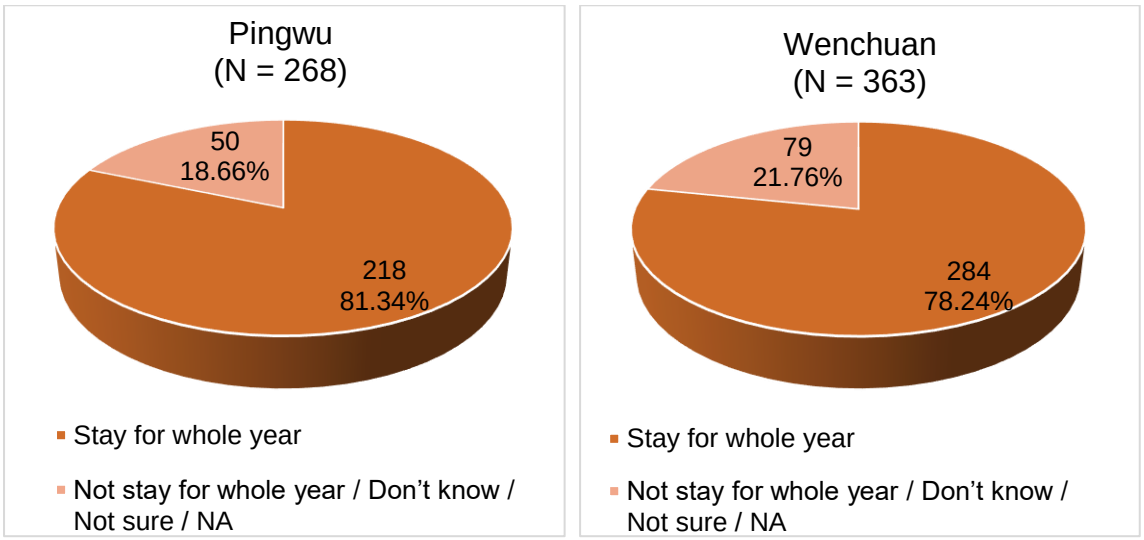


Figure 5.18 shows that in both counties, a great majority of the respondents resided in their communities for the whole year. The proportion in Pingwu (81.34%) was slightly higher than that in Wenchuan (78.24%). The minority Pingwu (18.66%) and Wenchuan (21.76%) respondents gave other answers.

Summary

The two counties were similar in their demographic conditions, except some differences in ethnical composition, educational attainment levels and occupation. Investigation on non-demographic independent variables of the two counties would further provide hints on what other factors, apart from demographic ones, might affect respondents' post-earthquake moving decisions (Hypothesis 1), debris flow risk perceptions (Hypothesis 2) and anticipated disaster responses (Hypothesis 3).

Non-demographic factors for testing Hypothesis 1

- Five groups composed of 25 Likert items that might directly affect the decision to move or not

In Hypothesis 1, demographic factors were put under “Group 1”. The respondents were further asked 25 questions regarding their possible consideration when deciding whether to move to reside in another place after the 2008 earthquake. The answers were set on a 5-point Likert-type rating scale, ranging from (1) Strongly disagreed, (2) Disagreed, (3) Neutral, (4) Agreed to (5) Strongly agreed.

The 25 Likert items in the form of statements measuring five subscales in both Pingwu and Wenchuan are shown in Table 5.7. They were put into five groups: 2A, 2B, 3A, 3B and 4.

The average score, standard deviation (SD) and standard error (SE) of each of the 25 items were calculated. The score of each of the five subscales were also obtained by summing up and averaging the scores of the items grouped under it. The higher the average score gained by a subscale, the bigger the consideration of that dimension by the respondents when they decided whether to move.

Table 5.7

25 Likert items measured in five groups

Group	Variable Likert item	Pingwu (N = 268)			Wenchuan (N = 356)		
		Mean	**SD**	**SE**	**Mean**	**SD**	**SE**
2A	**Factors regarding the exposure and susceptibility of survey respondents and their homes proposed in existing models (BBC, Alexander 1997, 2000, 2007, MOVE)**						
	(i). Whether the new place would be affected by earthquake.	3.42	0.97	0.06	3.46	0.90	0.05
	(ii). Whether the new place would be affected by debris flow.	3.40	0.95	0.06	3.49	0.91	0.05
	(iii). The topography and landscape of the new place.	3.38	0.95	0.06	3.34	0.92	0.05
	(iv). Whether the place I originally lived was safe.	3.45	0.96	0.06	3.27	0.89	0.05
	(v). Home's current location made me feel safer than the location before the Wenchuan earthquake.	3.49	0.86	0.05	3.32	0.98	0.05
	(i) to (v)	**3.43**	**0.63**	**0.04**	**3.38**	**0.66**	**0.04**
2B	**Other factors regarding survey respondents' homes NOT mentioned in existing models** **-- Cultural/ Historical/ Social cohesion / Family/ Ethnical / Neighbourhood factors**						
	(i). Whether I liked the place I originally lived and did I belong to the place.	3.02	0.84	0.05	2.96	0.78	0.04
	(ii). Whether my ancestors also resided in the place I originally lived.	3.05	0.83	0.05	2.93	0.75	0.04
	(iii). Whether I liked the neighbours of my original home.	2.91	0.86	0.05	2.84	0.75	0.04
	(iv). Whether my children studied nearby the place I originally lived.	2.84	0.84	0.05	2.97	0.82	0.04
	(v). Whether the new place had sufficient land to accommodate my family members.	3.29	0.93	0.06	3.33	0.84	0.04
	(vi). Whether the neighbours of my previous home were of the same ethnic group as me.	2.84	0.83	0.05	2.76	0.68	0.04
	(vii). Whether the neighbours of the place I would move to were of the same ethnic group as me.	2.82	0.81	0.05	2.77	0.68	0.04
	(i) to (vii)	**2.97**	**0.55**	**0.03**	**2.94**	**0.51**	**0.03**

(cont,) Group	Variable Likert item	Pingwu (N = 268) Mean	SD	SE	Wenchuan (N = 356) Mean	SD	SE
3A	**Factors regarding individual/ economic competencies (as part of coping capacity) proposed in existing models -- Financial support from various sources (BBC) or funding availability (Hogg 1980, cited in Alexander 2007, p.xvi-xvii) -- Economic vulnerability (Alexander 1997)**						
	(i). Whether I had the money to move.	3.38	0.95	0.06	3.37	0.86	0.05
	(ii). Whether I had sufficient money to build a new house somewhere else.	3.40	0.96	0.06	3.40	0.85	0.04
	(iii). Whether there was any subsidy to move to another place.	3.35	0.90	0.05	3.34	0.84	0.04
	(iv). Whether moving to somewhere else required me to give up my farmland.	2.98	0.92	0.06	2.90	0.82	0.04
	(v). Whether the new place was nearby my farmland.	3.11	0.94	0.06	3.07	0.90	0.05
	(i) to (v)	**3.24**	**0.66**	**0.04**	**3.22**	**0.62**	**0.03**
3B	**Factors regarding individual/ personal competencies (as part of coping capacity) NOT mentioned in existing models**						
	(i). Whether I were afraid of moving to a new place.	2.67	0.78	0.05	2.79	0.75	0.04
	(ii). Whether the moving process was too complicated for me and my family and could be handled.	3.03	0.91	0.06	3.21	0.83	0.04
	(iii). Whether I could tackle debris flow risk.	2.98	0.80	0.05	3.02	0.76	0.04
	(iv). Whether the government would take care of me, including the provision of accommodation if I am affected by debris flow.	2.90	0.81	0.05	3.09	0.79	0.04
	(v). Whether the government would provide training for me to tackle debris flow.	2.73	0.76	0.05	2.93	0.72	0.04
	(i) to (v)	**2.86**	**0.55**	**0.03**	**3.01**	**0.52**	**0.03**
4	**Factors regarding other coping capacities influenced by government or political institutions regarding the new residing place that can avoid geological risks NOT proposed in existing models**						
	(i). The government said whether the new residing place is safe.	3.27	0.96	0.06	3.46	0.89	0.05
	(ii). Whether the government had introduced effective geotechnical engineering measures, including sediment trap dam, to the new residing place.	2.87	0.85	0.05	3.12	0.81	0.04
	(iii). Whether the government had introduced effective disaster preparedness measures, including risk notifications, early warnings and disaster response, to the new residing place.	2.88	0.84	0.05	3.04	0.75	0.04
	(i) to (iii)	**3.01**	**0.67**	**0.04**	**3.21**	**0.68**	**0.04**

Three out of the five groups, namely factors regarding: exposure and susceptibility (Group 2A), respondents' homes (Group 2B) and individual economic competencies (Group 3A), yield similar mean scores from Pingwu and Wenchuan. The mean score for Group 2A is 3.43 (SD 0.63, SE 0.04) for Pingwu and 3.38 (SD 0.66, SE 0.04) for Wenchuan. For Group 2B, the mean score is 2.97 (SD 0.55, SE 0.03) for Pingwu and 2.94 (SD 0.51, SE 0.03) for Wenchuan. The mean score for Group 3A is 3.24 (SD 0.66, SE 0.04) for Pingwu and 3.22 (SD 0.62, SE 0.03) for Wenchuan. These mean when the respondents decided whether to move after the quake, considerations of these three groups of factors were very similar in both counties. However, the mean scores regarding personal competencies (Group 3B) and other coping capacities influenced by government on the new residing place that can avoid geological risks (Group 4) were different for the two counties. The mean score for Group 3B is 3.01 (SD 0.52, SE 0.03) in Wenchuan but only 2.86 (SD 0.55, SE 0.03) in Pingwu. The mean score for Group 4 is 3.21 (SD 0.68, SE 0.04) in Wenchuan and only 3.01 (SD 0.67, SE 0.04) in Pingwu. These indicate that Wenchuan respondents considered these two groups of factors more than their Pingwu counterparts when making moving decisions. These two groups of factors influenced more on Wenchuan respondents.

Non-demographic factors for testing Hypotheses 2 and 3 - that might affect risk perception and disaster response

Respondents' village affiliation, debris flow experience, knowledge of debris flows, perception of both substantial debris flow and community/home remoteness might affect their perception of existing community debris flow threat or anticipated behavioural response when see debris flow signs.

Village affiliation

All survey respondents were living in villages attacked by or exposed to post-2008 earthquake debris flow threat. Some villages were physically closer to debris flow risk sources or affected by debris flows more frequently.

The respondents were divided into groups according to their village affiliation. The 268 Pingwu respondents were from two villages. Xinjian Village had 138 residents and they are coded as 1 while the other 130 from Niufei Village are coded as 2.

The 363 Wenchuan respondents came from three villages. The 127 lived in Xingfu were coded as 1, the 115 from Longtan were coded as 2 while the other 121 resided in Wolongguan were coded as 3.

Experience of debris flow

Since all the five villages studied were affected by debris flows to various extent, the villagers could have certain experiences with debris flows. Significance of hazard experience was noted by vulnerability models (BBC; Wisner 2001). In this research, this is elaborated as the percentage of people having debris flow experience as in the MOVE framework.

- **Experience and Community risk perception**

To find the possible influence on community risk perception, the independent variable, respondents' debris flow experience, is evaluated on two levels: community and personal. Each respondent was asked:

(1) *In the past, had any debris flow occurred in your group/community?* and

(2) *Have you yourself experienced debris flow?*

These two questions tended to distinguish different debris flow experiences in terms of their different levels of impact, i.e. community and personal, respectively.

For each question, choices of answers specifying different time periods were provided. If a respondent had experienced debris flow before, he or she could select one or more time slot(s): (1) Yes, before 2008 Wenchuan earthquake. (2) Yes, 2008 Wenchuan earthquake to before 2013 Lushan earthquake, (3) Yes, 2013 Lushan earthquake and after, (4) Yes, but I forget exactly when. However, since the number of response on each of the four answers is too small, respondents giving a "Yes" answer, no matter which time slot they chose, would have their answers simply grouped as "Yes" during statistical analysis.

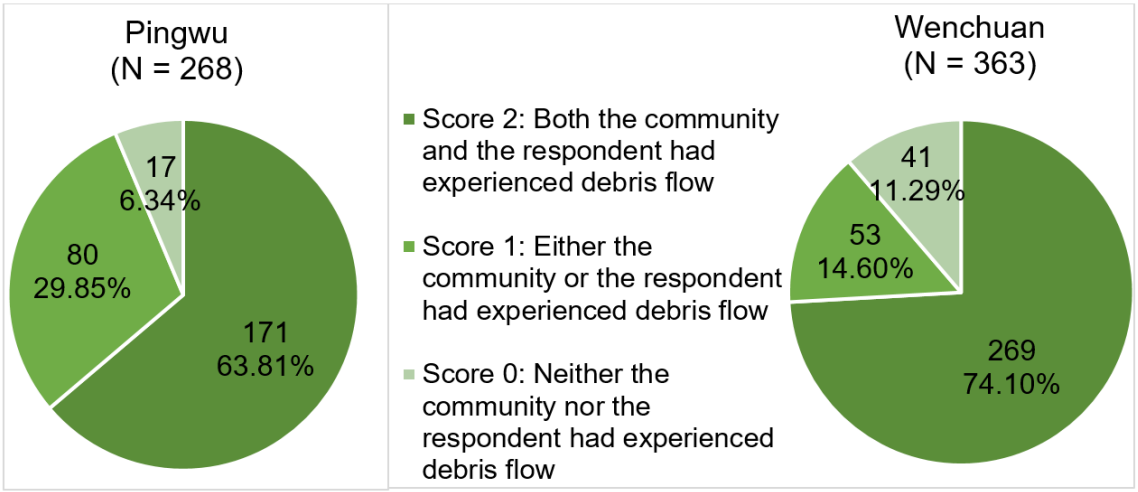
Answering "No / I don't know / I forget / Not applicable" to both the community and personal questions would score 0, replied "Yes" to one question would score 1, and replied "Yes" to both, i.e. more experienced in debris flow, would score 2.

In both counties, most respondents scored 2, followed by scored 1, and the least of them scored 0 (Figure 5.19).

In Pingwu, 63.81% of all respondents said their communities had debris flow occurred in the past, and they personally had experienced debris flow as well. The percentage was even higher in Wenchuan (74.10%).

In Pingwu, only 6.34% replied “no” to both questions. The percentage in Wenchuan was higher at 11.29%.

Figure 5.19 Community and personal experience of debris flow

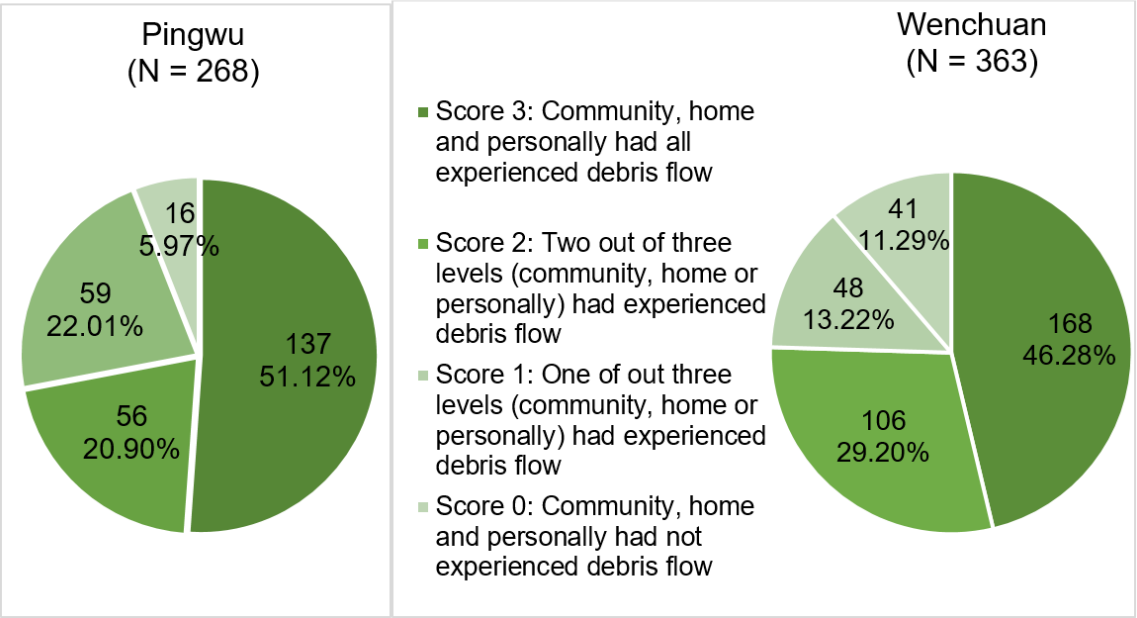


➢ **Experience and Disaster response at home**

In testing whether the respondents debris flow experiences would influence their disaster responses when they see debris flow signs at home, the independent variable, debris flow experience, is evaluated on three levels. Besides community and personal levels, each respondent was also asked to recall whether his or her home had been affected by debris flow in the past. Answering “no” to all three questions would score 0, “Yes” to one would score 1, “Yes” to two would score 2, and answering “Yes” to all three questions would score 3.

The trend in both counties are, again, quite similar. Most respondents scored 3, followed by 2 or 1, and the least of them scored 0 (Figure 5.20).

Figure 5.20 Community, home and personal experience of debris flow



A slight majority (51.12%) of all Pingwu respondents had experienced debris flow on all three levels. Only a small portion (5.97%) had never experienced before. The rest had experienced on one (22.01%) or two level(s) (20.90%).

For Wenchuan, the greatest portion (46.28%) of all respondents had experienced debris flow on all three levels. This percentage is slightly lower than that in Pingwu. The smallest portion (11.29%) had never experienced. The rest had experienced one (13.22%) or two levels (29.20%).

Perception of substantial debris flow

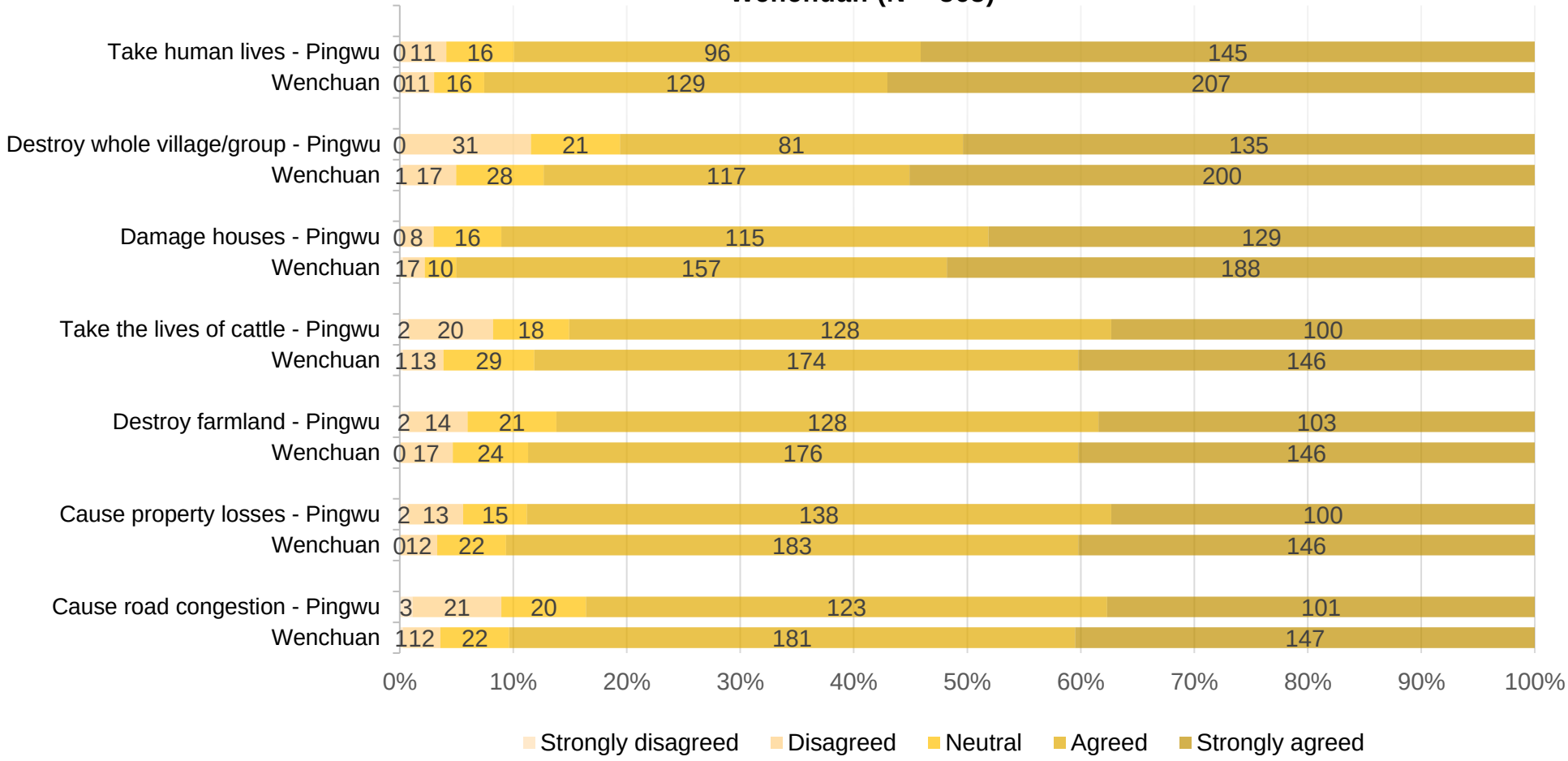
After the 2008 earthquake, the law stated that reconstruction should avoid region with substantial hazard risk (State Council 2008a). Perception of substantial debris flow reflects individual competencies in understanding debris flows which are particularly devastating. This is a new factor not mentioned in existing vulnerability models but helps to test Hypothesis 2 and 3.

The independent variable, perception of substantial debris flow, is measured on a five-level Likert scale, from (1) Strongly disagreed to (5) Strongly agreed. The respondents were given a set of seven statements and were asked whether they agreed those constitute to substantial debris flow (Figure 5.21). The higher the score means one perceived substantial debris flow as more dangerous. Each respondent would attain an average score out of the seven statements.

A great majority of at least 80% of respondents from both counties strongly agreed or agreed with all the seven statements, indicating most of them perceived substantial debris flow as dangerous in the seven aspects. In particular, over 90% of respondents from both counties strongly agreed or agreed that substantial debris flow could damage houses.

Conversely, the statement “A debris flow which can destroy the whole village or group/community” yielded the highest disagreement, with 11.57% and 4.96% of Pingwu and Wenchuan respondents strongly disagreed or disagreed.

Figure 5.21 Perception of substantial debris flow
Pingwu (N = 268)
Wenchuan (N = 363)



The overall perception of substantial debris flow as dangerous is also reflected by the average score of the answers to the seven statements. The mean scores of all the seven statements in both places are bigger than 4.1, with standard deviation ranged from .672 to 1.005, and standard error ranged between .035 and .061 (Table 5.8).

Table 5.8 Mean, standard deviation and standard error of substantial debris flow perception

Perception of substantial debris flow	County	Mean	Standard deviation	Standard error
Take human lives	Pingwu	4.39	.820	.050
	Wenchuan	4.47	.721	.038
Destroy whole village/group	Pingwu	4.19	1.005	.061
	Wenchuan	4.37	.839	.044
Damage houses	Pingwu	4.36	.729	.045
	Wenchuan	4.44	.672	.035
Take the lives of cattle	Pingwu	4.13	.889	.054
	Wenchuan	4.24	.770	.040
Destroy farmland	Pingwu	4.18	.842	.051
	Wenchuan	4.24	.774	.041
Cause property losses	Pingwu	4.20	.808	.049
	Wenchuan	4.28	.722	.038
Cause road congestion	Pingwu	4.11	.925	.057
	Wenchuan	4.27	.742	.039

Knowledge of debris flows

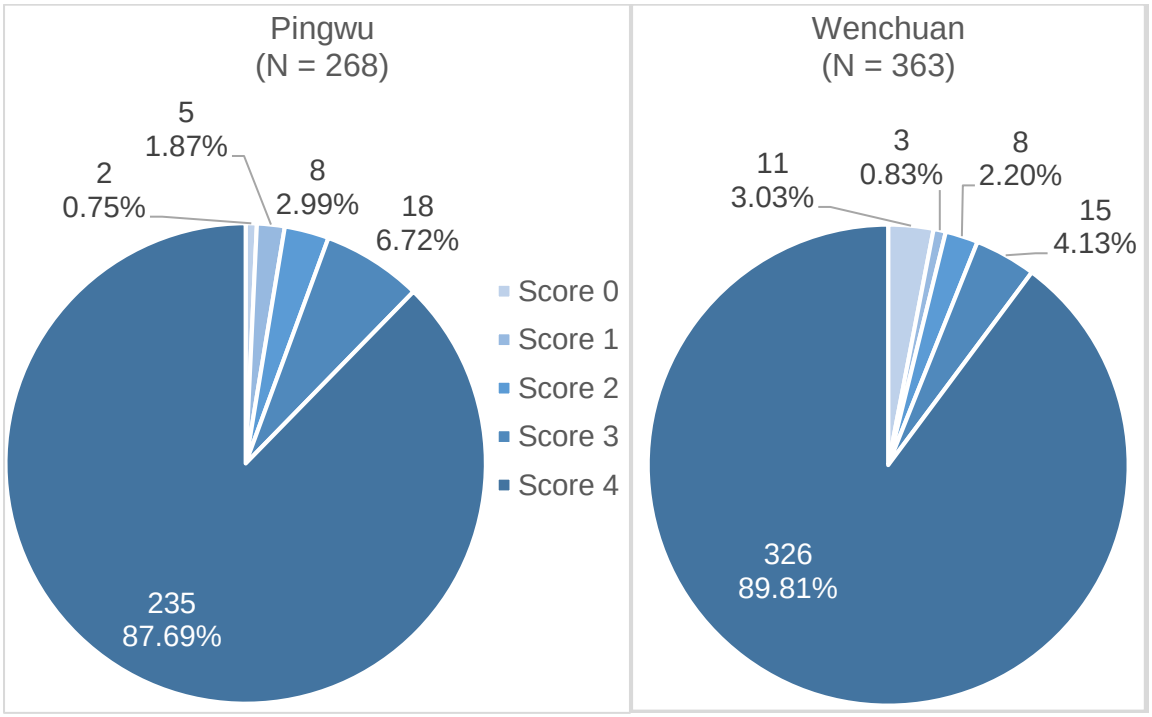
All the five villages studied were affected by debris flow to various extent. Therefore the villagers could have certain knowledge of this hazard. Significance of people's hazard knowledge was noted by various vulnerability models (BBC; MOVE; Wisner 2001; Alexander 2007). Investigating the level of debris flow knowledge in the study areas could help to assess how risk perception and disaster response might be affected. Regardless whether the respondents had experienced debris flow, their knowledge of this hazard is evaluated independently through four survey questions. The answer to each of these four questions should be "Yes":

1. Can debris flow cause casualties?
2. Can debris flow cause property losses?
3. Can debris flow cause economic consequences and losses?
4. Can debris flow cause transport problem and road congestion?

Respondents answering “Yes” to one question would score one mark. A maximum of four points could be gained.

A great majority of respondents in both Pingwu (87.69%) and Wenchuan (89.81%) got full score (Figure 5.22). Only 0.75% and 3.03% respectively scored zero.

Figure 5.22 Knowledge of debris flows (Score 0 to 4)



Respondents’ good debris flow knowledge is also reflected in the average score. Pingwu respondents have a mean score of 3.79 out of 4 (SE .040, SD .656) while Wenchuan respondents scored an average of 3.77 (SE .042, SD .798).

Perception of remoteness of community

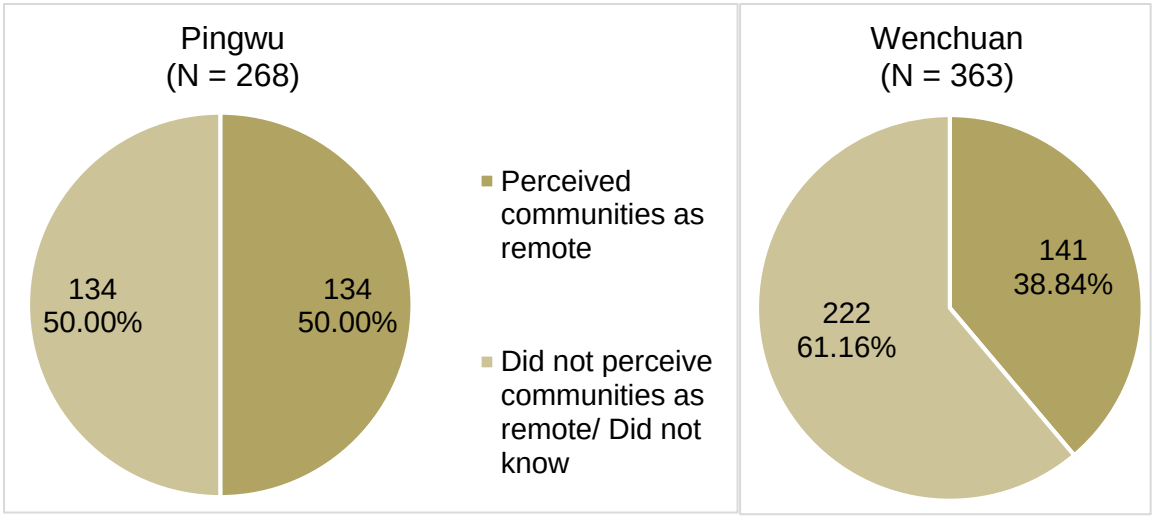
Isolation (Wisner 2001) and even family and social networks to tackle hazards (BBC) could relate to and/or affect vulnerability.

To test Hypothesis 2, the respondents were asked whether they perceived their communities as remote. Perception of remoteness, rather than actual remoteness, is used here. This is because, as noted in the methodology chapter, the actual remoteness of the study areas could be reflected by concrete indicators like distance from the provincial capital Chengdu. It duplicates the representativeness of an above mentioned variable “village affiliation” which is divided into five

categories according to the five studied villages with five different distances from Chengdu. Perception of remoteness is adopted also because by actual measures, the sampled populations in Pingwu and Wenchuan respectively should have very similar degrees of remoteness.

Perception of community remoteness is a binary, categorical variable. The answers are divided into “Yes” (coded as 1) and “No” or “I don’t know” (coded as 0).

Figure 5.23 Perception of remoteness of communities



The views in Pingwu were bipolar (Figure 5.23). Exactly half of the respondents perceived their communities as remote. The other half did not or simply did not know.

Unlike Pingwu, only about one-third of the Wenchuan respondents (38.84%) perceived their communities as remote. Majority of them (61.16%) did not or simply did not know.

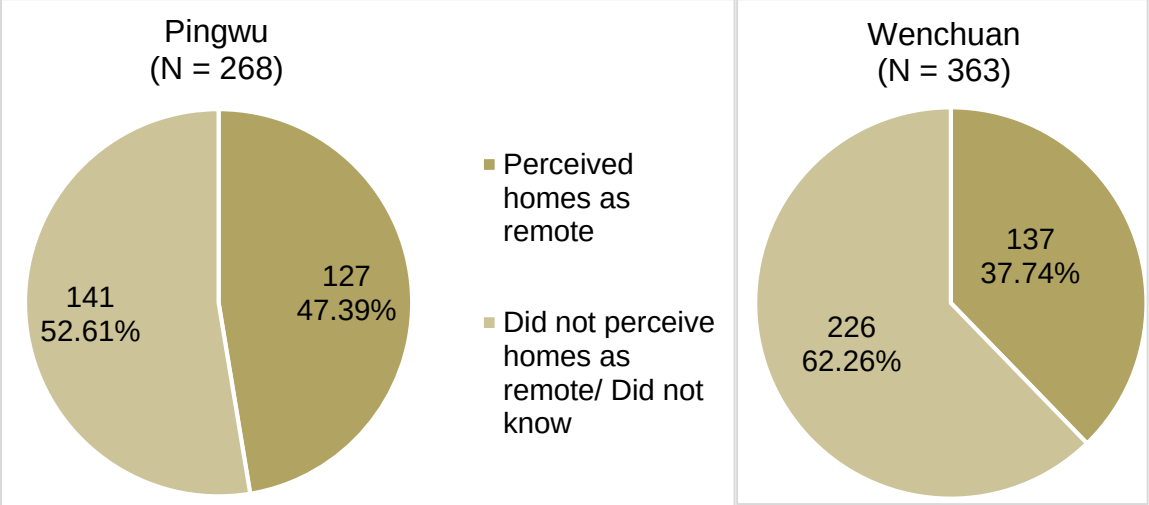
Perception of remoteness of home

To test Hypothesis 3, each respondent was asked whether he or she perceived his or her home, instead of community in Hypothesis 2, as particularly remote. The answers are also divided into two categorical, independent groups: “Yes” (coded as 1), and “No” or “I don’t know” (coded as 0).

Results reveal that the perception of home remoteness was quite similar to the perception of community remoteness for both counties (Figure 5.24). Slightly less

than half of all Pingwu (47.39%) and about one-third of Wenchuan (37.74%) respondents perceived their homes as remote. A slight majority in Pingwu (52.61%) and a bigger majority in Wenchuan (62.26%) did not perceive so or simply did not know.

Figure 5.24 Perception of remoteness of homes



Government risk reduction factors for testing Hypotheses 2 and 3 - that might affect risk perception and disaster response

Disaster risk perception and response behaviour might be affected by the effectiveness of disaster mitigation, preparedness and response measures imposed by the government after the earthquake. For instance, the government has imposed different forms of geotechnical engineering mitigation measures in debris flow affected villages. The government has also assessed debris flow risk regularly, disseminated the risk of debris flow through various publicity channels (e.g. booklet, disaster prevention cards, geohazard disaster prevention plan), promoting various early warning tools (e.g. website, siren/loud speaker, phone messaging, gong and shout) reachable in daily lives by rural villagers, designed evacuation route, organised risk reduction trainings and drills etc. Whether these disaster preparedness and response measures were aware of and to what extent they would influence risk perception and behaviour of the threatened villagers were evaluated in this thesis.

Government disaster mitigation (engineering) measures

After the 2008 earthquake, the government has introduced various kinds and scales of structural, geotechnical or engineering measures such as debris sediment trap dams, drainage channels and artificial step-pools in geohazard-affected communities, depending on local needs. The aim was to alleviate the potential impact of debris flow and other geohazard risks that might be induced by the earthquake. Some are less costly emergency risk reduction engineering measures while some are larger scale engineering mitigation.

- **Emergency risk reduction**

For those geohazard sites considered as easier to mitigate with lower cost and could finish construction in a shorter timeframe, emergency risk reduction engineering measures would be imposed by the Sichuan government (SGIO 2015a).

- **Engineering mitigation**

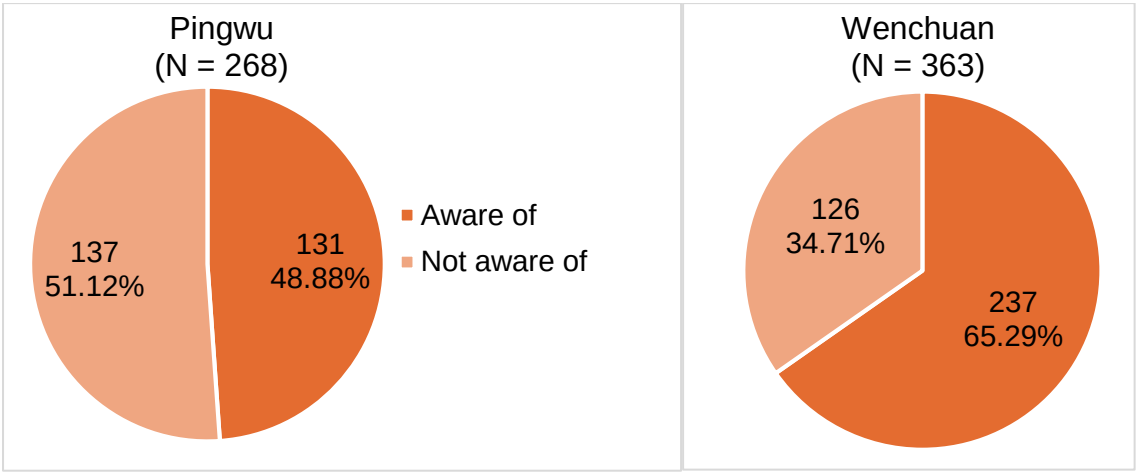
A more costly measure was engineering mitigation, usually adopted in relatively big scale geohazard sites with high risk, affecting cities, towns or settlement sites, great impact yet relocation was unsuitable (SGIO 2015a). Inspection and investigation must be done to evaluate the type, distribution, scale, cause, development trend and geohazard risk level before a mitigation plan is proposed (SGIO 2015a).

Rural residents' awareness of geotechnical engineering measures introduced in their communities were investigated. The answers are divided into two categorical, independent groups: (1) aware and (2) unaware.

The respondents were asked a set of four questions on whether their communities have introduced three specific kinds of geotechnical engineering measures that were common to resist debris flow in the study areas, together with a fourth one "others". The three measures were: sediment trap dam, drainage channel and artificial step-pool. If a respondent answered "Yes (aware of)" to at least one of the measures, the answer was coded as 1. If he or she replied "No (not aware of)" or "I don't know / I forget" to all questions, the answer was coded as 0.

Slightly less than half (48.88%) of Pingwu respondents were found aware of certain geotechnical engineering measure(s) introduced in their communities. Slightly more than half (51.12%) were unaware of (Figure 5.25).

Figure 5.25 Awareness of geotechnical engineering measures introduced in the communities



Conversely, in Wenchuan, the majority of respondents (65.29%) were aware of the introduction of certain structural measure(s) in their communities. Only 34.71% were unaware of or simply did not know.

Government disaster preparedness measures

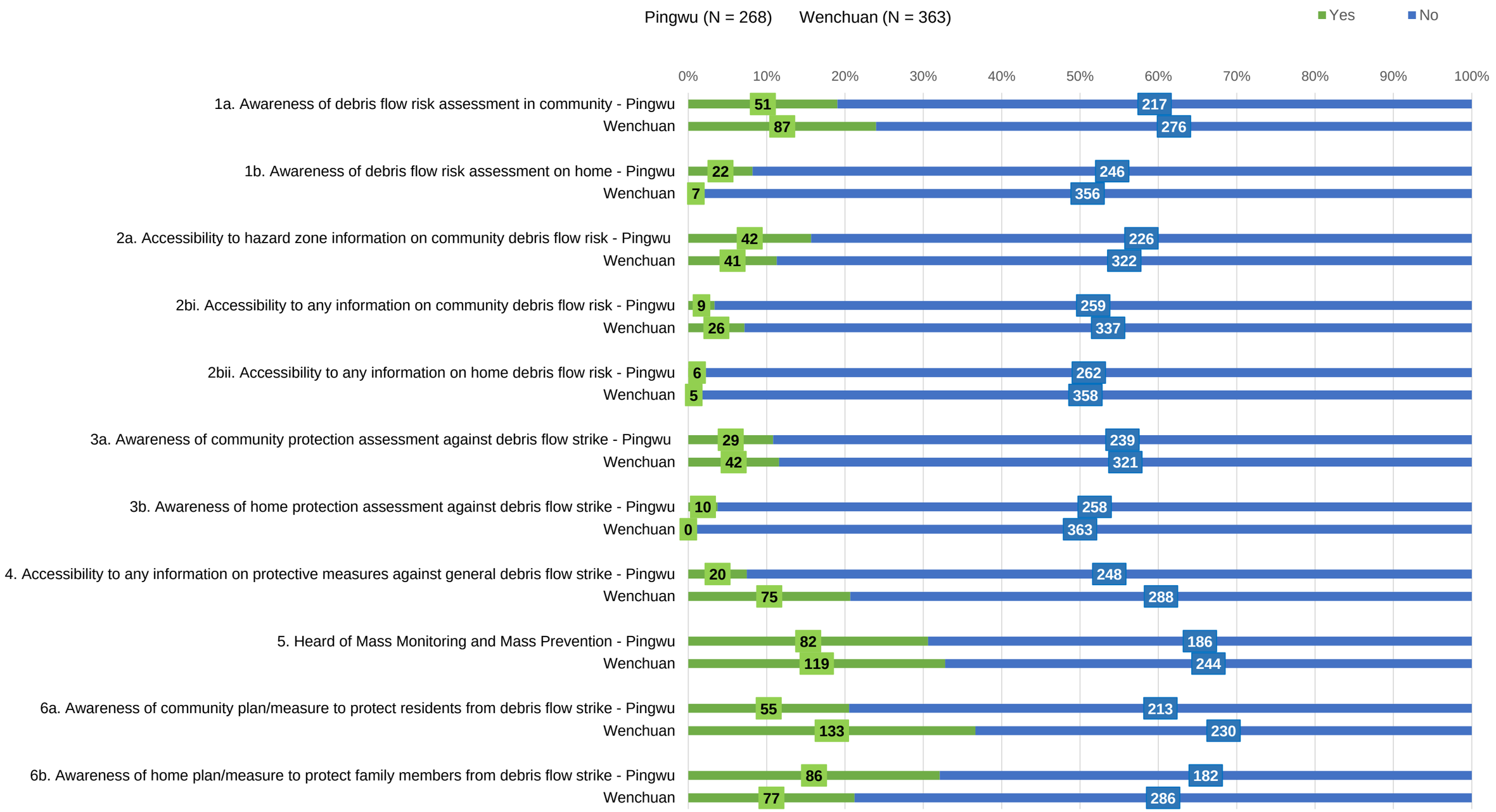
The Chinese government has introduced various disaster preparedness measures after the 2008 earthquake aiming to reduce risk of different geohazards, including debris flow.

A set of 11 questions, grouped under six categories, were asked in the survey to investigate whether the villagers were aware of the introduction of, or had accessed to, such government disaster preparedness measures in their communities or homes. Such measures include the assessment of debris flow risk and protection, information dissemination on debris flow risk, protective measures as well as Mass Monitoring and Mass Prevention (MMMP), and also protection plan. Most were introduced on a community level while a few were on individual homes. These measures might affect respondents' risk perceptions and/or their responses when see debris flow signs at home.

For each question, the respondents could answer either "Yes" or "No / I don't know / I forget / Not applicable" which were then coded as 1 and 0 respectively.

Figure 5.26 shows the survey outcomes of respondents' awareness of or accessibility to such 11 governmental disaster preparedness measures. The data is presented in Pingwu-Wenchuan pairs for easy comparison.

Figure 5.26 **Awareness of / Accessibility to government disaster preparedness measures**



Basically the respondents were not very aware of or accessed to the preparedness measures. Eight out of the 11 measures (sub-variable 1a to 4) were aware of or accessed by less than 25% of respondents in both counties.

The most aware of was “community plan or measure to protect residents” in Wenchuan (sub-variable 6a). A total of 133 out of 363 respondents were aware of it, yet this constituted to only 36.64% of the samples. The least aware of measure was “assessment on protection against debris flow hit on home” (sub-variable 3b). No Wenchuan respondent was aware of it.

Government disaster response measures and facilities

The government has also introduced various disaster response measures and facilities to the communities exposed to the Wenchuan earthquake induced debris flow risk.

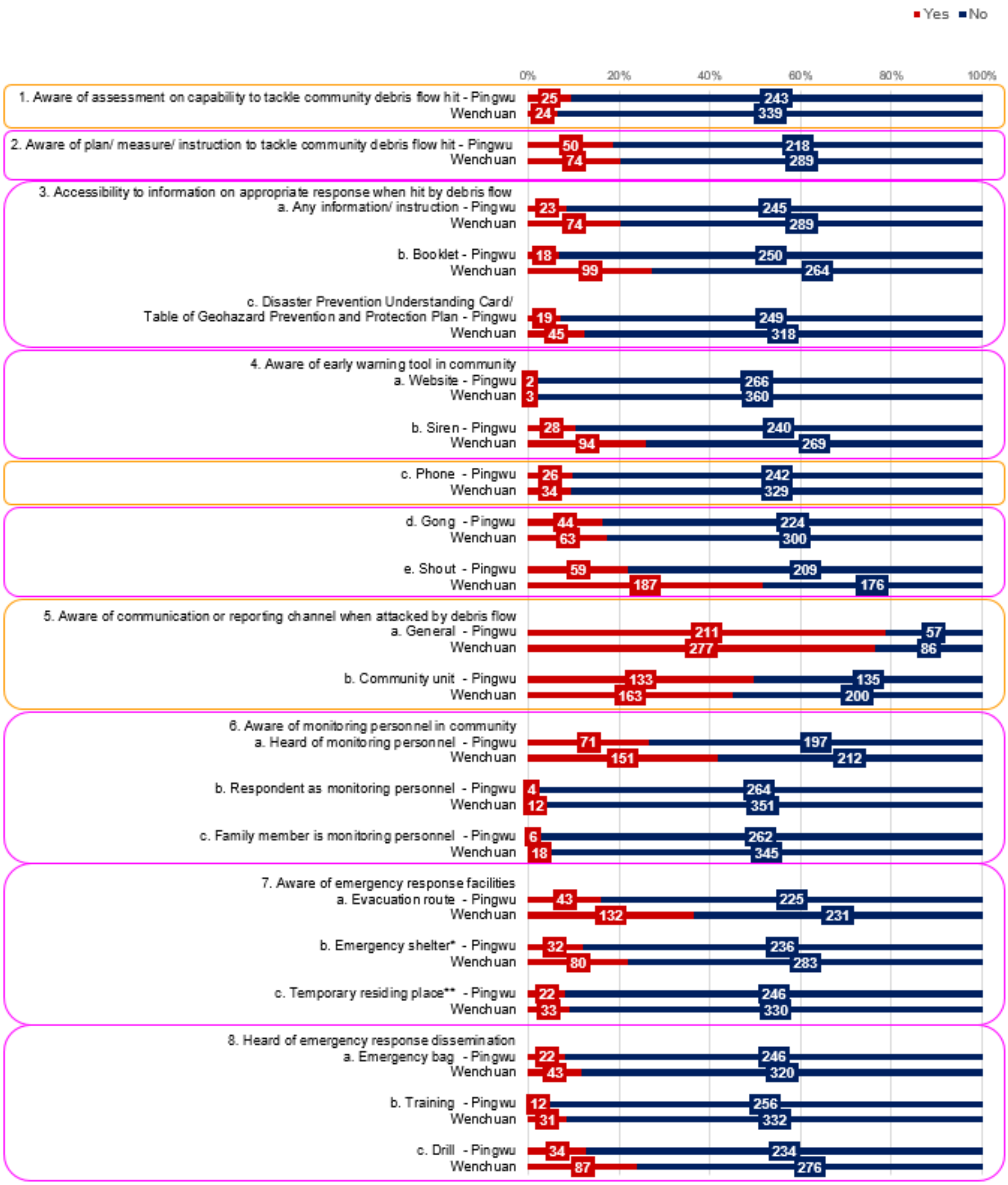
The respondents were asked a set of 21 questions categorised in eight groups regarding their awareness of or accessibility to 21 disaster response measures or facilities.

For each question, an answer “Yes”, meaning aware of or accessed to such measure or facility, was coded as 1, and “No / I don’t know / I forget / Not applicable” was coded as 0. The awareness of or accessibility to such measures or facilities might affect debris flow risk perception and/or disaster response.

The frequency distributions of the respondents’ answers to each question are listed in Figure 5.27. Pairs of Pingwu-Wenchuan data are presented for easy comparison.

Figure 5.27 Awareness of/ Accessibility to government disaster response measures and facilities

Pingwu (N = 268) Wenchuan (N = 363)



*In the survey, the term "emergency shelter" is similar to "assembly area" where the disaster-affected can quickly gather-together and stay safe during debris flow hit, but they probably cannot live there.
**Another term "temporary residing place" means a place where the disaster-affected can accommodate for days after a disaster attack.

Generally speaking, respondents' awareness of or accessibility to the 21 government disaster response measures or facilities was mainly lower than 50% in both counties. There were only two measures in which the aware group is bigger than the unaware group. The first one is the awareness of the communication channel when see debris flow signs in general situations (sub-variable 5a). Over 70% of respondents from both counties were aware of it. The second one is shouting. In Wenchuan, the respondents who were aware of shout as an early warning tool is slightly more than those who were unaware of. In Pingwu, however, most respondents were unaware of it.

When comparing the two counties, Wenchuan respondents' had higher awareness of or more accessible to five out of eight categories of disaster response measures or facilities (variables 2, 3, 6, 7 and 8, marked in pink brackets). Pingwu respondents were more aware of or more accessible to only two (variables 1 and 5, marked in orange brackets). For the remaining category, awareness of early warning tools (variable 4), Wenchuan respondents were more aware of four of them (sub-variables 4a, 4b, 4d and 4e), while Pingwu respondents were only slightly more aware of phone (variable 4c).

If the eight variables are broken down into 21 sub-variables, Wenchuan respondents were more aware of or more accessible to 17 of them, among which 12 yielded particularly higher awareness or accessibility. They are: all three types of information on appropriate response when debris flows strike (sub-variables 3a, 3b and 3c), two early warning tools, namely siren and shout (sub-variables 4b and 4e), all three aspects regarding monitoring personnel (sub-variables 6a, 6b and 6c), two of out three emergency response facilities (sub-variables 7a and 7b) and two out of three types of emergency response dissemination (sub-variables 8b and 8c).

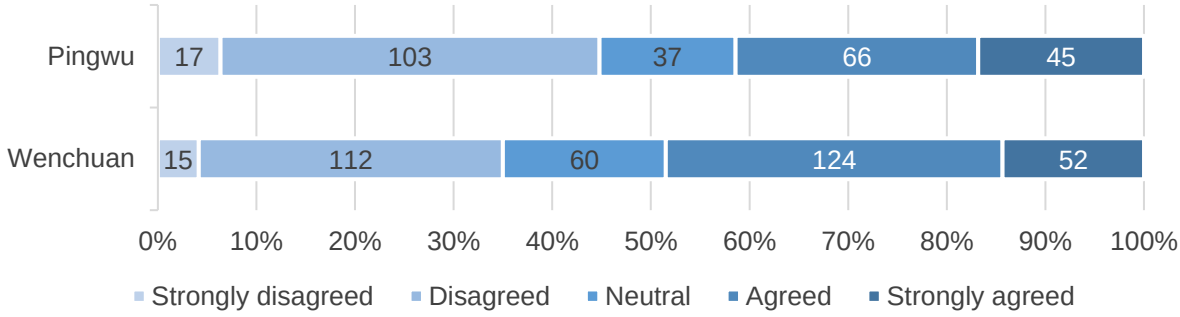
Conversely, Pingwu respondents were more aware of only four measures. Besides the use of phone as an early warning tool (sub-variable 4c), the other three are: assessment on capability to tackle community debris flow strike (sub-variable 1), as well as awareness of communication channels in both the general situation and on community level during debris flow attack (sub-variables 5a and 5b).

Perception of existing debris flow threat on homes for testing Hypotheses 3

Perception of existing debris flow threat on home might affect one's disaster response. Therefore respondents' risk perception of their homes were asked in the survey to test Hypothesis 3.

Results show that at least two in five respondents in both counties perceived their homes threatened by existing debris flow (Figure 5.28).

Figure 5.28 Perception of existing debris flow threat on homes



In Pingwu, (41.42%) perceived existing debris flow threat on their homes. A slightly bigger group (44.78%) held opposite views. The rest (13.80%) were neutral.

The contrary held in Wenchuan where more respondents (48.48%) perceived existing debris flow risks on their homes. Only 34.99% disagreed or strongly disagreed. The rest (16.53%) were neutral.

5.1.3 Summary and reflection

To test the three hypotheses, data regarding three dependent variables were collected by the questionnaire.

For Hypothesis 1 on relocation decision, survey results show that in both counties, the percentages of those having active behaviour of moving after the quake were bigger than those with passive behaviour of not moving, and was particularly obvious in Wenchuan.

For Hypothesis 2 on debris flow risk perception, over half of Pingwu respondents strongly agreed or agreed their communities were facing debris flow threat. Wenchuan had even more than two-third of respondents perceived the risk.

For Hypothesis 3 on anticipated disaster response, the distribution of respondents' answers in the two counties are very similar. Two-third in both places chose to run or escape, followed by about one-sixth would inform others, and around one-tenth would take refuge at home or so.

Data of a series of independent factors that might associate with the three dependent variables were also analysed. The two counties were found similar in their demographic conditions, with exceptions in ethnical composition, educational attainment levels and occupation.

In Pingwu, the Hans and the Qiangs were dominating while Wenchuan was comprised of a great proportion of Tibetans and a small number of Huis.

Pingwu respondents were generally less educated. About three-quarter were uneducated or received only primary education, compared to only half in Wenchuan where the greatest portion received at least secondary education.

In terms of occupation after the quake, over two-third of Pingwu respondents were farmers. In Wenchuan, non-farmers were slightly dominating.

Data on non-demographic independent factors was also collected to test the three hypotheses.

For Hypothesis 1, three out of five groups of statements composed of 25 Likert items, namely exposure and susceptibility, culture, and individual economic competencies yield similar mean scores in both counties. This indicates when the respondents decided whether to move after the quake, considerations of these three groups of factors were very similar in Pingwu and Wenchuan. However, the mean scores on personal competencies and other coping capacities influenced by government differ for the two counties. Wenchuan respondents considered these two factors more than their Pingwu counterparts.

For Hypothesis 2 and 3, the respondents were asked for their awareness of or accessibility to various government disaster risk reduction measures introduced after the quake.

Less than half of the Pingwu respondents were aware of certain geotechnical mitigation measure(s) introduced in their communities. A greater portion of about two-third in Wenchuan answered the same.

Respondents' awareness of or accessibility to both disaster preparedness and response measures were low. Eight out of the 11 preparedness measures were aware of or accessed by less than 25% of respondents in both counties.

For the 21 disaster response measures or facilities, respondents' awareness or accessibility was mainly lower than 50% in both counties. Wenchuan respondents were more aware of or more accessible to 17 measures while Pingwu respondents were more aware of only four.

This sub-section focuses on comparing the similarities and differences of the dependent and independent factors between the two selected counties based on the reasons noted in the beginning of this sub-section. However, this can be a limitation and some analyses might be missed due to this limitation.

Indeed, the data of the two counties can be combined into one and viewed as a single dataset. By doing so, other analyses utilising all 631 Sichuan samples across different sites could be done. In addition, breakdown of the dataset into five sample groups according to the five villages from which the data was collected can also be used as the basis for analysis. This might also allow other intended lines of comparison.

5.2 Hypothesis 1

The first hypothesis of this research states that "After the Wenchuan earthquake, among the rural populations there was a lack of consideration with institutional directives and disaster risk reduction measures when making relocation decisions."

5.2.1 Relocation decisions

To test Hypothesis 1, survey questions were designed to find the possible impacts of a series of independent variables on survey respondents' post-Wenchuan earthquake relocation decisions.

Some of these independent variables referenced the list of indicators covered by the frameworks of HOP, Model of Vulnerability Types, Vulnerability Equations, PAR, BBC and MOVE mentioned in the literature review. However, there are other factors not mentioned in existing models so far in the study areas that might also be relevant to relocation decisions. Such factors might be specific to the study areas and can be applied in other similar circumstances. If their impacts can be established, they can be used to achieve advances in theoretical understanding.

To facilitate analysis, the full set of independent variables are categorised into Group 1A, 1B, 2A, 2B, 3A, 3B and 4. Groups 1A, 2A and 3A referenced existing models. Group 1B, 2B, 3B and 4 are not mentioned in existing models.

5.2.2 Demographic/Socioeconomic factors

The thesis study two counties. As shown in Section 5.1, relocation decisions made by survey respondents of the two counties vary. Analysis of demographic and socioeconomic factors might help explain such difference in decision making.

Twelve demographic and socioeconomic factors were covered in testing Hypothesis 1. Nine were mentioned in existing vulnerability models (Group 1A) and three were not (Group 1B).

Group 1A – Demographic and socioeconomic factors proposed in existing models

1.1 Gender
1.2 Age
1.3 Ethnicity
1.4 Education
1.5 Household size
1.6 Annual per capita net income
1.7 Occupation before the Wenchuan earthquake

1.8 Occupation after the Wenchuan earthquake

1.9 Length of stay per year in the community

Group 1B – Demographic or socioeconomic factors NOT mentioned in existing models

1.10 Chinese literacy

1.11 Knowledge of Putonghua

1.12 Role in village

5.2.3 Relationship between demographic factors and respondents' decision to move or not

The nine demographic factors mentioned in existing models are categorical variables. Chi-square tests were conducted to examine any statistically significant relation between these variables and the decision to move to a new place after the 2008 earthquake respectively. Age and household size were also analysed as interval variables by *t*-Tests.

The three factors not mentioned in existing models but might be relevant to this research are Chinese literacy, knowledge of Putonghua and whether they had an official role in the village. These categorical variables are also analysed by Chi-square tests. Cramer's V, phi and Spearman's rho are used to find out the effect size of each association.

Study area 1 – Pingwu County

Results: Statistically significant factors in Pingwu

All 268 respondents replied to all demographic questions except that 54 did not know or did not want to tell their income and ten did not declare their ethnicity.

Table 5.9 shows the relationships between whether the respondents moved and each of the twelve respective categorical demographic variables. Chi-square tests with Yates' correction are applied to those independent variables with two categories. Pingwu respondents' decision to move or not were found to be statistically significantly associated with four factors, namely ethnicity, education (with two categories), occupation after the 2008 earthquake and length of stay in the community per year. They all have *p*-values of <.05.

Among these four factors, ethnicity and length of stay even have *p*-values of <.01. They have moderate association with whether the respondents moved. Education and occupation after the 2008 earthquake have weaker associations with moving decisions.

There was no statistically significant relationships between respondents' decision to move or not on one hand, and gender, annual per capita net income, occupation before the 2008 earthquake, age or household size on the other hand respectively.

Table 5.9

Relationship between Pingwu respondents' demography and their decision to move or not

The nine demographic factors mentioned in existing models					
Variable	***N***	***X²* value**	***df***	***p*-value**	**Cramer's V (Phi#)**
Gender (* = with Yates correction)	268	0.417 0.272*	1 1*	.518 .602*	.039 .032#
Ethnicity	**258**	**12.310**	**2**	**.002^^**	**.214**
Education (2 groups: Primary or below, secondary and above) (* = with Yates correction)	268	5.243 **4.615***	1 **1***	.022^ **.032*^**	.140 **.131#**
Education (3 groups: Uneducated, Primary, Secondary and above)	268	5.331	2	.070	.141
Annual per capita net income	214	.439	2	.803	.045
Occupation before 2008 earthquake (with Yates correction*)	268	1.474 1.148*	1 1*	.225 .284*	.074 .065#
Occupation after 2008 earthquake (with Yates correction*)	268	5.039 **4.458***	1 1*	.025^ **.035*^**	.137 **.129#**
Length of stay (with Yates correction*)	**268**	6.586 **5.796***	1 **1***	.010^^ **.016*^**	.157 **.147#**
Variable	***N***	***X²* value/ *t*-Test statistic***	***df***	***p*-value**	**Cramer's *V* (Phi#)/ Hedge's g***
Age (with Yates correction*)	268	0.146 0.062*	1 1*	.702 .804*	.023 .015#
Age (*t*-Test)	268	-1.211	258	.227	.146***
Household size (with Yates correction*)	268	0.098 0.026*	1 1*	.755 .872*	.019 .010#
Household size (*t*-test)	268	-.680	245	.497	.085***
The three demographic factors *not* mentioned in existing models					
Variable	***N***	***X²***	***df***	***p*-value**	**Cramer's V (Phi#)**
Chinese literacy (with Yates correction*)	268	.761 .552*	1 1	.383 .458*	.053 .045#
Knowledge of Putonghua	268	0.462	2	.794	.042
Role in village (with Yates correction*)	268	0.071 0.001*	1 1*	.789 .975*	.016 .002#

^ Statistically significant at the 0.05 level (2-tailed)
^^ Statistically significant at the 0.01 level (2-tailed)

Two-sample independent *t*-Tests were performed further to explore any statistically significant relationship between age and household size as interval variables respectively on one hand, and the decision to move on the other.

No significant difference is found between the mean age of the moved group (M = 53.54, SD = 17.34) and the stayed group (M = 55.94, SD = 15.02); $t(258)$ = -1.211, p = .227 (two-tailed).

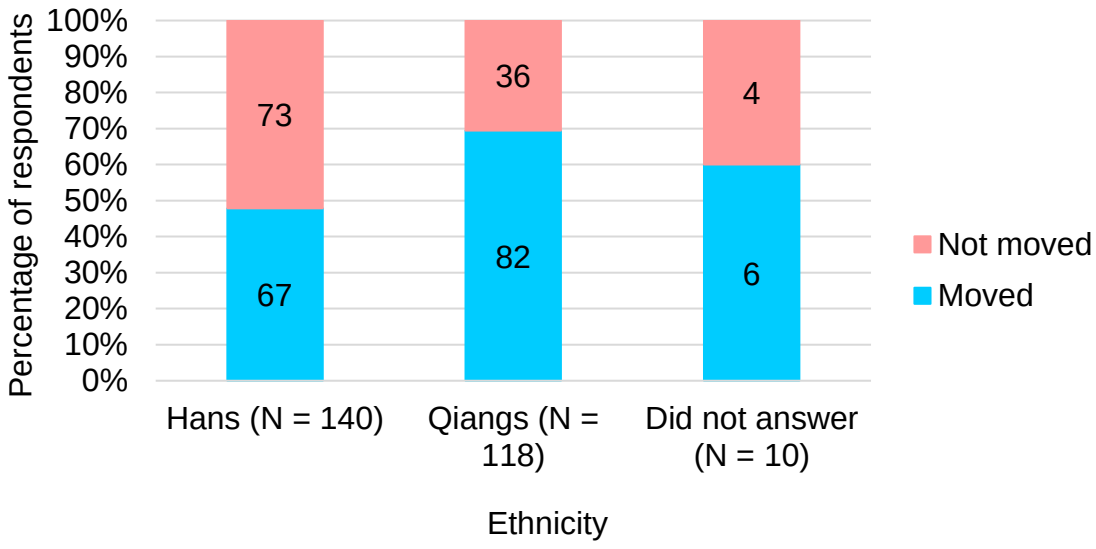
Household size also had no significant effect on the moving decision, $t(245)$ = -.680, p =.497 (two-tailed), although the moved group (M = 4.86, SD = 2.03) had a smaller average household size than the stayed group (M = 5.03, SD = 1.98).

As for the three demographic variables not mentioned in previous models but might be relevant in this research, namely Chinese literacy, knowledge of Putonghua and role in village, analysis show that they are not associated with moving decisions.

Ethnicity

Among the 268 Pingwu respondents, ten did not tell their ethnicity and were treated as missing values. Out of the 258 responding villagers, 140 were Hans. More than half of the Hans (52.14%) said they had not moved (Figure 5.29). Conversely, among the 118 Qiang respondents, 69.49% chose to move. These mean the Hans tended to stay in their original place while the Qiangs were more likely to move, $X^2(2, N=268) = 12.310$, p =. 002. There is a significant relationship between ethnicity and moving decision. The two variables are moderately associated (Cramer's V = .214).

Figure 5.29 Relation between Pingwu respondents' ethnicity and their decision to move or not (N = 258)



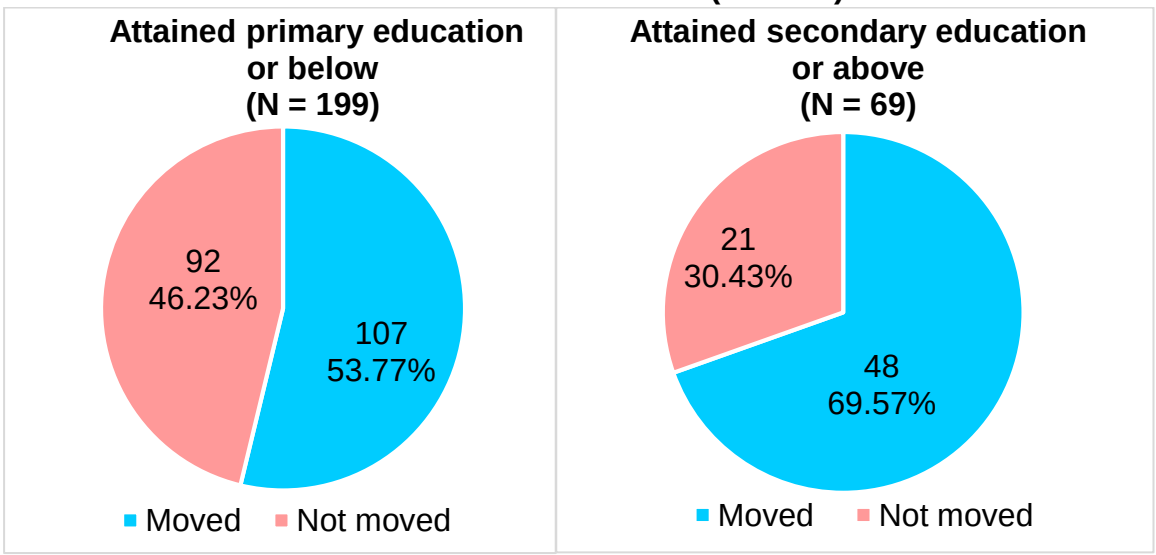
Education

A Chi-square test which divided respondents' education level into three categories: uneducated, primary and secondary or above could not found any significant relationship between education level and moving decision (Table 5.9). However, another Chi-square test with Yates' correction in which all 268 Pingwu respondents are grouped into two categories: the less educated (primary or below) and the more educated (secondary or above) shows a significant positive relationship between education level and moving decision, $X^2(1, N=268) = 4.615$, $p = .032$. The more educated ones were more likely to move while the less educated tended to stay in their original place relatively. Education is related to, or perhaps even confers, mobility, although the phi coefficient is .131, meaning the association between the two variables is weak.

Figure 5.30 shows that only 53.77% of those attained primary education or below in Pingwu decided to move after the Wenchuan earthquake while 69.57% of those received secondary education or above chose to move. The more educated ones were more likely to move.

On the other hand, 46.23% of those attained primary education or below chose to stay in their residing place after the earthquake but only 30.43% of those received secondary education or above made the same choice. The less educated ones were more likely to stay in their original place.

Figure 5.30 Relation between Pingwu respondents' educational attainment and their decision to move or not (N = 268)



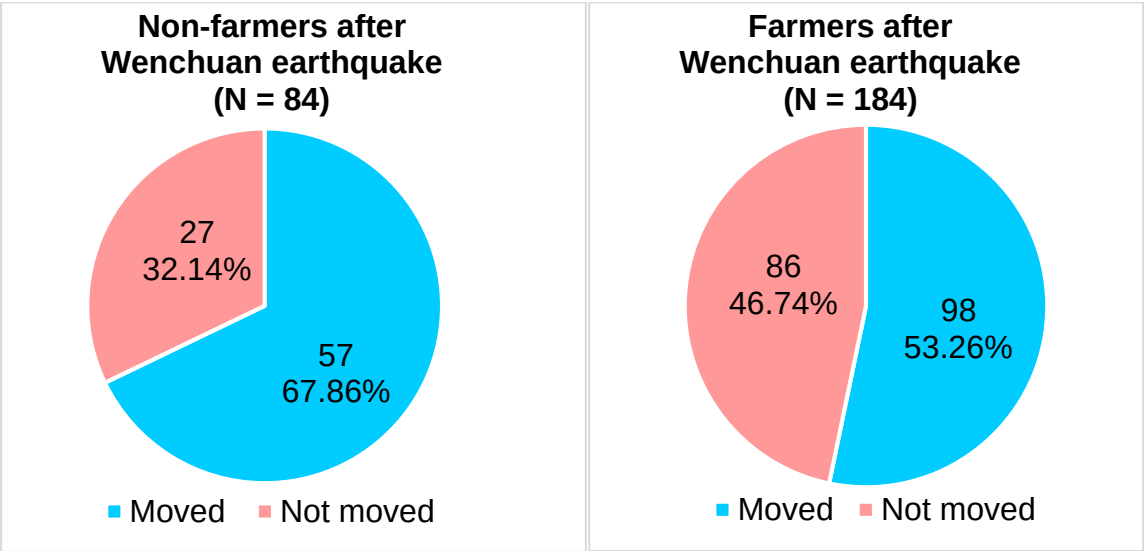
It is possible that the more educated also have more wealth and resources, which would make them easier to move. Two Chi-square tests were therefore carried out to see whether the wealthier higher educated respondents were more likely to move and whether the poorer less educated respondents were more likely to stay. No statistically significant relation could be found.

Occupation after the Wenchuan earthquake

There is also a statistical significant relationship between Pingwu respondents' occupation after the earthquake and their decisions to move. A Chi-square test with Yates' correction found that the non-farmers were more likely to move after the quake while the farmers tended to stay in their original residing place, X^2 (1, N=268) = 4.458, p = .035. But the association between the two variables is weak (phi coefficient = .129).

As shown in Figure 5.31, 67.86% of the non-farmers in Pingwu decided to move after quake while only 53.26% of the farmers chose to relocate. The non-farmers were more likely to move.

Figure 5.31 Relation between Pingwu respondents' occupation after the Wenchuan earthquake and their decision to move or not (N =268)



On the other hand, only 32.14% of the non-farmers chose to stay in their original residing place after the quake but 46.74% of the farmers made the same choice. The farmers were more likely to stay. Clearly, farmers were tied to the land and had constraints on their movement.

Although Pingwu respondents' occupation after the quake might help explain their moving decisions, the statistical results could also imply those who moved have had to take up non-farming livelihoods as they no longer occupied any land where they could farm.

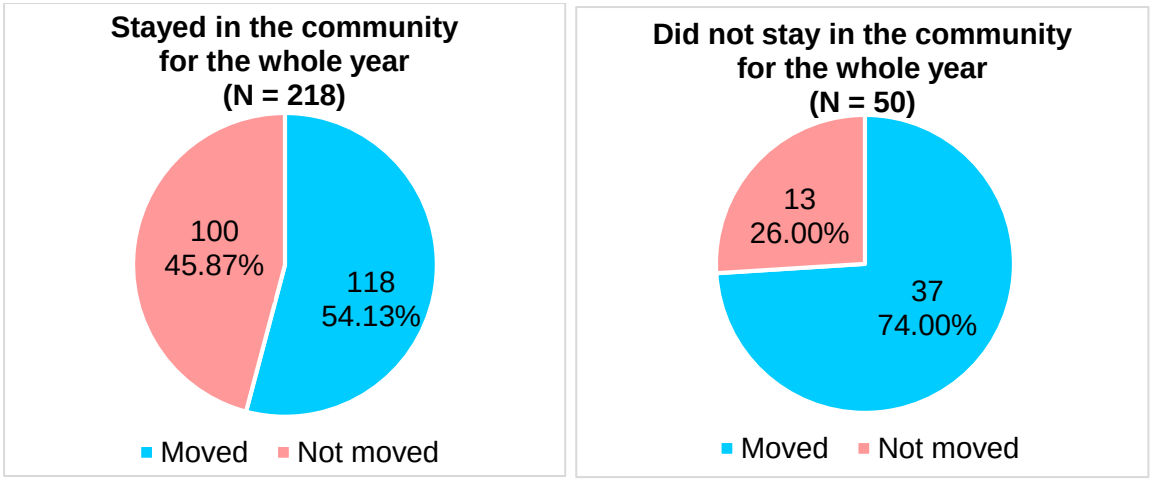
Length of stay in the community per year

The respondents' length of stay in the communities per year is also associated with their moving decisions.

If the Pingwu respondents were simply divided into two groups: those stayed for the whole year versus those not, and association between length of stay and decision of move is conducted by Chi-square test with Yates' correction, statistical significant results were yielded, $X_2(1, N=268) = 5.796$, $p = .016$, although the effect size phi = .147, indicating a weak relation.

Figure 5.32 shows that both groups of Pingwu respondents who stayed or not stayed in the community for the whole year were dominated by villagers who moved. However, as high as 74.00% of those who did not stay for the whole year chose to move (right pie chart). Only 54.13% of those who stayed for the whole year made the same decision (left pie chart). Those who stay shorter in the community were more likely to move.

Figure 5.32 Relation between Pingwu respondents' length of stay in the community per year and their moving decision (N = 268)



It is logical that those who are more transient are more likely to uproot and move. This point is explained further and elaborated in the upcoming discussion chapter.

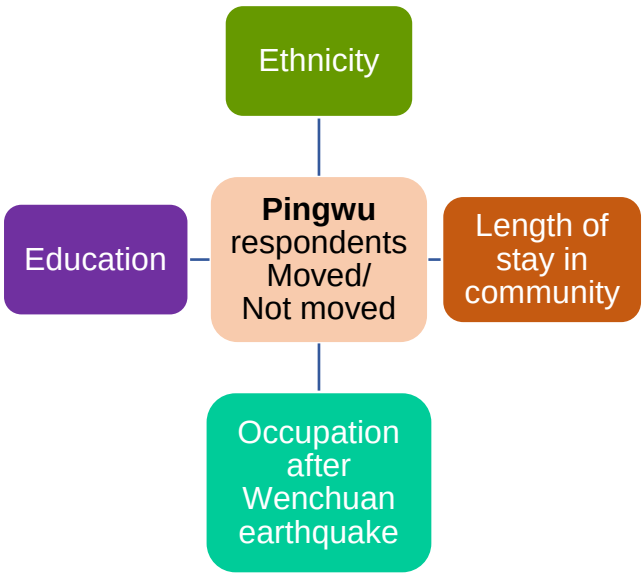
Regularities

When considering demographic factors, the more educated Qiangs who were non-farmers and lived in their communities for shorter period of time per year tended to actively behave after the 2008 earthquake in terms of deciding to move to another place to reside. The less educated Han farmers who lived in their communities for longer period of time per year were more passive and tended not to move after the quake. Table 5.10 and Figure 5.33 summarise the findings.

Table 5.10
Factors associated with moving decision in Pingwu

	More likely to move	**More likely to stay**
Ethnicity	Qiangs	Hans
Education (2 groups: Primary or below, Secondary and above)	Secondary or above	Primary or below
Occupation after earthquake	Non-farmers	Farmers
Length of stay	Not whole year	Whole year

Figure 5.33 Factors associated with moving decision in Pingwu



In the upcoming discussion chapter, explanations is given on possibly why these regularities exist.

This research reveals that ethnicity, among all demographic factors, of the Pingwu respondents had the biggest association with their moving decisions. The Hans tended to stay in their original place while the Qiangs were more likely to move. In order to understand more about the possible impact of ethnicity, together with other demographic factors, on moving decision, a multivariate analysis was further performed. The Pingwu respondents were divided into two ethnic groups: Hans and Qiangs. Their respective relations with other demographic factors together with their decision to move were tested. In short, education and length of stay (3 groups) respectively were having statistical significant associations with Hans' moving decision (Appendix 2).

In addition, in order to understand more about how other statistical significant demographic factors combined together might affect Pingwu respondents' moving decision, several other multivariate analyses were further done. The Pingwu respondents were divided according to their educational attainment, occupation after the Wenchuan earthquake, as well as length of stay in the community per year. In what ways their respective relations with other demographic factors impacted respondents' decision to move were tested.

The findings show that the lower educated Hans, the Han farmers, and the Hans who stayed in their community for the whole year were more likely to stay in their original place after the quake. The more educated ones who stayed in the community for full year were also relatively less likely to move.

Those attained higher education and did not stay in the community for the whole year were much more likely to move. The lower educated Qiangs, Qiang farmers, and the Qiangs who stayed in their community for the whole year were also more likely to move.

Study area 2 – Wenchuan

Results: Statistically significant factors in Wenchuan

The relationships between whether the Wenchuan respondents moved after the 2008 earthquake and each of the twelve respective categorical demographic variables are shown in Table 5.11. Among all 363 respondents, seven did not reply whether they moved and their answers were not analysed in testing Hypothesis 1,

therefore $N = 356$. A small number of respondents did not tell their education level, Chinese literacy, whether they knew Putonghua, occupation after Wenchuan earthquake, and 44 were unwilling to tell or did not know their income.

Chi-square tests were conducted and found that one demographic factor, ethnicity, had statistical significant yet weak association with moving decision, with p-values $<.05$ (two-tailed).

No statistical significant relationship between respondents' moving decision and each of all other 11 demographic variables was found, regardless such variables were mentioned or not mentioned in existing vulnerability models.

Besides categorising into nominal groups, respondents' ages and household sizes were also analysed as interval variables by two-sample independent t-Tests.

Excluding the seven respondents who did not answer whether they moved, the t-Test results show no significant difference between the mean age of those who moved ($M = 48.51$, $SD = 18.353$) and not moved ($M = 46.63$, $SD = 18.114$); $t(169) = .864$, $p = .389$ (two-tailed). The effect size Hedge's g is .103, indicating a weak relation. Similarly, the household sizes had no significant effect on moving decisions, $t(169) = 1.170$, $p = .244$ (two-tailed), although the moved group ($M = 5.03$, $SD = 1.741$) had a bigger average household size than the not moved group ($M = 4.79$, $SD = 1.713$). The effect size Hedge's g is .138, also indicating a weak relation.

Table 5.11

Relationship between Wenchuan respondents' demography and their decision to move or not

The nine demographic factors mentioned in existing models					
Variable	***N***	***X*² value (Fisher's Exact test value**)**	***df***	***p*-value**	**Cramer's *V* (Phi#)**
Gender (* = with Yates correction)	356	.121 .051*	1 1	.728 .821*	.018 .0120#
Ethnicity	**356**	**9.993****	**--**	**.012^**	**--**
Education (2 groups: Primary or below, secondary and above) (* = with Yates correction)	354	.444 .297*	1 1*	.505 .586*	.035 -.029#
Education (3 groups: Uneducated, Primary, Secondary and above)	354	1.135	2	.567	.057
Annual per capita net income	312	.185	2	.912	.024
Occupation before 2008 earthquake (with Yates correction*)	356	.011 .000*	1 1*	.917 1.000*	.006 .000#
Occupation after 2008 earthquake (with Yates correction*)	354	.239 .136*	1 1*	.625 .712*	.026 -.020#
Length of stay (with Yates correction*)	356	1.221 .922*	1 1*	.269 .337*	.059 -.051#
Variable	***N***	***X*² value/ *t*-Test statistic*****	***df***	***p*-value**	**Cramer's *V* (Phi#)/ Hedge's g*****
Age (2 groups) (* = with Yates correction)	356	.559 .365*	1 1*	.455 .545*	.040 .032#
Age (*t*-Test)	356	.864***	169	.389	.103***
Household size (2 groups) (* = with Yates correction)	356	.005 .000*	1 1*	.945 1.000*	.004 .000#
Household size (*t*-test)	356	1.170***	169	.244	.138***
The three demographic factors *not* mentioned in existing models					
Variable	***N***	***X*²**	***df***	***p*-value**	**Cramer's *V* (Phi#)**
Chinese literacy (* = with Yates correction)	350	1.844 1.482*	1 1*	.174 .223*	.073 -.065#
Knowledge of Putonghua	351	2.914	2	.233	.091
Role in village (with Yates correction*)	356	.246 .052*	1 1*	.620 .819*	.026 -.012#

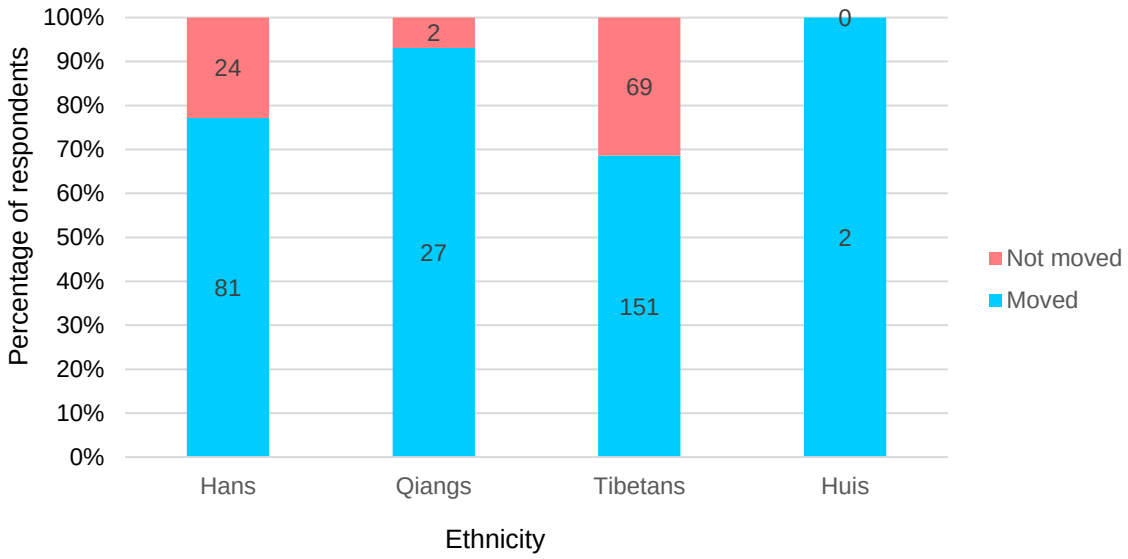
^ Statistically significant at the 0.05 level (2-tailed)

Ethnicity

The Wenchuan respondents came from four ethnic groups. Out of all 356 Wenchuan villagers responded to whether they moved or not after the earthquake, the Tibetans constituted to the greatest portion (N = 220), followed by the Hans (N = 105), the Qiangs (N = 29) and finally the Huis (N = 2).

Figure 5.34 shows that across all responding ethnic groups in Wenchuan, at least two-third of the respondents said they had moved. Apart from the only two Huis who both said they moved, the Qiangs had the greatest portion of moved respondents (93.10%, 27/29), meaning they were the most likely to move. This was followed by the Hans (77.14%), and then the Tibetans (68.64%) who were the most likely to stay. There is a statistical significant relationship between ethnicity and moving decision with a Fisher's exact test value 9.993 (p = .012, N = 356).

Figure 5.34 Relation between Wenchuan respondents' ethnicity and their decision to move or not (N = 356)



Regularities

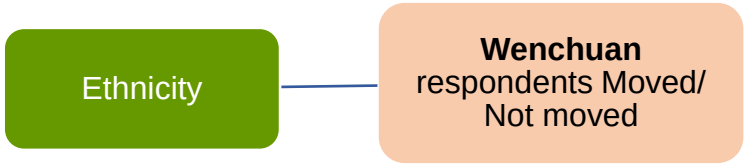
This means the Qiangs behaved actively in terms of relocating to another place after the quake. The Tibetans were more passive and tended to stay (Table 5.12).

Table 5.12

Factor associated with moving decision in Wenchuan

	More likely to move	**More likely to stay**
Ethnicity	Qiangs	Tibetans

Figure 5.35 Factor associated with moving decision in Wenchuan



Ethnicity, among all demographic factors, of the Wenchuan respondents had the biggest association with their moving decision (Figure 5.35). To understand more about the possible impact of ethnicity, together with other demographic factors, on respondents' moving decision, a multivariate analysis was done by dividing the Wenchuan respondents into three ethnic groups: Hans, Qiangs and Tibetans. The two Huis were again skipped in the analysis. Significant relations were found between moving decision and Han's length of stay (Appendix 2).

5.2.4 Factors directly affecting the decision to move or not

Besides the demographic factors (Group 1), 25 items regarding the respondents' possible consideration when deciding whether to move after the 2008 earthquake were rated. A total of 25 statements were stated and the survey respondents in both Pingwu and Wenchuan were asked:

"What factors did you consider when you decided whether to move or not?"

They rated each statement on a 5-point Likert-type rating scale which ranges from (1) Strongly disagreed, (2) Disagreed, (3) Neutral, (4) Agreed to (5) Strongly agreed. The 25 Likert items were grouped into five constructs (Group 2A, 2B, 3A, 3B and 4) as shown in Figure 3.1. Likert-type scale analysis was conducted.

5.2.5 Results of Pingwu County and Wenchuan County

The 25 items in the form of statements measuring five subscales in both Pingwu and Wenchuan are listed in Table 5.13. Each subscale is analysed by dividing into "moved" group and "not moved" group. For every individual respondent, the score of each subscale are obtained by summing up and averaging the scores of the items grouped under it. The higher the average score gained, the bigger the consideration of that subscale by the individual when he or she decided whether to move.

Two-sample independent *t*-Tests were then performed to compare the mean scores of the "moved" group and the "not moved" group of each of the five constructs in both counties. The effect sizes telling how much the moved group differs from the not moved group were found out by Hedges' *g*. The relations between the scores of each construct and the decision of moved or not moved are presented in Table 5.13.

Table 5.13
25 Likert items measured in five constructs
(PW stands for Pingwu, WC stands for Wenchuan)

Group	Variable Likert item	Not moved Mean	Moved Mean	*t*	*p* (two-tailed)	*Hedges' g*
2A	**Factors regarding the exposure and susceptibility of survey respondents and their homes proposed in existing models (BBC, Alexander 1997, 2000, 2007, MOVE)** (i). Whether the new place would be affected by earthquake. (ii). Whether the new place would be affected by debris flow. (iii). The topography and landscape of the new place. (iv). Whether the place I originally lived was safe. (v). Home's current location made me feel safer than the location before the Wenchuan earthquake.	PW 3.23 WC 3.12	PW 3.57 WC 3.47	PW 4.935 WC 5.581	**PW .000** **WC .000**	**PW 0.57** **WC 0.53**
2B	**Other factors regarding survey respondents' homes NOT mentioned in existing models** **-- Cultural/ Historical/ Social cohesion / Family/ Ethnical / Neighbourhood factors** (i). Whether I liked the place I originally lived and did I belong to the place. (ii). Whether my ancestors also resided in the place I originally lived. (iii). Whether I liked the neighbours of my original home. (iv). Whether my children studied nearby the place I originally lived. (v). Whether the new place had sufficient land to accommodate my family members. (vi). Whether the neighbours of my previous home were of the same ethnic group as me. (vii). Whether the neighbours of the place I would move to were of the same ethnic group as me.	PW 3.12 WC 3.03	PW 2.86 WC 2.90	PW -4.185 WC -2.721	**PW .000** **WC .007**	**PW -0.47** **WC -0.25**

Group	Variable Likert item	Not moved Mean	Moved Mean	*t*	*p* (two-tailed)	*Hedges' g*
3A	**Factors regarding individual/ economic competencies (as part of coping capacity) proposed in existing models** **-- Financial support from various sources (BBC) or funding availability (Hogg 1980, cited in Alexander 2007, p.xvi-xvii)** **-- Economic vulnerability (Alexander 1997)** (i). Whether I had the money to move. (ii). Whether I had sufficient money to build a new house somewhere else. (iii). Whether there was any subsidy to move to another place. (iv). Whether moving to somewhere else required me to give up my farmland. (v). Whether the new place was nearby my farmland.	PW 3.27 WC 3.18	PW 3.23 WC 3.23	PW -0.470 WC 0.897	PW .638 WC .371	PW -0.05 WC 0.088
3B	**Factors regarding individual/ personal competencies (as part of coping capacity) NOT mentioned in existing models** (i). Whether I were afraid of moving to a new place. (ii). Whether the moving process was too complicated for me and my family and could be handled. (iii). Whether I could tackle debris flow risk. (iv). Whether the government would take care of me, including the provision of accommodation if I am affected by debris flow. (v). Whether the government would provide training for me to tackle debris flow.	PW 3.04 WC 3.07	PW 2.73 WC 2.99	PW -5.045 WC -1.675	**PW .000** WC .095	**PW -0.58** WC -0.15
4	**Factors regarding other coping capacities influenced by government or political institutions regarding the new residing place that can avoid geological risks NOT proposed in existing models** (i). The government said whether the new residing place is safe. (ii). Whether the government had introduced effective geotechnical engineering measures, including sediment trap dam, to the new residing place. (iii). Whether the government had introduced effective disaster preparedness measures, including risk notifications, early warnings and disaster response, to the new residing place.	PW 3.04 WC 3.08	PW 2.98 WC 3.25	PW -0.690 WC 2.983	PW .491 **WC .003**	PW -0.08 **WC 0.26**

Pingwu

Respondents' consideration of exposure and susceptibility of themselves and their homes proposed in existing models (Group 2A) was based on what they perceived rather than their actual exposure. The actual exposure of each respondent was different, and is out of the scope of this study to verify. To avoid any mislead, "consideration" is the focus of the question.

In Pingwu, a statistically significant difference (t (260) = 4.9354, p = .000) was observed between the moved group (M = 3.57, SE = 0.05681) and the not moved group (M = 3.23, SE = 0.04120). The observed difference between the sample means (3.57-3.23) is convincing enough to say that the average scores of the exposure and susceptibility consideration factor between those who moved and not moved differ significantly. The magnitude of the differences in the means shows a medium-sized effect (Hedges' g = 0.57). Those moved were more concerned and more sensitive about disaster risk exposure and susceptibility than those did not, but not necessarily more exposed to hazards.

Another significant difference (t (247) = -4.18495, p = 0.000) with a medium-sized effect (Hedges' g = -0.47) was found when comparing the moved group (M = 2.86, SE = 0.0518) and the not moved group (M = 3.12, SE = 0.0325) in Pingwu on respondents' consideration of the socio-cultural and ethnical variable (Group 2B). The observed difference between the sample means (2.86-3.12) is compelling enough to say that the average scores of the socio-cultural and ethnical variable between those who moved and not moved differ significantly. Those who did not move were more concerned about their cultural and historical links to a place as well as their social cohesion and ethnical affiliation with the residents there. The contents of this variable as a whole regarding respondents' homes were not mentioned in existing models.

Individual economic competencies, as part of coping capacity, proposed in existing models in terms of financial support from various sources or funding availability as well as economic vulnerability (Group 3A) were analysed. There was no significant difference (t (257) = -0.47047, p = .6384) in the score of this financial and economic variable for the moved group (M = 3.23, SE = 0.06245) and the not moved group

(*M* = 3.27, *SE* = 0.0435) in Pingwu, and the effect size was small (Hedges' *g* = -0.05).

Factors regarding individual or personal competencies, as part of coping capacity, not mentioned in existing models (Group 3B) were also investigated. A meaningful difference (*t* (257) = -5.04496, *p* =.000) in the means for those who moved (*M* = 2.73, *SE* =0.05008) and not moved (*M* = 3.04, *SE* =0.0349) is found, with a medium-sized effect of Hedges' *g* = -0.58. The observed difference between the sample means (2.73-3.04) can tell that the average scores of individual personal competencies variable between those who moved and not moved differ significantly. Those did not move were more concerned about their competencies and coping capacities to move and to tackle debris flow than those moved.

The last construct involves the consideration of other coping capacities influenced by government or political institutions in the new residing place that can avoid geological risks (Group 4). This variable was not proposed in existing models. However, no significant difference (*t* (256) = -0.69009, *p* = 0.4908) between the scores of the Pingwu moved group (*M* = 2.98, *SE* = 0.0636) and not moved group (*M* = 3.04, *SE* = 0.0441) is found. The effect size is small (Hedges' *g* = -0.08). These findings indicate that the "institutional directives and disaster risk reduction measures" in Hypothesis 1 were not considered by Pingwu respondents when they made their relocation decisions.

Wenchuan

In Wenchuan, similar outcomes as in Pingwu were found with regard to factors on the exposure and susceptibility of survey respondents and their homes proposed in existing models (Group 2A). A statistically significant difference (*t* (278) = 5.581, *p* = .000) was observed between the moved group (*M* = 3.47, *SE* = .0439) and the not moved group (*M* = 3.12, *SE* = .0435). The observed difference between the sample means (3.47-3.12) is convincing enough to say that the average scores of the exposure and susceptibility factor between those who moved and not moved differ significantly. The magnitude of the differences in the means shows a medium-sized effect (Hedges' *g* = 0.53), indicating those moved were more concerned about disaster risk exposure and susceptibility than those did not.

As for the cultural, historical, social cohesion, family, ethnical and neighbourhood factors regarding survey respondents' homes not mentioned in existing models (Group 2B), a statistically significant difference (t (302) = -2.721, p = .007) with a small-sized effect (Hedges' g = -0.25) was also found between the moved group (M = 2.90, SE = .0346) and the not moved group (M = 3.03, SE = .0313) in Wenchuan. The observed difference between the sample means (2.90-3.03) is compelling enough to say that the average scores of the socio-cultural and ethnical variables between those who moved and not moved differ significantly. Those who did not move were more concerned about their cultural and historical links to a place as well as their social cohesion and ethnical affiliation with the residents there. However, the impact of these socio-cultural factors on moving decision was more obvious in Pingwu than in Wenchuan because Pingwu got a smaller p-value and a bigger Hedges' g.

As for individual economic competencies proposed in existing models in terms of financial support from various sources or funding availability as well as economic vulnerability (Group 3A), no significant difference (t (255) = .897, p = .371) between the Wenchuan moved group (M = 3.23, SE = .0418) and the not moved group (M = 3.18, SE = .0454) was found. The effect was small-sized (Hedges' g = 0.088). As in Pingwu, the moving decision of the Wenchuan respondents was not differentiated by their consideration of financial or economic competencies.

Regarding individual or personal competency factors not mentioned in existing models (Group 3B), analysis also does not show a meaningful difference (t (303) = -1.675, p = .095) in the means for those who moved (M = 2.99, SE = .0354) and not moved (M = 3.07, SE = .0318). Unlike Pingwu, the observed difference between the sample means in Wenchuan (2.99-3.07) is not convincing enough to say that the average score of individual personal competencies variables between those moved and not moved differ significantly, and the effect size was small, with Hedges' g = -0.15.

As for other coping capacities influenced by government or political institutions in the new residing place that can avoid geological risks and not proposed in existing models (Group 4), a significant difference (t (335) = 2.983, p = .003) between the scores of the Wenchuan moved group (M = 3.25, SE = .0468) and not moved group

(*M* = 3.08, *SE* = .0358) exists. The observed difference between the sample means (3.25-3.08) implies that the average scores of this variable between those who moved and not moved differ significantly, although the effect size was small (Hedges' *g* = 0.26). Unlike Pingwu, the decision to move or not was differentiated by Wenchuan respondents' consideration of their geological risks coping capacities influenced by government in the new residing place. The "institutional directives and disaster risk reduction measures" in Hypothesis 1 were considered by Wenchuan respondents when they made their relocation decisions.

5.2.6 Summary and reflection of Hypothesis 1 results

Section 5.2 of this chapter presents the results of Hypothesis 1 testing. Any association between each demographic factor and the five constructs on one hand and the respondents' relocation decisions on the other are revealed.

Pingwu respondents' relocation decisions were found to be statistically significantly related to their ethnicity, length of stay in the community per year, education and occupation after the 2008 earthquake.

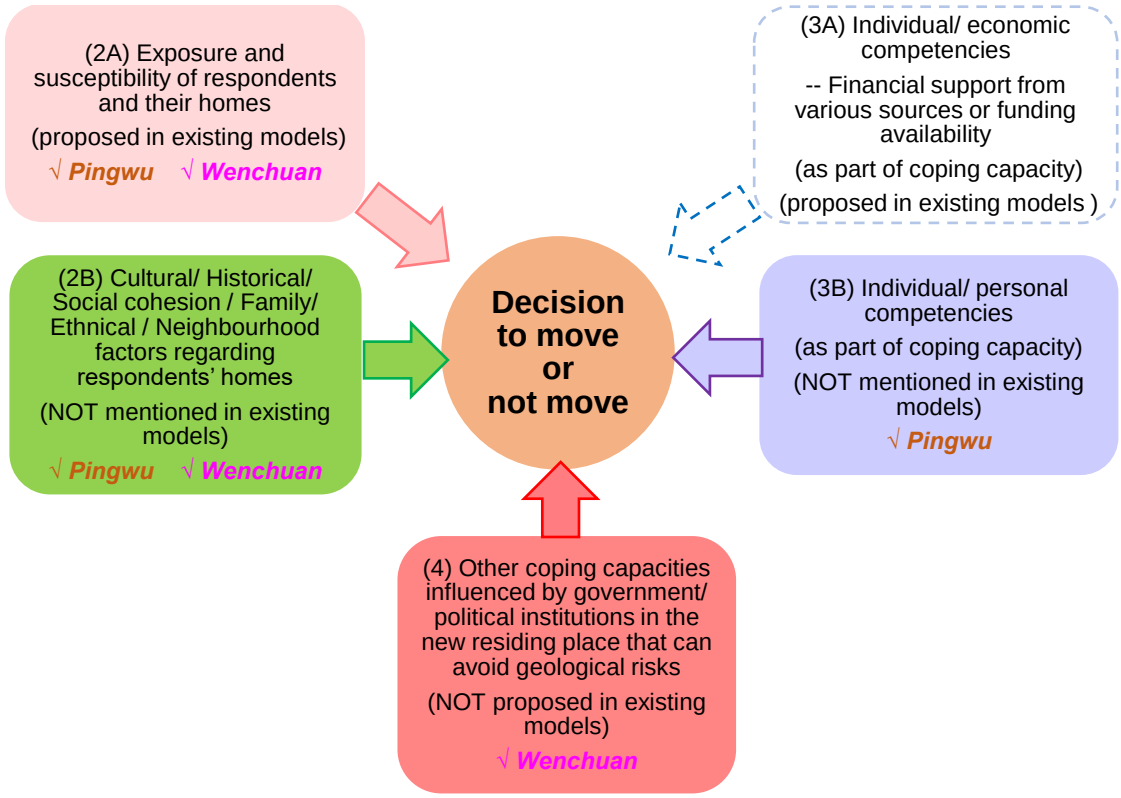
Ethnicity had the biggest association. The Hans tended to stay in their original place while the Qiangs were more likely to move. The more educated, non-farmers and those living in their communities shorter per year tended to actively behave in terms of relocating after the quake. The less educated, farmers and those living in their communities longer per year were more passive and tended to stay.

In Wenchuan, only one demographic factor, ethnicity, was found to have statistical significant association with moving decision. The Qiangs behaved actively in terms of post-earthquake relocation. The Tibetans were more passive and tended to stay.

Since the results reveal that ethnicity is the only demographic factor having statistical significant relation with respondents' decisions to move in both Pingwu and Wenchuan, further analysis is conducted on each ethnic group and looks into the overall combination of factors that might influence their moving decisions. The detailed findings are presented in Appendix 2.

Regarding respondents' consideration of the 25 non-demographic items grouped in five constructs when deciding whether to move after the quake, a summary of the relations in the two counties is shown in Figure 5.36.

Figure 5.36 Effect of the five non-demographic constructs on Pingwu and Wenchuan respondents' decision to move or not



Statistically significant differences were observed between the sample means of the moved and the not moved groups in both Pingwu and Wenchuan on exposure and susceptibility of the respondents themselves and their homes (Group 2A). Those who moved were more concerned about disaster risk exposure and susceptibility than those did not.

For the consideration of socio-cultural and ethnical factors (Group 2B), statistical significant differences of the sample means between those who moved and not moved were also found in both Pingwu and Wenchuan. Those who did not move were more concerned about their cultural and historical links to a place as well as social cohesion and ethnical affiliation with the residents there. However, the association of these socio-cultural factors with moving decision was more obvious in Pingwu than in Wenchuan.

In both counties, no significant difference was found in the average scores of those who moved and not moved with regard to the consideration of individual economic or financial competencies (Group 3A). Moving decisions of respondents in both counties were not differentiated by such consideration.

For the consideration of individual or personal competency factors (Group 3B), a significant difference in the means of those who moved and not moved is found in Pingwu. Those did not move were more concerned about their competencies and coping capacities to move and to tackle debris flow than those moved. Unlike Pingwu, the observed difference between the sample means in Wenchuan is not convincing enough to say that the average scores of individual personal competencies variables between those moved and not moved differ significantly.

As for the last construct involving geological risks coping capacities influenced by government in the new residing place (Group 4), no significant difference between the average scores of the moved and the not moved groups is found in Pingwu. Conversely, the sample means of the two Wenchuan groups differ significantly. Unlike Pingwu, Wenchuan respondents' moving decisions were differentiated by consideration of their coping capacities influenced by government.

This means when making moving decisions, "institutional directives and disaster risk reduction measures" noted in Hypothesis 1 were not considered by Pingwu respondents but were considered by their Wenchuan counterparts. **Hypothesis 1 which states that *"After the Wenchuan earthquake, among the rural populations there was a lack of consideration with institutional directives and disaster risk reduction measures when making relocation decisions."* is rejected in Wenchuan.**

Throughout the results presentation, similarities and differences in Pingwu and Wenchuan are described and compared. Explanations for any variations in the possible impact of government disaster risk reduction measures in the two counties can be referenced by other places having different conditions but similar risk. Treating the data in two sets based on the two study areas, however, can lead to the leave out of some analyses.

Other analyses using all samples across different study sites in this thesis could be performed if all data is combined into one set. For instance, different relocation decisions of individuals with different demographic characteristics or considerations across the complete sample set could be compared.

5.3 Hypothesis 2

The second hypothesis of this research stated that the rural populations living in remote mountainous areas have developed perceptions of geological risk that were generally more advanced than the government measures for disaster mitigation, preparedness and response imposed after the Wenchuan earthquake. To test Hypothesis 2, factors (independent variables) that could affect debris flow risk perception (dependent variable) are identified.

5.3.1 Results of study area 1 – Pingwu County

Relationships between demographic/socioeconomic factors and perceptions of existing community debris flow threat

Demographic and socioeconomic factors can be key variables affecting risk perception. This section examines 12 demographic factors and see if they were related to Pingwu respondents' perception of existing community debris flow threat. The 12 factors include: gender, age, ethnicity, education level, Chinese literacy, Putonghua knowledge, number of family members living in the same house, income level, occupation before and after the Wenchuan earthquake respectively, role in village and length of stay in one's community per year.

Survey results show that three demographic variables: age, ethnicity and occupation after the Wenchuan earthquake, were statistically significantly associated with Pingwu respondents' risk perceptions. However, the other nine were not (Table 5.14).

Table 5.14

Statistical relationships between each demographic/socioeconomic factor and existing community debris flow risk perception in Pingwu

Demographic/ Socioeconomic factor	***N*=**	**Mean rank (0)**	**Mean rank (1)**	***U*-value/ #Chi-square value/ ##Fisher Exact value**	***df***	***p*-value (2-tailed)** (*Mann-Whitney U) (**Correlation) (#Chi-square) (##Fisher Exact)	**Correlation coefficient / Effect size** (**Spearman's rho r_s) (#Cramer's V)
Gender (Male VS Female)	268	126.28	141.16	7894.000	--	*.103	**.100
Age (18 to 64 VS 65 or above)	**268**	**140.42**	**121.07**	**6524.500**	**--**	**.049^**	**-.120**
Ethnicity (Qiang VS Han)	**258**	**102.33**	**152.40**	**5054.000**	**--**	**.000^^**	**-.350**
Education level (3 groups) (Uneducated VS Primary VS Secondary and above)	268	--	--	#10.998	8	#.202	#.143
Education level (2 groups) (Primary or below VS Secondary and above)	268	136.10	129.88	6547.000	--	*.549	**-.037
Chinese literacy (No VS Yes/Partial)	268	133.62	134.97	8095.500	--	*.888	**-.009
Knowledge of Putonghua (Know VS Don't know VS Can understand but cannot speak)	268	--	--	#6.417	8	#.601	#.109
Household size (1 to 3 persons VS 4 or more persons)	268	118.24	138.89	5086.500	--	*.062	**.114
Annual per capita net income (Below and on poverty line RMB 2855 VS Above poverty line RMB 2856 to below rural population annual per capita net income RMB 10771 VS rural population annual per capita net income RMB 10772 and above)	214	--	--	##8.565	--	##.340	--

(cont.)

Demographic/ Socioeconomic factor	***N*=**	**Mean rank (0)**	**Mean rank (1)**	***U*-value/ #Chi-square value/ ##Fisher Exact value**	***df***	***p*-value (2-tailed)** (*Mann-Whitney U) (**Correlation) (#Chi-square) (##Fisher Exact)	**Correlation coefficient / Effect size** (**Spearman's rho r_s) (#Cramer's V)
Occupation before Wenchuan earthquake (Non-farmer VS Farmer)	268	122.16	138.61	5907.000	--	*.116	**.096
Occupation after Wenchuan earthquake (Non-farmer VS Farmer)	**268**	**119.38**	**141.40**	**6457.500**	--	**.024^**	**.138**
Role in village (No/ Don't know VS Yes)	268	132.73	156.45	2041.000	--	*.173	** -.084
Length of stay in one's group/ community per year (Not stay for whole year/ Don't know/ Not sure/ NA VS Stay for whole year)	268	132.59	134.94	5354.500	--	*.842	**.012

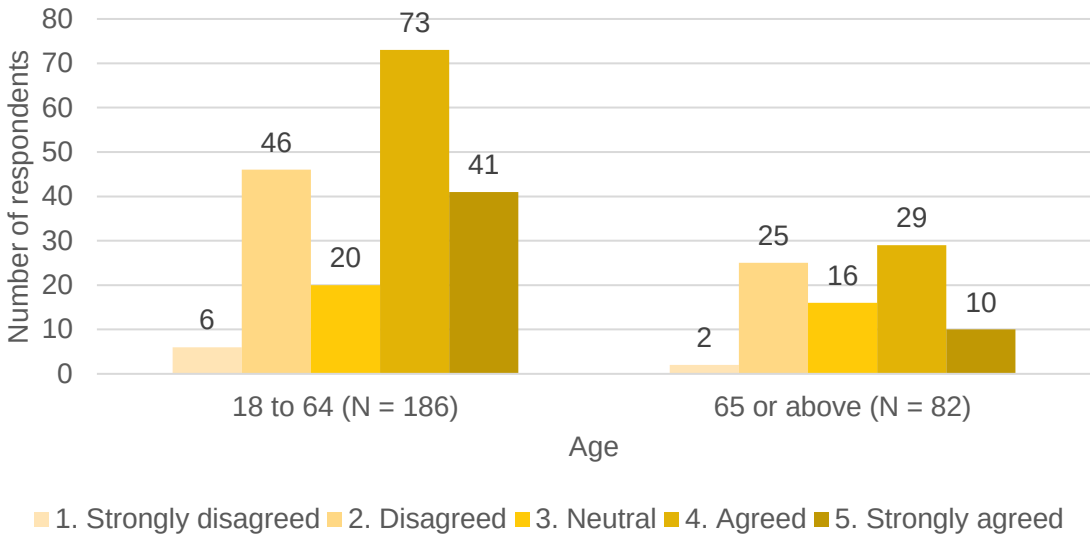
^Correlation is significant at the 0.05 level (2-tailed)

^^Correlation is significant at the 0.01 level (2-tailed)

Age

Frequency distribution of Pingwu respondents in two age groups and their respective perception of existing community debris flow threat is shown in Figure 5.37. Majority (61.29%) of the working-age group (aged 18 to 64) strongly agreed or agreed that there were existing community debris flow threat, yet only 47.57% of the elderly group (aged 65 or above) perceived the same. On the other hand, only 27.96% of the working-age respondents but a greater portion (32.93%) of the elderly group did not perceive existing debris flow risk.

Figure 5.37 Relationship between Pingwu respondents' age and their perception of existing community debris flow threat



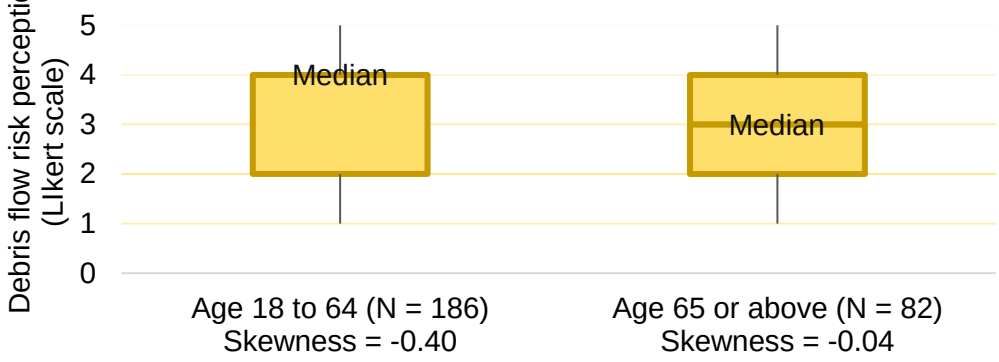
	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Age	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
18 to 64	6 (3.23%)	46 (24.73%)	20 (10.75%)	73 (39.25%)	41 (22.04%)	186 (100.00%)
65 or above	2 (2.44%)	25 (30.49%)	16 (19.51%)	29 (35.37%)	10 (12.20%)	82 (100.00%)
Total	**8 (2.99%)**	**71 (26.49%)**	**36 (13.43 %)**	**102 (38.06 %)**	**51 (19.03%)**	**268 (100.00%)**

The histograms in Figure 5.37 show that debris flow risk perceptions of those aged 18 to 64 in Pingwu were in left-skewed distribution, or negatively skewed, with skewness at -0.40, while the elderly persons held quite opposite views on debris flow risk. Distribution of the elderly group was symmetrical but bimodal as there are two peaks with almost mirror images.

The boxplots in Figure 5.38 indicate central tendency (median) and dispersion (range) of the dataset. The boxes consist of the middle 50% of respondents in terms of their risk perception.

The left boxplot shows that median debris flow risk perception of the younger group was 4 (Agreed). It is closer to the upper end of the distribution, meaning less variation of risk perception above the median and more variation below. The right boxplot shows that median debris flow risk perception of the elder persons was 3 (Neutral).

Figure 5.38 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their age (N = 268)



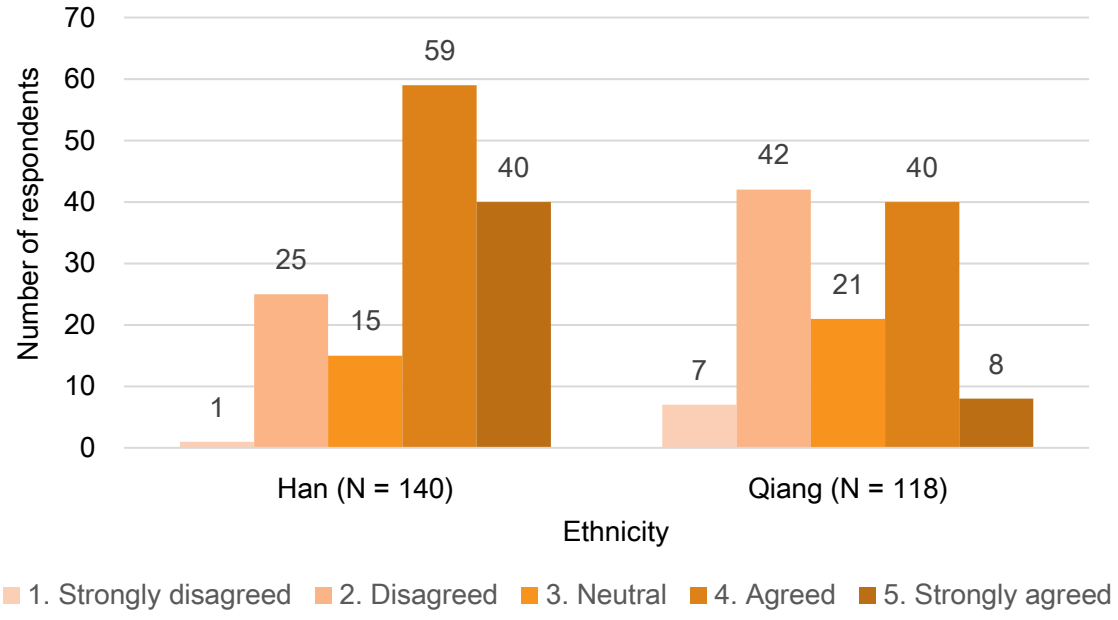
A Mann-Whitney *U* test shows that the working-age group has a statistically significantly higher mean rank (140.42), that is, a higher debris flow risk perception, than the non-working-age elderly group (mean rank = 121.07) (U = 6524.500, p = .049). A Spearman's correlation also finds a statistical significant but weak negative correlation at the 0.05 level (2-tailed) (r_s = -.120, N = 268, p = .049).

Ethnicity

Respondents in Pingwu County were from two ethnic groups: Hans and Qiangs.

As shown in Figure 5.39, among the 258 Pingwu respondents who disclosed their ethnicity, a majority (70.714%) of Hans yet only a minority (40.68%) of Qiangs perceived existing debris flow risk in their communities. Conversely, only 18.571% of the Hans but 41.52% of the Qiangs did not perceive the risk.

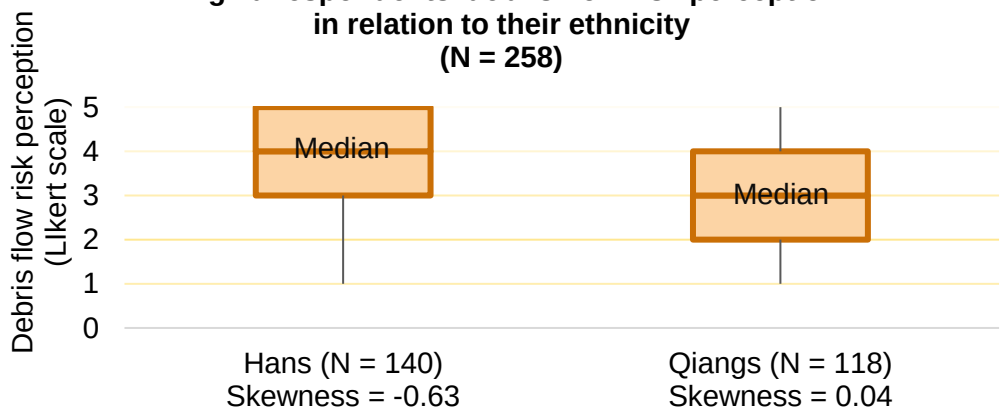
Figure 5.39 Relationship between Pingwu respondents' ethnicity and their perception of existing community debris flow threat



	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Ethnicity	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Han	1 (0.714%)	25 (17.857%)	15 (10.714%)	59 (42.143%)	40 (28.571%)	**140 (100.00%)**
Qiang	7 (5.93%)	42 (35.59%)	21 (17.80%)	40 (33.90%)	8 (6.78%)	**118 (100.00%)**
Total	**8 (3.10%)**	**67 (25.97%)**	**36 (13.95%)**	**99 (38.37%)**	**48 (18.61%)**	**258 (100.00%)**

Debris flow risk perceptions of the Hans were in left-skewed distribution (Figure 5.40), with skewness equals to -0.63. Distribution of the Qiangs was symmetrical but bimodal with two peaks of almost mirror images, meaning they had quite opposite views on debris flow risk.

Figure 5.40 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their ethnicity (N = 258)



The median debris flow risk perception of the Hans was 4 (Agreed) and no whisker is on the upper end of the left boxplot. Both the median and the box are closer to the upper end of the distribution, meaning less variation of risk perception above the median and more variation below. The right boxplot shows that median debris flow risk perception of the Qiangs was 3 (Neutral).

A Mann-Whitney *U* test shows that the Hans has a statistically significant higher mean rank (152.40), that is, a higher debris flow risk perception, than the Qiangs (mean rank = 102.33) (U = 5054.000, p = .000).

A Spearman's correlation also finds a statistical significant and moderate negative correlation between ethnicity and perception of existing community debris flow threat at the 0.01 level (2-tailed) (r_s = -.350, N = 258, p = .000).

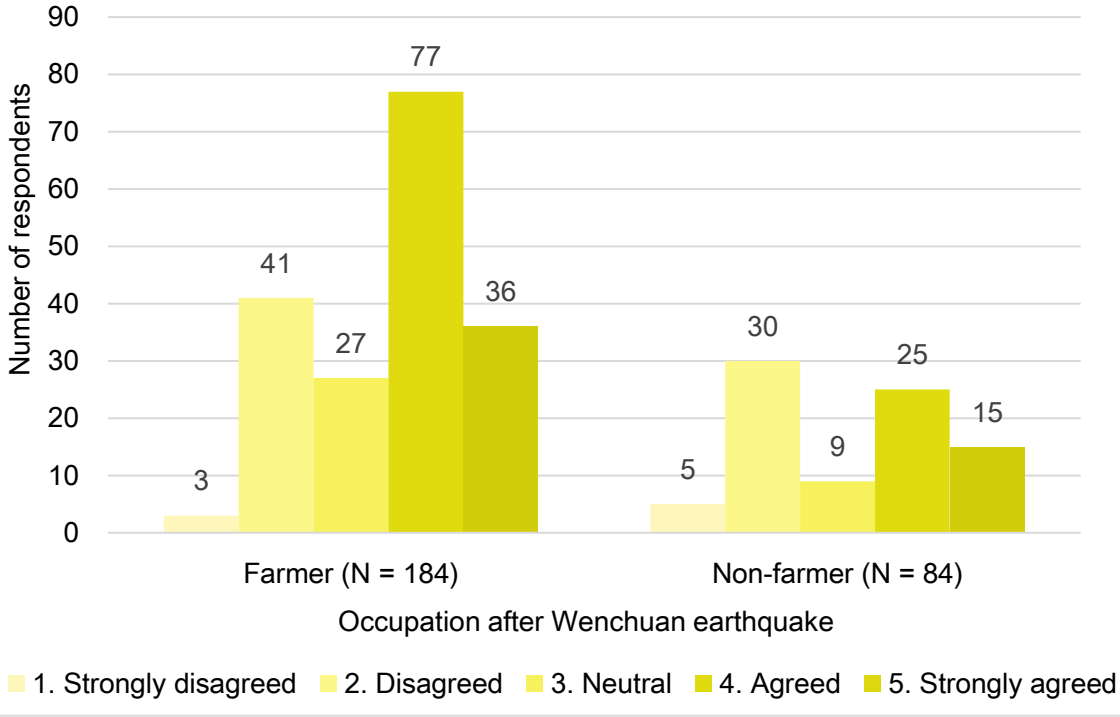
Occupation after the Wenchuan earthquake

Occupation of the respondents after the earthquake was divided into non-farmers and farmers. Observations are not normally distributed (Figure 5.41). The non-farmers had more polarised views on debris flow risk than the farmers.

Among the 268 Pingwu respondents, the majority of farmers (61.42%) and only a minority (47.619%) of non-farmers perceived existing communities debris flow risk. Conversely, only 23.91% of the farmers but 41.666% of the non-farmers did not perceive such threats.

The histograms in Figure 5.41 show that Pingwu farmers' debris flow risk perceptions were in left-skewed distribution while the non-farmers had quite opposite views. Distribution of the non-farmers was quite symmetrical with skewness equals 0.02 but bimodal.

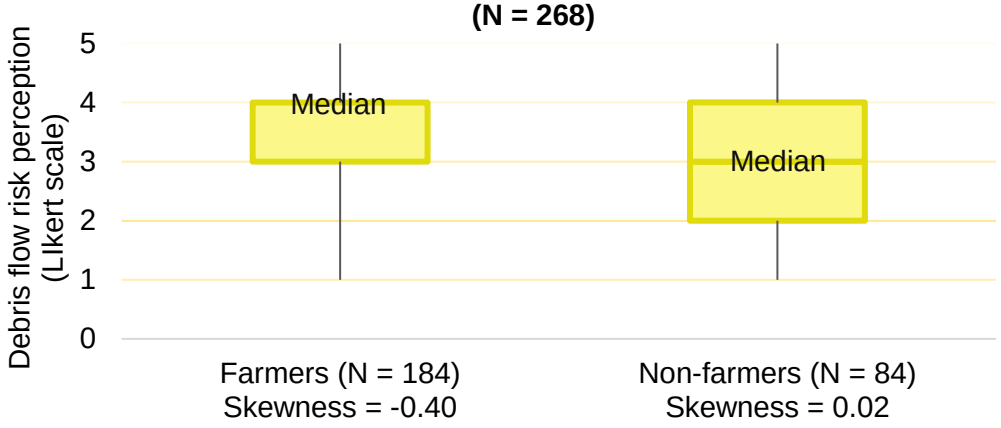
Figure 5.41 Relationship between Pingwu respondents' occupation after the Wenchuan earthquake and their perception of existing community debris flow threat



	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Occupation after earthquake	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Farmer	3 (1.63%)	41 (22.28%)	27 (14.67%)	77 (41.85%)	36 (19.57%)	**184 (100.00%)**
Non-farmer	5 (5.952%)	30 (35.714%)	9 (10.714%)	25 (29.762%)	15 (17.857%)	**84 (100.00%)**
Total	**8 (2.99%)**	**71 (26.49%)**	**36 (13.43%)**	**102 (38.06%)**	**51 (19.03%)**	**268 (100.00%)**

The boxplots in Figure 5.42 show that median debris flow risk perception of the non-farmers and the farmers was 3 (Neutral) and 4 (Agreed) respectively. The left boxplot is closer to the upper end of the distribution, meaning less variation of risk perception above the median and more variation below.

Figure 5.42 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their occupation after Wenchuan earthquake (N = 268)



According to a Mann-Whitney *U* test, the farmers had a statistically significant higher mean rank (141.40), that is, perceived higher debris flow risk, than the non-farmers (mean rank = 119.38) (U = 6457.500, p = .024). A Spearman's correlation between respondents' post-earthquake occupation and their perception of community existing debris flow risk is significant at the 0.05 level (2-tailed), although it is weak positive monotonic (r_s =.138, N = 268, p = .024).

Regularities

Two sets of regularities in terms of demographic and socioeconomic variables were found associated with Pingwu respondents' perception of existing community debris flow threat. The younger Han farmers perceived higher risk while the elder Qiang non-farmers were less agreed that their communities had risk (Table 5.15).

Table 5.15

Demographic/Socioeconomic variables having statistical significant relationships with perception of existing community debris flow threat in Pingwu

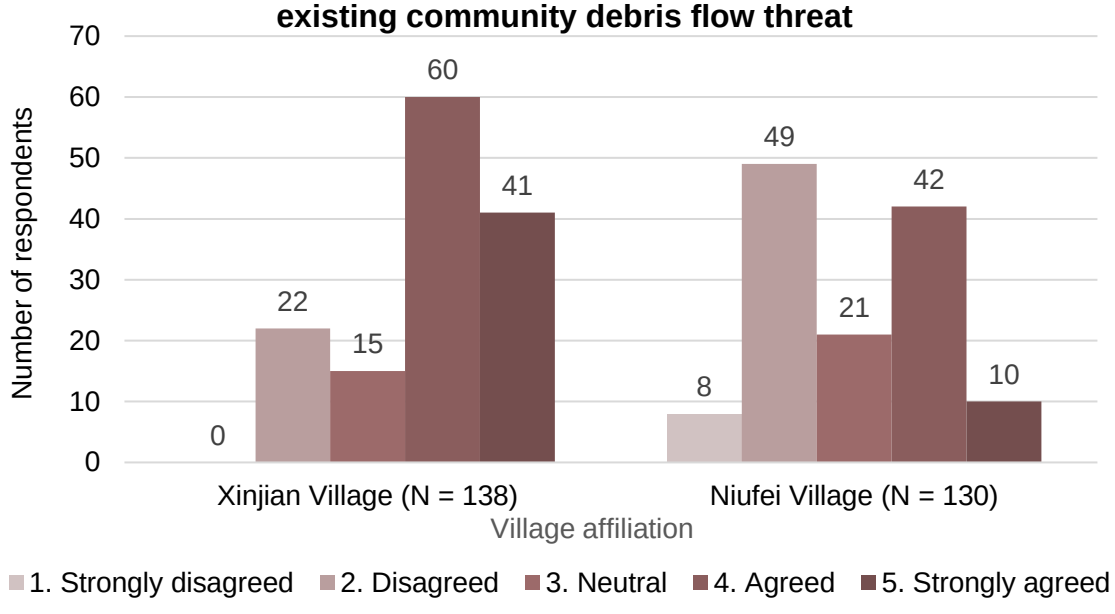
	Pingwu respondents' perception of existing community debris flow risk	
Demographic or socioeconomic factor	**Strongly disagreed/ Disagreed (Lower risk perception)**	**Strongly agreed/ Agreed (Higher risk perception)**
Age (18 to 64 VS 65 or above)	Aged 65 or above	Aged 18 to 64
Ethnicity (Qiang VS Han)	Qiang	Han
Occupation after Wenchuan earthquake (Non-farmer VS Farmer)	Non-farmer	Farmer

Relationship between non-demographic factors and perception of existing community debris flow threat

Village affiliation

The distributions of existing community debris flow threat perception in the two Pingwu villages are shown in Figure 5.43. A total of about three-quarter of Xinjian villagers strongly agreed (29.71%) or agreed (43.48%) their communities were at risk (left histogram). Conversely, a greater portion of Niufei villagers either strongly disagreed (6.154%) or disagreed (37.692%) that their communities were threatened (right histogram). Niufei respondents had more opposing views on community debris flow risk than their Xinjian counterparts.

Figure 5.43 Relationship between village affiliation of Pingwu respondents and their perception of existing community debris flow threat

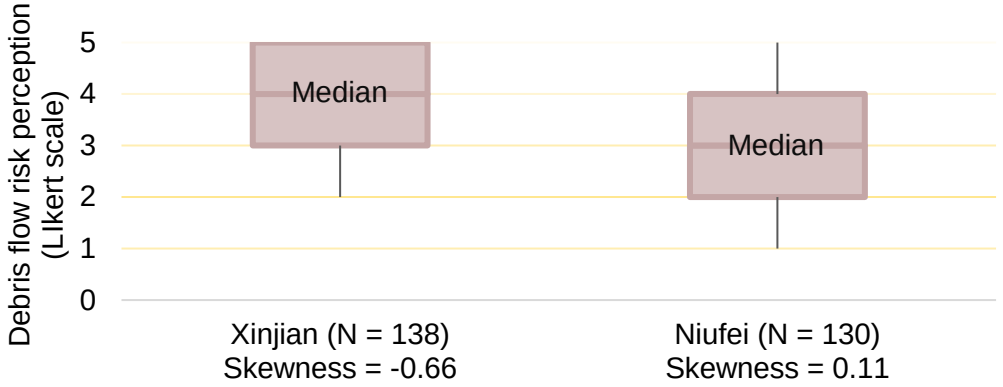


	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Village affiliation	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Xinjian Village	0 (0.00%)	22 (15.94%)	15 (10.87%)	60 (43.48%)	41 (29.71%)	138 (100.00%)
Niufei Village	8 (6.154%)	49 (37.692%)	21 (16.154%)	42 (32.308%)	10 (7.692%)	130 (100.00%)

The histograms show that debris flow risk perception distribution of Xinjian respondents were negatively skewed with skewness equals to -0.66. Risk perception distribution of Niufei villagers were relatively symmetrical with skewness equals to 0.11 but with two peaks.

In Figure 5.44, there is no whisker on the upper end of the left boxplot. The degrees of spread of risk perceptions in Xinjian were smaller than in Niufei. Median debris flow risk perception of the Xinjian villagers was 4 (Agreed). It is closer to the upper end of the distribution, meaning less variation of risk perception above the median and more variation below. The right boxplot shows that median debris flow risk perception of the Niufei respondents was 3 (Neutral).

Figure 5.44 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their village affiliation (N = 268)



A Mann-Whitney *U* test was introduced to determine any association between village affiliation and risk perception. The difference between the mean ranks of Xinjian villagers' risk perception (162.20) and Niufei villagers' (105.10) is statistically significant. Perception of existing community debris flow risk in Xinjian was statistically significantly higher than in Niufei (U = 5147.500, p = .000). Niufei respondents were less agreed that their communities were at risk.

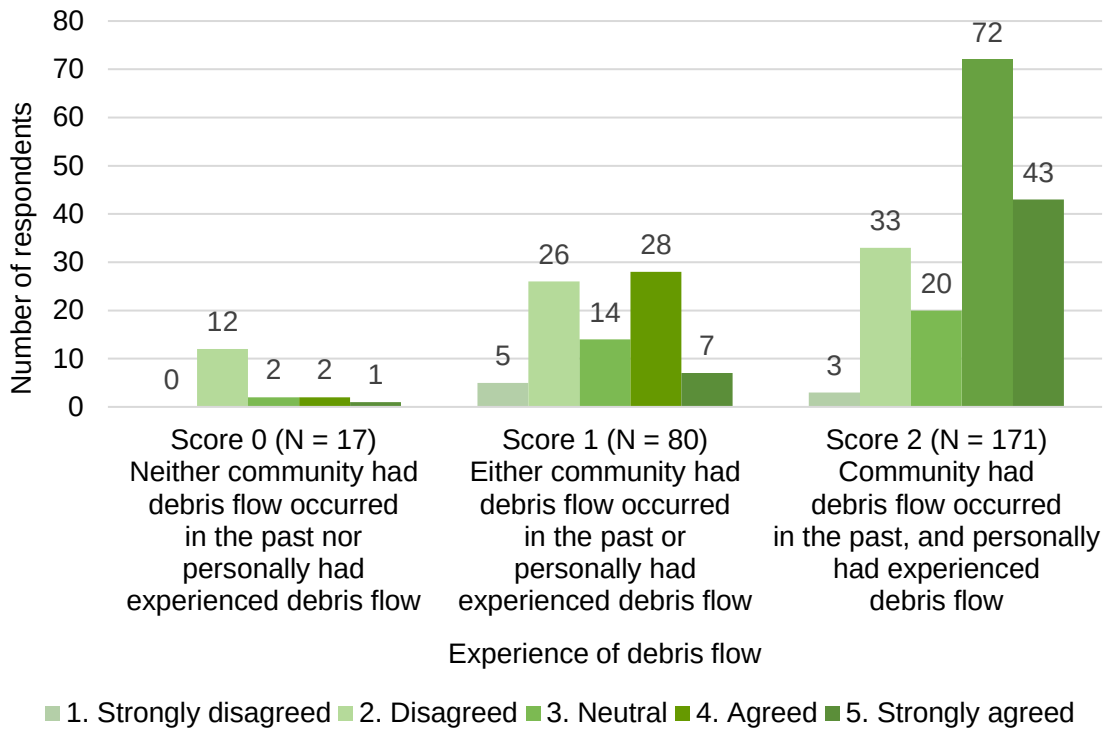
A Spearman's correlation between respondents' village affiliation and their debris flow risk perception is also significant and negatively moderately correlated at the 0.01 level (2-tailed) (r_s = -.385, N = 268, p = .000).

Experience of debris flow

Survey results show that in Pingwu, the more debris flow experience one had, the higher existing community debris flow risk one perceived (Figure 5.45). Those who had the most debris flow experience (Score 2) were more agreed that their communities were at risk. More than two-third of those who had personally experienced debris flow and their communities also had debris flow occurred in the past either agreed (42.105%) or strongly agreed (25.146%) that their communities

had existing debris flow threat (right histogram). Villagers scored 1 had the most polarised views on existing community debris flow risk (middle histogram). A majority (70.588%) of those who had neither experienced debris flow personally or on a community level (Score 0) did not perceive such risk at all (left histogram). This means debris flow risk perception of those who scored 2 was the highest, followed by those who scored 1, and then those who scored 0.

Figure 5.45 Relationship between debris flow experience of Pingwu respondents and their perception of existing community debris flow threat



	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Experience of debris flow	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Score 0	0 (0.00%)	12 (70.588%)	2 (11.765%)	2 (11.765%)	1 (5.882%)	17 (100.00%)
Score 1	5 (6.25%)	26 (32.50%)	14 (17.50%)	28 (35.00%)	7 (8.75%)	80 (100.00%)
Score 2	3 (1.754%)	33 (19.298%)	20 (11.696%)	72 (42.105%)	43 (25.146%)	171 (100.00%)

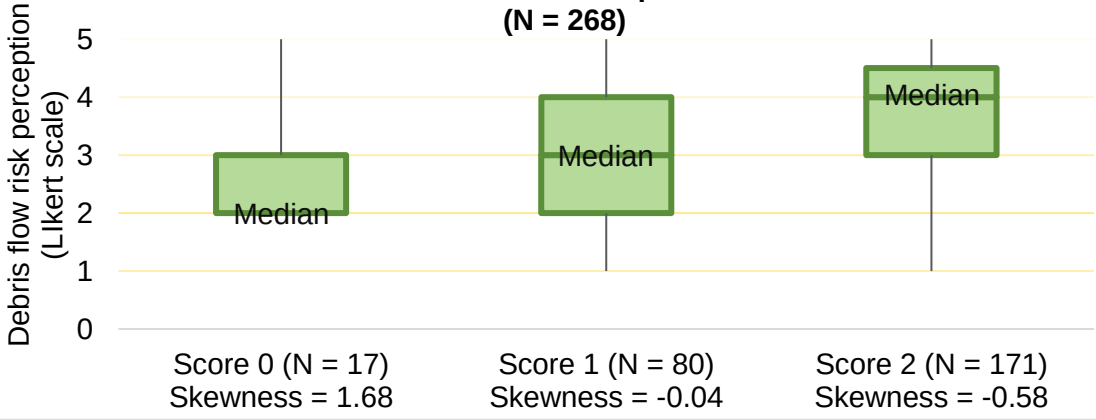
The left boxplot of Figure 5.46 shows that for those who had never experienced debris flow (Score 0), the median debris flow risk perception was 2 (Disagreed). There is no whisker on the lower end of the box, indicating the right skewness of risk perceptions or positively skewed distribution, and is highly skewed at 1.68. The

degrees of spread of risk perceptions among this group were slightly smaller than those of the two other groups.

The median risk perception of those with most debris flow experience (Score 2) was 4 (Agreed). Their risk perception distribution is less skewed and left-skewed with skewness equals to -0.58 (right boxplot). Both the box and the median are closer to the upper end of the distribution, meaning less variation of risk perception above the median and more variation below.

For those who had either one form of debris flow experience, the median risk perception is 3 (Neutral) (middle boxplot). Distribution of their risk perception was fairly symmetrical but with two peaks of almost mirror images, indicating their opposite views on debris flow risk (middle histogram).

Figure 5.46 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their debris flow experience (N = 268)



According to Spearman's correlation, experiences of debris flow and perception of existing community debris flow risk is statistically significantly correlated at the 0.01 level (2-tailed). Those Pingwu respondents who had no debris flow experience at all had a lower risk perception. Those with the most debris flow experiences tended to have the highest risk perception, although the correlation is weak to moderate positive monotonic (r_s = .313, N = 268, p = .000).

Perception of substantial debris flow

In what ways a person define "substantial debris flow" might affect his/her debris flow risk perception. A Spearman's correlation finds that Pingwu respondents' overall perception of substantial debris flow (based on the average score of the

seven statements regarding substantial debris flow characteristics) were statistically significantly correlated with their perception of existing community debris flow risk at the 0.01 level (2-tailed). Those who perceived substantial debris flow as more dangerous tended to perceive more existing threat in their communities, although it was a weak positive monotonic correlation (r_S = .182, N = 268, p = .003).

Detailed relations between Pingwu respondents' perception of each of the seven substantial debris flow characteristics and their perception of existing community debris flow threat were further investigated (Table 5.16).

Five out of seven were found to have statistical significant positive relation with debris flow risk perception, with Spearman's rho ranging from .128 to .212. Although their respective relations were weak, the results still indicate the more dangerous the respondents perceived substantial debris flow in the five aspects, the more they perceived existing debris flow threat affecting their communities.

Table 5.16

Statistical relationships between Pingwu respondents' perceptions of each of the seven substantial debris flow characteristics and their perceptions of existing community debris flow threat

Statements on perception of substantial debris flow	*N*=	Correlation *p*-value	Spearman's rho r_s
(1). Substantial debris flow can take human lives	**268**	**.036^**	**.128**
(2). Substantial debris flow can destroy the whole village or the whole group/community	268	.172	.084
(3). Substantial debris flow can damage houses	268	.054	.118
(4). Substantial debris flow can the lives of cattle	**268**	**.008^^**	**.161**
(5). Substantial debris flow can destroy farmland	**268**	**.005^^**	**.173**
(6). Substantial debris flow can cause property losses	**268**	**.000^^**	**.212**
(7). Substantial debris flow can cause road congestion	**268**	**.003^^**	**.182**

^Correlation is significant at the 0.05 level (2-tailed)
^^Correlation is significant at the 0.01 level (2-tailed)

Knowledge of debris flows

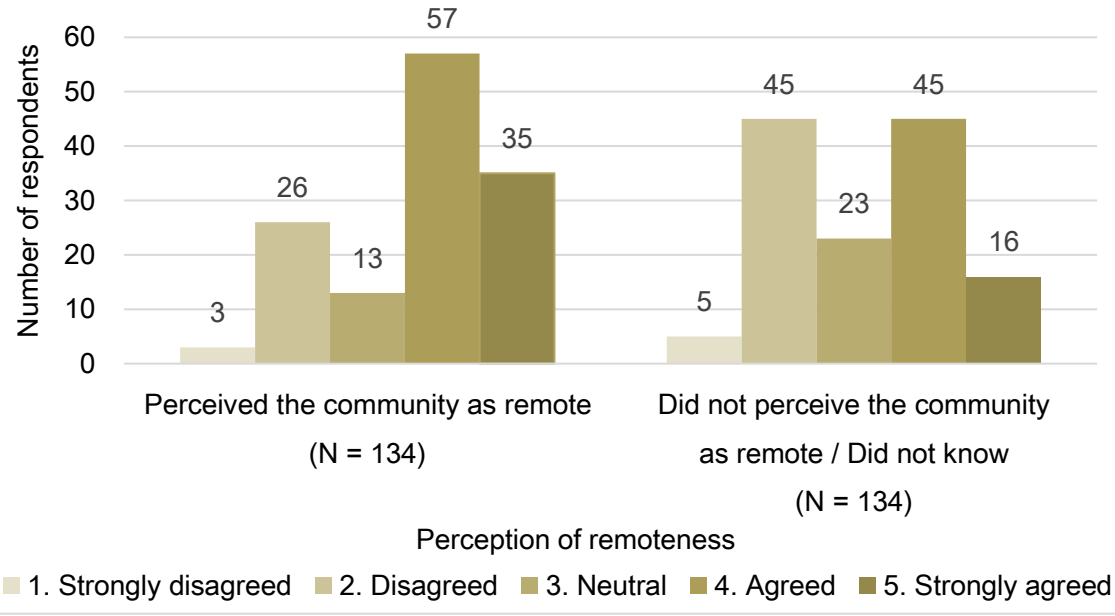
A Spearman's correlation reveals that Pingwu respondents' knowledge of debris flows (with a scale 0 to 4, derived from the answers of four survey questions listed in Section 5.1) and their perceptions of existing community debris flow risk is not statistically significantly associated (r_S = -.067, N = 268, p = .273).

Perception of remoteness of community

In Pingwu, those who perceived their communities as remote were more agreed that their communities were threatened by existing debris flow, when compared to those who did not perceive the remoteness.

Among those who perceived their communities as remote, 68.66% strongly agreed or agreed that their communities were at risk (Figure 5.47). Only 21.64% did not. In contrary, for those who did not perceive their communities as remote, only 45.522% perceived the threat, 37.313% did not think they were at risk.

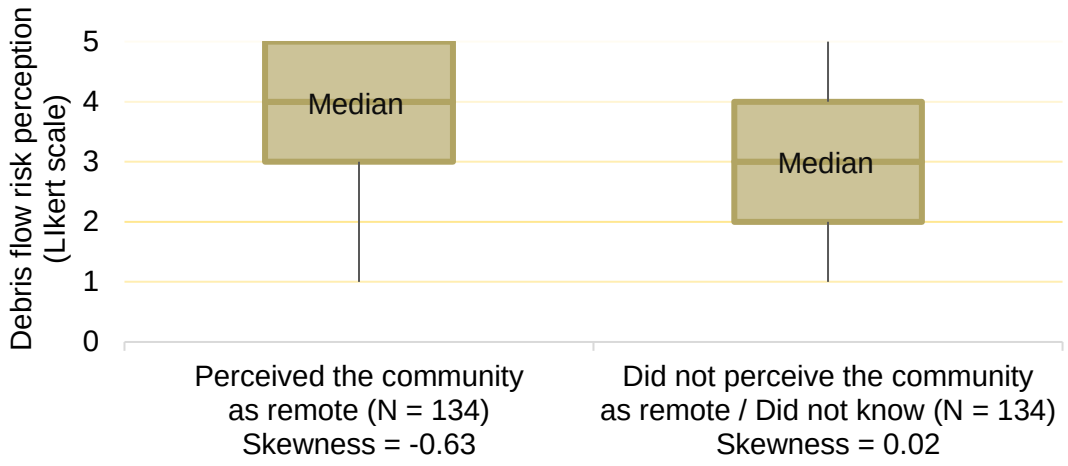
Figure 5.47 Relationship between Pingwu respondents' perception of remoteness of their communities and their perception of existing community debris flow threat



	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Perception of remoteness	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	3 (2.24%)	26 (19.40%)	13 (9.70%)	57 (42.54%)	35 (26.12%)	**134 (100.00%)**
No	5 (3.731%)	45 (33.582%)	23 (17.164%)	45 (33.582%)	16 (11.940%)	**134 (100.00%)**
Total	**8 (2.985%)**	**71 (26.49%)**	**36 (13.43%)**	**102 (38.06%)**	**51 (19.03%)**	**268 (100.00%)**

Figure 5.48 shows that the median debris flow risk perception of those who perceived their communities as remote was 4 (Agreed). There is no whisker on the upper end of the left boxplot. Both the median and the box are closer to the upper end of the distribution, meaning less variation of risk perception above the median and more variation below. The distribution was left-skewed, with skewness equals to -0.63. However, those who did not perceive their communities as remote or did not know at all had quite opposite views on debris flow risk with skewness at 0.02. Their risk perception distribution was almost symmetrical but bimodal. The right boxplot indicates the median debris flow risk perception of these Pingwu respondents was 3 (Neutral). Nevertheless, the degree of spread of risk perception was similar for the two groups.

Figure 5.48 Boxplot showing distribution of Pingwu respondents' debris flow risk perception in relation to their perception of community remoteness (N = 268)



A Mann-Whitney *U* test shows that those who perceived their communities as remote has a statistically significant higher mean rank (152.39), that is, a higher debris flow risk perception, than the other group (mean rank = 116.61) (U = 6580.500, p = .000).

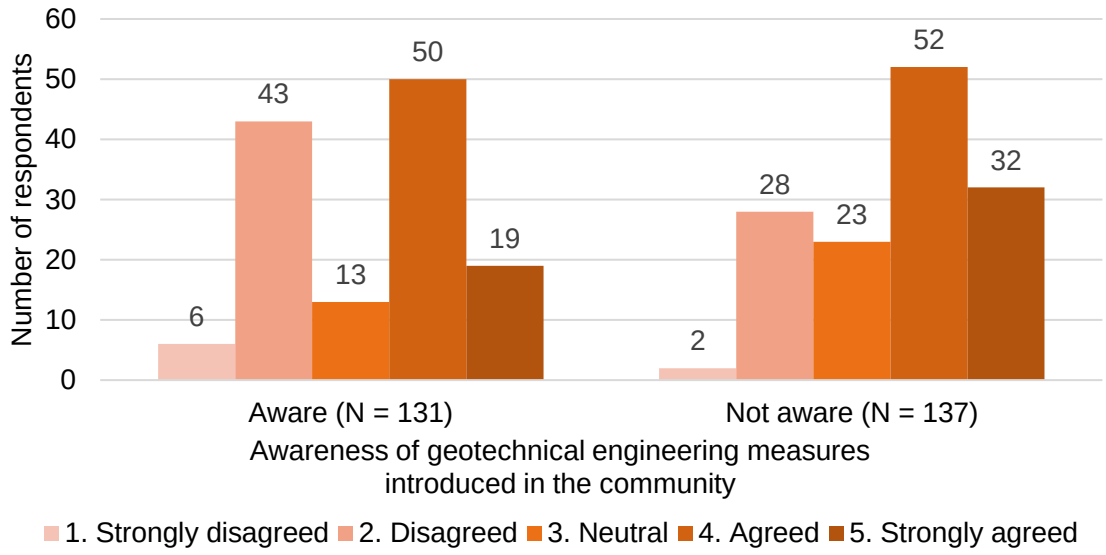
Although the Spearman's correlation between perception of remoteness and perception of community existing debris flow risk is statistically significant at the 0.01 level (2-tailed), it is weak positive monotonic (r_s = .242, N = 268, p = .000).

Relationships between government disaster risk reduction measures and perceptions of existing community debris flow threat

Government disaster mitigation (engineering) measures

The respective distribution of existing community debris flow risk perception of Pingwu respondents who were aware and unaware of government engineering mitigation measures is shown in Figure 5.49. The observations are not normally distributed.

Figure 5.49 Relationship between Pingwu respondents' awareness of geotechnical engineering measures introduced in community and their perception of existing community debris flow threat

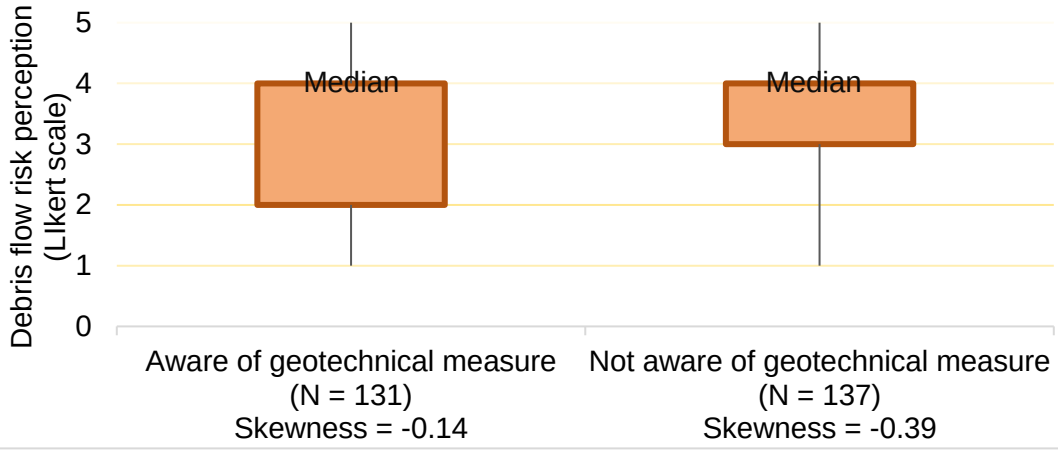


	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Aware of geotechnical engineering measures	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	6 (4.580%)	43 (32.824%)	13 (9.924%)	50 (38.168%)	19 (14.504%)	**131 (100.00%)**
No	2 (1.460%)	28 (20.438%)	23 (16.788%)	52 (37.956%)	32 (23.358%)	**137 (100.00%)**
Total	**8 (2.99%)**	**71 (26.49%)**	**36 (13.43%)**	**102 (38.06%)**	**51 (19.03%)**	**268 (100.00%)**

The majority (61.314%) of those who were unaware of the geotechnical measures perceived their communities having debris flow risk. For those who were aware of such measures, only about half (52.672%) perceived the risk. On the other hand, 37.404% of those who were aware of the measures and a smaller portion (21.898%) of those who were unaware did not perceive debris flow risk.

Median debris flow risk perceptions of both the aware and the unaware groups were 4 (Agreed). Both medians are closer to the upper end of the boxplots distribution, meaning less variation of risk perception above the median and more variation below (Figure 5.50). However, those who were aware of the geotechnical measures had quite polarised views on debris flow risk (Figure 5.49). The distribution of their risk perception is relatively symmetrical with skewness at -0.14 but bimodal. The degree of spread of risk perception was slightly bigger than that of the unaware group. The unaware group were in left-skewed distribution, with skewness at -0.39 (right boxplot in Figure 5.50), meaning they were more agreed that their communities were at risk.

Figure 5.50 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their awareness of geotechnical measures (N = 268)



A Mann-Whitney *U* test shows that the group who were unaware of or did not know whether geotechnical measures were introduced in their communities has a statistically significant higher mean rank (145.38), meaning a higher debris flow risk perception, than the aware group (mean rank = 123.12) (U = 7482.5, p = .014). Although the association between awareness of community geotechnical measures and perception of existing debris flow risk is statistically significant at the 0.05 level (2-tailed), Spearman's correlation finds that it was weak negative monotonic (r_s = -.150, N = 268, p = .014).

Government disaster preparedness measures

Among the seven government disaster preparedness measures covered in this research, Mann-Whitney *U* tests reveal that respondents' awareness of the introduction of five were positively related with community existing debris flow risk perception while two were negatively related in Pingwu. However, the *p*-values of the seven pairs of variable were between .082 and .663, according to Spearman's rank correlations, indicating the relations were statistically insignificant. The Spearman's rho correlation coefficient of the five positively and the two negatively related variables were between .030 to .106 and -.027 to -.060 respectively, meaning the relationships were weak (Table 5.17).

Table 5.17

Statistical relationships between Pingwu respondents' awareness of / accessibility to each government disaster preparedness measure and their perceptions of existing community debris flow threat

Government disaster preparedness measures	Mean rank (0)	Mean rank (1)	*U*-value	Correlation *p*-value	Spearman's rho r_s
1. Awareness of debris flow risk assessment in community	130.68	150.76	4704.000	.082	.106
2a. Accessibility to information on debris flow risk - Hazard zone information on community	132.67	144.36	4332.000	.350	.057
2b. Accessibility to information on debris flow risk - Any information on community	133.87	152.72	1001.500	.455	.046
3. Awareness of assessment on protection against debris flow strike in community	133.74	140.78	3283.500	.631	.030
4. Accessibility to any information on protective measures against general debris flow strike	135.76	118.83	2166.500	.327	-.060
5. Heard of Mass Monitoring and Mass Prevention	130.59	143.37	6899.000	.195	.079
6. Awareness of plan/measure imposed on community to protect residents from debris flow strike	135.51	130.60	5643.000	.663	-.027

Government disaster response measures and facilities

Among the 21 government disaster response measures or facilities being evaluated, respondents' awareness of four early warning measures in Pingwu yielded statistically significant relationship with their perception of existing community debris flow threat. The other 17 did not, according to Mann-Whitney *U* tests and Spearman's correlations (Table 5.18). The correlations are statistically significant at the 0.01 level (2-tailed) for phone and gong, and 0.05 level (2-tailed) for website and shout. The observations are not normally distributed.

Table 5.18

Statistical relationships between Pingwu respondents' awareness of / accessibility to each government disaster response measure or facility and their perceptions of existing community debris flow threat

Government disaster response measures or facilities	Mean rank (0)	Mean rank (1)	*U*-value	Correlation *p*-value	Spearman's rho r_s
1. Awareness of assessment on capability to tackle debris flow hit in community	133.71	142.18	2845.500	.588	.033
2. Awareness of plan/measure/instruction to tackle debris flow hit in community	131.26	148.63	4743.500	.136	.091
3. Accessibility to information on appropriate response when hit by debris flow					
a. Any information /instruction	132.48	156.04	2322.000	.146	.089
b. Booklet	136.26	110.06	1810.000	.148	-.089
c. Card/ Table	133.67	145.39	2158.500	.508	.041
4. Awareness of early warning					
a. Website	133.68	243.00	49.000	**.038^**	**.127**
b. Siren	136.69	115.71	2834.000	.157	-.087
c. Phone	128.51	190.27	1696.000	**.000^^**	**.247**
d. Gong	126.55	174.97	3147.500	**.000^^**	**.242**
e. Shout	129.29	152.95	5077.000	**.030^**	**.132**

(cont.)

Government disaster response measures or facilities	Mean rank (0)	Mean rank (1)	*U*-value	Correlation *p*-value	Spearman's rho r_s
5. Awareness of communication					
a. General	131.26	135.37	5829.000	.711	.023
b. Community unit	136.85	132.11	8660.000	.602	-.032
6. Awareness of monitoring personnel					
a. Heard of	137.03	127.48	6495.000	.353	-.057
b. Respondent	134.51	133.63	524.500	.981	-.001
c. Family member	135.12	107.58	624.500	.370	-.055
7. Awareness of emergency response facilities					
a. Evacuation route	132.05	147.34	4285.500	.216	.076
b. Emergency shelter	133.91	138.88	3636.000	.723	.022
c. Temporary residing place	134.79	131.27	2635.000	.832	-.013
8. Awareness of emergency response dissemination					
a. Emergency bag	133.73	143.09	2517.000	.572	.035
b. Training	136.19	98.54	1104.500	.086	-.105
c. Drill	131.60	154.46	3299.500	.093	.103

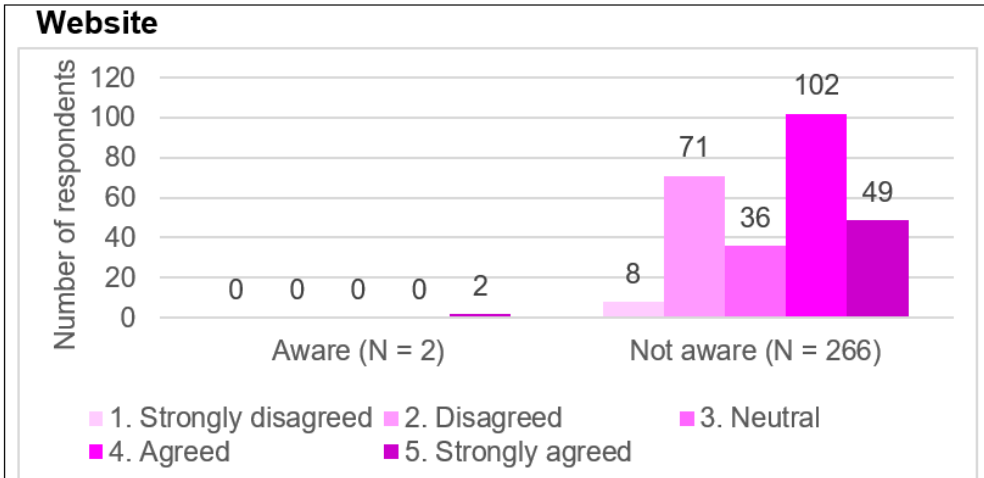
^Correlation is significant at the 0.05 level (2-tailed)

^^Correlation is significant at the 0.01 level (2-tailed)

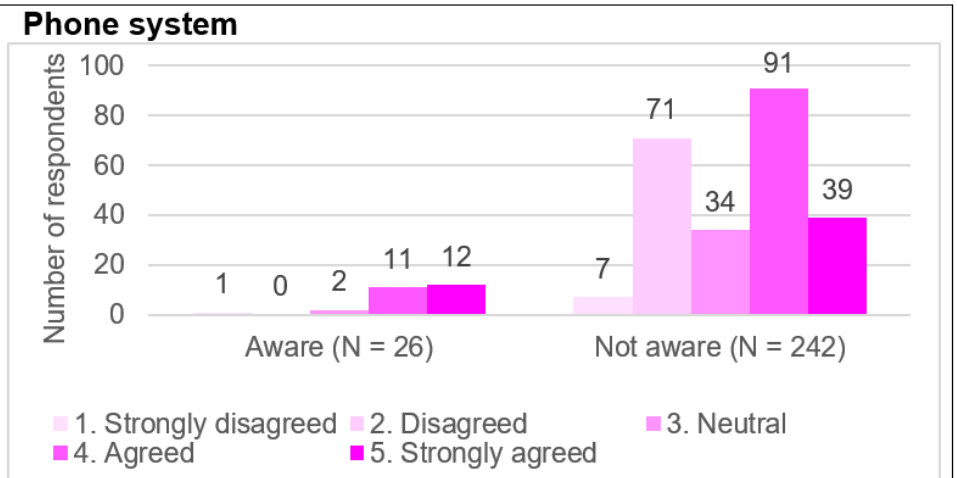
➢ **Early warning disaster response measures: Website, Phone, Gong and Shout**

The relationships between Pingwu respondents' awareness of four respective early warning disaster response measures which impacted their communities and their perception of existing community debris flow threat are illustrated in Figure 5.51.

Figure 5.51 Relationship between Pingwu respondents' awareness of four early warning disaster response measures in the community and their perception of existing community debris flow threat

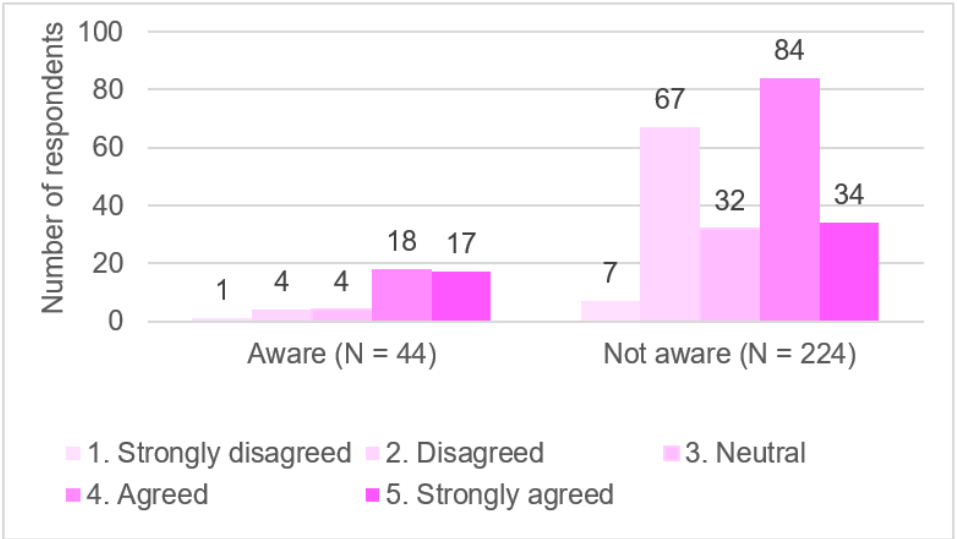


	Perception of debris flow threat (Likert scale 1 to 5)					
Awareness of website	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	2 (100.00%)	2 **(100.00%)**
No	8 (3.01%)	71 (26.69%)	36 (13.53%)	102 (38.35%)	49 (18.42%)	266 **(100.00%)**
Total	**8 (2.99%)**	**71 (26.49%)**	**36 (13.43%)**	**102 (38.06%)**	**51 (19.03%)**	**268 (100.00%)**



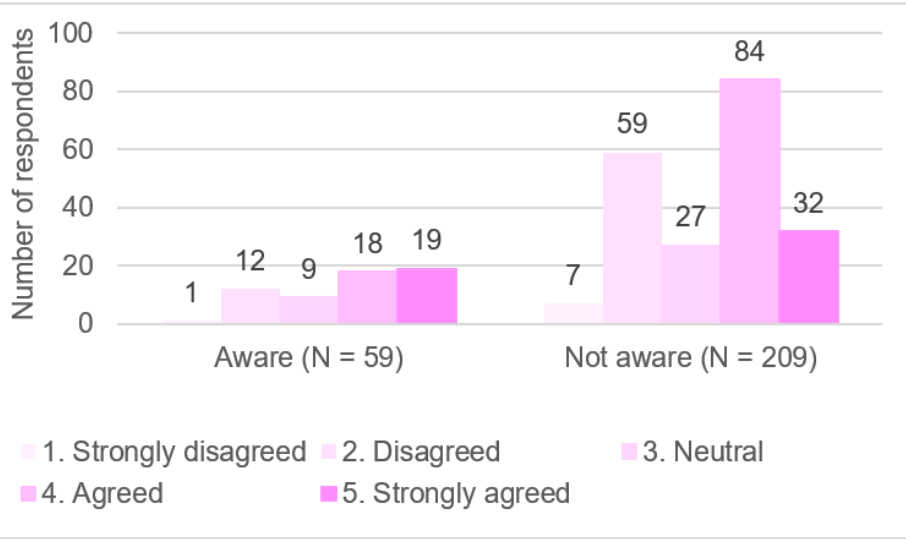
	Perception of debris flow threat (Likert scale 1 to 5)					
Awareness of phone system	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	1 (3.85%)	0 (0.00%)	2 (7.69%)	11 (42.31%)	12 (46.15%)	26 (100.00%)
No	7 (2.89%)	71 (29.34%)	34 (14.05%)	91 (37.60%)	39 (16.12%)	242 (100.00%)
Total	**8 (2.99%)**	**71 (26.49%)**	**36 (13.43%)**	**102 (38.06%)**	**51 (19.03%)**	**268 (100.00%)**

Gong



	Perception of debris flow threat (Likert scale 1 to 5)					
Awareness of gong	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	1 (2.27%)	4 (9.09%)	4 (9.09%)	18 (40.91%)	17 (38.64%)	44 (100.00%)
No	7 (3.13%)	67 (29.91%)	32 (14.29%)	84 (37.50%)	34 (15.18%)	224 (100.00%)
Total	**8 (2.99%)**	**71 (26.49%)**	**36 (13.43%)**	**102 (38.06%)**	**51 (19.03%)**	**268 (100.00%)**

Shout



	Perception of debris flow threat (Likert scale 1 to 5)					
Awareness of shout	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	1 (1.69%)	12 (20.34%)	9 (15.25%)	18 (30.51%)	19 (32.20%)	59 (100.00%)
No	7 (3.35%)	59 (28.23%)	27 (12.92%)	84 (40.19%)	32 (15.31%)	209 (100.00%)
Total	**8 (2.99%)**	**71 (26.49%)**	**36 (13.43%)**	**102 (38.06%)**	**51 (19.03%)**	**268 (100.00%)**

Although how Pingwu respondents' debris flow risk perceptions were related to their awareness of the four early warning tools are not identical, some trends and regularities were found.

When first look into those who were aware of the early warning tools (Table 5.19), a great majority strongly agreed or agreed that they perceived existing community debris flow threat. Except for website which only had two respondents aware of it and therefore inappropriate for evaluation, as high as 88.46% of those who were aware of phone perceived debris flow risk, followed by 79.55% of gong and 62.71% of shout.

For those who were unaware of the community early warning tools, respective distribution of debris flow risk perception were very similar across all four tools. However, only slightly over half of the respondents strongly agreed or agreed there were debris flow risks, while less than one-third did not perceive the risk.

Table 5.19

Relation between early warning tools awareness and debris flow risk perception

	Perception of existing community debris flow threat		
Aware of early warning by	**Strongly disagreed/ Disagreed**	**Neutral**	**Strongly agreed/ Agreed**
Website	0.00% (0/2)	0.00% (0/2)	100.00% (2/2)
Phone	3.85% (1/26)	7.69% (2/26)	88.46% (23/26)
Gong	11.36% (5/44)	9.09% (4/44)	79.55% (35/44)
Shout	22.03% (13/59)	15.25% (9/59)	62.71% (37/59)

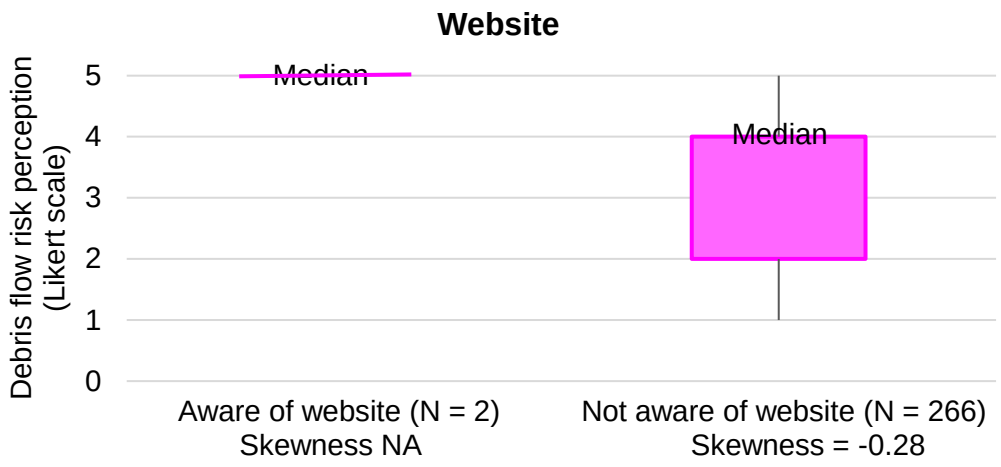
	Perception of existing community debris flow threat		
Not aware of early warning by	**Strongly disagreed/ Disagreed**	**Neutral**	**Strongly agreed/ Agreed**
Website	29.70% (79/266)	13.53% (36/266)	56.77% (151/266)
Phone	32.23% (78/242)	14.05% (34/242)	53.72% (130/242)
Gong	33.04% (74/224)	14.29% (32/224)	52.68% (118/224)
Shout	31.58% (66/209)	12.92% (27/209)	55.50% (116/209)

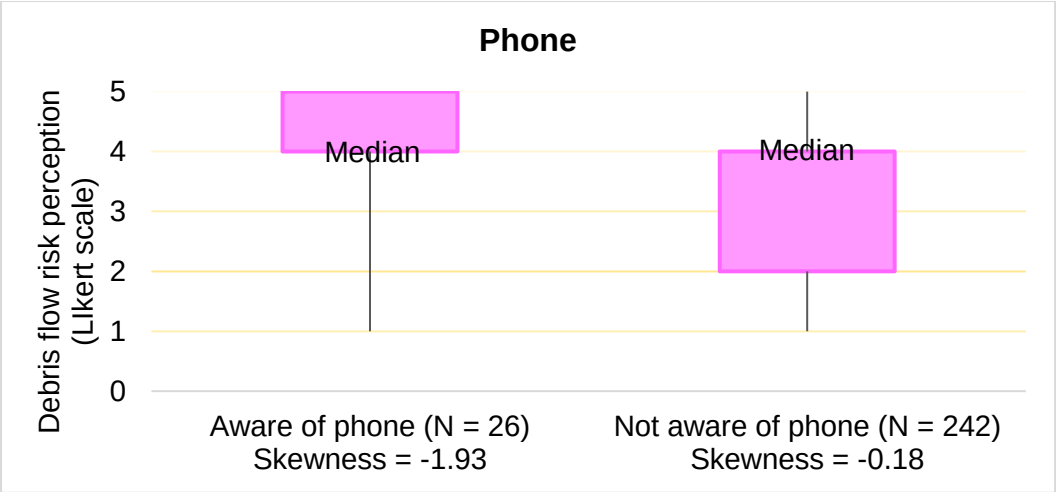
Median debris flow risk perception of all respondent groups, no matter they were aware or not aware of the application of individual early warning tools in their communities, was 4 (Agreed). The only exception was the website aware group (5 Strongly agreed) which only had two respondents.

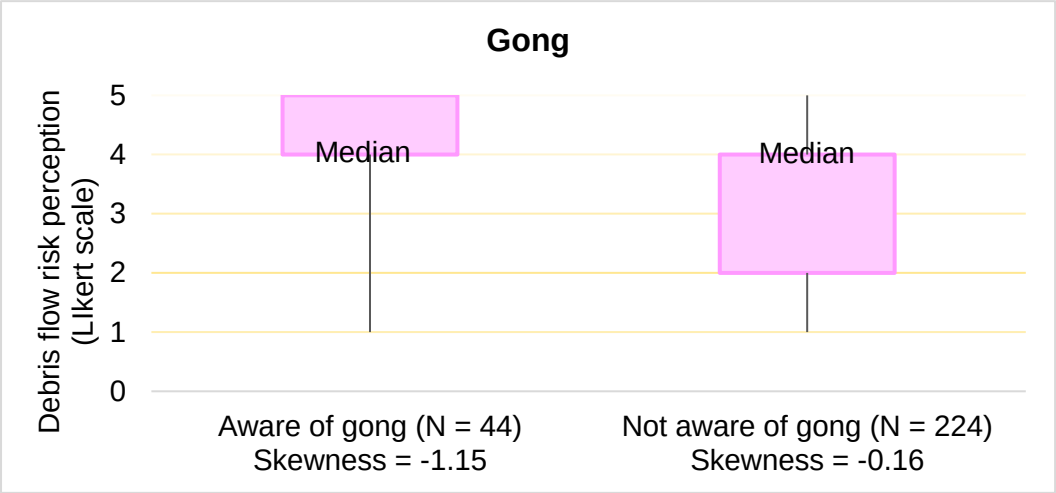
The median, skewness and quartiles of risk perceptions of Pingwu respondents who were aware and unaware of the four early warning tools are presented in Figure 5.52. For each of the four early warning tools aware groups, there is no whisker on the upper end of the boxes (left boxplots). Their debris flow risk perceptions were all in left-skewed distribution, except for website in which skewness is not applicable. Risk perception distribution of the four unaware groups were less skewed (right boxplots), indicating relatively symmetrical distribution.

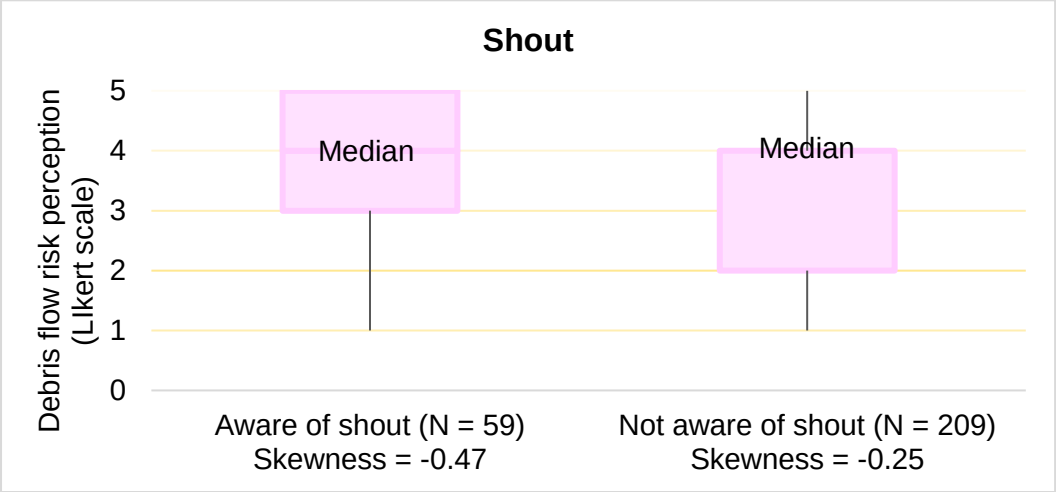
All two website-aware respondents strongly agreed that their place had debris flow risk especially when compared with the website unaware group. The degrees of spread of risk perception among those who were unaware of website were much bigger.

Figure 5.52 Boxplots showing distribution of Pingwu respondents' debris flow risk perception in relation to their awareness of four early warning tools applied in their communities









Mann-Whitney *U* tests find that Pingwu respondents' awareness of the four separate types of early warning tools had similar impacts on their debris flow risk perceptions.

Those who were unaware of or did not know whether website, phone call/ messaging, gong or shouting was an early warning tool applicable in their communities had lower mean ranks (133.68 for website; 128.51 for phone; 126.55 for gong; 129.29 for shout), that is, lower debris flow risk perceptions. They were less agreed that their communities were having debris flow risk. On the contrary, those who were aware of had higher mean ranks (243.00 for website; 190.27 for phone; 174.97 for gong; 152.95 for shout), that is, higher debris flow risk perception. They were more agreed that their communities were at risk.

The differences between the two sets of mean rank for website, phone, gong and shout were statistically significant. Debris flow risk perception of those who were unaware of the four early warning tools was statistically significantly lower than those who were aware of (Website: U = 49.000, p = .038; Phone: U = 1696.000, p = .000; Gong: U = 3147.500, p = .000; Shout: U = 5077.000, p = .030). The correlations were significant at the 0.05 level (2-tailed) for website and shout, and 0.01 level (2-tailed) for phone and gong, although they were weak positive monotonic (Website: r_s = .127, N = 268; Phone: r_s = .247, N = 268; Gong: r_s = .242, N = 268; Shout: r_s = .132, N = 268).

The relative efficacy of the various means of early warning is to be noted. Except for website which was only aware of by two respondents and therefore might not be representative for evaluation, it is clear that awareness of phone call/messaging was the most effective in influencing risk perception in Pingwu, followed by gong, with shouting being the least effective among the three tools (Table 5.18). The pros and cons of the warning methods as well as their relative effectiveness are evaluated in the discussion chapter.

5.3.2 Summary of Hypothesis 2 results in Pingwu

Among the 46 selected sub-variables grouped under nine independent factors, 12 appeared to have statistical significant influence on Pingwu respondents' debris flow risk perception, including five government measures. Apart from geotechnical disaster mitigation (engineering) measures, four early warning tools could also be impactful.

Three demographic factors, namely age, ethnicity and occupation after the Wenchuan earthquake, as well as four non-demographic and non-governmental variables, namely village affiliation, experience of debris flow, perception of substantial debris flow and community remoteness, probably also influenced debris flow risk perception. Figure 5.53 shows all the potential factors that might relate to debris flow risk perception, and highlights those appeared to have actual impact on Pingwu. Figure 5.54 summarises only those possibly influential factors for easy reference.

The second hypothesis of this research which states that *"the rural populations living in remote mountainous areas have developed perceptions of geological risk that are now generally more advanced than the measures for disaster mitigation, preparedness and response imposed by the government since the earthquake"* is accepted in the Pingwu scenario.

Figure 5.53

Factors associated with Pingwu respondents' perceptions of existing community debris flow threat

(among all other tested but non-associated factors marked in white)

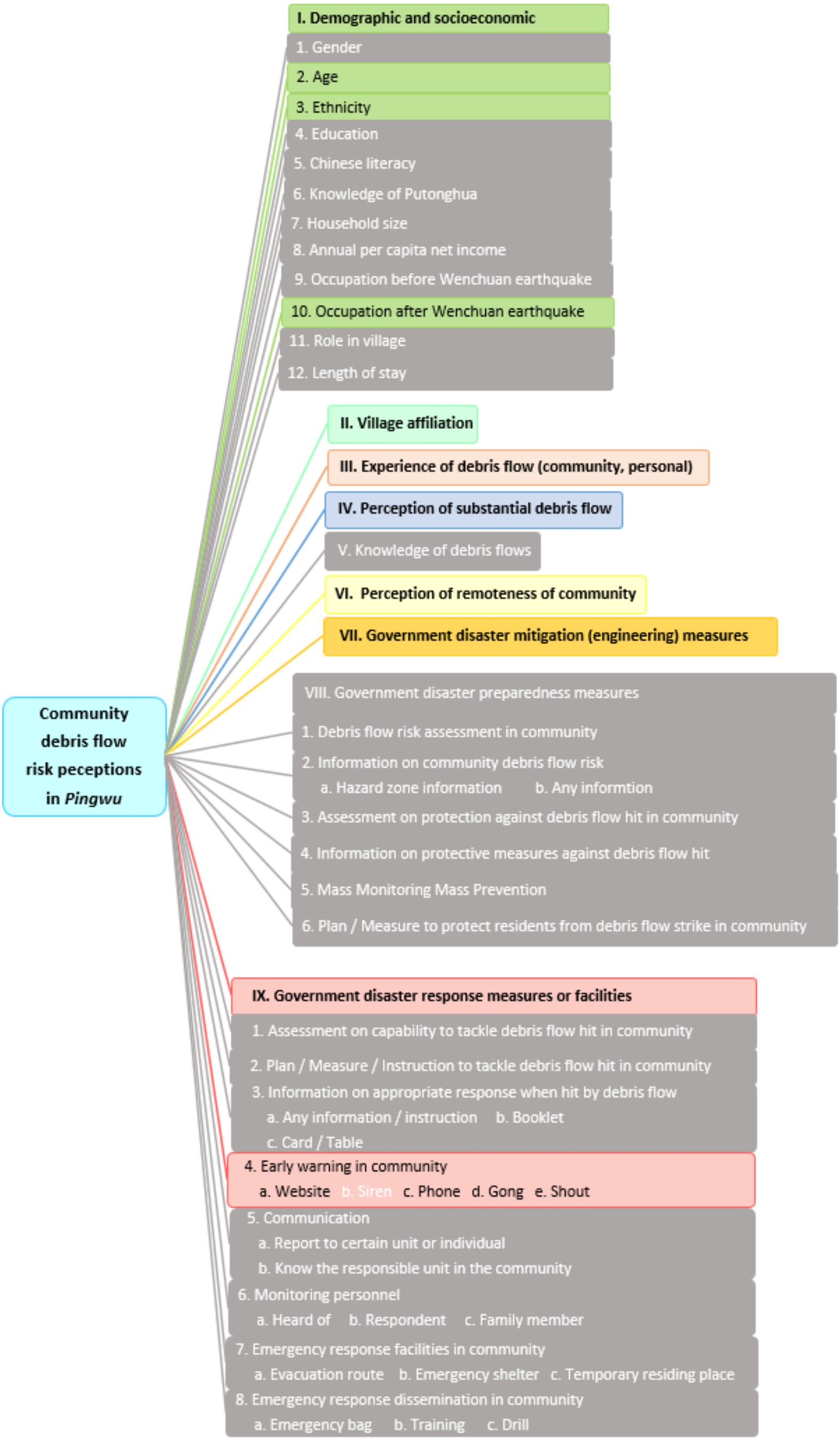
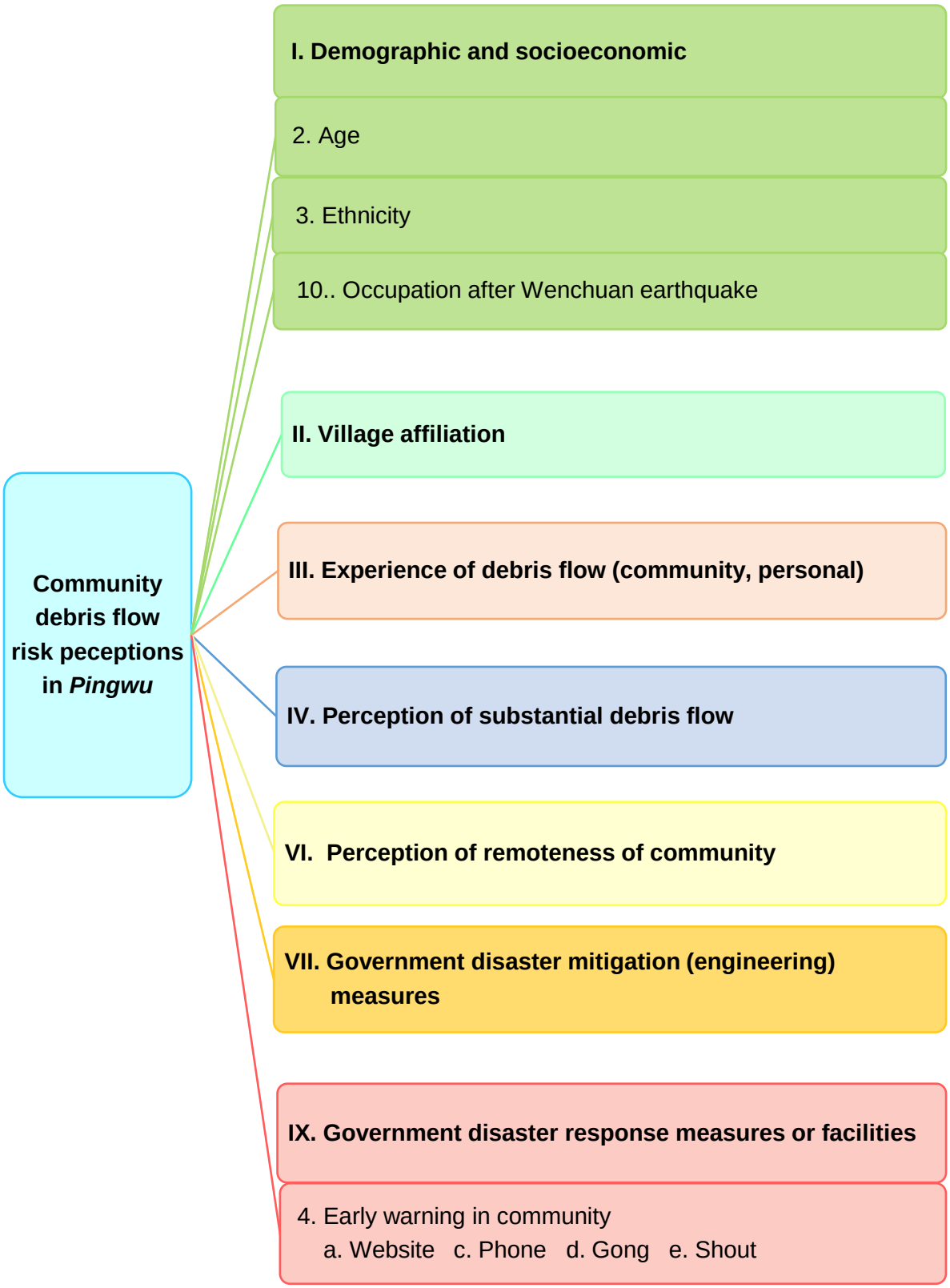


Figure 5.54

Factors associated with Pingwu respondents' perceptions of existing community debris flow threat



5.3.3 Results of study area 2 – Wenchuan County

Relationship between demographic/socioeconomic factors and perception of existing community debris flow threat

Unlike in Pingwu where three out of the twelve tested demographic variables, namely age, ethnicity and occupation after the Wenchuan earthquake, were found to be statistically significantly related to respondents' debris flow risk perception, only ethnicity had such association in Wenchuan. Apart from the Huis which had just two respondents in this research, the Tibetans had the highest debris flow risk perception while the Qiangs had the lowest. The other eleven demographic and socioeconomic factors had no statistical significant association with Wenchuan respondents' debris flow risk perception. Table 5.20 summarises the statistical findings.

Table 5.20

Statistical relationships between each demographic/socioeconomic factor and existing community debris flow risk perception in Wenchuan

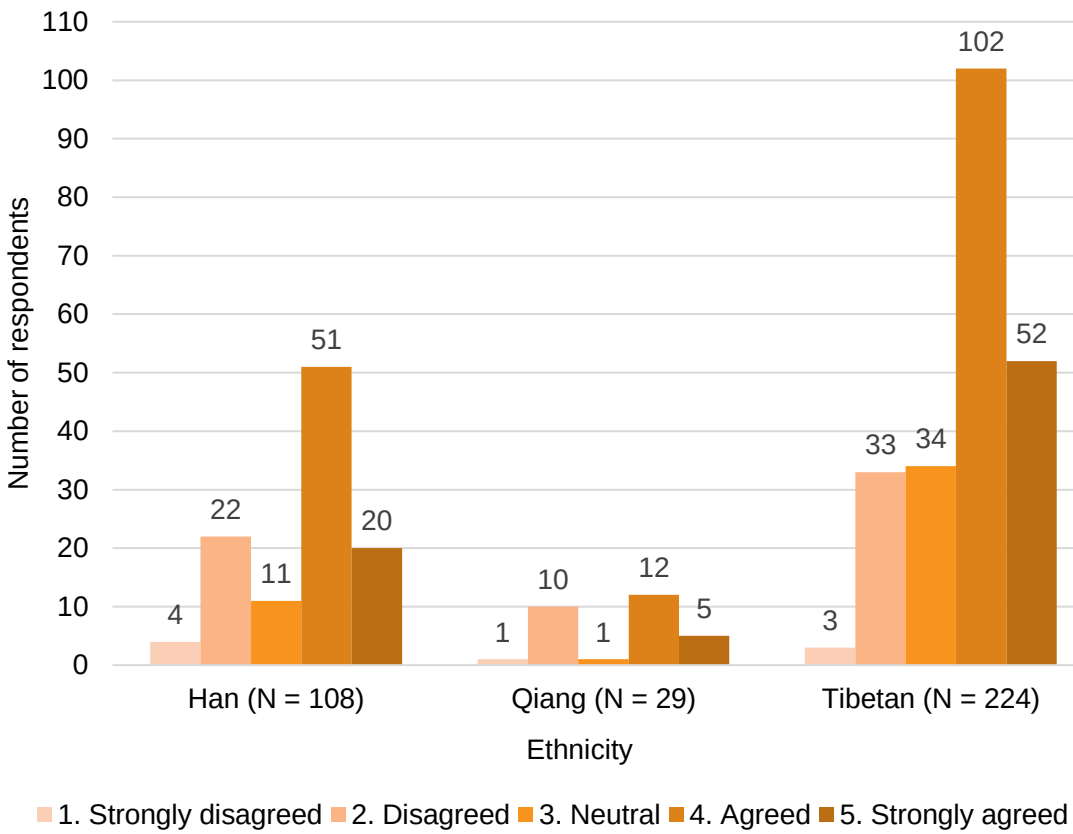
Demographic/Socioeconomic factor	***N*=**	**Mean rank (0)**	**Mean rank (1)**	***U*-value/ #Chi-square value/ ##Fisher Exact value**	***df***	***p*-value (2-tailed)** (*Mann-Whitney *U*) (**Correlation) (#Chi-square) (##Fisher Exact)	**Correlation coefficient/ Effect size** (**Spearman's rho r_s) (#Cramer's *V*)
Gender (Male VS Female)	363	189.35	177.16	*14709.000	--	*.251	**-.060
Age (18 to 64 VS 65 or above)	363	185.51	169.96	*10533.500	--	*.211	**-.066
Ethnicity (Han VS Qiang VS Tibetan VS Hui)	**363**	**--**	**--**	**##12.059**	**--**	**##.042^**	**--**
Education level (3 groups) (Uneducated VS Primary VS Secondary and above)	361	--	--	#3.067	8	#.930	#.065
Education level (2 groups) (Primary or below VS Secondary and above)	361	177.71	185.48	*15227.000	--	*.457	**.039
Chinese literacy (No VS Yes/Partial)	357	175.34	180.20	*11514.000	--	*.685	**.022
Knowledge of Putonghua (Know VS Don't know VS Can understand but cannot speak)	358	--	--	#3.887	8	#.867	#.074
Household size (1 to 3 persons VS 4 or more persons)	363	167.17	184.82	*7985.000	--	*.213	**.066
Annual per capita net income (Below and on poverty line RMB 2855 VS Above poverty line RMB 2856 to below rural population annual per capita net income RMB 10771 VS rural population annual per capita net income RMB 10772 and above)	319	--	--	##7.536	--	##.452	--
Occupation before Wenchuan earthquake (Non-farmer VS Farmer)	363	185.22	179.84	*15371.500	--	*.611	**-.027
Occupation after Wenchuan earthquake (Non-farmer VS Farmer)	361	175.32	186.71	*15261.500	--	*.271	**.058
Role in village (No/ Don't know VS Yes)	363	179.71	223.50	*2479.500	--	*.060	**.099
Length of stay in one's group/ community per year (Not stay for whole year / Don't know / Not sure / NA VS Stay for whole year)	363	188.08	180.31	*10738.000	--	*.538	**-.032

^Correlation is significant at the 0.05 level (2-tailed)

Ethnicity

The relationship between ethnicity of Wenchuan respondents and their perception of existing community debris flow threat is shown in Figure 5.55. Since there were only two Hui villagers in Wenchuan responding to the survey (one disagreed while the other agreed that there was existing community debris flow threat), comparing risk perception of the Huis and other ethnic groups is unreasonable. The two Huis were therefore skipped from the analysis.

Figure 5.55 Relationship between Wenchuan respondents' ethnicity and their perception of existing community debris flow threat



	Perception of debris flow threat (Likert scale 1 to 5)					
Ethnicity	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Hans	4 (3.70%)	22 (20.37%)	11 (10.19%)	51 (47.22%)	20 (18.52%)	108 (100.00%)
Qiangs	1 (3.45%)	10 (34.48%)	1 (3.45%)	12 (41.38%)	5 (17.24%)	29 (100.00%)
Tibetans	3 (1.34%)	33 (14.73%)	34 (15.18%)	102 (45.54%)	52 (23.21%)	224 (100.00%)

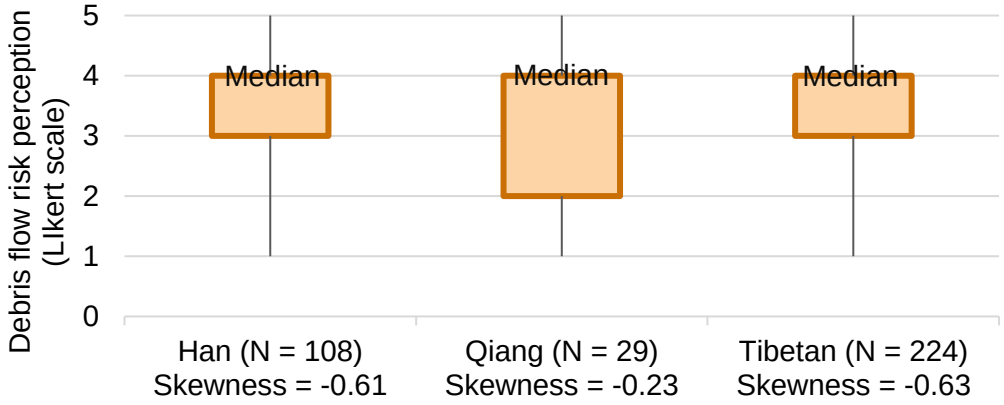
The majority of the Wenchuan respondents from three out of four ethnic groups strongly agreed or agreed that their communities were threatened by existing debris flow. The ethnic group having the greatest proportion of such perception was the Tibetan (68.75%), followed by the Han (65.74%) and then the Qiang (58.62%).[3]

On the contrary, more than one-third (37.93%) of the Qiangs strongly disagreed or disagreed that their communities were at risk, followed by a smaller percentage (24.07%) among the Hans and only 16.07% of the Tibetans.

The histograms show that debris flow risk perceptions of both the Hans and the Qiangs in Wenchuan were in similar trends of those in Pingwu.

Risk perceptions of all three ethnic groups in Wenchuan were in left-skewed distribution (Figure 5.56). Those of the Hans and the Tibetans were almost of the same skewness at -0.61 and -.063 respectively. Distribution of risk perceptions of the Qiangs was fairly symmetrical with skewness equals to -0.23 but bimodal, meaning they had quite opposite views on debris flow risk.

Figure 5.56 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their ethnicity (N = 361)



The median debris flow risk perceptions of all three ethnic groups were 4 (Agreed). All the three medians and the three boxes are closer to the upper end of the distribution, meaning less variation of risk perception above the median and more below.

[3] Chi-square test of independence could not be computed because there is insufficient memory of the computer SPSS software. Therefore the strongly disagreed and the disagreed groups were merged while the strongly agreed and the agreed groups were also merged for analysis.

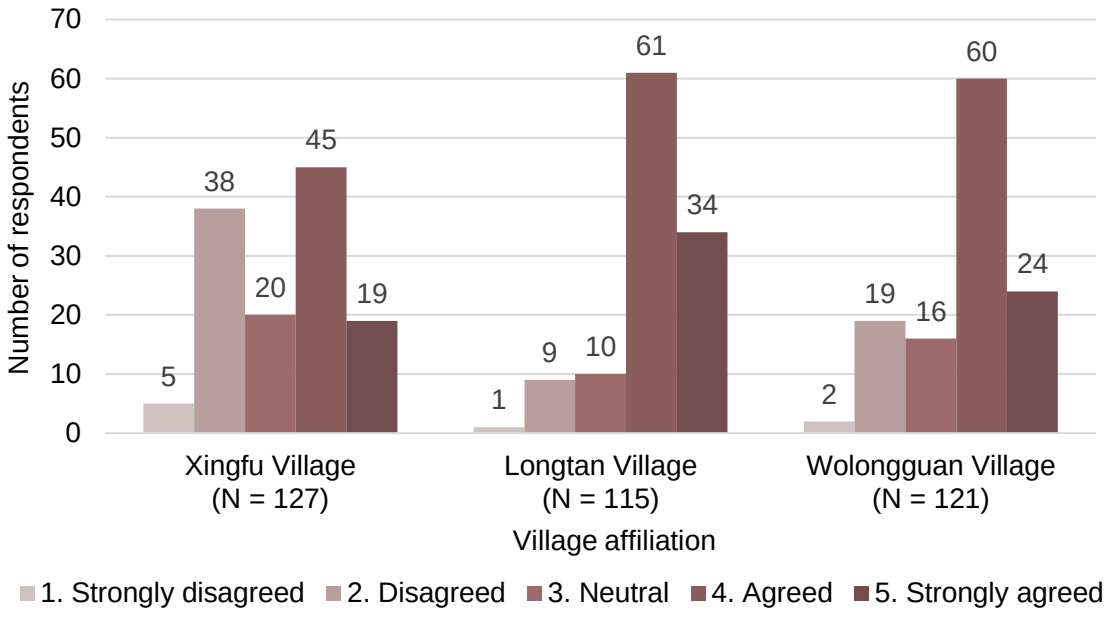
The correlation between Wenchuan respondents' ethnicity and their perception of debris flow threat is statistically significant at the 0.05 level (2-tailed) with a Fisher's exact test value 12.059 (p = .042, N = 363).

Relationship between non-demographic factors and perception of existing community debris flow threat

Village affiliation

The distribution of Wenchuan respondents' perception of existing community debris flow risk is shown in Figure 5.57. In all three villages, over half of the respondents perceived their communities were at risk.

Figure 5.57 Relationship between village affiliation of Wenchuan respondents and their perception of existing community debris flow threat



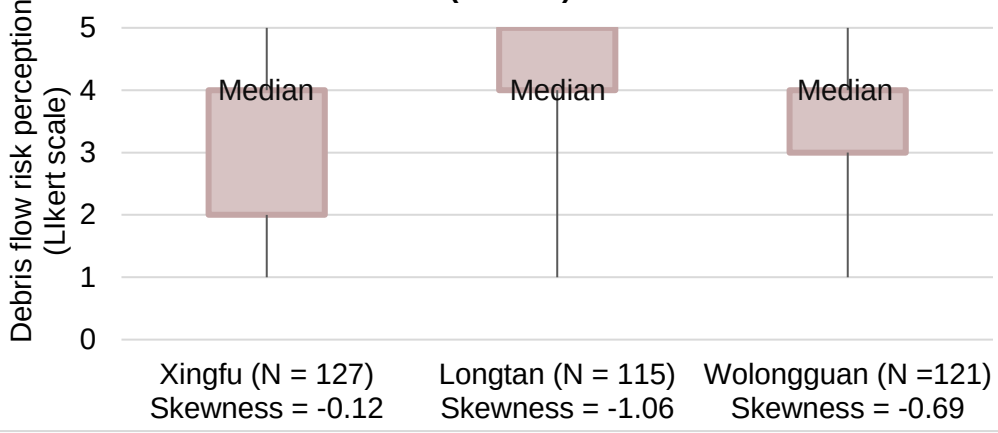
	Perception of debris flow threat (Likert scale 1 to 5)					
Village affiliation	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Xingfu Village	5 (3.94%)	38 (29.92%)	20 (15.75%)	45 (35.43%)	19 (14.96%)	127 (100.00%)
Longtan Village	1 (0.87%)	9 (7.83%)	10 (8.70%)	61 (53.04%)	34 (29.57%)	115 (100.00%)
Wolongguan Village	2 (1.65%)	19 (15.70%)	16 (13.22%)	60 (49.59%)	24 (19.83%)	121 (100.00%)

However, the risk perception of the three groups of villagers were different. Longtan villagers had the highest risk perception while those living in Xingfu had the lowest.

A great majority of the Longtan villagers strongly agreed (29.57%) or agreed (53.04%) that their communities were having debris flow risk (middle histogram), followed by a slightly smaller portion (19.83% strongly agreed and 49.59% agreed) in Wolongguan (right histogram), and finally the smallest portion in Xingfu (14.96% strongly agreed and 35.43% agreed) (left histogram).

The histograms show that debris flow risk perception distribution of Xingfu villagers was relatively symmetrical but with two peaks. However, risk perceptions from the three Wenchuan villages were all with negative skewness ranging from -0.12 to -1.06, and that of Longtan Village was highly skewed. Figure 5.58 shows that the median debris flow risk perception in all three villages were 4 (Agreed).

Figure 5.58 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their village affiliation (N = 363)



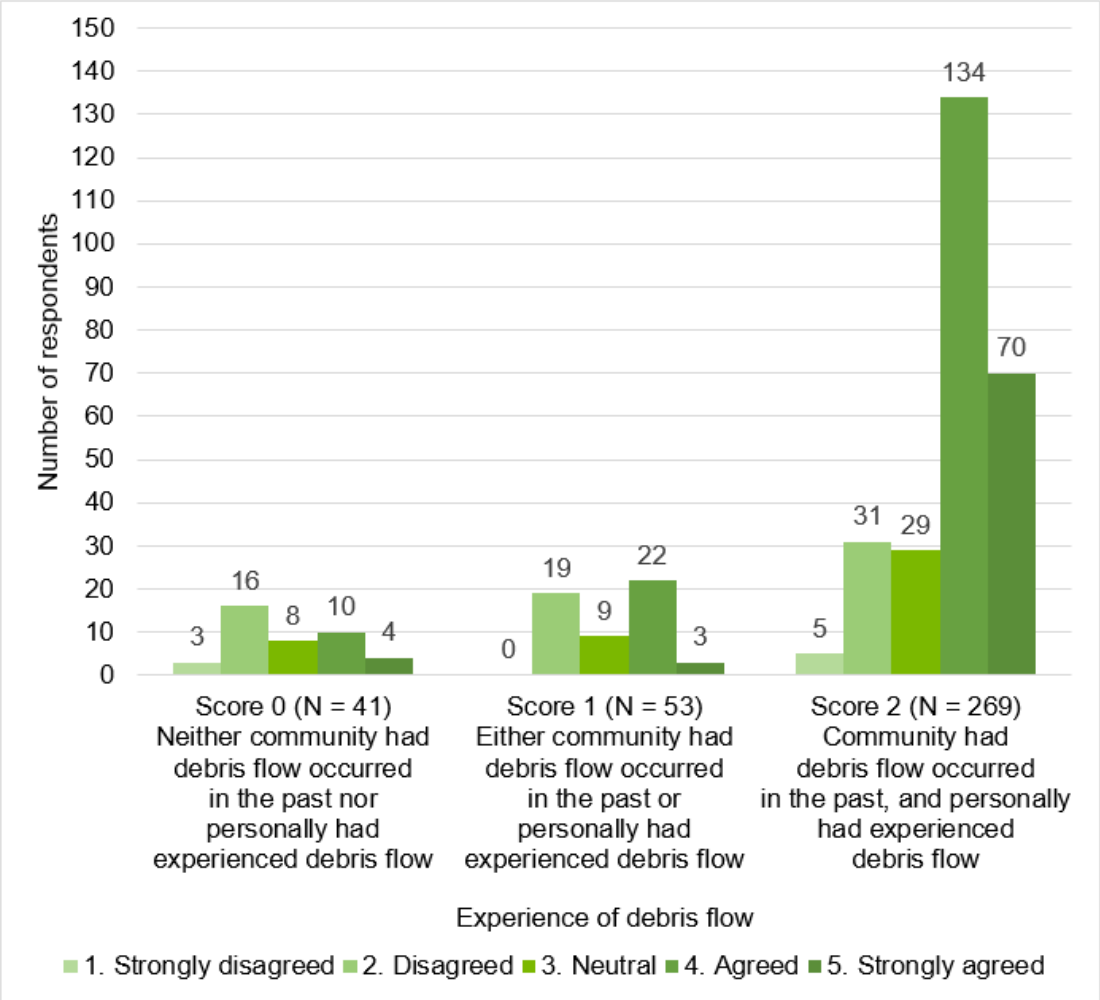
A Chi-square test reveals that the relation between village affiliation and perception of existing community debris flow threat was statistically significant at the 0.01 level (2-tailed), X^2 (8, N = 363) 32.971, p = .000. The effect size Cramer's V = .213, indicating a moderate relation.

Experience of debris flow

In Wenchuan, those with more experiences tended to have higher risk perceptions (Figure 5.59). This is consistent with Pingwu.

Figure 5.59

Relationship between debris flow experience of Wenchuan respondents and their perception of existing community debris flow threat



	Perception of debris flow threat (Likert scale 1 to 5)					
Experience of debris flow	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Score 2	5 (1.859%)	31 (11.524%)	29 (10.781%)	134 (49.814%)	70 (26.022%)	269 (100.00%)
Score 1	0 (0.00%)	19 (35.85%)	9 (16.98%)	22 (41.51%)	3 (5.66%)	53 (100.00%)
Score 0	3 (7.32%)	16 (39.02%)	8 (19.51%)	10 (24.39%)	4 (9.76%)	41 (100.00%)

More than three-quarter of those who personally experienced and lived in communities hit by debris flow (Score 2, right histogram) agreed (49.81%) or strongly agreed (26.02%) that their places were threatened by existing debris flow. For those who had never experienced debris flow (Score 0, left histogram), almost half disagreed (39.02%) or strongly disagreed (7.32%) that their communities were at risk. Distribution of risk perception of those experienced one type of debris flow

(Score 1, middle histogram) fell between the two, and were quite divided in how they perceived community debris flow threat.

In Wenchuan, risk perceptions of those who had never experienced debris flow were in fairly symmetrical distribution with skewness at 0.30, which is different from the positively skewed Pingwu counterparts. Those who had either one form of debris flow experience also had quite opposite views on debris flow risk, with symmetrical but bimodal risk perception distribution with two peaks of almost mirror images. This is similar to the Pingwu situation. Also similar to Pingwu, those Wenchuan respondents with most debris flow experience were in left-skewed distribution with skewness equals to -0.91.

Figure 5.60 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their debris flow experience (N = 363)

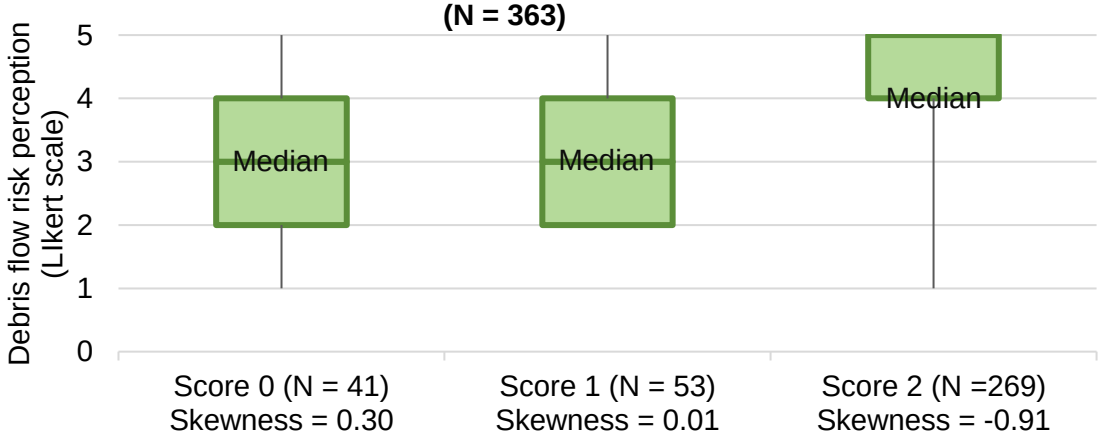


Figure 5.60 shows that those Score 0 or 1 (left and middle boxplots) had median risk perception both at 3 (Neutral). The median debris flow risk perception of those Score 2 (right boxplot) was 4 (Agreed). Both the box and the median are closer to the upper end of the distribution, meaning less variation of risk perception above the median and more variation below.

Same as the case in Pingwu, the Spearman's correlation between Wenchuan respondents' debris flow experiences and perception of community existing debris flow risk is statistically significant at the 0.01 level (2-tailed), and it is weak to moderate positive monotonic (r_s = .334, N = 363, p = .000). This means the more debris flow experience one had, the higher debris flow risk one perceived.

Perception of substantial debris flow

Same as in Pingwu, the overall perception of substantial debris flow was statistically significantly correlated with perception of existing community debris flow risk in Wenchuan at the 0.01 level (2-tailed), although it was weak positive monotonic (r_S = .200, N = 363, p = .000), according to Spearman's correlation. Respondents who perceived substantial debris flow as more dangerous tended to perceive higher risk.

Detailed relations between Wenchuan respondents' perceptions of individual substantial debris flow characteristics and risk perceptions are further explored (Table 5.21). Six out of seven sub-variables were found to have statistical significant positive relation with perception of existing debris flow threat, with Spearman's rho ranging from .132 to .242. Although their respective relations were weak, the results still indicate the more dangerous substantial debris flow the respondents perceived in the six aspects, the higher existing community debris flow risk they perceived.

Table 5.21

Statistical relationships between Wenchuan respondents' perceptions of each of the seven substantial debris flow characteristics and their perceptions of existing community debris flow threat

Statements on perception of substantial debris flow	*N*=	Correlation *p*-value	Spearman's rho r_s
(1). Substantial debris flow can take human lives	363	.063	.098
(2). Substantial debris flow can destroy the whole village or the whole group/community	**363**	**.012^**	**.132**
(3). Substantial debris flow can damage houses	**363**	**.002^^**	**.162**
(4). Substantial debris flow can the lives of cattle	**363**	**.000^^**	**.228**
(5). Substantial debris flow can destroy farmland	**363**	**.000^^**	**.242**
(6). Substantial debris flow can cause property losses	**363**	**.000^^**	**.226**
(7). Substantial debris flow can cause road congestion	**363**	**.000^^**	**.210**

^Correlation is significant at the 0.05 level (2-tailed)

^^Correlation is significant at the 0.01 level (2-tailed)

Knowledge of debris flows

Regarding the relationship between Wenchuan respondents' knowledge of debris flows (with a scale 0 to 4) and their perception of existing community debris flow risk, a Spearman's correlation finds no statistical significant relationship (r_s = .095, N = 363, p = .071) as in Pingwu.

Perception of remoteness of community

A Mann-Whitney *U* test shows that those Wenchuan respondents who perceived their communities as remote had a higher mean rank (192.07), or perceived higher debris flow risk, than the other group (mean rank = 175.60). However, unlike Pingwu, the difference between the two mean ranks is statistically insignificant in Wenchuan (*U* = 14231.000, p = .122).

Relationship between government disaster risk reduction measures and perception of existing community debris flow threat

Government disaster mitigation (engineering) measures

In Wenchuan, those who were unaware of or did not know whether geotechnical engineering measures were introduced in their communities has a higher mean rank (186.83), that is, a higher debris flow risk perception, than others (mean rank = 179.43), according to a Mann-Whitney *U* test. However, the difference between the two mean ranks is statistically insignificant (*U* = 14323.000, p = .498).

Government disaster preparedness measures

Wenchuan respondents' awareness of all seven disaster preparedness measures imposed by the government were found positively related to their perception of existing community debris flow risk. However, Spearman's rho of the seven sub-variables were between .006 and .122, indicating their respective relationships with risk perception were weak. Only "heard of mass monitoring and mass prevention" and debris flow risk perception were statistically significantly associated at the 0.05 level (2-tailed) with p = .020 (Table 5.22).

Table 5.22 Statistical relationships between Wenchuan respondents' awareness of / accessibility to each government disaster preparedness measure and their perceptions of existing community debris flow threat

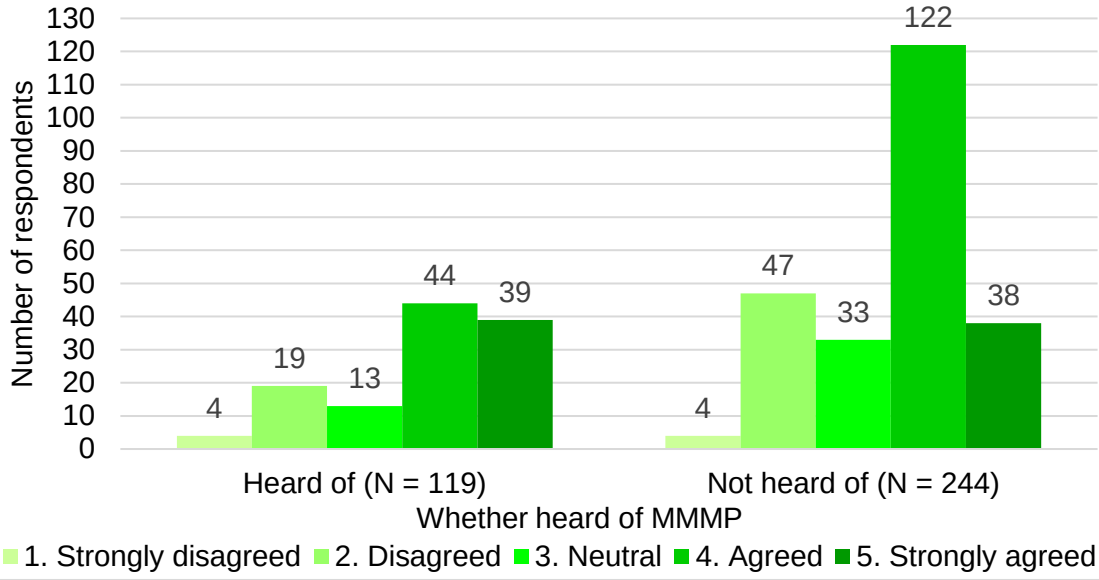
Government disaster preparedness measures	Mean rank (0)	Mean rank (1)	*U*-value	Correlation *p*-value	Spearman's rho r_s
1. Awareness of debris flow risk assessment in community	177.90	195.01	10874.000	.159	.074
2a. Accessibility to information on debris flow risk - Hazard zone information on community	181.80	183.60	6535.500	.913	.006
2b. Accessibility to information on debris flow risk - Any information on community	181.60	187.19	4246.000	.781	.015
3. Awareness of assessment on protection against debris flow strike in community	180.82	191.05	6361.000	.529	.033
4. Accessibility to any information on protective measures against general debris flow strike	180.39	188.17	10337.000	.544	.032
5. Heard of Mass Monitoring and Mass Prevention	173.62	199.18	12473.000	.020^	.122
6. Awareness of plan/measure imposed on community to protect residents from debris flow strike	175.97	192.42	13909.000	.127	.080

^ Correlation is significant at the 0.05 level (2-tailed).

➢ **Heard of Mass Monitoring and Mass Prevention (MMMP) System**

In Wenchuan, a total of about two thirds of both groups who had heard of or not heard of MMMP perceived existing community debris flow threat (Figure 5.61). If look closer, however, among those who had heard of MMMP, as high as 32.77% strongly agreed there was existing threat. For those who had not heard of MMMP, only 15.57% strongly agreed they were at risk.

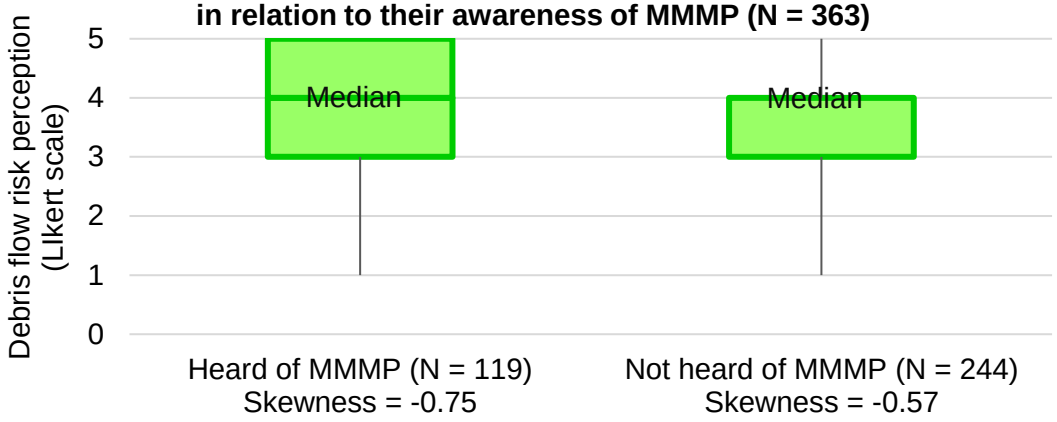
Figure 5.61 Relationship between whether the Wenchuan respondents had heard of MMMP and their perception of existing community debris flow threat



	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Heard of MMMP	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	4 (3.36%)	19 (15.97%)	13 (10.92%)	44 (36.97%)	39 (32.77%)	119 (100.00%)
No	4 (1.64%)	47 (19.26%)	33 (13.52%)	122 (50.00%)	38 (15.57%)	244 (100.00%)
Total	**8 (2.20%)**	**66 (18.18%)**	**46 (12.67%)**	**166 (45.73%)**	**77 (21.21%)**	**363 (100.00%)**

Figure 5.62 shows that the median debris flow risk perceptions of both the heard of MMMP and the not heard of groups were 4 (Agreed). Both medians are closer to the upper end of the distribution, meaning less variation of risk perception above the median and more below. Both distributions were left-skewed at -0.75 and -0.57 respectively.

Figure 5.62 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their awareness of MMMP (N = 363)



Those who had not heard of MMMP has a statistically significant lower mean rank (173.62), that is, perceived lower debris flow risk, than those who had heard of (mean rank = 199.18) (U = 12473.000, p = .020), according to a Mann-Whitney U test. Although the correlation is significant at the 0.05 level (2-tailed), it is weak positive monotonic (r_s = .122, N = 363).

Government disaster response measures and facilities

Among the 21 community disaster response measures or facilities being tested, Wenchuan respondents' awareness of three yielded statistical significant relationships with perception of existing community debris flow threat, according to Mann-Whitney U tests and Spearman's correlations.

As shown in Table 5.23, the correlation is statistically significant at the 0.01 level (2-tailed) for one early warning measure: gong. This is the same as in Pingwu. For another two measures: accessibility to card or table and the respondents being the monitoring personnel, their correlations with debris flow risk perception are significant at the 0.05 level (2-tailed). The Spearman's rho of the three variables were between .104 and .137, indicating the respective relationships with risk perception were weak. The statistical findings of Pingwu are also shown in Table 5.23 for easy comparison.

Table 5.23 Statistical relationships between respondents' awareness of / accessibility to each government disaster response measure or facility and their perceptions of existing community debris flow threat – Pingwu VS Wenchuan

Government disaster response measures or facilities	Study area	Mean rank (0)	Mean rank (1)	*U*-value	Correlation *p*-value	Spearman's rho r_s
1. Awareness of assessment on capability to tackle debris flow hit in community	Pingwu Wenchuan	133.71 182.54	142.18 174.42	2845.500 3886.000	.588 .698	.033 -.020
2. Awareness of plan /measure/ Instruction to tackle debris flow hit in community	Pingwu Wenchuan	131.26 179.05	148.63 193.52	4743.500 9840.500	.136 .262	.091 .059
3. Accessibility to information on appropriate response when hit by debris flow						
a. Any information /instruction	Pingwu Wenchuan	132.48 184.59	156.04 171.89	2322.000 9944.500	.146 .324	.089 -.052
b. Booklet	Pingwu Wenchuan	136.26 181.31	110.06 183.84	1810.000 12886.000	.148 .829	-.089 .011
c. Card/ Table	Pingwu **Wenchuan**	133.67 **178.14**	145.39 **209.24**	2158.500 **5929.000**	.508 **.048^**	.041 **.104**
4. Awareness of early warning						
a. Website	**Pingwu** Wenchuan	**133.68** 182.27	**243.00** 149.50	**49.000** 442.500	**.038^** .568	**.127** -.030
b. Siren	Pingwu Wenchuan	136.69 176.05	115.71 199.03	2834.000 11042.500	.157 .052	-.087 .102
c. Phone	**Pingwu** Wenchuan	**128.51** 180.98	**190.27** 191.87	**1696.000** 5257.500	**.000^^** .542	**.247** .032
d. Gong	**Pingwu** **Wenchuan**	**126.55** **175.83**	**174.97** **211.40**	**3147.500** **7597.500**	**.000^^** **.009^^**	**.242** **.137**
e. Shout	**Pingwu** Wenchuan	**129.29** 183.59	**152.95** 180.51	**5077.000** 16176.500	**.030^** .767	**.132** -.016

(cont.)

5. Awareness of communication						
a. General	Pingwu	131.26	135.37	5829.000	.711	.023
	Wenchuan	175.03	184.16	11312.000	.455	.039
b. Community unit	Pingwu	136.85	132.11	8660.000	.602	-.032
	Wenchuan	175.75	189.67	15049.000	.182	.070
6. Awareness of monitoring personnel						
a. Heard of	Pingwu	137.03	127.48	6495.000	.353	-.057
	Wenchuan	178.55	186.85	15274.000	.431	.041
b. Respondent	Pingwu	134.51	133.63	524.500	.981	-.001
	Wenchuan	**179.95**	**241.92**	**1387.000**	**.032^**	**.112**
c. Family member	Pingwu	135.12	107.58	624.500	.370	-.055
	Wenchuan	181.26	196.22	2849.000	.532	.033
7. Awareness of emergency response facilities						
a. Evacuation route	Pingwu	132.05	147.34	4285.500	.216	.076
	Wenchuan	178.87	187.47	14523.500	.426	.042
b. Emergency shelter	Pingwu	133.91	138.88	3636.000	.723	.022
	Wenchuan	182.21	181.26	11260.500	.939	-.004
c. Temporary residing place	Pingwu	134.79	131.27	2635.000	.832	-.013
	Wenchuan	184.43	157.70	4643.000	.139	-.078
8. Awareness of emergency response dissemination						
a. Emergency bag	Pingwu	133.73	143.09	2517.000	.572	.035
	Wenchuan	181.07	188.93	6582.000	.625	.026
b. Training	Pingwu	136.19	98.54	1104.500	.086	-.105
	Wenchuan	179.71	206.50	4386.500	.149	.076
c. Drill	Pingwu	131.60	154.46	3299.500	.093	.103
	Wenchuan	179.64	189.49	11354.000	.418	.043

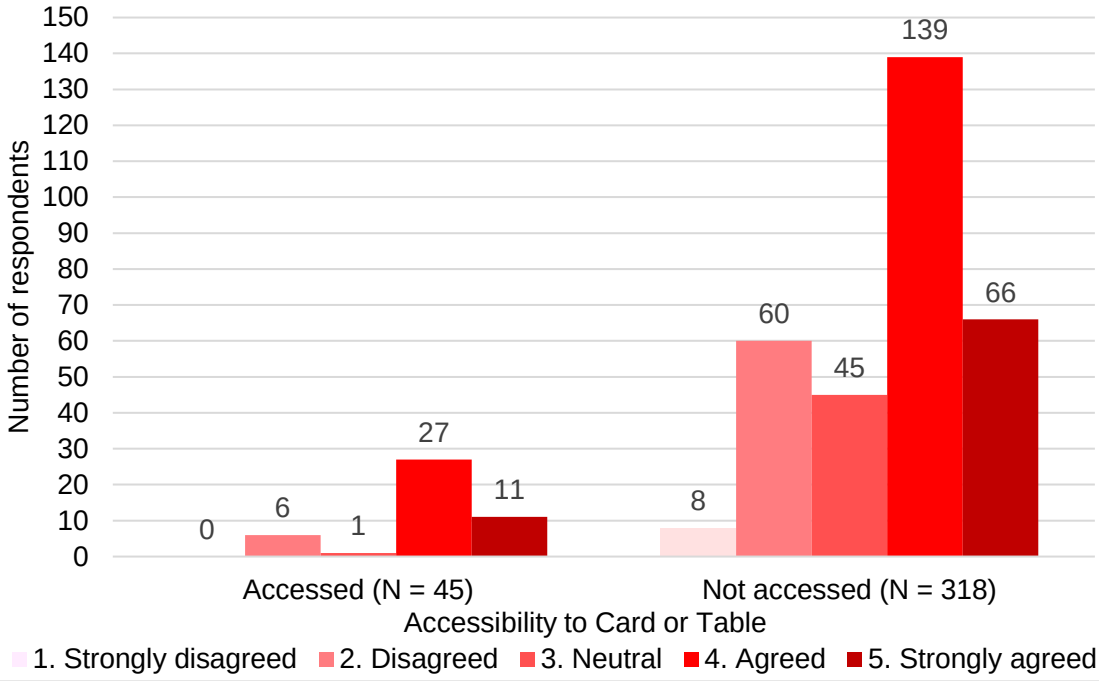
^Correlation is significant at the 0.05 level (2-tailed)

^^Correlation is significant at the 0.01 level (2-tailed)

➢ **Disaster Prevention Understanding Cards or Geohazard Prevention and Protection Plan Table**

The relationship between Wenchuan respondents' accessibility to the Two Cards One Table as a source of information on appropriate debris flow response and their perceptions of existing community debris flow threat is shown in Figure 5.63.

Figure 5.63 Relationship between Wenchuan respondents' accessibility to Card or Table and their perception of existing community debris flow threat

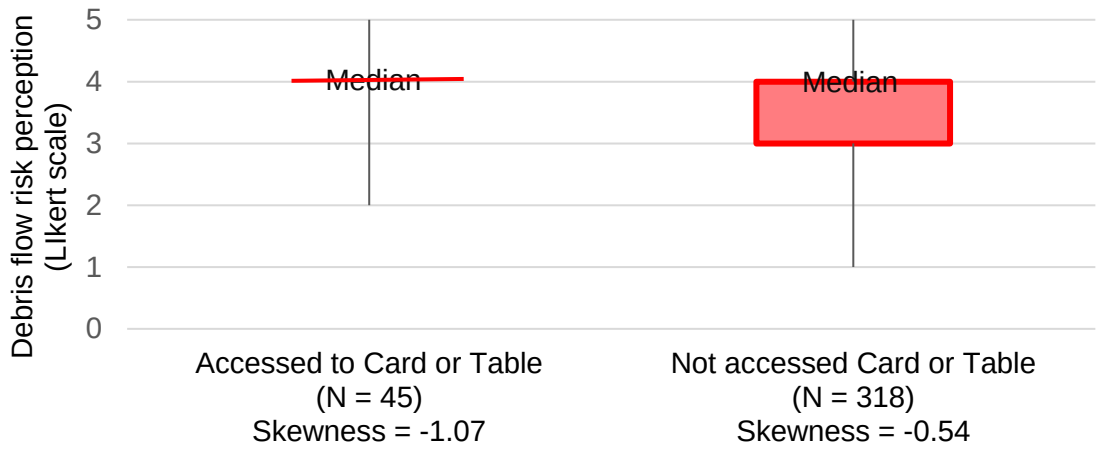


	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Accessibility to Card or Table	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	0 (0.00%)	6 (13.33%)	1 (2.22%)	27 (60.00%)	11 (24.44%)	**45 (100.00%)**
No	8 (2.52%)	60 (18.87%)	45 (14.15%)	139 (43.71%)	66 (20.75%)	**318 (100.00%)**
Total	**8 (2.20%)**	**66 (18.18%)**	**46 (12.67%)**	**166 (45.73%)**	**77 (21.21%)**	**363 (100.00%)**

A great majority (84.44%) of the 45 Wenchuan respondents who had accessed Card or Table strongly agreed or agreed that their communities were at risk. Only 64.46% of the non-accessed group perceived the risk. In contrary, only 13.33% of the Card or Table accessed group did not perceive debris flow risk but the proportion of the non-accessed group was higher at 21.39%.

In Wenchuan, median debris flow risk perceptions of both groups who had and had not accessed the Card or Table were 4 (Agreed), that is closer to the upper end of the distribution, meaning less variation of risk perception above the median and more variation below (Figure 5.64). Both distributions were negatively skewed, with the accessed group more skewed with skewness at -1.07 (left boxplot). All the first, second and third quartiles of risk perceptions of this group fell on Likert scale 4, meaning most respondents of this group agreed their communities were threatened by existing debris flow.

Figure 5.64 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their accessibility to the Card or Table (N = 363)

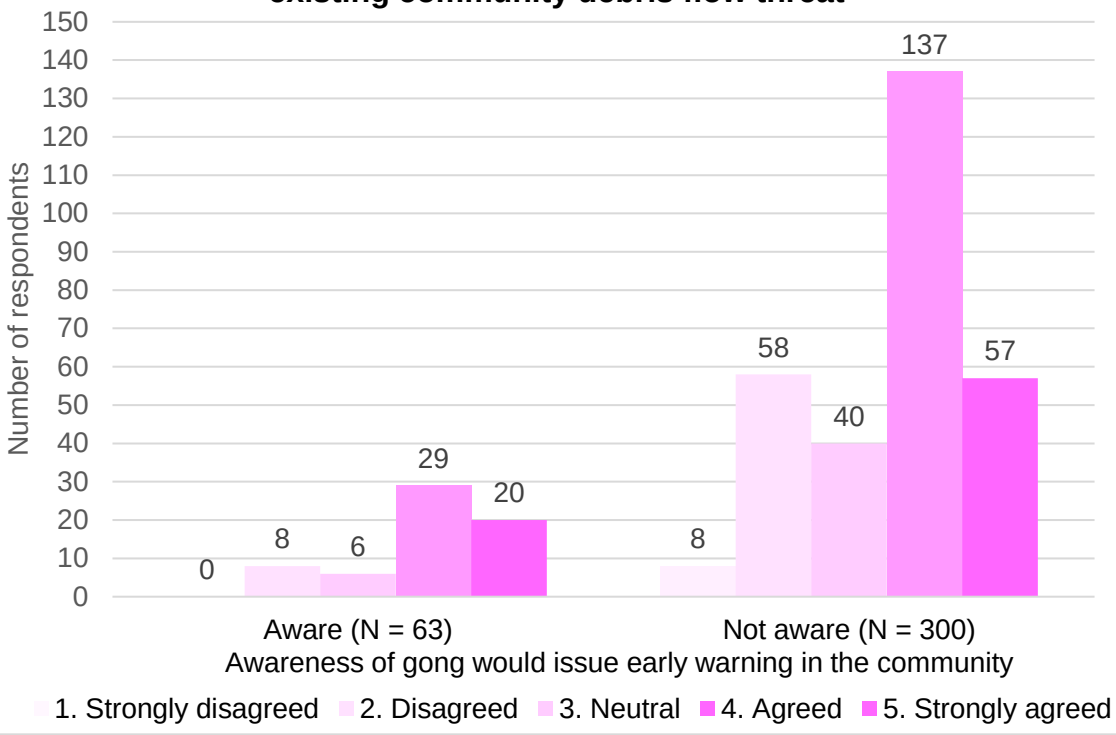


A Mann-Whitney *U* test shows that the group which had not accessed any Card or Table has a statistically significant lower mean rank (178.14), meaning a lower debris flow risk perception, than the accessed group (mean rank = 209.24) (U = 5929.000, p = .048). The correlation is significant at the 0.05 level (2-tailed) but is weak positive monotonic (r_s = .104, N = 363).

➢ **Early warning disaster response measure: Gong**

A majority (77.78%) of the 63 Wenchuan respondents who were aware of the use of gong to issue debris flow early warning in their communities strongly agreed or agreed there was debris flow threatening their communities. Only 12.70% perceived no risk. For those who were unaware of gong as an early warning tool, only 64.67% perceived debris flow risk.

Figure 5.65 Relationship between Wenchuan respondents' awareness of using gong for debris flow early warning in community and their perception of existing community debris flow threat

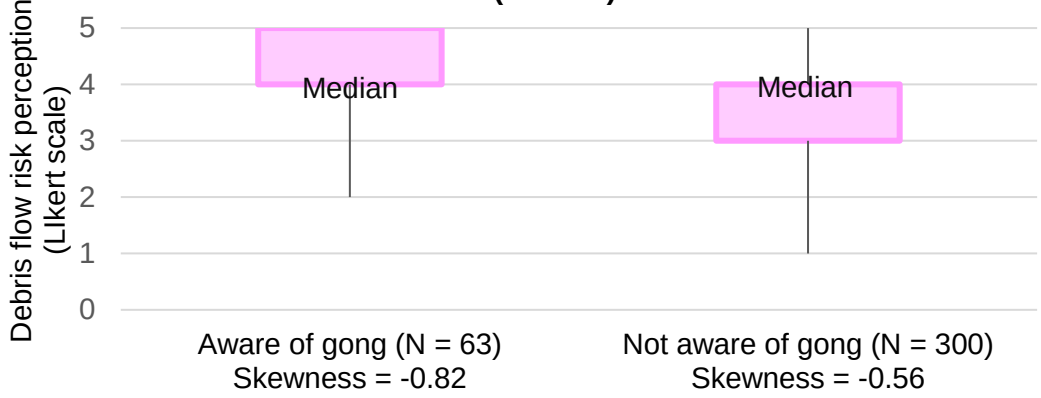


	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Awareness of gong	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	0 (0.00%)	8 (12.70%)	6 (9.52%)	29 (46.03%)	20 (31.75%)	**63 (100%)**
No	8 (2.67%)	58 (19.33%)	40 (13.33%)	137 (45.67%)	57 (19.00%)	**300 (100%)**
Total	8 (2.20%)	66 (18.18%)	46 (12.67%)	166 (45.73%)	77 (21.21%)	**363 (100%)**

In Wenchuan, the median debris flow risk perceptions of both the gong-aware and unaware groups were 4 (Agreed), that is closer to the upper end of the distribution, meaning less variation of risk perception above the median and more variation below (Figure 5.66). Risk perception distributions of both groups were left-skewed with skewness at -0.82 and -0.56 respectively.

Similar to Pingwu, risk perception distribution of those who were unaware of gong in Wenchuan were less skewed and relatively symmetrical (right boxplot) compared to the aware group (left boxplot). For the aware group, there is no whisker on the upper end of the box, indicating a higher risk perception. The degrees of spread of risk perceptions among this aware group were smaller.

Figure 5.66 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to their awareness of gong (N = 363)



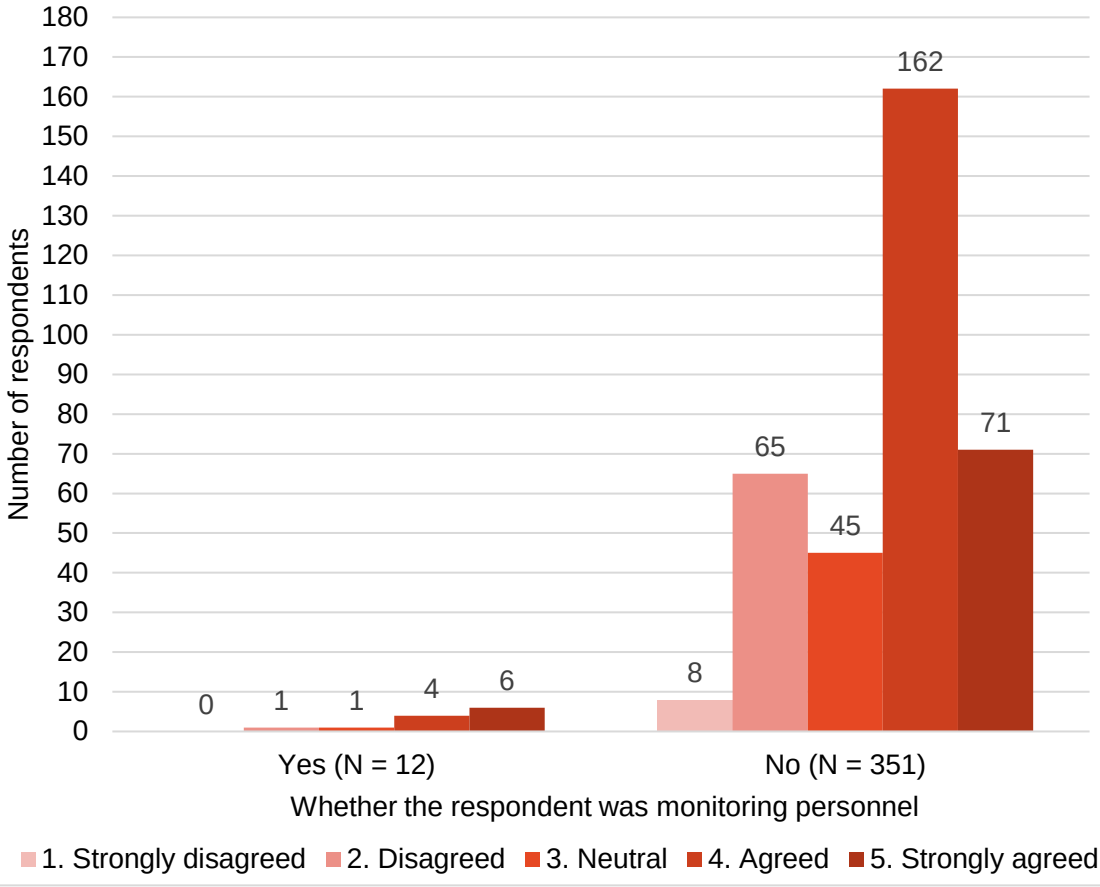
A Mann-Whitney *U* test shows that the respondents who were unaware of or did not know whether gong was introduced as a community early warning tool has a statistically significant lower mean rank (175.83), that is perceived lower debris flow risk than the aware group (mean rank = 211.40) (U = 7597.500, p = .009). The correlation is significant at the 0.01 level (2-tailed) but is weak positive monotonic (r_s = .137, N = 363, p = .009).

- **Monitoring personnel: Respondent**

Villagers performed as monitoring personnel might have higher disaster risk perceptions because they were in the front line to monitor and tackle hazards.

A great majority (83.33%) of the 12 Wenchuan respondents who were monitoring personnel strongly agreed or agreed that there was debris flow threatening their communities. Only a small portion (8.33%) held opposite views. Among the 351 non-monitoring personnel Wenchuan respondents, only 66.38% perceived community debris flow risk. About 20.80% did not perceive risk.

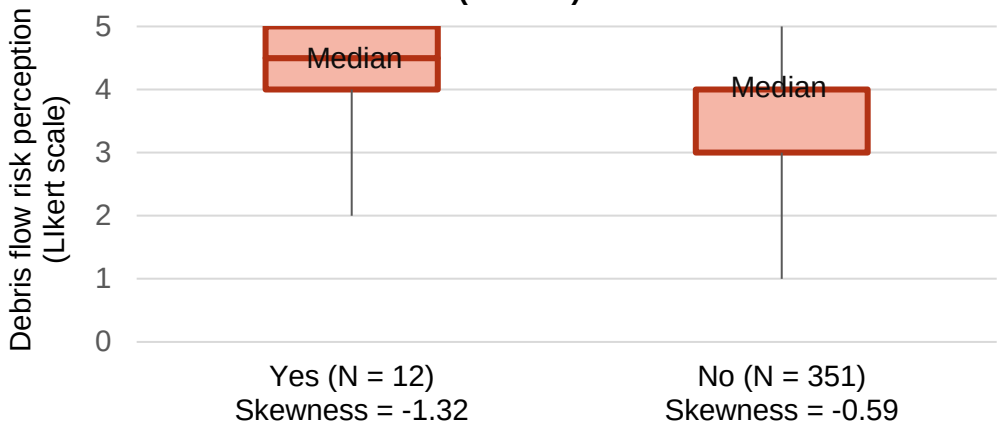
Figure 5.67 Relationship between whether the Wenchuan respondents were monitoring personnel and their perception of existing community debris flow threat



	Perception of existing community debris flow threat (Likert scale 1 to 5)					
Whether the respondent was monitoring personnel	**1 Strongly disagreed**	**2 Disagreed**	**3 Neutral**	**4 Agreed**	**5 Strongly agreed**	**Total**
Yes	0 (0.00%)	1 (8.33%)	1 (8.33%)	4 (33.33%)	6 (50.00%)	12 (100.00%)
No	8 (2.28%)	65 (18.52%)	45 (12.82%)	162 (46.15%)	71 (20.23%)	351 (100.00%)
Total	**8 (2.20%)**	**66 (18.18%)**	**46 (12.67%)**	**166 (45.73%)**	**77 (21.21%)**	**363 (100.00%)**

Debris flow risk perceptions of both the monitoring personnel and the non-monitoring personnel groups in Wenchuan were in left-skewed distribution. Both medians are closer to the upper end of the distribution (Figure 5.68), meaning less variation of risk perception above the median and more variation below. However, the median of the monitoring personnel group (left boxplot) is slightly higher at 4.5 when compared to 4 of the other group (right boxplot), and with skewness at -1.32, indicating a highly skewed distribution.

Figure 5.68 Boxplots showing distribution of Wenchuan respondents' debris flow risk perception in relation to whether they were monitoring personnel (N = 363)



However, it might neither be fair nor effective to compare the responses of 12 people against those of 351. Therefore the results and analysis here can be of reference but more samples might be required to get a more precise relation between whether the respondents were monitoring personnel and debris flow risk perception.

Despite the limitation of the big difference between the sizes of the two responding groups, a Mann-Whitney *U* test shows that the monitoring personnel group has a statistically significant higher mean rank (241.92), that is perceived higher debris flow risk, than the non-monitoring personnel group (mean rank = 179.95) (U = 1387.000, p = .032). The correlation is significant at the 0.05 level (2-tailed), but is weak positive monotonic (r_s = .112, N = 363, p = .032).

5.3.4 Summary of Hypothesis 2 results in Wenchuan

Among the 46 selected sub-variables grouped under nine independent factors, eight appeared to have statistical significant influence on Wenchuan respondents' debris flow risk perceptions. Half of these eight sub-variables are government measures, including one disaster preparedness and three disaster response measures. Unlike Pingwu, geotechnical mitigation (engineering) measures and three early warning tools were probably not impacting risk perception in Wenchuan.

Ethnicity is the only demographic factor significantly associated with risk perception in Wenchuan. Same as Pingwu, three non-demographic and non-governmental variables, namely village affiliation, experience of debris flow and perception of

substantial debris flow, could have affected Wenchuan respondents' debris flow risk perceptions. Figure 5.69 shows all the potential factors that might relate to debris flow risk perception, and highlights those appeared to have actual impact on Wenchuan. Figure 5.70 summarises only those possibly influential factors for easy reference.

Figure 5.69
Factors associated with Wenchuan respondents' perceptions of existing community debris flow threat
(among all other tested but non-associated factors marked in white)

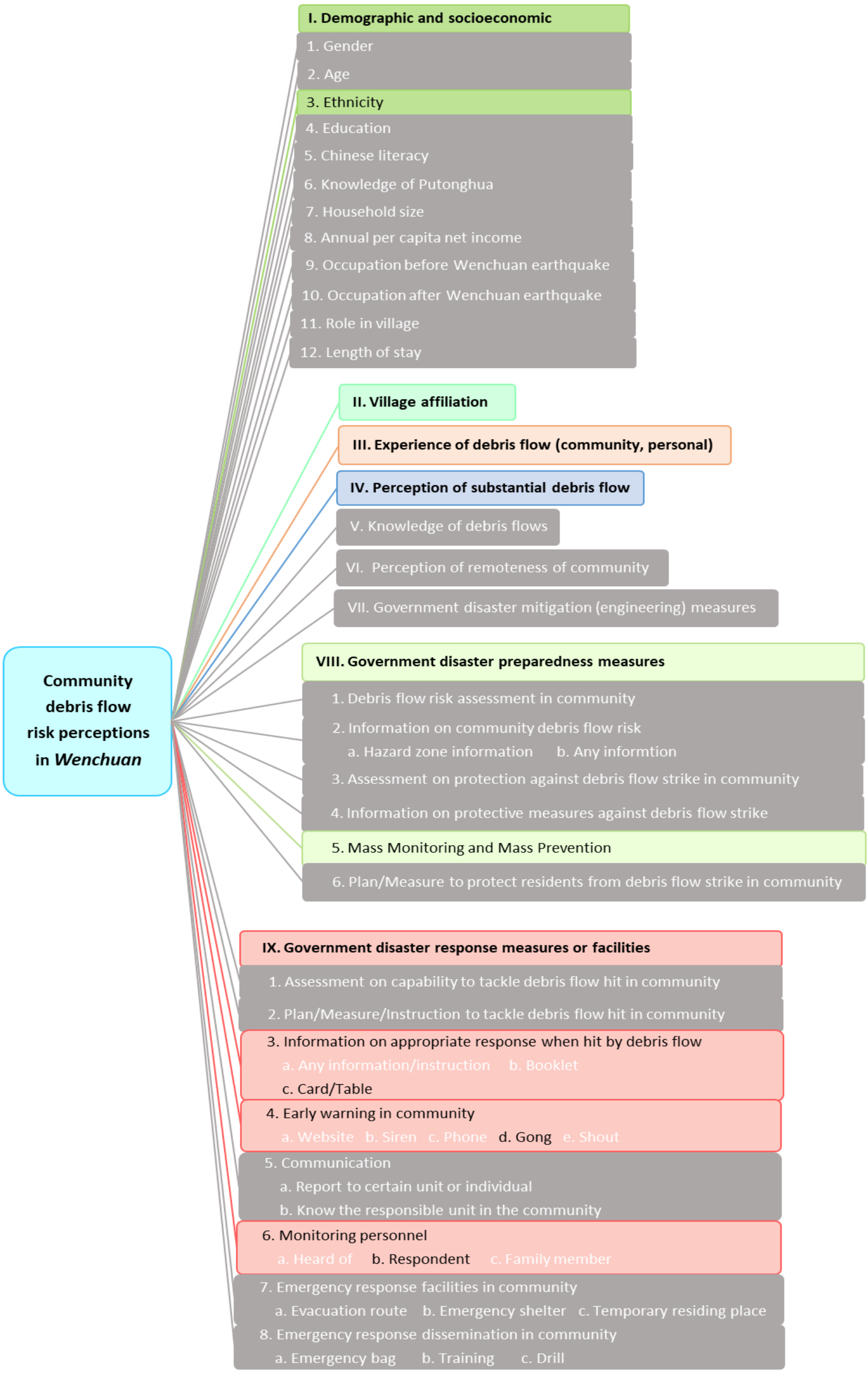
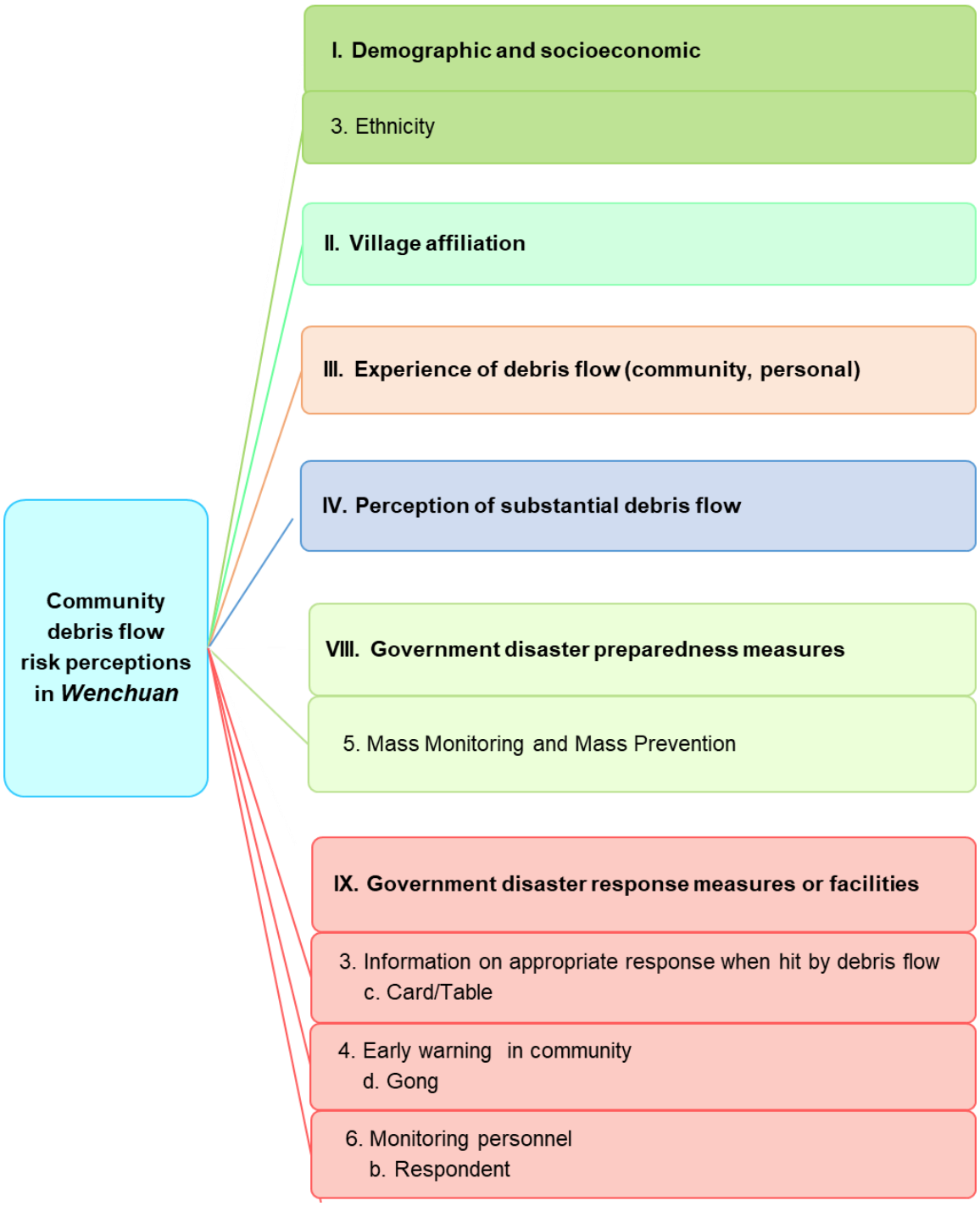


Figure 5.70

Factors associated with Wenchuan respondents' perceptions of existing community debris flow threat



As in Pingwu, the second hypothesis of this research which states that *"the rural populations living in remote mountainous areas have developed perceptions of geological risk that are now generally more advanced than the measures for disaster mitigation, preparedness and response imposed by the government since the earthquake"* is also accepted in the Wenchuan scenario.

5.3.5 Reflection of Hypothesis 2 results

Section 5.3 of this chapter presents the results of testing Hypothesis 2. The hypothesis is accepted in both study areas. Any association between each independent variable and the respondents' debris flow risk perceptions are revealed. Similarities and differences in Pingwu and Wenchuan are described and compared. The different explanations for any variations in the possible impact of government disaster risk reduction measures in the two counties can be referenced by other places having different conditions but similar debris flow risk. Separating the data into two sets according to the two study areas, however, can be a limitation leading to the missing of some analyses.

If the data of the two counties can be combined into a single dataset, other intended lines of comparative analysis utilising all samples across different sites being studied in this thesis could be done. For instance, different risk perceptions of different types of household headed by individuals with different age, ethnicity or experience across the complete sample could be found by comparison.

5.4 Hypothesis 3

Hypothesis 3 states that *"Disaster response behaviour of the rural populations living in remote mountainous regions of Sichuan is affected by their awareness of government disaster risk reduction measures."*

In order to find out what independent variables could possibly affected respondents' anticipated disaster response (the dependent variable), the following survey question was asked:

"In the future, what will you do in the first place when you are at home and see signs of debris flow?"

In parallel, what factors (the independent variables) could influence respondents' anticipated disaster response behaviour were explored.

5.4.1 Results of study area 1 – Pingwu County

Relationships between demographic/socioeconomic factors and anticipated disaster responses when see signs of debris flow at home

Two demographic variables, age and role in village, were found to be statistically significantly associated with the respondents' anticipated behaviour when see signs of debris flow at home.

Gender, ethnicity, education-related variables like education level, Chinese literacy and knowledge of Putonghua, household variables like household size and annual per capita net income, occupation before and after the Wenchuan earthquake, as well as community-affiliation variables like length of stay in one's community per year, were not statistically significantly related to respondents' future disaster responses.

The table shows the sample sizes (N), degree of freedom (*df*), and Chi-square value (X^2 value) or Fisher's exact test value of the association between each independent variable and the dependent variable. Statistical significance *p*-value (2-tailed) and effect size (Cramer's *V*) are also shown.

Table 5.24

Statistical relationships between each demographic/socioeconomic factor and anticipated disaster responses in Pingwu

Demographic/ Socioeconomic factor	N	*df*	X^2 value *Fisher's Exact Test value	*p*-value (2-tailed)	Cramer's *V*
Gender (Male VS Female)	268	3	3.312	.346	.111
Age (18 to 64 VS 65 or above)	**268**	**3**	**11.321**	**.010^^**	**.206**
Ethnicity (Qiang VS Han)	258	3	3.642	.303	.119
Education level (Uneducated VS Primary VS Secondary and above)	268	6	11.352	.078	.146
Chinese literacy (No VS Yes/Partial)	268	3	6.322	.097	.154
Knowledge of Putonghua (Know VS Don't know VS Can understand but cannot speak)	268	6	4.044	.671	.087
Household size (1 to 3 persons VS 4 or more persons)	268	3	.418	.936	.039

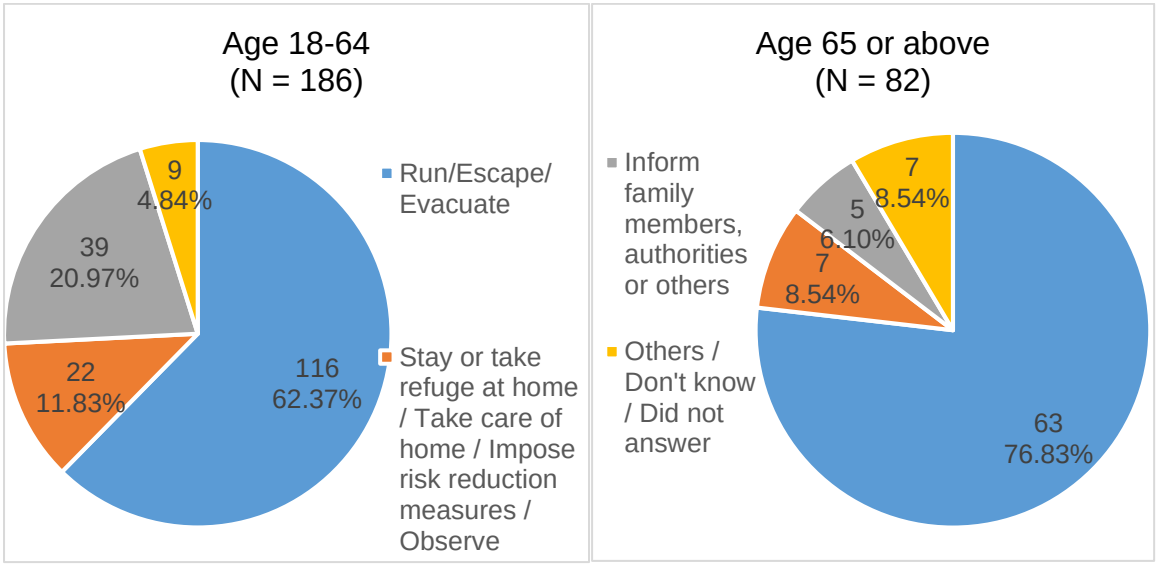
Annual per capita net income (Below and on poverty line RMB 2855 VS Above poverty line RMB 2856 to below rural population annual per capita net income RMB 10771 VS rural population annual per capita net income RMB 10772 and above)	214	--	*5.013	.495	--
Occupation before Wenchuan earthquake (Non-farmer VS Farmer)	268	3	1.536	.674	.076
Occupation after Wenchuan earthquake (Non-farmer VS Farmer)	268	3	2.277	.517	.092
Role in village (No/ Don't know VS Yes)	**268**	**--**	***8.744**	**.019^**	**--**
Length of stay in one's group/ community per year (Not stay for whole year/ Don't know/ Not sure/ NA VS Stay for whole year)	268	3	4.627	.201	.131

^Significant at the 0.05 level (2-tailed)
^^Significant at the 0.01 level (2-tailed)

Age

Among the 186 Pingwu respondents aged 18 to 64, the majority (62.37%) said they would run, escape or evacuate when they are at home and see debris flow signs in the future (Figure 5.71). Only 11.83% would stay or take refuge at home, take care of home, impose risk reduction measures or observe. Another 20.97% would inform family members, authorities or others.

Figure 5.71
Relations between Pingwu respondents' age and their anticipated disaster responses



For those 82 respondents aged 65 or above, a greater portion (76.83%) said they would run. Only 8.54% would stay at home. An even smaller portion (6.10%) would inform others.

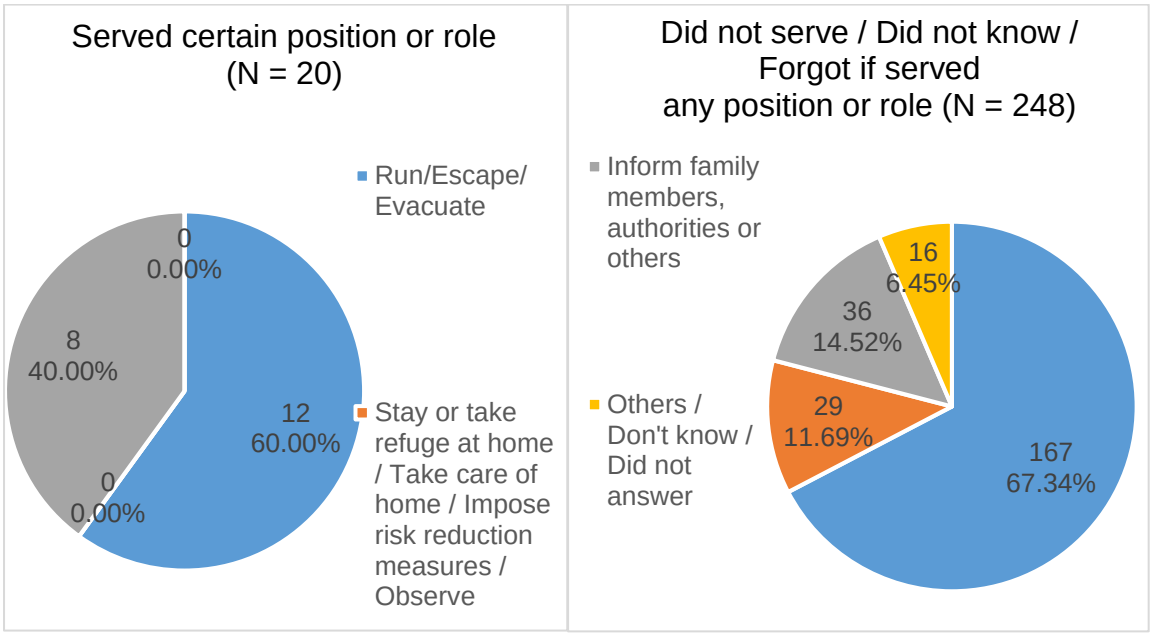
Pingwu respondents' age and their anticipated behaviour when see signs of debris flow at home was statistically significantly related, X^2 (3, N = 268) = 11.321, p = .010. The effect size Cramer's V = .206 indicates the relation is moderate.

In other words, the older Pingwu respondents were more likely to evacuate than the younger ones. The younger group was more likely to inform others and slightly more likely to take refuge at home than the elderly group.

Role in village

Whether the Pingwu respondents served any village position or role and their anticipated behaviour when see debris flow signs at home are statistically significantly related, with a Fisher's exact test value 8.744 (N = 268, p = .019).

Figure 5.72
Relations between Pingwu respondents' role in village and their anticipated disaster responses



Among the 248 respondents who did not serve any village role, did not know or forgot at all, 67.34% would run, escape or evacuate. Another 11.69% would stay or take refuge at home, take care of home, impose risk reduction measures or observe. Only 14.52% would inform family members, authorities or others.

Similarly, for those 20 respondents who served certain role in the village, 60.00% would run, escape or evacuate. However, the rest (40.00%) would only inform family members, authorities or others. None of them would take refuge at home, gave other answers or did not know.

In other words, those who did not serve any village role, did not know or forgot at all, were more likely to run on one hand while also more likely to stay on the other than those who held certain role. Those who served certain village role were much more likely to inform others than other respondents.

Relationships between non-demographic factors and anticipated disaster responses

Village affiliation, Experience of debris flow, Perception of substantial debris flow, Knowledge of debris flows and Perception of remoteness of home

In Pingwu, each individual variable in the series of non-demographic factors and how the respondents would behave when see debris flow signs at home was found not statistically significantly associated (Table 5.25).

Table 5.25
Statistical relationships between each non-demographic factor and anticipated disaster responses in Pingwu

	N	*df*	X^2 *value/ *Fisher Exact Test value*	*p*-value (2-tailed)	Cramer's *V*
Village affiliation	268	3	5.923	.115	.149
Experience of debris flow	268	--	*10.725	.257	--
Perception of substantial debris flow:					
(1). can take human lives;	268	--	*14.205	.257	--
(2). can destroy the whole village or the whole group/community;	268	--	*11.535	.204	--
(3). can damage houses;	268	--	*11.910	.150	--
(4). can take the lives of cattle;	268	--	*16.328	.124	--
(5). can destroy farmland;	268	--	*12.993	.304	--
(6). can cause property loss;	268	--	*15.286	.156	--
(7). can cause road congestion.	268	--	*17.102	.093	--
Knowledge of debris flows	268	--	*13.416	.212	--
Perception of remoteness of home	268	3	3.462	.326	.114

Relationships between government disaster risk reduction measures and anticipated disaster responses

Government disaster mitigation (engineering) measures

A Chi-square test shows that there was no statistical significant association between Pingwu respondents' awareness of government disaster mitigation measures and how they would behave if see debris flow signs at home (X^2 (3, N = 268) = 2.098, p = .552). The effect size Cramer's V = .088, meaning it was not generally useful.

Government disaster preparedness measures

Among the government disaster preparedness measures, Pingwu respondents' awareness of or accessibility to four were found influential on their anticipated behaviour if they see debris flow signs at home. However, awareness of debris flow risk assessment both in community and on home as well as accessibility to two types of debris flow risk information were non-influential.

Table 5.26 summarises the sample size (N), degree of freedom (*df*), Chi-square value (X^2 value) or Fisher's exact test value, statistical significance level (p-value) and effect size (Cramer's V value) of each of the paired variables.

Statistical analysis finds that Pingwu respondents' anticipated behaviour when see debris flow signs at home were statistically significantly related to both their awareness of assessment on debris flow protection in their communities (Fisher's exact test value = 8.160, N = 268, p = .031) and their accessibility to any information on protective measures against general debris flow hit (Fisher's exact test value = 8.477, N = 268, p = .022).

Their anticipated disaster responses were also statistically significantly associated with whether they had ever heard of MMMP, X^2 (3, N = 268) = 10.788, p = .013, with a moderate effect (Cramer's V = .201), and their awareness of any community plan or measure to protect residents from debris flow strike, X^2 (3, N = 268) = 10.048, p = .018, with a weak effect (Cramer's V = .194).

Table 5.26

Statistical relationships between Pingwu respondents' awareness of / accessibility to each government disaster preparedness measure and their anticipated disaster responses

Government disaster preparedness measures	N	*df*	X^2 value *Fisher Exact Test value	*p*-value (2-tailed)	Cramer's *V*
1. Awareness of debris flow risk assessment					
a. in community	268	3	6.453	.092	.155
b. on home	268	--	*4.810	.150	--
2a. Accessibility to information on debris flow risk - Hazard zone information on community	268	--	*3.731	.287	--
2b. Accessibility to information on debris flow risk					
- Any information on community	268	--	*2.109	.493	--
- Any information on home	268	--	*.498	1.000	--
3. Awareness of assessment on protection against debris flow strike					
a. in community	**268**	--	***8.160**	**.031^**	--
b. on home	268	--	*1.311	.693	--
4. Accessibility to any information on protective measures against general debris flow strike	**268**	--	***8.477**	**.022^**	--
5. Heard of Mass Monitoring and Mass Prevention	**268**	**3**	**10.788**	**.013^**	**.201**
6. Awareness of plan/measure imposed on					
a. community to protect residents from debris flow strike	**268**	**3**	**10.048**	**.018^**	**.194**
b. home to protect family members from debris flow strike	268	3	3.624	.305	.116

^Significant at the 0.05 level (2-tailed)

In short, for the four variables that were statistically significantly associated with the anticipated behaviour, the effect sizes of association were .201 or below, indicating their relations were weak to moderate. Pingwu respondents' awareness of or accessibility to four government disaster preparedness measures slightly or moderately affected their anticipated disaster responses when they see debris flow signs at home.

When comparing the accessed or aware groups with the non-accessed or unaware groups in more detail, some important trends can be found. Except "heard of MMMP", those who were unaware of or had not accessed the other three government disaster preparedness measures were more likely to run, escape or

evacuate (67.74% to 69.46%) than the accessed or aware ones (44.83% to 60.00%). The biggest discrepancy is found regarding the awareness of assessment on community debris flow protection. As high as 69.46% of the unaware group would run, escape or evacuate, much higher than the 44.83% of the aware group.

Looking separately into the groups of those who were unaware of or inaccessible to the four statistically significantly influential variables, very similar anticipated disaster responses could be found (the four right pie charts in Figure 5.73)

About two-third anticipated they would run, escape or evacuate when see debris flow signs at home. Approximately 10% to 15% would choose to stay or take refuge at home, take care of home, impose risk reduction measures or observe. Another 14% would inform family members, authorities or others.

In contrary, anticipated disaster responses of those who were aware of or had accessed to the four variables were quite varied.

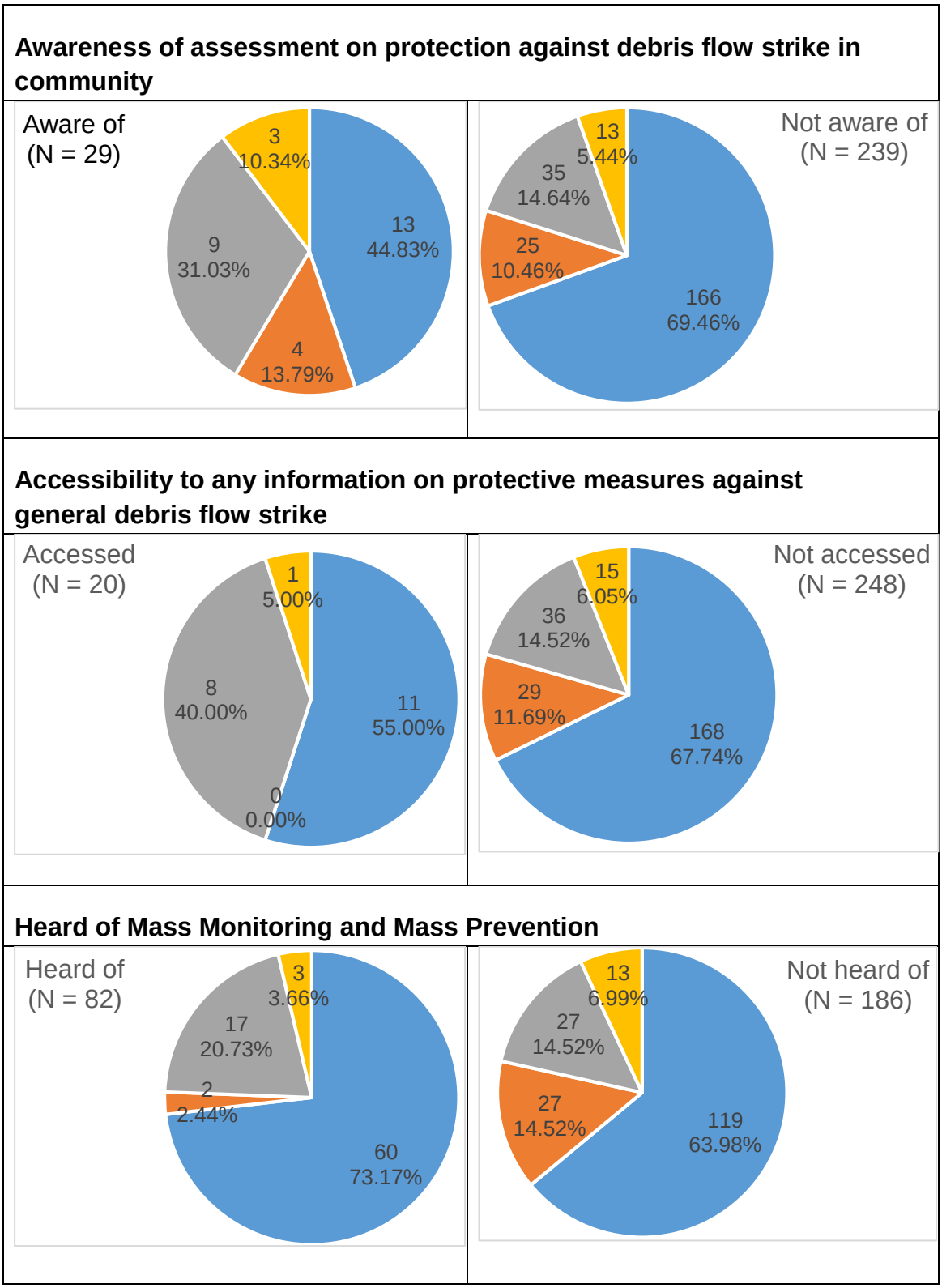
As shown in the left column of Figure 5.73, those who would run, escape or evacuate if see signs of debris flow at home constituted to as high as 73.17% of those who had heard of MMMP, but only 44.83% of those who were aware of certain community assessment on debris flow protection.

Only a very small portion of those who had heard of MMMP (2.44%), or were aware of certain community plan or measure to protect residents from debris flow strike (3.64%), and even none (0.00%) of those who had accessed certain information on protective measures against general debris flow hit would stay or take refuge at home, take care of home, impose risk reduction measures or observe. However, as much as 13.79% of those who were aware of certain community assessment on debris flow protection would choose to stay.

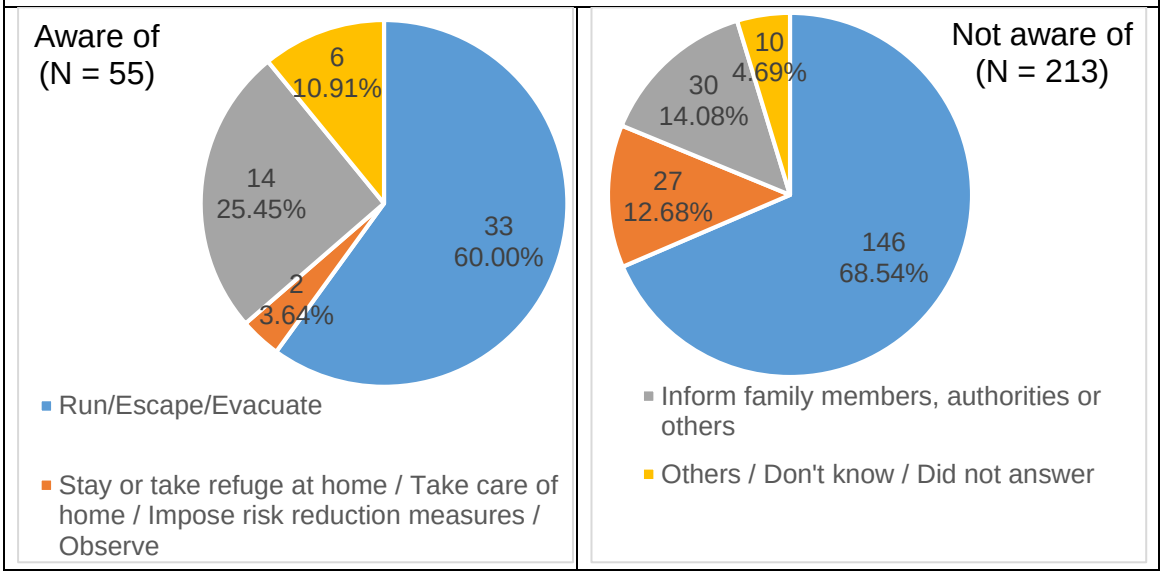
Among those who had heard of MMMP, 20.73% would inform family members, authorities or others. However, almost a double portion (40.00%) of those who had accessed protective measures information against general debris flow strike would also inform others.

Figure 5.73

Relations between Pingwu respondents' awareness of / accessibility to each government disaster preparedness measure and their anticipated disaster responses



Awareness of plan or measure imposed on community to protect residents from debris flow strike



A total of 13.79% of those who were aware of assessment on community debris flow protection would choose to stay at home, and this proportion is higher than the unaware group (10.46%). However, opposite trends hold for the other three measures. Those who were unaware of or had not accessed the three other measures were much more likely to stay at home (11.69% to 14.52%) than the accessed or aware groups (0.00% to 3.64%).

In particular, those who had not accessed any information on protective measures against general debris flow hit, as well as those who were unaware of any community plan or measure to protect residents from debris flow strike, were both more likely to run, and more likely to have an apparently opposite behaviour: to stay.

Those who had accessed or were aware of any of the four measures were more likely to inform family members, authorities or others (20.73% to 40.00%) than the non-accessed or unaware villagers (14.08% to 14.64%). In particular, 40.00% of those who had accessed protective measures information against general debris flow hit would inform others, which is approximately triple of the non-accessed group (14.52%).

Government disaster response measures and facilities

Among the seven categories of government disaster response measures or facilities, Pingwu respondents' awareness of or accessibility to the introduction of four (with five sub-variables) were found to be statistically significantly associated with their anticipated disaster responses when they see debris flow signs at home.

The five sub-variables are: respondents' accessibility to any information or instruction on appropriate debris flow response, with a Fisher's exact test value 8.194 (N = 268, p = .028); heard of monitoring personnel (X^2 (3, N = 268) = 14.225, p = .003) with a moderate effect size (Cramer's V = .230); awareness of two debris flow emergency response facilities, namely evacuation route and emergency shelter location in the community, with Fisher's exact test values 8.393 (N = 268, p = .033) and 8.146 (N = 268, p = .032) respectively; whether heard of community geohazard drill, with a Fisher's exact test value 8.657 (N = 268, p = .026).

Table 5.27 summarises the statistical relationships of each of the paired variables.

Table 5.27

Statistical relations between Pingwu respondents' awareness of / accessibility to each government disaster response measure or facility and their anticipated disaster responses

Government disaster response measures or facilities	N	*df*	X^2 value *Fisher Exact Test value	*p*-value (2-tailed)	Cramer's *V*
1. Awareness of assessment on capability to tackle debris flow hit in community	268	--	*5.159	.136	--
2. Awareness of plan/measure/instruction to tackle debris flow hit in community	268	3	5.076	.166	.138
3. Accessibility to information on appropriate response when hit by debris flow (which told explicitly on how to respond if encounter debris flow)					
a. Any information/instruction	**268**	**--**	***8.194**	**.028^**	**--**
b. Booklet	268	--	*5.285	.118	--
c. Card/Table	268	--	*5.183	.124	--
4. Awareness of early warning					
a. Website	268	--	*3.543	.335	--
b. Siren	268	--	*1.741	.668	--
c. Phone	268	--	*1.574	.692	--
d. Gong	268	--	*2.436	.475	--
e. Shout	268	3	4.837	.184	.134
5. Awareness of monitoring personnel					
a. Heard of	**268**	**3**	**14.225**	**.003^^**	**.230**
b. Respondent	268	--	*2.895	.380	--
c. Family member	268	--	*3.495	.199	--
6. Awareness of emergency response facilities					
a. Evacuation route	**268**	**--**	***8.393**	**.033^**	**--**
b. Emergency shelter	**268**	**--**	***8.146**	**.032^**	**--**
c. Temporary residing place	268	--	*3.163	.335	--
7. Awareness of emergency response dissemination					
a. Emergency bag	268	--	*3.022	.380	--
b. Training	268	--	*6.435	.055	--
c. Drill	**268**	**--**	***8.657**	**.026^**	**--**

^Significant at the 0.05 level (2-tailed)

^^Significant at the 0.01 level (2-tailed)

When further compare the two columns of pie charts in Figure 5.74, more important observations can be found. Those who had not accessed, not heard of or unaware of such five government disaster response measures or facilities (right column) were more likely to run, escape or evacuate (67.01% to 69.33%) as well as more likely to stay at home (11.02% to 14.21%) than the accessed, heard of or aware groups (run: 50.00% to 66.20% and stay: 0.00% to 9.38%) (left column). Instead, those who had accessed, heard of or were aware of such measures or facilities were much more likely to inform others (25.00% to 35.29%) than the non-accessed, not heard of or unaware groups (12.69% to 15.25%). In particular, among those who had heard of community geohazard drill, as much as 35.29% would inform others, which is more than double of those who had not heard of.

As in the case of disaster preparedness measures, for those who were inaccessible to or unaware of any of the five sub-variables, their anticipated disaster responses were very similar (pie charts on the right column in Figure 5.74). About two-third of the respondents would run, escape or evacuate when see debris flow signs at home. Approximately 11% to 15% anticipated they would stay or take refuge at home, take care of home, impose risk reduction measures or observe. Another 12% to 16% would inform family members, authorities or others.

In contrary, anticipated behaviour of those who were aware of or had accessed the five disaster response measures were quite varied. Again, this is quite similar to the case of disaster preparedness measures.

The left column of Figure 5.74 shows that those who would run, escape or evacuate if see signs of debris flow at home constituted to as high as 66.20% of those who had heard of monitoring personnel. This is similar to the percentage of the not heard of group. However, among those who were aware of either of the two debris flow emergency response facilities in the community, that is evacuation route or shelter location, only 53.49% and 50.00% of the respective respondents would run.

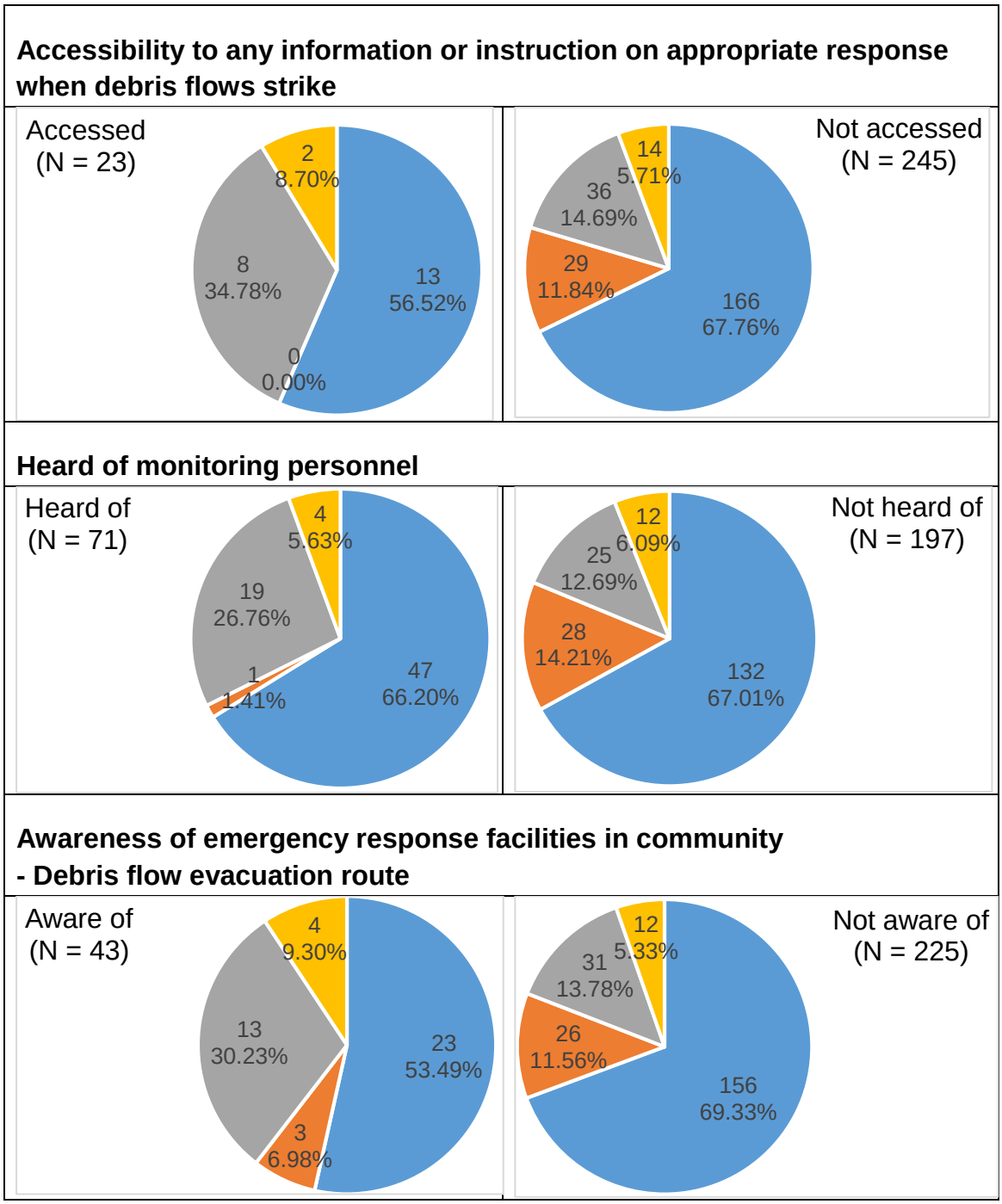
Another 9.38% and 6.98% of those who were aware of emergency shelter location and evacuation route respectively would stay or take refuge at home, take care of home, impose risk reduction measures or observe. However, none of those who

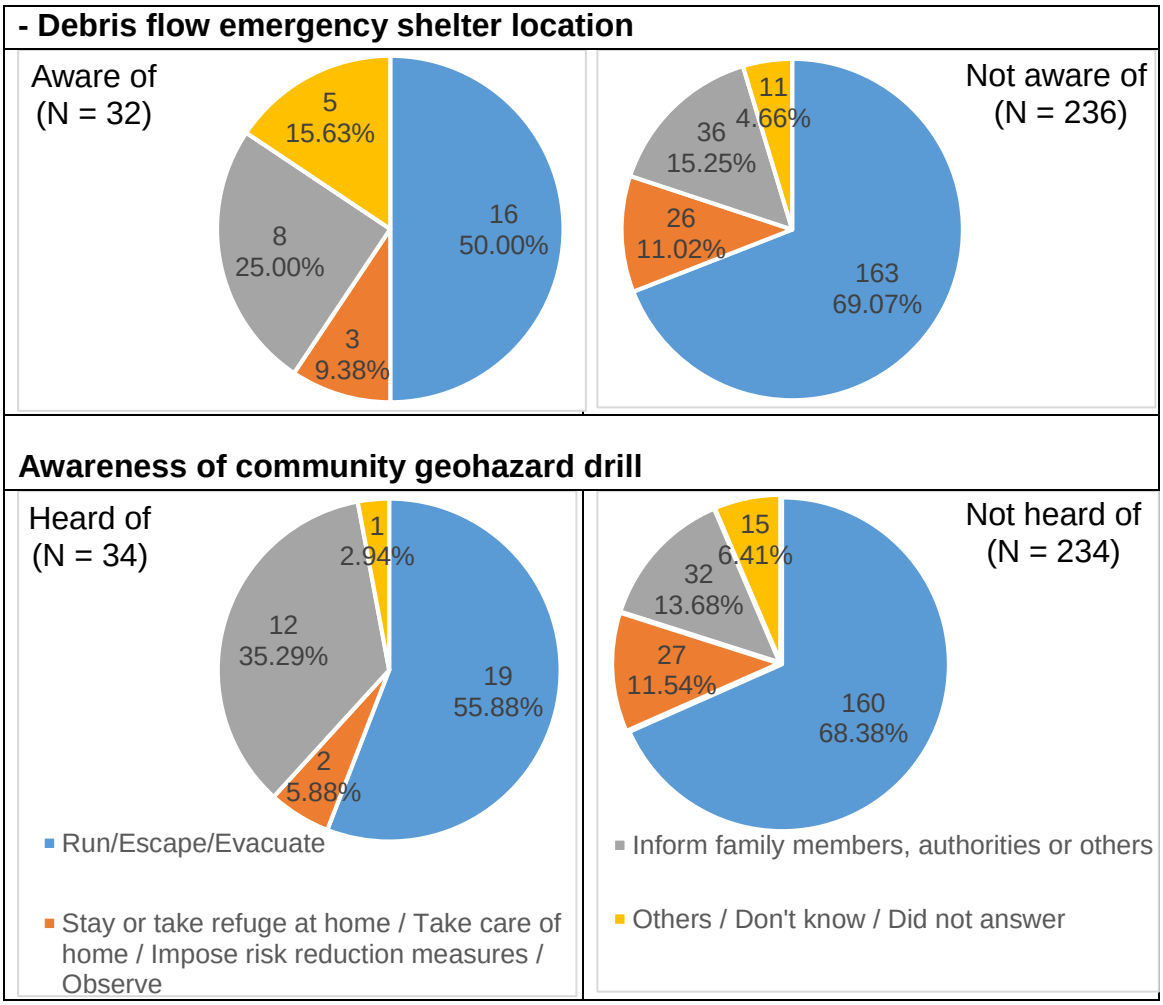
had accessed certain information or instruction on appropriate debris flow response would stay at home.

Among those who had heard of community geohazard drill, as much as 35.29% would inform family members, authorities or others. However, for those who were aware of emergency shelter location, only 25% would inform others.

Figure 5.74

Relations between Pingwu respondents' accessibility to / awareness of each government disaster response measure or facility and their anticipated disaster responses





Perception of existing debris flow threat on home

Perception of existing debris flow threat on one's home might affect anticipated disaster response when see debris flow signs at home. The respondents were therefore asked to judge their perceptions of existing debris flow threat on their homes. However, no statistical significant association between the two variables was found (X^2 (6, N = 268) = 8.430, p = .208). The effect size Cramer's V = .125, was weak.

5.4.2 Summary of Hypothesis 3 results in Pingwu

In Pingwu, a total of ten independent variables categorised as I to X with 54 sub-variables were tested to determine if they are associated with the anticipated behaviour when see signs of debris flow at home. Three independent variables, including 11 sub-variables were found to be statistically significantly associated with the dependent variable.

Sub-variables affecting Pingwu respondents' disaster response

Two demographic and socioeconomic sub-variables, age and role in village, were found related to, and would influence, anticipated disaster response.

Respondents' awareness of or accessibility to four government disaster preparedness measures was also associated with, and impacted, their anticipated behaviour. These include assessment on protection against debris flow strike in community, information on protective measures against general debris flow strike, MMMP as well as community plan or measure to protect residents from debris flow strike.

In addition, respondents' awareness of or accessibility to five government disaster response measures or facilities, namely information or instruction on appropriate debris flow response, monitoring personnel, evacuation route, emergency shelter and drill were also statistically significantly related to, and would affect, anticipated debris flow response behaviour.

The impacts of government disaster risk reduction measures on Pingwu respondents' anticipated behavioural responses implied that Hypothesis 3 which states that "*Disaster response behaviour of the rural populations living in remote mountainous regions of Sichuan is affected by their awareness of government disaster risk reduction measures.*" is accepted in the Pingwu scenario.

Figure 5.75 summarises the overall findings for Hypothesis 3 in Pingwu, while Figure 5.76 extracts those independent variables which are statistically significantly associated with, and could affect, Pingwu respondents' future behavioural responses when see debris flow signs at home.

Figure 5.75
Factors associated with Pingwu respondents' anticipated behavioural responses when see debris flow signs at home
(among all other tested but non-associated factors marked in white)

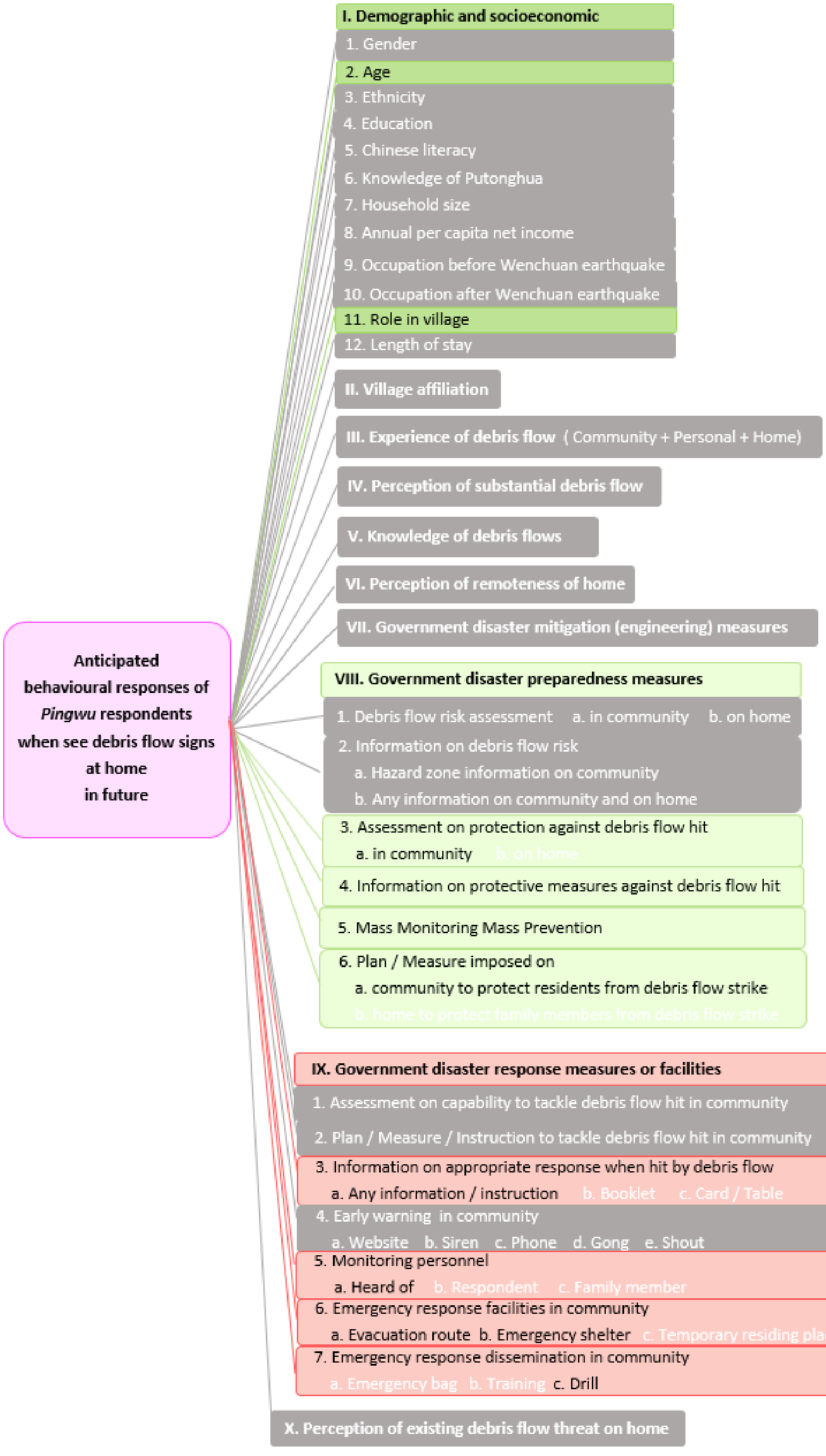
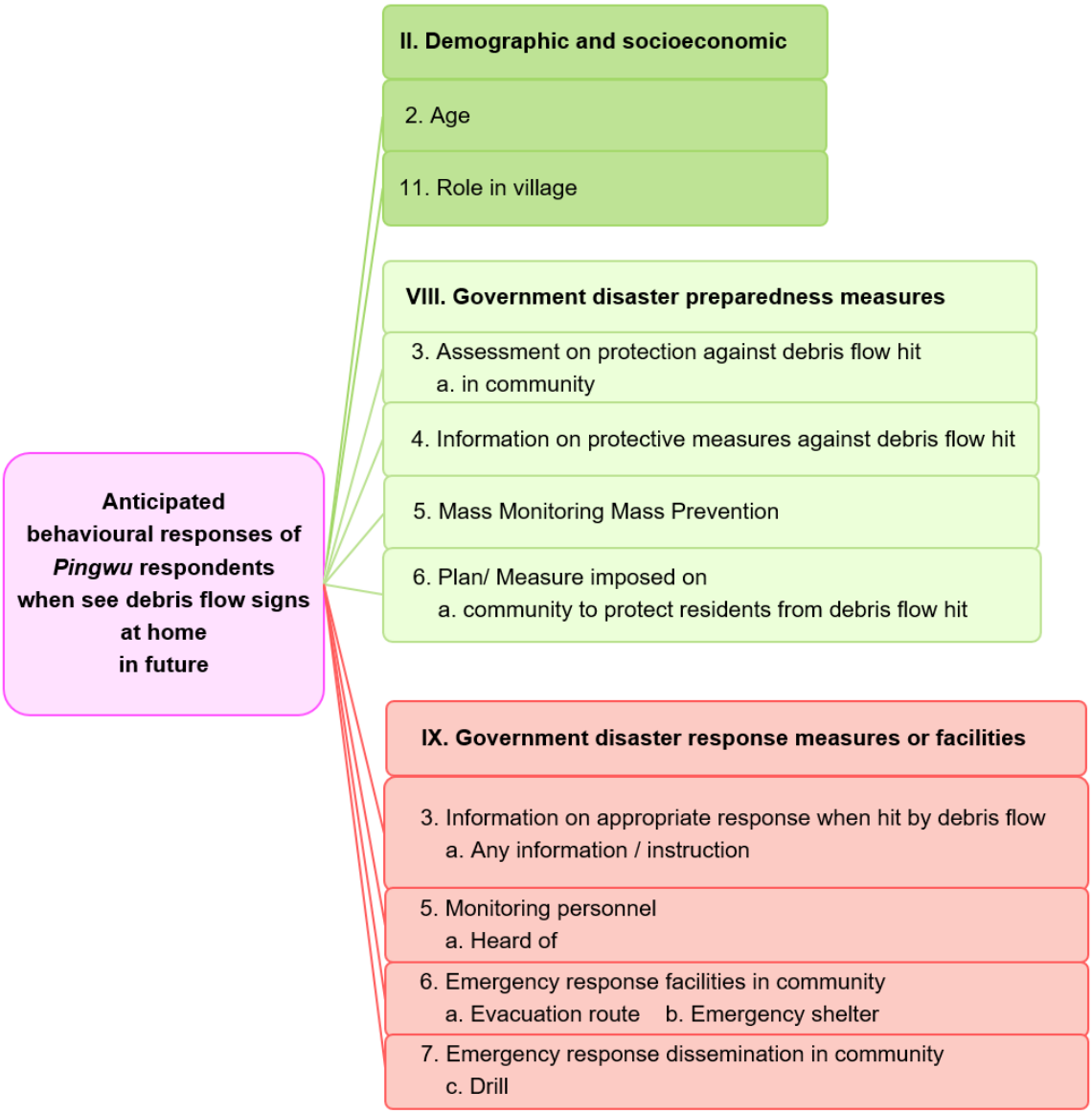


Figure 5.76
Factors associated with Pingwu respondents' anticipated behavioural responses when see debris flow signs at home



5.4.3 Results of study area 2 – Wenchuan County

Relationships between demographic/socioeconomic factors and anticipated disaster responses when see signs of debris flow at home

In Wenchuan, two demographic variables, occupation after Wenchuan earthquake and role in village, were found to be statistically significantly associated with the respondents' anticipated behaviour when see signs of debris flow at home (Table 5.28).

The other ten demographic factors being tested were not statistically significantly related to respondents' anticipated disaster response. These ten variables are gender, age, ethnicity and education-related variables including education level, Chinese literacy, and knowledge of Putonghua, household variables like household size and annual per capita net income, occupation before Wenchuan earthquake, as well as community-affiliation variables like length of stay in one's community per year.

Table 5.28

Statistical relationships between each demographic/socioeconomic factor and anticipated disaster responses in Wenchuan

Demographic/ Socioeconomic factor	N	*df*	X^2 value *Fisher's Exact Test value	*p*-value (2-tailed)	Cramer's *V*
Gender (Male VS Female)	363	3	7.643	.054	.145
Age (18 to 64 VS 65 or above)	363	3	6.975	.073	.139
Ethnicity (Tibetan VS Han VS Qiang VS Hui)	363	--	*8.585	.464	--
Education level (2 groups) (Primary and below VS Secondary and above)	361	3	2.613	.455	.085
Education level (3 groups) (Uneducated VS Primary VS Secondary and above)	361	6	5.124	.528	.084
Education level (4 groups) (Uneducated VS Primary VS Secondary VS Tertiary and above)	361	9	10.824	.288	.100
Chinese literacy (No VS Yes/Partial)	357	3	5.101	.165	.120
Knowledge of Putonghua (Know VS Don't know VS Can understand but cannot speak)	358	6	6.472	.372	.095

Household size (1 to 3 persons VS 4 or more persons)	363	--	*.332	.955	--
Annual per capita net income (Below and on poverty line RMB 2855 VS Above poverty line RMB 2856 to below rural population annual per capita net income RMB 10771 VS rural population annual per capita net income RMB 10772 and above)	319	--	*5.237	.484	--
Occupation before Wenchuan earthquake (Non-farmer VS Farmer)	363	3	4.737	.192	.114
Occupation after Wenchuan earthquake (Non-farmer VS Farmer)	**361**	**3**	**10.765**	**.013^**	**.173**
Length of stay in one's group/ community per year (Not stay for whole year/ Don't know/ Not sure/ NA VS Stay for whole year)	363	3	1.259	.739	.059
Role in village (No/ Don't know/ Forgot/ Not answer VS Yes)	**363**	**--**	***11.894**	**.004^^**	**--**

^Significant at the 0.05 level (2-tailed)
^^Significant at the 0.01 level (2-tailed)

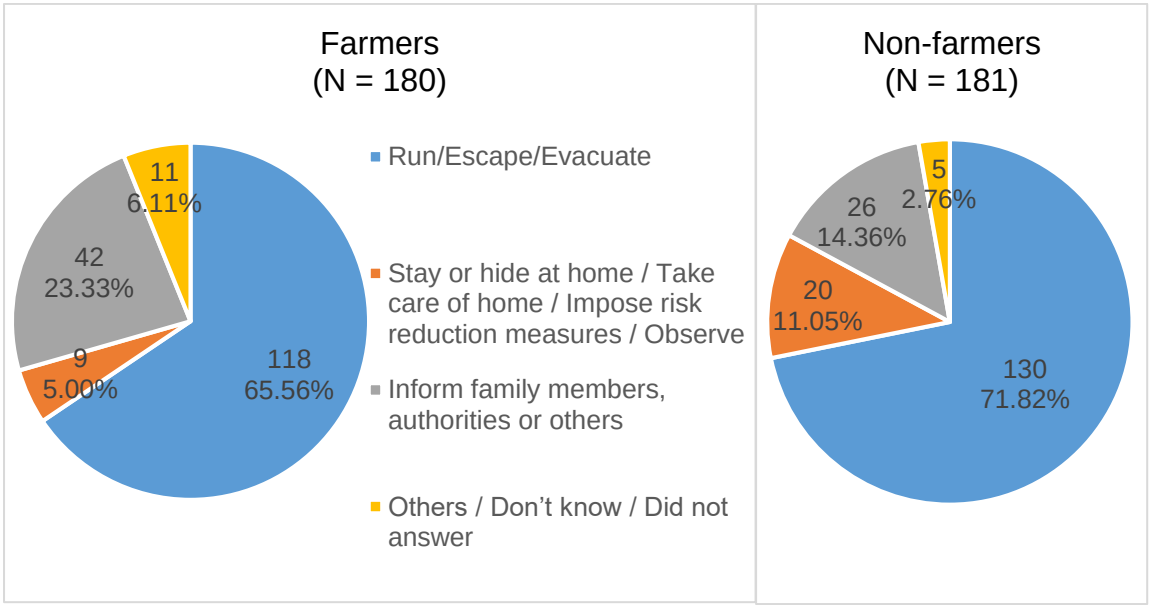
Occupation after Wenchuan earthquake

Among the 181 non-farmers in Wenchuan, 71.82% would run, escape or evacuate when see signs of debris flow at home in the future. About 11.05% would stay or take refuge at home. Another 14.36% would inform family members, authorities or others.

For the 180 farmers, 65.56% said they would run. Only 5.00% would stay at home, which is less than half of the non-farmer group (11.05%). Another 23.33% would inform others. This proportion is much higher than the non-farmer group (14.36%).

Figure 5.77

Relations between Wenchuan respondents' occupation after Wenchuan earthquake and their anticipated disaster responses



A Chi-square test finds that Wenchuan respondents' occupation after the earthquake and their anticipated behavioural responses when see signs of debris flow at home was statistically significantly related, X^2 (3, N = 361) = 10.765, p = .013. The effect size Cramer's V = .173, indicating a weak association.

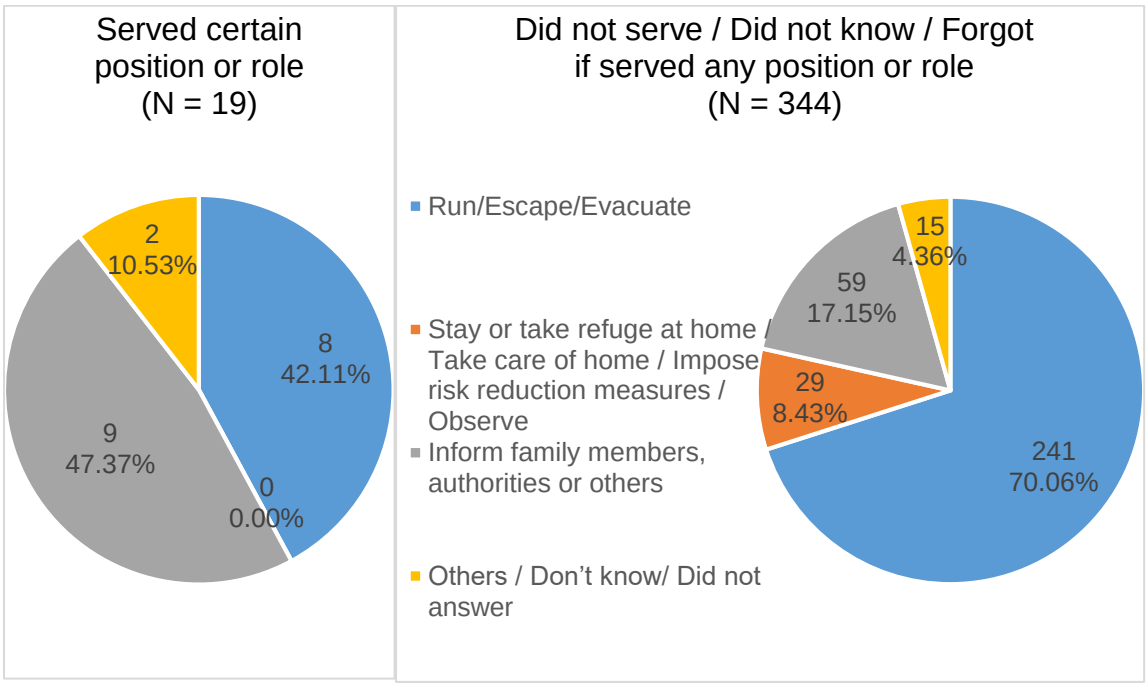
This means when compared to the farmers, the Wenchuan non-farmers were slightly more likely to run, escape or evacuate, or more likely to stay of take refuge at home. In contrary, the farmers were more likely to inform family members, authorities or others than the non-farmers.

Role in village

Among the 344 Wenchuan respondents who did not serve any village role, did not know or forgot if they served, the majority (70.06%) said they would run, escape or evacuate when see debris flow signs at home. A small portion of 8.43% would stay or take refuge at home, take care of home, impose risk reduction measures or observe. Another 17.15% would inform family members, authorities or others.

Figure 5.78

Relations between Wenchuan respondents' role in village and their anticipated disaster responses



For those 19 Wenchuan respondents who served certain village role, the greatest portion (47.37%) anticipated they would inform others when they see signs of debris flow at home; followed by 42.11% who would evacuate. None would take refuge at home.

The relation between whether the Wenchuan respondents served any village role and their anticipated disaster response was statistically significant, with a Fisher's exact test value 11.894 (N = 363, p = .004).

Those served certain village role were much more likely to inform family members, authorities or others than the rest. In contrary, those who did not serve any village role, did not know or forgot if they served, were much more likely to run, escape or evacuate and also more likely to stay or take refuge at home, take care of home, impose risk reduction measures or observe when see debris flow signs at home.

Relationships between non-demographic factors and anticipated disaster responses

Village affiliation, Experience of debris flow, Perception of substantial debris flow, Knowledge of debris flows and Perception of remoteness of home

Analysis finds that, in Wenchuan, there were statistical significant associations between how the respondents would behave when see signs of debris flow at home on one hand and two respective non-demographic factors on the other (Table 5.29). The two factors are perception of substantial debris flow and perception of remoteness of home. Three other non-demographic factors, namely village affiliation, debris flow experience and knowledge of debris flows had no statistical significant influence on anticipated disaster response.

Table 5.29

Statistical relationships between each non-demographic factor and anticipated disaster responses in Wenchuan

Non-demographic factor	N	*df*	X^2 *value* **Fisher Exact Test value*	*p*-value (2-tailed)	Cramer's *V*
Village affiliation	363	6	6.405	.379	.094
Experience of debris flow	363	--	*7.721	.550	--
Perception of substantial debris flow					
(1). Substantial debris flow can take human lives	363	-	*8.237	.423	-
(2). Substantial debris flow can destroy the whole village or the whole group/community	363	-	*13.205	.373	-
(3). Substantial debris flow can damage houses	363	-	*12.717	.374	-
(4). Substantial debris flow can take the lives of cattle	**363**	**-**	***23.404**	**.015^**	**-**
(5). Substantial debris flow can destroy farmland	**363**	**-**	***21.575**	**.005^^**	**-**
(6). Substantial debris flow can cause property loss	363	-	*12.179	.145	-
(7). Substantial debris flow can cause road congestion	**363**	**-**	***19.948**	**.049^**	**-**
Knowledge of debris flows	363	--	8.024	.674	--
Perception of remoteness of home	363	3	8.744	.033	.155

^Correlation is significant at the 0.05 level (2-tailed)

^^Correlation is significant at the 0.01 level (2-tailed)

Perception of substantial debris flow

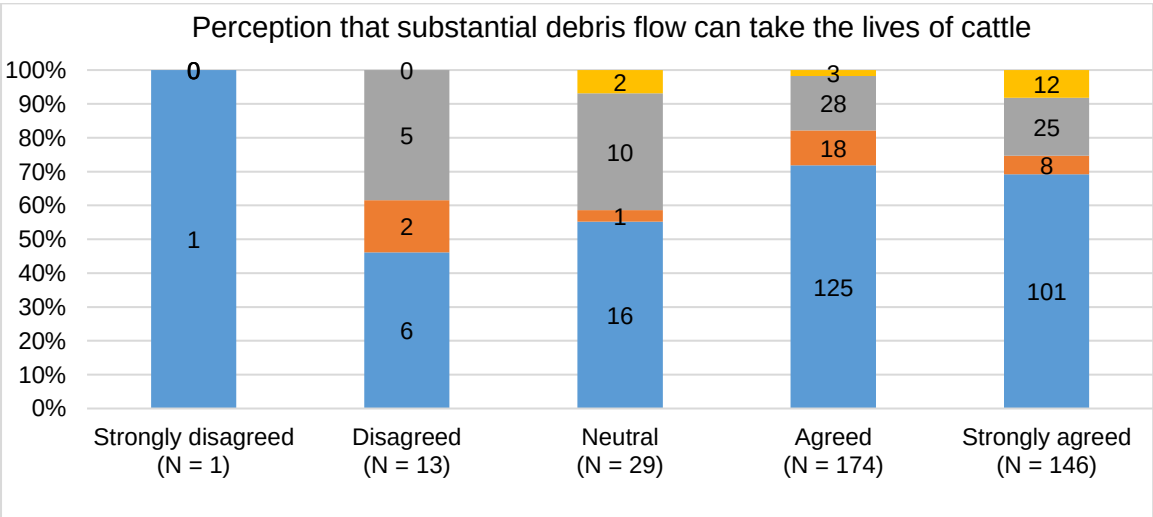
In Wenchuan, among the seven aspects of perception of substantial debris flow, three were statistically significantly associated with anticipated disaster responses respectively. The three aspects are substantial debris flow could “take the lives of cattle” (Fisher’s exact test value = 23.404 (N = 363, *p* = .015)), “destroy farmland” (Fisher’s exact test value = 21.575 (N = 363, *p* = .005)) and “cause road congestion” (Fisher’s exact test value =19.948 (N = 363, *p* = .049)).

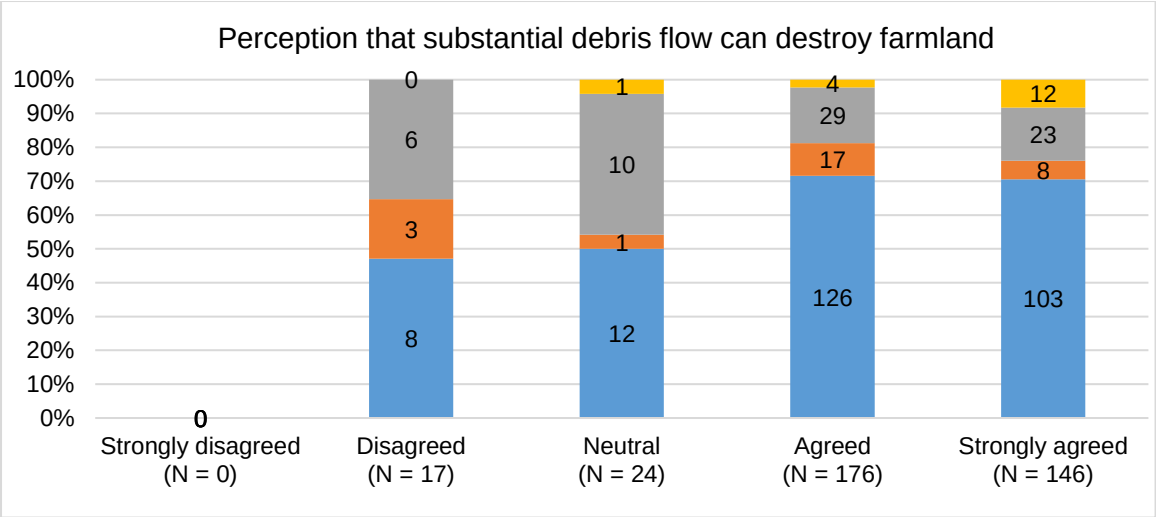
The three sets of stacked columns (Figure 5.79) show the anticipated behavioural responses when the Wenchuan respondents see debris flow signs at home, and their respective relations with perceptions of whether substantial debris flow can take the lives of cattle, destroy farmland and cause road congestion.

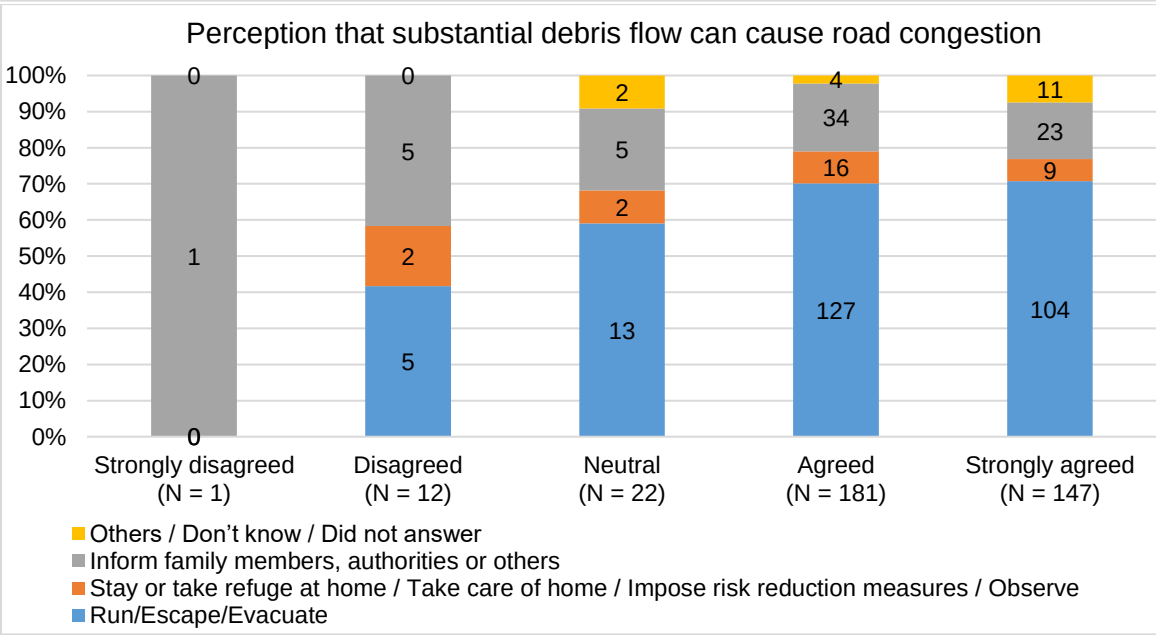
The distributions of the anticipated disaster responses were very similar for the three aspects of substantial debris flow perceptions. Those who agreed or strongly agreed that substantial debris flow can take the lives of cattle, destroy farmland or cause road congestion were more likely to run, escape or evacuate. Conversely, those who disagreed or strongly disagreed were more likely to inform family members, authorities or others, or to stay or take refuge at home, impose risk reduction measures or observe the situation.

Figure 5.79

Stacked columns showing three aspects of perceptions of substantial debris flow and their respective relations with anticipated disaster responses when respondents in Wenchuan see debris flow signs at home (N = 363)







Perception of remoteness of home

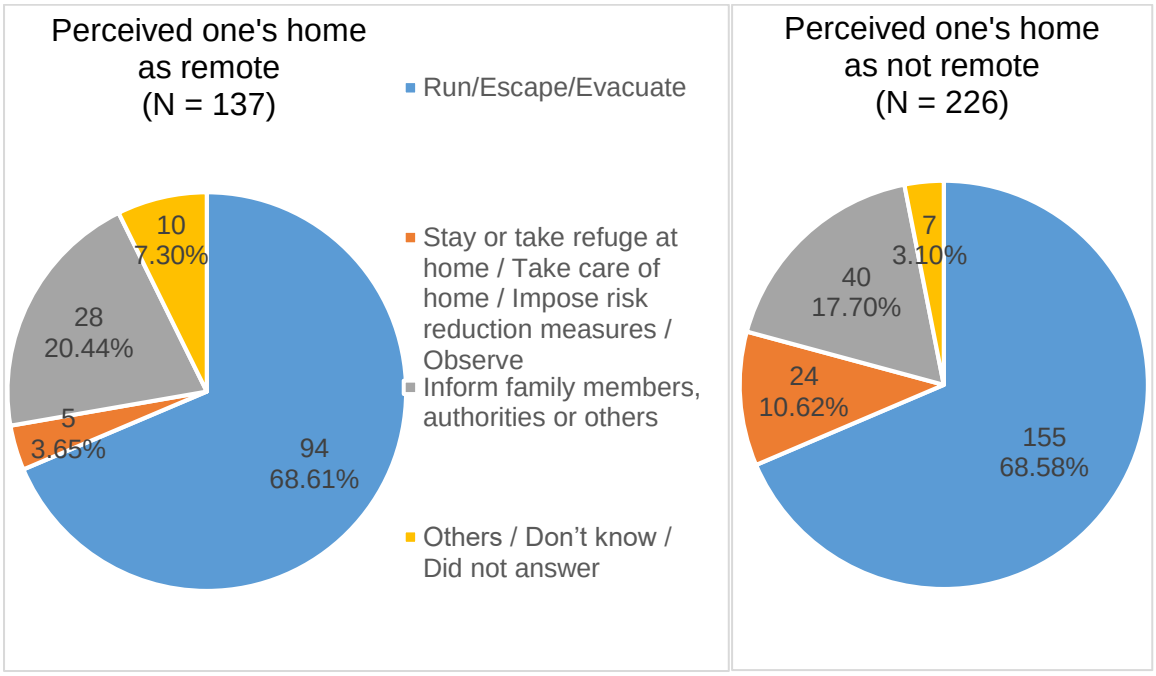
Among the 137 Wenchuan respondents who perceived the location of their homes as remote, 68.61% said they would run, escape or evacuate if they see debris flow signs at home. Almost the same proportion (68.58%) of the 226 respondents who did not perceive the remoteness also anticipated they would run.

The main difference between the two groups was that only 3.65% of those who perceived the remoteness would stay or take refuge at home, take care of home, impose risk reduction measures or observe. Those who did not perceive their homes as remote were much more likely to stay (10.62%).

Those who perceived their homes as remote were also slightly more likely to inform family members, authorities or others (20.44%) than those who did not perceive the remoteness (17.70%).

Figure 5.80

Relations between Wenchuan respondents' perception of remoteness of home and their anticipated disaster responses



Wenchuan respondents' perception of remoteness of their homes and how they would behave when see debris flow signs at home was statistically significantly associated, X^2 (3, N = 363) = 8.744, p = .033, with a weak effect (Cramer's V = .155).

Relationships between government disaster risk reduction measures and anticipated disaster responses

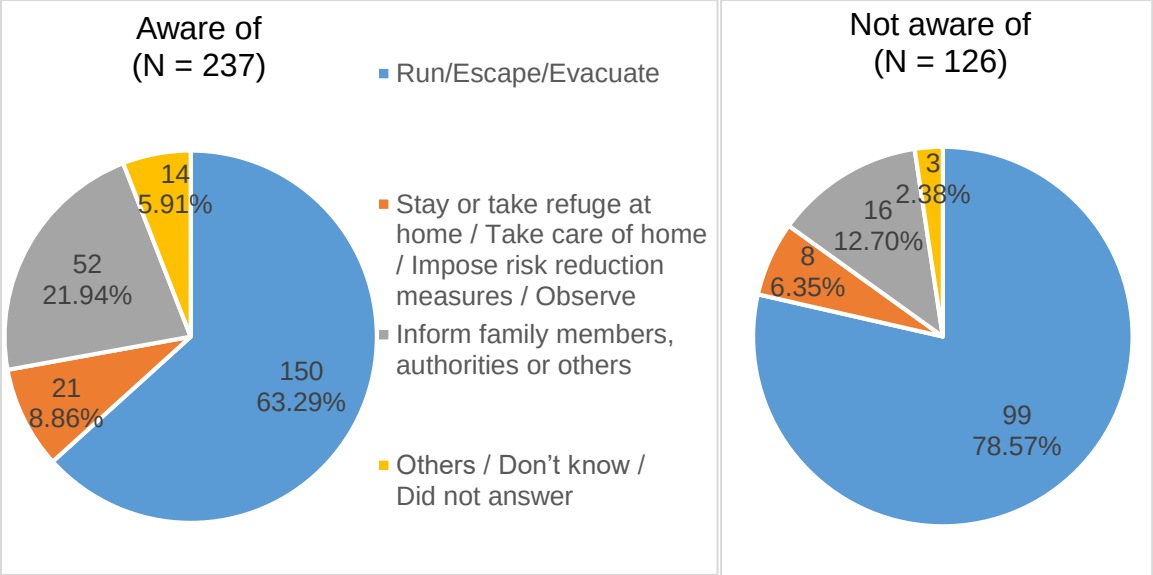
Government disaster mitigation (engineering) measures

Among the 126 Wenchuan respondents who were unaware of the existence of any geotechnical measure in their communities, as high as 78.57% anticipated they would run, escape or evacuate when see debris flow signs at home. Only 6.35% would stay or take refuge at home, take care of home, impose risk reduction measures or observe. Another 12.70% would inform family members, authorities or others.

For those 237 respondents who were aware of the imposition of certain geotechnical measure, only 63.29% would run. Another 8.86% would stay. As much as 21.94% would inform others.

Figure 5.81

Relations between Wenchuan respondents' awareness of government disaster mitigation (engineering) measures and their anticipated disaster responses



Wenchuan respondents' awareness of existence of disaster geotechnical mitigation measures and how they would behave when see debris flow signs at home was statistically significant related, X^2 (3, N = 363) = 9.385, p = .025, although the effect size was weak (Cramer's V = .161).

In other words, those who were unaware of the geotechnical measures in their communities were more likely to escape than those who were aware of. The aware group was more likely to inform others, or simply stay at home, than the unaware group.

Government disaster preparedness measures

Among the disaster preparedness measures imposed by the government, Wenchuan respondents' awareness of or accessibility to two were found influencing their anticipated behaviour when they see signs of debris flow at home.

A Chi-square test finds that awareness of community debris flow risk assessment was statistically significantly associated with anticipated disaster response, X^2 (3,

N = 363) = 10.497, *p* = .015, although the effect was weak (Cramer's *V* = .170) Table 5.30.

Respondents' accessibility to any information on community debris flow risk was also statistically significantly related to their anticipated behaviour, with a Fisher's exact test value 16.259 (N = 363, *p* = .001).

It is worth noting that these two variables were not statistically significantly related to the anticipated disaster responses in Pingwu. At the same time, the four disaster preparedness variables affected Pingwu were not influential in Wenchuan.

Table 5.30

Statistical relationships between Wenchuan respondents' awareness of / accessibility to each government disaster preparedness measure and their anticipated disaster responses

Government disaster preparedness measures	N	*df*	X^2 value *Fisher Exact Test value	*p*-value (2-tailed)	Cramer's *V*
1. Awareness of debris flow risk assessment					
a. in community	363	3	10.497	.015^	.170
b. on home	363	--	3.826*	.194	--
2a. Accessibility to information on debris flow risk - Hazard zone information on community	363	--	4.220*	.222	--
2b. Accessibility to information on debris flow risk					
- Any information on community	363	--	*16.259	.001^^	-- *(.222)*
- Any information on home	363	--	*.479	1.000	--
3. Awareness of assessment on protection against debris flow strike					
a. in community	363	--	*1.817	.622	--
b. on home	363	NA[1]	NA[1]	NA[1]	NA[1]
4. Accessibility to any information on protective measures against general debris flow strike	363	3	5.589	.133	.124
5. Heard of Mass Monitoring and Mass Prevention	363	3	6.329	.097	.132
6. Awareness of plan/measure imposed on					
a. community to protect residents from debris flow strike	363	3	1.825	.610	.071
b. home to protect family members from debris flow strike	363	3	4.056	.255	.106

^Significant at the 0.05 level (2-tailed)

^^Significant at the 0.01 level (2-tailed)

[1]NA – Not applicable because all respondents replied "No", "I don't know" or "I forget" which were all coded as 0.

Through further comparison of the aware or accessed groups with the unaware or non-accessed groups, more observations can be found (Figure 5.82). Those who had not accessed or were unaware of such two government disaster preparedness measures in Wenchuan were more likely to run, escape or evacuate (71.22% to 71.38%) than the accessed or aware ones (34.62% to 59.77%). Particularly, for those who had not accessed community debris flow risk information, the run portion was double that of the accessed group.

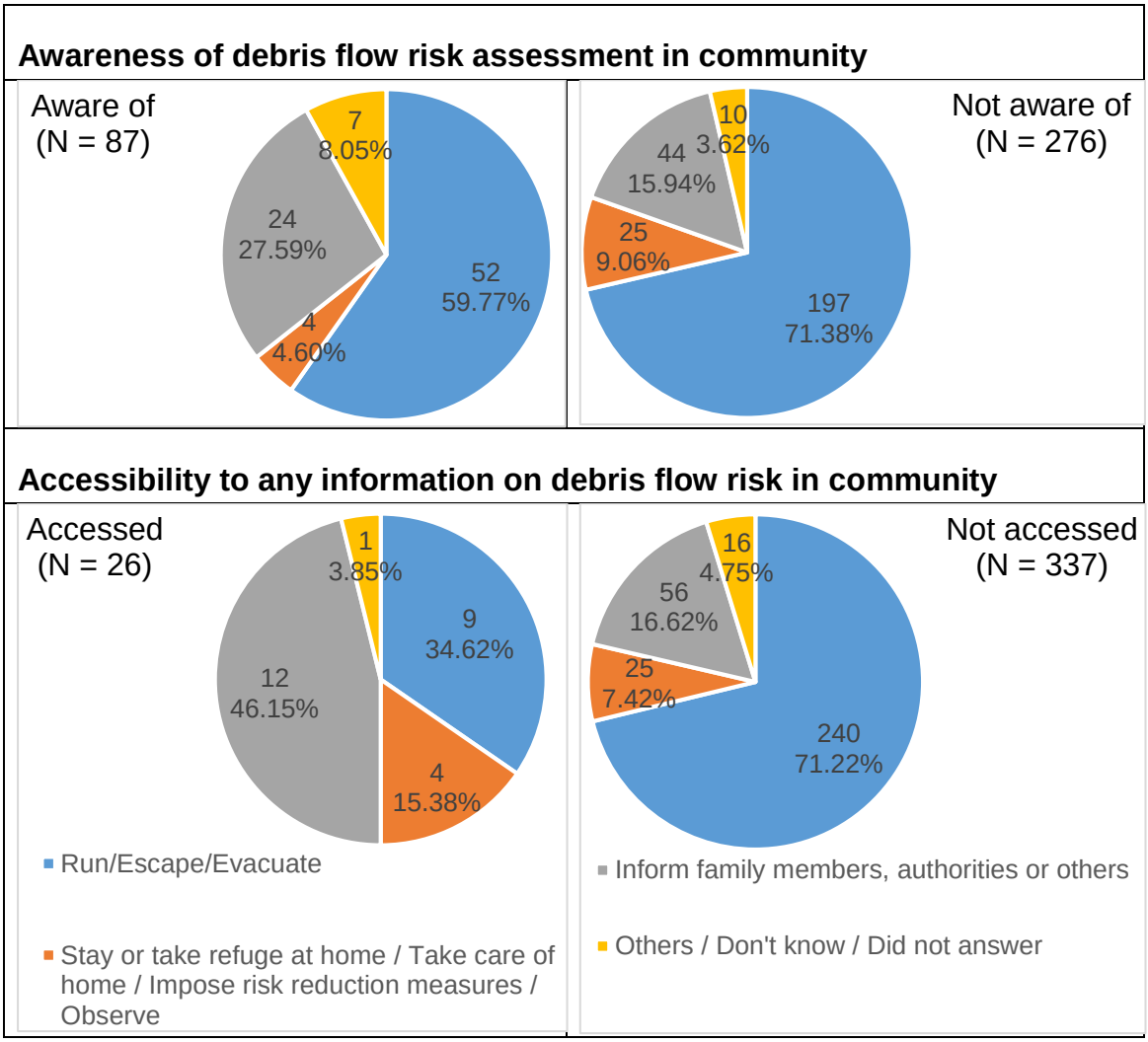
In contrary, the accessed or aware groups were much more likely to inform others (27.59% to 46.15%) than the non-accessed or unaware ones (15.94% to 16.62%). Particularly, when compared with the non-accessed group, almost triple of those who had accessed community debris flow risk information would inform others. However, the trend of those who chose to stay at home was inconclusive. Those who were aware of community debris flow risk assessment were less likely to stay at home (4.60%) than the unaware group (9.06%). Yet those who had accessed certain information on community debris flow risk were more likely to stay (15.38%) than the non-accessed group (7.42%).

When look separately into those who were unaware of or inaccessible to the two significant sub-variables, very similar anticipated disaster responses were found. This is similar to Pingwu.

More than two-third of those who were unaware of any debris flow risk assessment in their communities (71.38%) and had not accessed any information on community debris flow risk (71.22%) said they would run, escape or evacuate when see debris flow signs at home in the future (right pie charts in Figure 5.82). Only 9.06% and 7.42% would stay or take refuge at home, take care of home, impose risk reduction measures or observe. Those anticipated they would inform family members, authorities or others constituted to 15.94% and 16.62%, of the two respondent groups respectively.

Figure 5.82

Relations between Wenchuan respondents' awareness of / accessibility to each government disaster preparedness measure and their anticipated disaster responses



In contrary, those who were aware of or had accessed to the two variables had varied anticipated disaster responses (left column of Figure 5.82). This is again similar to the Pingwu situation.

Among those 87 Wenchuan respondents who were aware of debris flow risk assessment on community, 59.77% anticipated they would run, escape or evacuate when see signs of debris flow at home. But for those 26 respondents who had accessed community debris flow risk information, only 34.62% would run.

A very small portion (4.60%) of those who were aware of debris flow risk assessment on community would stay or take refuge at home, take care of home,

impose risk reduction measures or observe. However, 15.38% of those who had accessed certain information on community debris flow risk would stay.

Among those who were aware of community debris flow risk assessment, only 27.59% would inform family members, authorities or others. Yet the biggest portion (46.15%) of those who had accessed certain community debris flow risk information would inform people.

Government disaster response measures and facilities

Among the seven categories of disaster response measures or facilities imposed by the government, Wenchuan respondents' awareness of the introduction of four (with six sub-variables) were found to be statistically significantly associated with how they would behave when see debris flow signs at home (Table 5.31).

The Sichuan government has introduced various channels to spread information telling explicitly how to appropriately respond if encounter debris flow. Wenchuan respondents' accessibility to two forms of information, namely booklet and Card/ Table, were influential to their future debris flow responses. Their anticipated disaster response was statistically significantly related to accessibility to booklet (X^2 (3, N = 363) = 12.913, p = .005 with a weak effect size (Cramer's V = .189)) and accessibility to card or table (Fisher's exact test value 8.602 (N = 363, p = .028)) respectively.

In terms of debris flow early warning, awareness of website and shout as two separate tools on one hand and anticipated behaviour on the other were both statistically significantly related, with a Fisher's exact test value 8.978 (N = 363, p = .026) and X^2 (3, N = 363) = 14.984, p = .002 respectively. The effect size of shout was moderate, with Cramer's V = .203.

Statistical significant relation between whether the respondents were monitoring personnel and their anticipated debris flow response is reflected by the Fisher's exact test value 17.373 (N = 363, p = .000). Furthermore, awareness of any debris flow evacuation route in the community and anticipated disaster response was statistically significantly related, X^2 (3, N = 363) = 13.641, p = .003, although the effect size was weak (Cramer's V = .194).

Table 5.31

Statistical relationships between Wenchuan respondents' awareness of / accessibility to each government disaster response measure or facility and their anticipated disaster responses

Government disaster response measures or facilities	N	*df*	X^2 value *Fisher Exact Test value	*p*-value (2-tailed)	Cramer's *V*
1. Awareness of assessment on capability to tackle debris flow hit in community	363	--	*2.343	.461	--
2. Awareness of plan/measure/instruction to tackle debris flow hit in community	363	3	6.417	.093	.133
3. Accessibility to information on appropriate response when hit by debris flow (which told explicitly on how to respond if encounter debris flow)					
a. Any information /instruction	363	3	1.209	.751	.058
b. Booklet	**363**	**3**	**12.913**	**.005^^**	**.189**
c. Card/ Table	**363**	**--**	***8.602**	**.028^**	**-- *(.163)***
4. Awareness of early warning					
a. Website	**363**	**--**	***8.978**	**.026^**	***– (.190)***
b. Siren	363	3	2.744	.433	.087
c. Phone	363	--	*4.055	.241	--
d. Gong	363	3	5.780	.123	.126
e. Shout	**363**	**3**	**14.984**	**.002^^**	**.203**
5. Awareness of monitoring personnel					
a. Heard of	363	3	7.687	.053	.146
b. Respondent	**363**	**--**	***17.373**	**.000^^**	**-- *(.237)***
c. Family member	363	--	*.929	.844	--
6. Awareness of emergency response facilities					
a. Evacuation route	**363**	**3**	**13.641**	**.003**	**.194**
b. Emergency shelter	363	3	6.336	.096	.132
c. Temporary residing place	363	--	*3.093	.349	--
7. Awareness of emergency response dissemination					
a. Emergency bag	363	--	*6.915	.063	--
b. Training	363	--	*.935	.852	--
c. Drill	363	3	5.121	.163	.119

^Significant at the 0.05 level (2-tailed)

^^Significant at the 0.01 level (2-tailed)

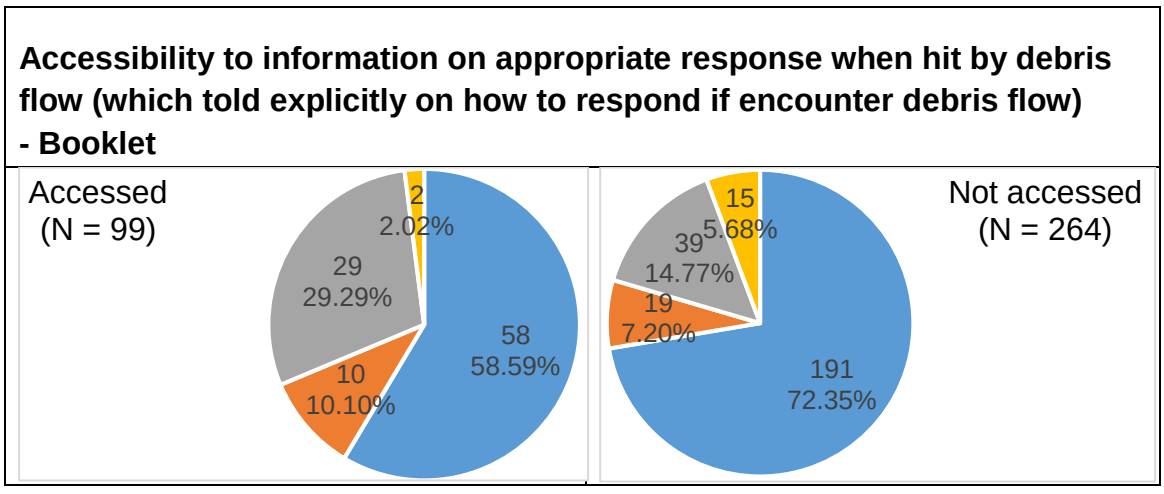
When comparing the accessed or aware groups with the non-accessed or unaware ones, several key findings are revealed (Figure 5.83). Those who had not accessed or unaware of the six significant government disaster response measures or facilities were more likely to run, escape or evacuate (69.17% to 77.84%) than the accessed or aware groups (0.00% to 59.89%) if see debris flow signs at home. The accessed or aware groups were much more likely to inform others (25.13% to 100.00%) than the non-accessed or unaware counterparts (11.93% to 18.06%). These impacts are similar to that of disaster preparedness measures in Wenchuan and disaster response measures in Pingwu.

In particular, the biggest portion (66.67%) of the monitoring personnel respondents would inform family members, authorities or others, and this is almost four times of the non-monitoring personnel group (17.09%). In addition, those who were aware of shout were more likely to stay or take refuge at home (10.16%) than the unaware group (5.68%).

As in Pingwu, those Wenchuan respondents who were inaccessible to or unaware of each of the six significant disaster response measures had very similar anticipated behaviour (right column in Figure 5.83). A majority of about 69% to 78% would run. Approximately 5% to 9% anticipated they would stay. Another 11% to 18% would inform others.

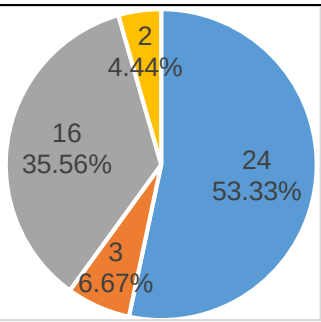
Figure 5.83

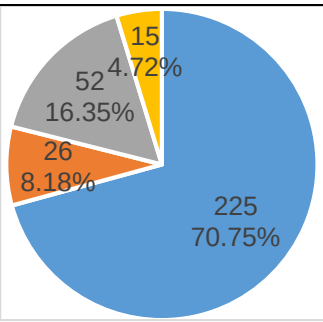
Relations between Wenchuan respondents' accessibility to / awareness of each government disaster response measure or facility and their anticipated disaster responses



- Card/ Table

Accessed
(N = 45)



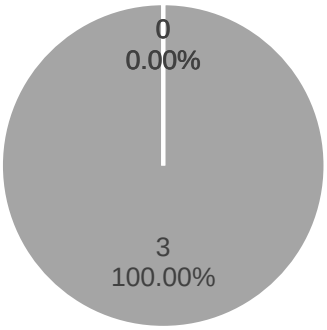


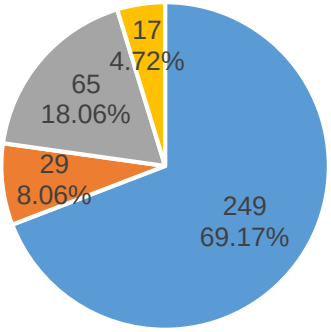
Not accessed
(N = 318)

Awareness of debris flow early warning tool

- Website

Aware of
(N = 3)

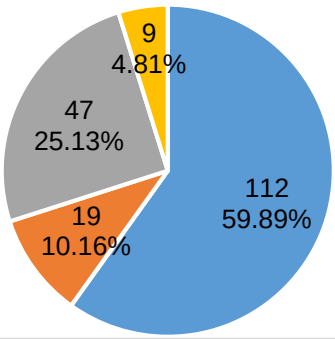


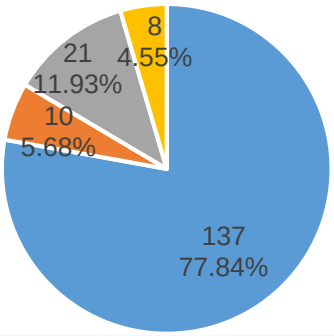


Not aware of
(N = 360)

- Shout

Aware of
(N = 187)

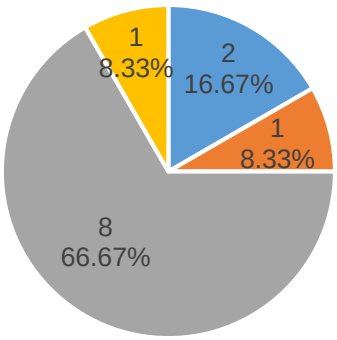


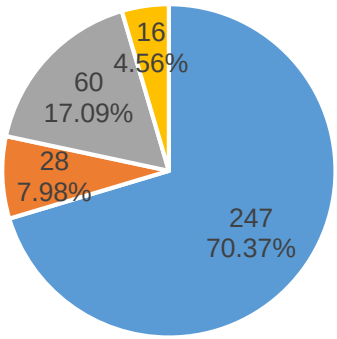


Not aware of
(N = 176)

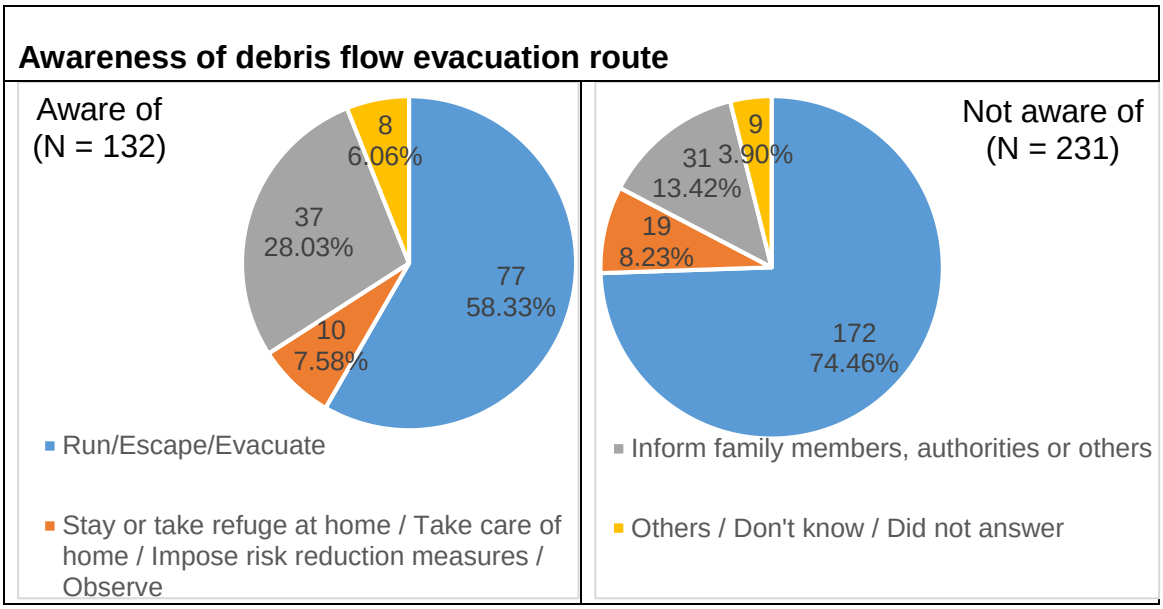
Respondent as monitoring personnel

Yes
(N = 12)





No
(N = 351)



Anticipated disaster responses of those who were aware of or had accessed the six sub-variables were relatively varied. Again, this is quite similar to the Pingwu situations, as well as the case of preparedness measures in Wenchuan. Here for instance, anticipated responding behaviour of those who had accessed booklet and card or table were slightly different; and in particular, anticipated behaviour of the website-aware and shout-aware groups were very different.

As shown in the left column of Figure 5.83, none of the Wenchuan respondents (0.00%) who were aware of website as an early warning tool would run, despite only three respondents being involved. However, 59.89% of those were aware of shout as an early warning tool would escape. Similarly, slightly more than half of those who had accessed to booklet (58.59%), card or table (53.33%), or were aware of certain debris flow evacuation route in the community (58.33%) would run. Conversely, only 16.67% of the monitoring personnel respondents would react the same.

For those who had accessed booklet and card or table, 10.10% and 6.67% respectively would stay or take refuge at home, take care of home, impose risk reduction measures or observe. Similarly, for the monitoring personnel respondents and those who were aware of certain debris flow evacuation route in the community, 8.33% and 7.58% would stay. In terms of early warning tools, however, although 10.16% of the shout-aware group would choose to stay, none of the website-aware (0.00%) would respond the same.

Around one-third of those who had accessed booklet (29.29%), accessed card or table (35.56%), or were aware of certain debris flow evacuation route in the community (28.03%) would inform family members, authorities or others when see debris flow signs at home. However, as high as 66.67% of the monitoring personnel respondents would respond the same. As for early warning tools, only 25.13% of those who were aware of shout would inform other people. Yet all the website-aware respondents (100.00%) anticipated they would inform others.

Perception of existing debris flow threat on home

A Chi-square test found no statistical significant relation between the respondents' perception of existing debris flow threat on one's home and how they would behave when they see debris flow signs at home in the future (X^2 (6, N = 363) = 4.517, p = .607). The effect size Cramer's V = .079, indicating the association is not generally useful.

5.4.4 Summary of Hypothesis 3 results in Wenchuan

The third hypothesis stated that *"Disaster response behaviour of the rural populations living in remote mountainous regions of Sichuan is affected by their awareness of government disaster risk reduction measures."* "Disaster response" here means what the respondents would do in the first place, or anticipated behaviour, when they see debris flow signs at home in the future.

To test Hypothesis 3, the respective relations between respondents' awareness of government disaster mitigation, preparedness and response measures and their anticipated behaviour were revealed. Other factors that might relate to and affect respondents' anticipated debris flow behavioural response were also tested in this section.

As in Pingwu, a total of ten independent variables categorised as I to X with 54 sub-variables were tested in Wenchuan. Six independent variables, including 15 sub-variables, were found to be statistically significantly related to and had influence on Wenchuan respondents' preparedness for disaster response, the dependent variable. In particular, awareness of certain government disaster risk reduction measures or facilities were found impactful.

Sub-variables affecting Wenchuan respondents' disaster responses

Two demographic and socioeconomic sub-variables, occupation after 2008 earthquake and role in village, were found related to and influenced anticipated behavioural response.

Respondents' perceptions of substantial debris flow in three aspects, namely taking cattle lives, destroying farmland and causing road congestion, as well as their perceptions of remoteness of home were also associated with, and had impact on, their future anticipated behaviour when see signs of debris flow at home.

In terms of disaster risk reduction measures imposed by the government, Wenchuan respondents' awareness of mitigation (engineering) measures was related to their anticipated behavioural responses.

Two disaster preparedness measures introduced by the government, namely awareness of assessment and information accessibility on community debris flow risk, were also found associated with, and have impact on, respondents' anticipated behaviour. Moreover, awareness of or accessibility to six government disaster response measures and facilities, including booklet, card or table on appropriate response when hit by debris flow, website and shouting as early warning tools, evacuation route as emergency response facilities, as well as whether the respondents were monitoring personnel, were all related to, and affected respondents' anticipated debris flow responses.

The impacts of government disaster risk reduction measures on Wenchuan respondents' anticipated disaster responses implied that Hypothesis 3 is accepted.

Figure 5.84 summarises the overall findings of Hypothesis 3 in Wenchuan, while Figure 5.85 extracts those independent variables which are statistically significantly associated with, and could in turn affect, Wenchuan respondents' future behavioural responses when see signs of debris flow at home.

Figure 5.84

Factors associated with Wenchuan respondents' anticipated behavioural responses when see debris flow signs at home
(among all other tested but non-associated factors marked in white)

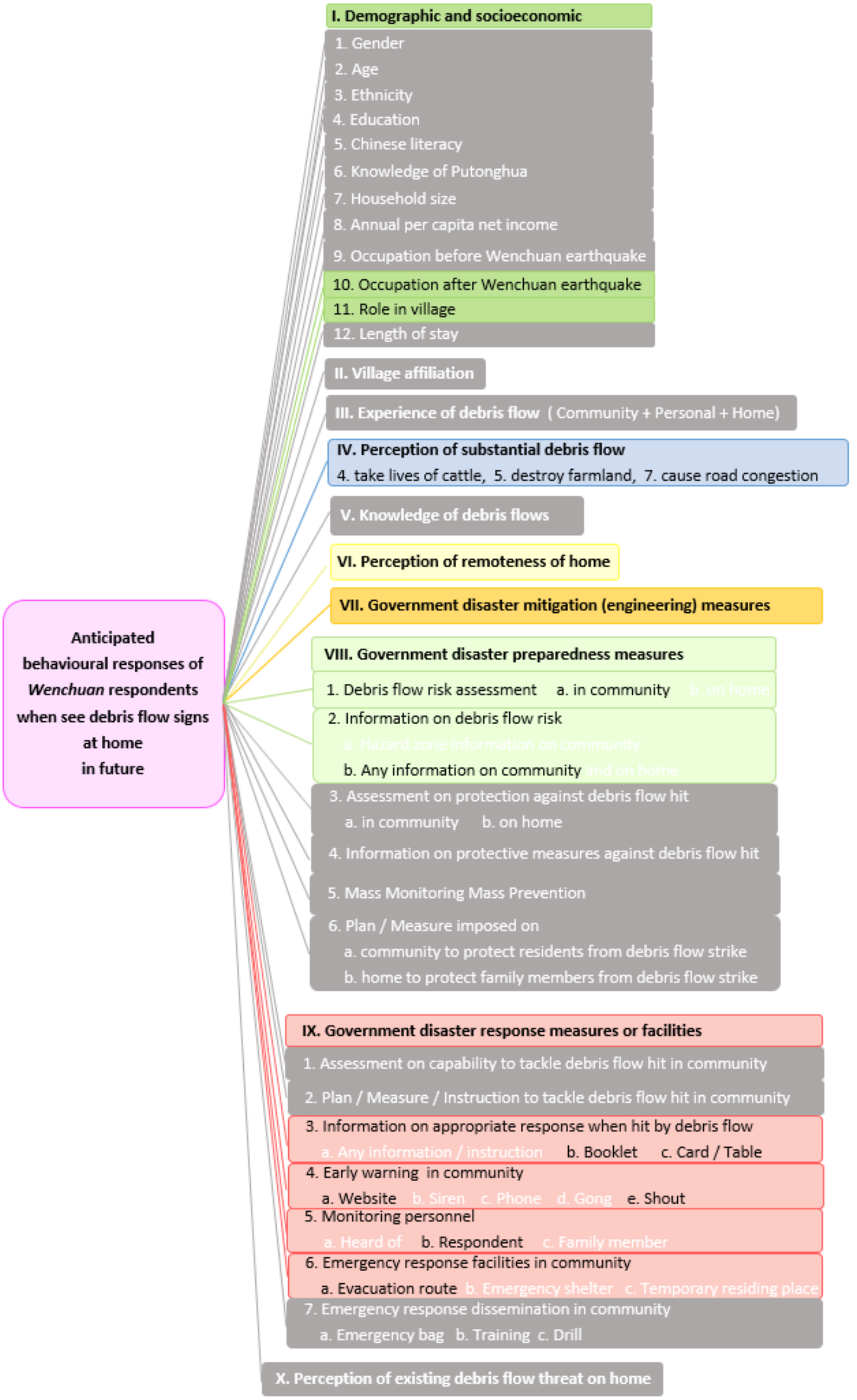
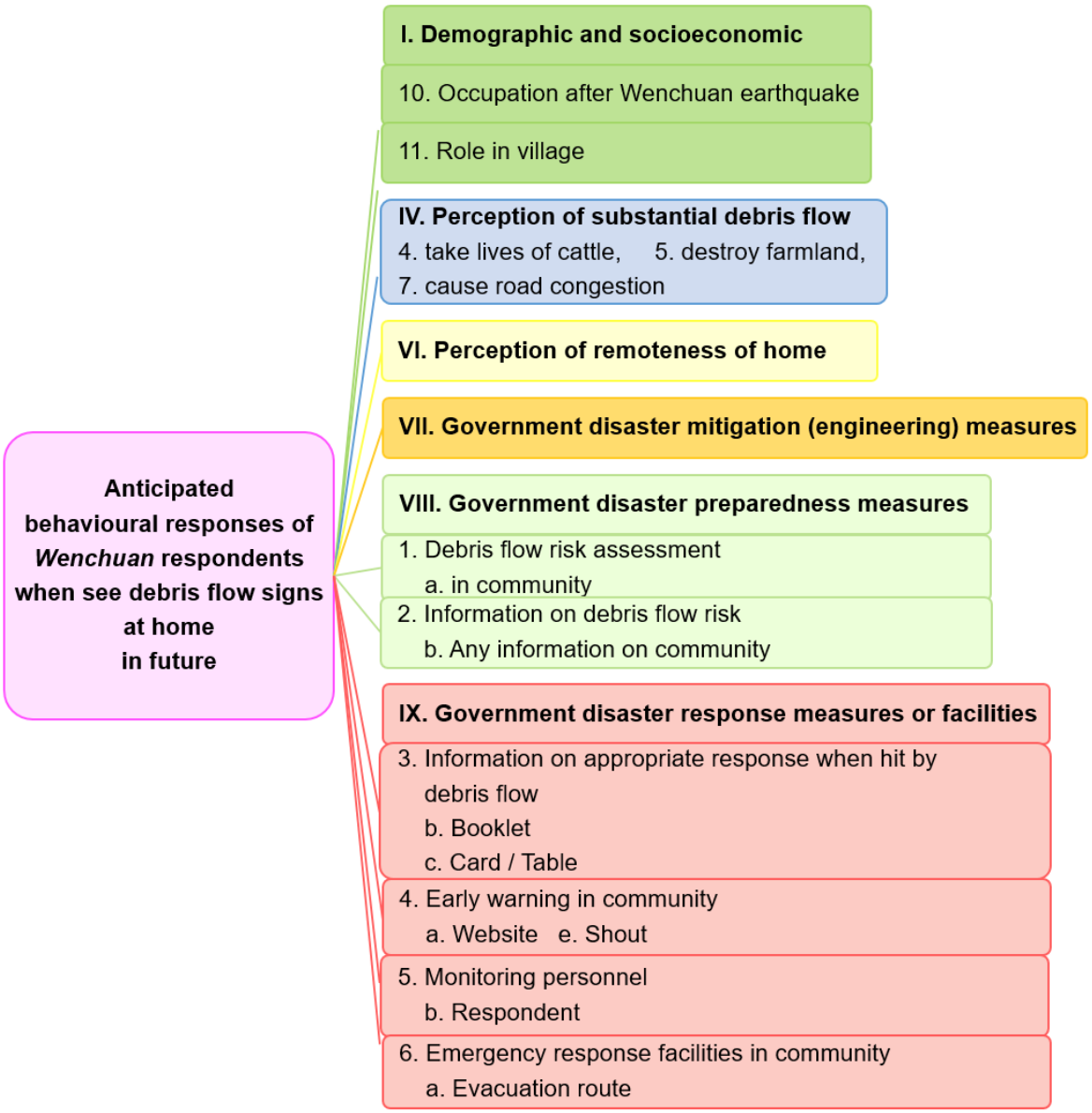


Figure 5.85

Factors associated with Wenchuan respondents' anticipated behavioural responses when see debris flow signs at home



5.4.5 Reflection of Hypothesis 3 results

Section 5.4 of this chapter presents the results of testing Hypothesis 3. As for Hypothesis 2, Hypothesis 3 is also accepted in both study areas. Any relations between each independent variable and the respondents' anticipated disaster responses are displayed. Similarities and differences of the two study areas are described and compared. The different explanations for any variations in the effectiveness of government disaster risk reduction initiatives in the two counties can be referenced by other areas facing similar geohazard risk but with different conditions. However, separating the data into two sets to represent the two study areas can be a limitation which might lead to the missing of some analyses.

If the data of the two counties can be combined into one, other intended lines of comparative analysis utilising all samples across different sites in Sichuan as a whole could be done. For example, the anticipated disaster response of different types of household across the complete sample could be compared. By viewing the complete dataset as a single population, anticipated response behaviour of households headed by male and female, or lone elderly households could be found different by comparison.

Chapter 6
Discussion

6.1 Hypothesis 1

6.1.1 Introduction

According to previous vulnerability models, socioeconomic characteristic is one of the major aspects leading to vulnerability (BBC by Bogardi and Birkmann 2004 and Cardona 1999; HOP by Cutter and Solecki 1989; PAR by Blaikie *et al.* 1994 and Wisner *et al.* 2004; MOVE by Vinchon *et al.* 2011). Age, gender, race and class were found particularly influential on disaster recovery (Finch *et al.* 2010). However, not all socioeconomic variables mentioned in these models can be applied to the post-Wenchuan earthquake situation. Disaster recovery in terms of post-disaster relocation decision could be influenced by various factors other than social vulnerability.

In particular, the acceptance of Hypothesis 1 in Pingwu but rejection in Wenchuan reveal that the influence of institutional directives and disaster risk reduction measures (Group 4 construct) on rural residents' relocation decisions can be complex in a post-earthquake scenario like the one addressed in this research. This section discusses and tries to provide explanations on how institutional factor, together with different vulnerability indicators and other factors, could impact people's moving decisions in the two study areas.

6.1.2 Results from Pingwu and Wenchuan

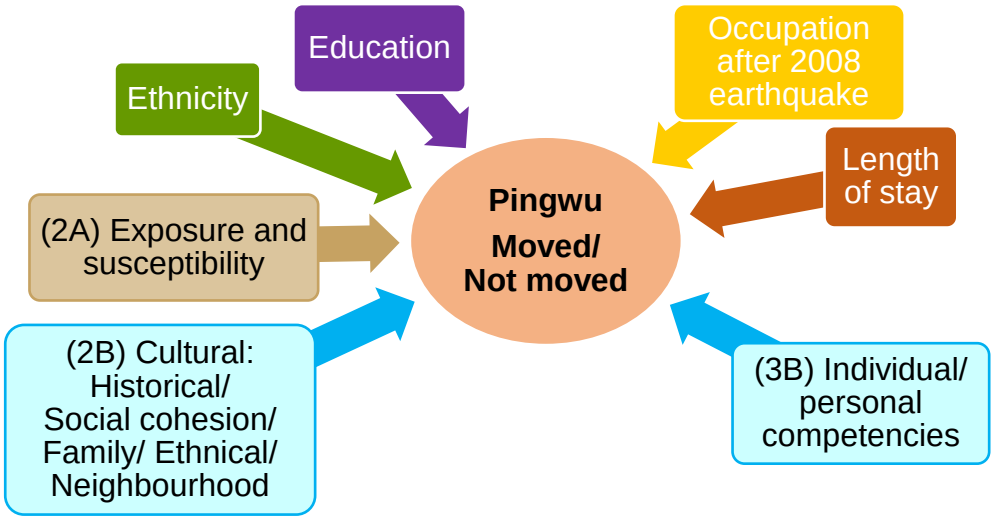
Pingwu

Pingwu respondent's decision of move or not after the 2008 earthquake could be affected by four demographic variables and three non-demographic ones.

Figure 6.1 shows that the Qiangs, non-farmers with higher education who stayed in the community for a shorter period per year were more likely to move. Those more considered about their hazard exposure and susceptibility, less considered about cultural, historical and social cohesion, family, ethnical or neighbourhood affiliation, or personal competencies were also more likely to relocate.

On the contrary, Han farmers with less education residing in the community for a longer period of time per year were more likely to stay in their original place after the 2008 earthquake. Those less considered about their hazard exposure and susceptibility, but more considered about cultural, historical, social, family, ethnical cohesion, or personal competencies were also more likely to stay.

Figure 6.1 Factors that could affect Pingwu respondents' decision to move or not



	More likely to move	More likely to stay
Ethnicity	Qiangs	Hans
Education (2 groups: Primary or below, Secondary and above)	Secondary or above	Primary or below
Occupation after earthquake	Non-farmers	Farmers
Length of stay	Not whole year	Whole year
Exposure and susceptibility	More considered	Less considered
Cultural/ Historical/ Social cohesion/ Family/ Ethnical/ Neighbourhood	Less considered	More considered
Individual/ personal competencies	Less considered	More considered

Wenchuan

The decision of move or not of the Wenchuan respondents were possibly affected by fewer factors when compared to Pingwu. One demographic variable and three non-demographic ones were found influential (Figure 6.2).

The Qiangs and those more considered about their hazard exposure and susceptibility but less concerned about cultural, historical and social cohesion,

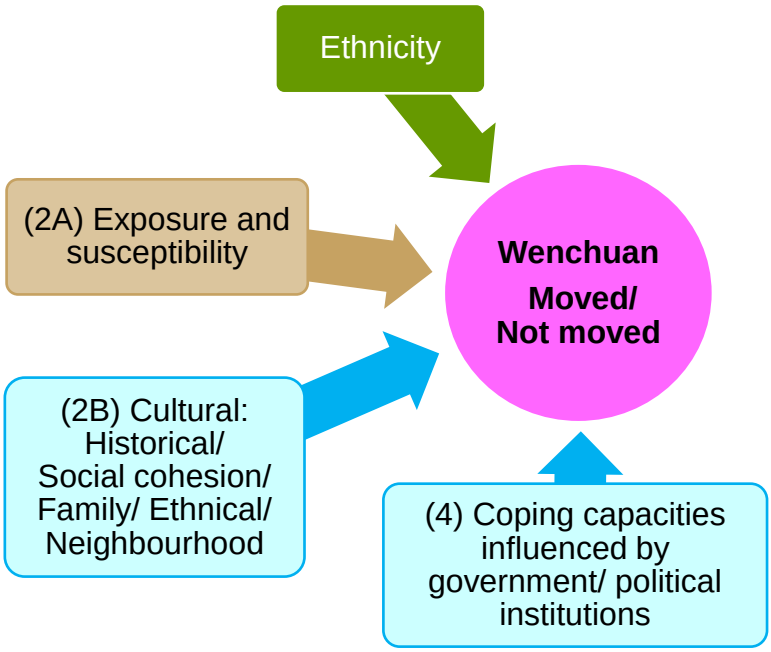
family, ethnical or neighbourhood affiliation were more likely to move after the quake.

In Wenchuan, those more considered about geological risk avoidance coping capacities influenced by government in the new residing place were also more likely to move.

On the other hand, those more considered about cultural, historical, social, family, ethnic cohesion but less considered about their hazard exposure and susceptibility and coping capacities influenced by government in the new residing place were more likely to stay in their original place.

Figure 6.2

Factors that could affect Wenchuan respondents' decision to move or not



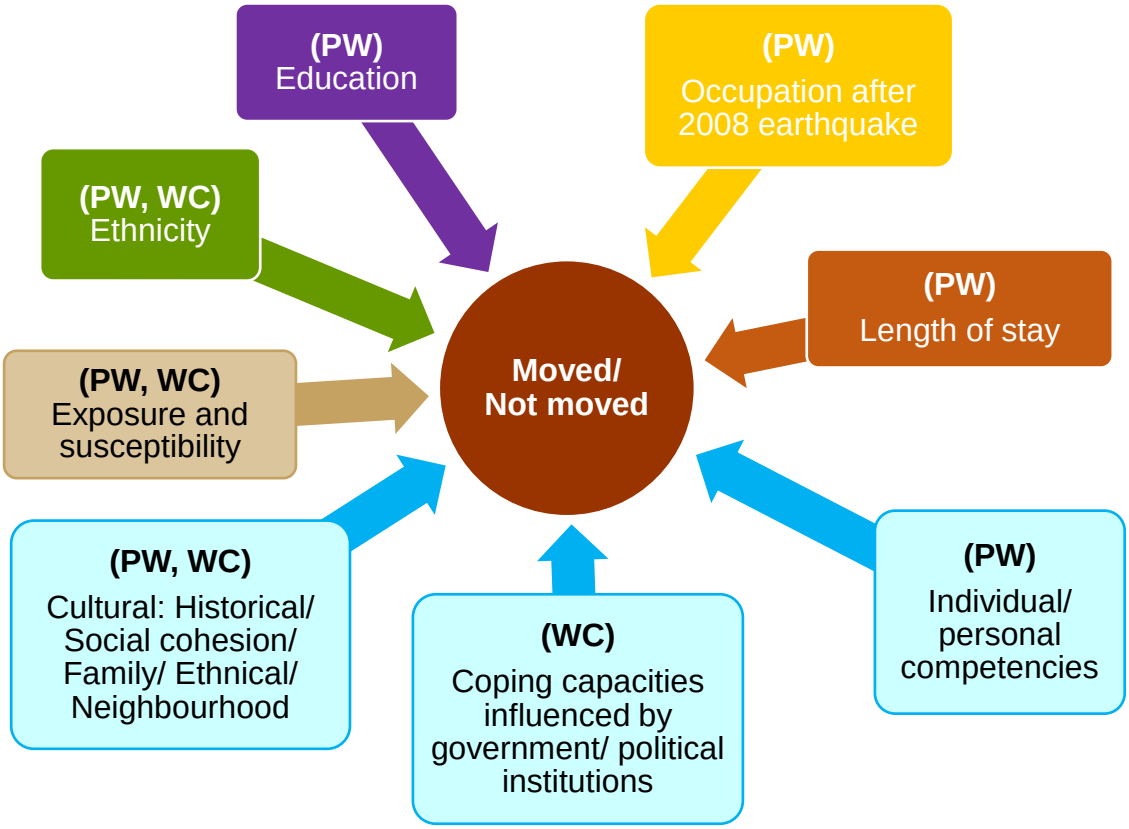
	More likely to move	More likely to stay
Ethnicity	Qiangs	Tibetans
Exposure and susceptibility	More considered	Less considered
Cultural/ Historical/ Social cohesion/ Family/ Ethnical/ Neighbourhood	Less considered	More considered
Other coping capacities influenced by government/ political institutions in the new residing place that can avoid geological risks	More considered	Less considered

Comparison of results from the two counties

Combining the above results on Pingwu and Wenchuan, Figure 6.3 shows a summary of the variables that could have contributed to respondents' moving decisions. Ethnicity is the only demographic variable appeared to be influential in both study areas. As for the five non-demographic constructs developed to test Hypothesis 1, two constructs, namely cultural factors as well as exposure and susceptibility affected the decisions to move in both places. Some other factors, however, could have only impacted respondents' moving decisions in one study area but not the other. Education, occupation, length of stay and individual competencies could have affected moving decisions in Pingwu only, while government-influenced coping capacities were only impactful in Wenchuan.

Figure 6.3

Factors that could affect Pingwu and Wenchuan respondents' decision to move or not



6.1.3 Discussion of the results

Demographic variables

Ethnicity (Pingwu and Wenchuan)

In this research, ethnicity is found relating to the moving decisions in both study areas after the Wenchuan earthquake. Ethnicity is also the only tested demographic factor associated with the moving decisions. Ethnicity could have affected recovery. This outcome is important because research on geohazards recovery discrepancies among different ethnic groups in China is limited. Outside China, similar findings showed that responses and recovery towards the same disaster varied among populations of different races and classes (Elliott and Pais 2006), caused by impact of different socioeconomic conditions during difficult times (Bolin and Bolton 1986).

Sichuan accommodates residents of different ethnicities, such as Han, Tibet and Qiang. Previous individual research on Sichuan suggested that the Hans are more ready to migrate to another place than the Qiangs (Wang *et al.* 2017). However, this study on Pingwu and Wenchuan consistently found an opposite result – instead it was the ethnic minority Qiangs, regardless of their demographic characteristics, were more likely to move after the Wenchuan earthquake. Conversely, the Hans were more likely to stay. This echoes a study by Chen *et al.* (2013) on China's Yangtze River Delta which applied Cutter *et al.* (2003)'s Social Vulnerability Index. It found that ethnic minorities, or specifically the non-Hans, had higher social vulnerability.

Qiang is a small ethnic minority group in China with an overwhelming percentage living in Sichuan Province. Qiang has a nomadic history of thousands of years and most of them resided in hilly or mountainous areas (NEAC 2022b, 2022c; Wen *et al.* 2015) 2000 meters above sea level (CPG 2008b). As revealed by other scholars, minorities are relatively more exposed to hazard risks (Cvetkovich and Earle 1992). Marginalisation of the disadvantaged race or class were considered as linking to environmental inequalities and hazard risk exposure (Bolin 2007). As in the USA, variation of disaster influence on different people were notably inferred by difference in their races and classes, where the racial minorities black and the poor suffered most (Hartman and Squires 2006; Lavelle 2006).

The Wenchuan earthquake seriously hit this old ethnic group Qiang. Over 80% of the approximate 306,100 Qiang population lived in the hardest-hit places, including Beichuan Qiang Autonomous County as well as Maoxian (Mao County), Wenchuan and Lixian (Li County) in Aba Tibetan and Qiang Autonomous Prefecture, with their ethnics and culture almost devastated (CPG 2008a). Approximately one-tenth of its population lost their lives in this mega disaster (CCTV 2008). Their settlement landscapes were altered (Wen *et al.* 2015). Therefore no matter they were young or old, male or female, farmer or non-farmer, rich or poor, they desired or even needed to leave their original residing places devastated by the quake and to move elsewhere. What they concerned most was safety. However, unlike ethnic minorities in the US, such as the Alaskan (Davis 1986), the Mexican (Aptekar 1990) or the blacks, who were found deprived or needs neglected (Fothergill *et al.* 1999) and encountered more difficulties during restoration, leading to stunted recovery (Peacock and Girard 1997; Zottarelli 2008) and more vulnerable (Fussell *et al.* 2010; Rhodes and Tran 2012), the situation in the study areas of this thesis was different. Special attention on infrastructure rebuilt, settlement reconstruction as well as cultural preservation and recovery were given to this originally marginalised ethnic group by the government, the Qiangs themselves, scholars, NGOs and the press (CPG 2008a; Wang and Prott 2016; Qiu 2016; Zhang 2018). This echoes previous literature suggesting that people of different races in the same place tended to recover differently after a disaster was caused by impact of aid variation and complication of institutional system (Bolin and Bolton 1986).

Consideration of the five constructs of non-demographic factors of different ethnic groups could also be taken into account. As noted in the results chapter, both the Qiangs and the Tibetans in Wenchuan who considered more about their personal or homes' hazard exposure and susceptibility were more likely to move. In fact after the 2008 earthquake, some locations where the Tibetans and the Qiangs resided, such as those in the Aba Tibetan (Zang) and Qiang Autonomous Prefecture where Wenchuan is located, continued to be threatened and even attacked by debris flows (Hu and Yang 2013; Ding *et al.* 2019; Ji *et al.* 2020; Yao *et al.* 2022). This echoes the similar situation after the hit of Hurricane Katrina in which the underprivileged and those having bigger destruction in their houses were more likely to leave their places (Myers *et al.* 2008).

Moreover, those Qiangs in Pingwu who were less concern about the sociocultural and personal competencies variables were more likely to move. It is reasonable that those who were less culturally and socially affiliated to their original homes had a smaller pulling factor to stay. Those who cared much about their own coping capacity in tackling debris flow might not be confident in facing the hazard if they move, and therefore they would choose to stay.

In Wenchuan, influence of government on Qiang respondents' coping capacities had a positive impact on their moving decisions. Similarly, the Wenchuan Tibetan respondents' moving decision were positively influenced by what the government did in affecting their coping capacities. In other words, for both ethnic groups in Wenchuan, those who considered more about what the government did to avoid geological risks in the new locations were more likely to move.

This reflects that in Wenchuan, both the Qiang and the Tibetan respondents relied on the government and trusted what the government did to reduce disaster risk in the new locations, which in turn encouraged them to move to and had the confidence to settle in such new sites.

However, movement involving government can be a form of social control (Fritz and Mathewson 1957; Barton 1963; Dynes 1970; Pelling and Dill 2008). Government provision of reconstruction in a new location could have certain underlying administrative or political reason, such as facilitating service provision, planning, management, enforcement and resource mobilisation (Sim and Huang 2012; Dickinson 2013; Johnson and Olshansky 2013). Indeed, the act of moving and satisfaction with moving are different. Post-disaster relocation were often not welcomed or found satisfying, with the level of self-determination and sense of ownership being crucial, especially for the indigenous and marginalised groups (UNHCR 2015; Iuchi and Mutter 2020). Davis and Alexander (2016) critically investigated the case of Wenchuan and found that the relocation there seemed to be greatly supported by the local people because the place had already been transformed from a town to a cemetery. Although how far government options for movement were welcomed, or how suitable they were, is not the focus of this

research, it would be an important case study if it is successful in these terms. A follow-up study with closer interview with movers could help to establish this.

Education (Pingwu)

Educational attainment was widely considered as an important variable influencing decision making of the disaster-affected population in terms of how they recovered from disasters and in turn reduced their vulnerability (Fussell *et al.* 2010; Muttarak and Lutz 2014; Hoffmann and Blecha 2020).

The results of this research on Pingwu are consistent to those of previous studies. As shown in the results chapter, educational attainment is statistically significantly related to respondents' decision to move or not after the quake. The less educated Pingwu villagers were more likely to stay in their original place. They were more reluctant to move to a new place might because they have to leave their source of livelihood, such as farmland. A new location could be difficult for them to adapt to because they might not be able to possess farmland or to get a new job to earn their living.

On the contrary, the more educated Pingwu respondents were more likely to move and tried avoid geohazard threats. They might notice that moving to a new residing place could reduce their risk. They could also be more capable to cope with new environment than the less educated. However, in the other study area in this research, Wenchuan, no statistical significant relationship is found between educational attainment and recovery. The Wenchuan result echoes another study focused on the 2008 earthquake which found that educational attainment had not positively affected disaster recovery (Tse *et al.* 2014).

According to an official explanation, resettlement of Wenchuan villagers was based on a combined consideration of post-disaster settlement, geohazard avoidance, ecological protection and tourism development (CPG 2009). In this regard, villagers' decisions to move or not might not be affected by demographic and personal factors like education, but a set of variables confined by the government.

Occupation after Wenchuan earthquake (Pingwu)

After the Wenchuan earthquake, majority of the Pingwu respondents were still farmers. This research shows that in Pingwu, the farmers were more likely to stay than the non-farmers whereas the non-farmers were more likely to move. No such statistical significant relation was found in Wenchuan where majority of the respondents were non-famers.

Occupation affects relocation decision is not unique in Sichuan or China. Occupation is closely linked with livelihood. People rely on their occupation to earn their living. If a relocation plan might affect one's occupation and hence livelihood, one might consider carefully whether to move.

For instance, after the 2004 South Asia Tsunami, the Sri Lankan government introduced coastal buffer zones to prohibit development to protect the communities. Those with houses damaged within the zones were relocated elsewhere (Jayasuriya *et al.* 2006). Most residents of a district who needed to move were not satisfied about the new location probably because they could no longer live near the sea where they did their fishing and related livelihood activities (Ratnayake and Rameezdeen 2008).

Another example is in Indonesia. After the 1992 Flores earthquake and tsunami struck, some communities were moved away from a small island. However, such a relocation severely affected fisheries and plantation which were the main sources of income. Many fishermen therefore moved nearer to the shoreline again a few years later. Many farmers even moved back to their original village since the new farmland offered to them was distanced from their new settlement area. Some others needed to commute between the new settlement site and the original island to farm (Boen *et al.* 2001).

Farmers rely their livelihood on their farmlands. Once they relocate to another site, their farmland might not be secured and their livelihood or even lifestyle would be affected (Chen *et al.* 2021). In vulnerability models, occupation is included as one of the 11 independent factors in the Social Vulnerability Index (SoVI) (Cutter *et al.* 2003). In the BBC framework, occupation is considered when evaluate vulnerabilities (Birkmann and Wisner 2006). The MOVE framework also suggested

that socioeconomic vulnerability can be reflected by financial deprivation which can be indicated by unemployment (Vinchon *et al.* 2011). These echo the idea of livelihoods at risk in the PAR model (Blaikie *et al.* 1994; Wisner *et al.* 2004). Specifically, Alexander (1997) argued that disaster can result in occupation loss through damaging of production means or business, constituting to economic vulnerability,

These explain why Pingwu farmers were more reluctant to move elsewhere after the Wenchuan earthquake than the non-farmers, and not so comply with government requirement to avoid potential disaster areas. Conversely, non-famers are less attached to the land and their cost of moving elsewhere should be lower. However, as mentioned in the results chapter, some non-farmers were originally farmers. There is a possibility that some of them were forced to change their occupation and moved elsewhere after the quake because they lost their land. But this is out of scope of this study and the impact can be investigated in further studies.

Length of stay (Pingwu)

Survey results on Pingwu show that those respondents who did not stay in their communities for the whole year were more likely to move. Those who accommodated for the whole year were more likely to stay in their original place.

These findings are consistent with a previous study which suggested that duration of residence influenced moving decision because the longer the residence duration means more social ties established, higher gratification of facilities and better knowledge of the place (Speare 1974).

On the other hand, it is logical that those who are more transient are more ready, hence more likely to uproot and move. As mention, a great amount of rural people in China are “floating populations”. According to Chinese census, population floated from rural to urban amounted to 249 million in year 2020, increased by 106 million in ten years’ time (State Council 2021a). They spent at least part of the year working outside their hometown and even in another province. In practice they left behind their parents and children in their rural homes and have their second accommodation in their working township or city (Qian 2017; CLB 2021). Majority

of the interviewed floating population inclined to settle in urban areas permanently (Xie *et al.* 2017). Residents working outside their hometown were also found contributed less on earthquake recovery when compared to those working locally (Wang *et al.* 2017). It is sensible that this group of floating people are more feasible and more likely to move elsewhere when needed, such as when their houses in hometown are devastated by disaster or the cost of rebuilding their homes in-situ is high. This is particularly true for Pingwu because the two villages being studied are more remote and economically more backward than the three Wenchuan villages. The push factor for the floating Pingwu respondents to move elsewhere after the quake could therefore be much stronger.

Indeed, if the survey was conducted at a different time of the year, a different sample of interviewees might have been generated, hence could have changed the results. As mentioned in Chapter 3, a great portion of young adults in the study areas worked in cities for most of the year, causing a possible underrepresentation of them while overrepresentation of other demographic groups. However, the ultimate responding group could reflect the demographic reality or the actual residents residing in rural mountainous areas in China for most of the year. When this group of villagers encounter debris flow, they need to rely on themselves rather than their young but absent family members. Learning their perception and behaviour is particularly crucial to reduce the risk of this more vulnerable group. In addition, the survey was conducted during summer rainy season when debris flows are particularly active. The data collected should better represent those who would actually encounter debris flows in future summers.

Gender

Gender has been widely considered as an important demographic variable relating to and affecting vulnerability (Morrow and Enarson 1996; Cutter *et al*. 2000, 2003), hazard avoidance, disaster response and recovery. In particular, women faced higher risks and more adverse conditions during disasters, were more vulnerable and were even more psychologically fragile when compared to men partly because of their dependency role in the family (I¸sık *et al.* 2015; Rhodes and Tran 2012; Falk 2012). Unique roles and duties in the family were also suggested to be causing the ethnic minorities Qiang and Tibetan women facing higher risks than men in Sichuan (Wang *et al.* 2017).

Special indicators, guidelines and training were therefore introduced to enhance women' capacities in reducing disaster risks and improving resilience to disasters across different regions (UNISDR, UNDP and IUCN 2009; IFRC 2010; Oxfam 2011; UNDP 2016; World Bank 2019; IFRC and UNICEF 2021). However, this research on Sichuan found that the respondents' actual moving decision in both study areas had no statistical significant relation with gender. This is echoed by another study on China where no statistical significant relation was found between gender and relocation willingness of Three Gorges households (Xu *et al.* 2017).

The outcome of this research can be explained by the fact that moving and changing the place of residence is a family issue, especially in China where the concept of "home" always means members of a family should live together under the same roof. Moving is not a decision an individual male or female can make for oneself. Even though the moving tendency of a man and a woman within a household might vary, they might not be able to act solely according to his or her individual inclination. This helps explain the lack of disparity between male and female in terms of their moving decisions as a hazard avoidance measure.

Non-demographic variables

Among the five constructs comprising non-demographic variables developed for testing Hypothesis 1, two were found to be statistically significantly affected respondents' decision to move in both study areas, another one influenced Pingwu, one influenced Wenchuan, while one had no impact at all.

Exposure and susceptibility (Pingwu and Wenchuan)

In both Pingwu and Wenchuan, those respondents who were more considered about exposure and susceptibility of themselves and their homes were more likely to move. On the contrary, those who were less considered about this physical variable were more likely to stay in their original place. Whether the new place would be affected by earthquake or debris flow, topography and landscape of the new place, safeness of the old and new location, all reflected the exposure and susceptibility of the respondents and their homes, and affected their moving decisions. This finding echoes what were proposed in some existing models (BBC; Alexander 1997, 2000, 2007; MOVE). It also aligns with a post-Wenchuan

earthquake study which found a positive association between perceived severity of earthquake occurrence and relocation willingness (Xu, D. *et al.* 2020).

After the Wenchuan earthquake, many Sichuan residents were exposed to new or reactivated debris flow risks triggered by the quake. In order to protect themselves, many of them not just willing, but had already moved to places where they believed were safer and could avoid or at least eliminate risks. Therefore it is sensible that those who were more considered about hazard risk exposure and susceptibility were more likely to move after the quake, and complied with government suggestion to avoid potential disaster areas. On the contrary, those who were less considered about risk exposure and susceptibility were less likely to have the incentive to move, hence did not comply with government instructions.

Disaster displacement occur when vulnerable people are exposed to a disaster but unable to tackle the impacts and forced to leave their place (PDD 2022). After the Wenchuan earthquake, thousands of Sichuanese were displaced and many were forced to resettle elsewhere in the province. They did comply the government requirement to avoid geohazard risk areas. Some others, though not displaced, have been exposed and became more susceptible to higher geohazard risks. If the risk they have been exposed to is still under a tolerance limit, some of them would continue to live in risk areas.

Cultural consideration: Historical/ Social cohesion / Family/ Ethnical / Neighbourhood factors (not mentioned in existing models) (Pingwu and Wenchuan)

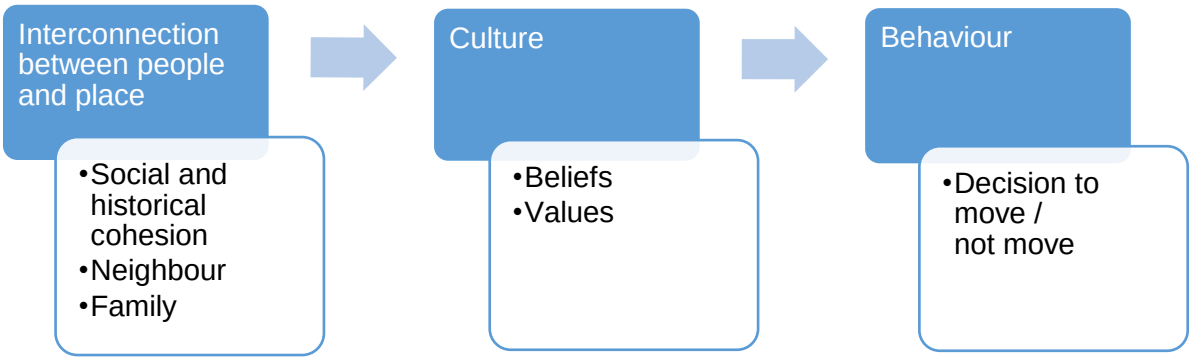
Survey results of this research found that the respondents of both Pingwu and Wenchuan considered a set of cultural factors when made their moving decision. Those who considered more seriously about their social and historical links to a place as well as their social cohesion and ethnical affiliation with the residents there were more likely to stay in their original place and chose not to move, even though the place was facing debris flow risk and the respondents should select another residence site to avoid potential disaster. Those who considered less about this cultural construct were more likely to move.

Such results indicate that culture, which embeds beliefs, historical and social elements, can shape action and behaviour (Schaefer 2013) in disaster situations (Swidler 1986), and post-disaster decision making (Oliver-Smith 1996; Zaman 1988). Metamorphosis of the set of cultural elements could affect disaster recovery (Alexander 2012b). Culture is one of the key thematic components of susceptibility as suggested by the MOVE framework (Vinchon *et al.* 2011).

But how can culture affects behaviour, particularly whether to move after an earthquake in this research? Based on the survey findings, the author would argue the beliefs and values embed in one's culture act as inducing factors. Such beliefs and values are influenced by and developed through interconnection between the people and the place or community they live in, which comprises the social and historical environment they interact with, the neighbour surrounding them and the family they belong to. Figure 6.4 illustrates the relations among the variables.

Figure 6.4

Relations among people, place, culture and behaviour



In the past few decades there were active discussions in a variety of academic disciplines about how people interact with the space and the place they live in. The literatures discussed cultivation of cultures and people's relation with the places nurturing them. Geographer Yi-Fu Tuan (1974, 1977) expanded the notion of place to include human attachment to the environment, and highlighted the ties between people and place, or what he called "topophilia". Edward C. Relph (1976) examined the concept of place and proposed that people's relationships with places are comparable to relationships with other people. Scholar of physical setting and behaviour change Fritz Steele (1981) applied the idea of sense of place to present

how people connect with a place, notably regarding their attitudes, beliefs, perceptions and explanation. John Eyles (1985) as well as Steven Feld and Keith H. Basso (1996) published two books with the same title “Senses of place”, attempted to analyse the idea from geography and anthropology perspectives respectively. In short, the sensation and interpretation of a place by different people are different, hence relation between a place and a person is different from one to another.

In the past three decades or so, these cultural concepts were adopted and developed in disaster studies. Chamlee-Wright and Storr (2009), through studying the case of hurricane Katrina in the USA in 2005, found that what people believed about the uniqueness of a place, or their sense of place, affected their disaster response. The same was also illustrated in the study areas of this research.

Disasters can uproot a community and is particularly distressing for those attached to their place, hence those having strong cultural identity in Pingwu and Wenchuan could refuse to relocate after the disaster as noted by Oliver-Smith (1982). In post-earthquake Sichuan, cultural values, social and psychological support embedded in a community could have avoided people to move elsewhere but taken the risk to stay in dangerous locations (Mileti and Passerini 1996).

In recent years, scholars applied the concept of sense of place to study geohazard risk in China, including a discussion of negative impacts of disregarding social elements in developing a sense of place in new settlements after the 2008 earthquake (Wu 2014). Xu *et al.* (2017) found that in the Three Gorges area, both place identity and place dependence were negatively related to relocation willingness. A similar research framework was applied to test the post-Wenchuan earthquake situation and found that people’s willingness to relocate after the quake was negatively related to their place identity but positively related to place dependence (Xu, D. *et al.* 2020; Zhou *et al.* 2021). However, a wish to move should be differentiated from a decision to move (Speare 1974). The literatures on China mainly focused on relocation willingness and limited to the evaluation of sense of place.

Whether and how people's actual decision to move in post-earthquake rural China was influenced by cultural factors is still underexplored, particularly in terms of social and historical cohesion and attachment to their original residing place, family, neighbourhood and ethnical affiliation. This research looks into a set of these factors not mentioned in existing literatures collectively. In the survey, this set of factors was grouped into a construct of culture comprised of seven self-evaluating questions (see Table 5.12 - 25 Likert items measured in the results chapter).

The seven questions asked in the survey are listed below *(in italic)*:

- **On social and historical cohesion**

"When I decided to move or not, whether I liked the place I originally lived and did I belong to the place?"
"Whether my ancestors also resided in the place I originally lived?"
"Whether my children studied nearby the place I originally lived?"

- **On neighbours**

"Whether I liked the neighbours of my original home?"
"Whether the neighbours of my previous home were of the same ethnic group as me?"
"Whether the neighbours of the place I would move to were of the same ethnic group as me?"

- **On family**

"Whether the new residing place had sufficient land to accommodate their family members?"

Survey results show that social and historical cohesion, in terms of a good sense of belonging to the originally living place, having the ancestors resided there, having the children studied nearby, together with good neighbourhood relations and ethnical proximity, as well as satisfying family ties, would made the respondents more affiliated to the place they originally lived and less likely to move.

Social and historical cohesion

The situations from Pingwu and Wenchuan echo previous evidences that the more social capital and networks a community has, the cost of leaving the place increase,

the people are hence less likely to migrate out and relocate in post-disaster situations (Aldrich 2010, 2012b). In particular, if social networks form the basis of social capital (Lin *et al.* 2001), people having bigger and deeper social network in a place would consider it more when decide whether to stay or to move.

Community was identified as the foundation of disaster resilience (Dynes 2005). The crucial positive, and in some cases negative, function of civil society, community ties, social capital networks and social cohesion on recovery of disasters (Ersing and Kost 2012; Aldrich and Meyer 2015; Sobhaninia 2023), including earthquakes (Aldrich 2010, 2012a, 2012b), was evident. Social, and cultural and historical cohesion (Hogg 1980; Nakagawa and Shaw 2004) also affected the effectiveness of reconstruction.

On the positive side, a broader community could effectively mobilise and supply resources to a local community after a disaster (Shepherd and Williams 2014). The value of social capital and networks lies in their pragmatic use of providing disaster related assistance from material aid (Beggs *et al.* 1996) to psychological support (Kaniasty and Norris 1993). Social capital could also make the vulnerable stronger (Lovekamp and Arlikatti 2013).

Obvious positive impact of social capital network on aid receipt and post-disaster recovery of the disaster-affected populations was also evident in eleven places in western part of China (Zhao 2007).

In China, Spring Festival (or Chinese New Year) network counts how many people a household encounters during the Festival, is a measurement of social capital and network one has (Bian *et al.* 2005). During the Wenchuan earthquake recovery, those Sichuan households with bigger Spring Festival networks gained more assistance to apply for government aid, received more housing reconstruction grants, hence recovered faster and easier (Tse *et al.* 2014; Wei and Han 2018).

Another study on the aftermath of the Wenchuan earthquake discovered that social networks also contributed to rescue, information provision as well as social and mental health support (Zhao 2013). Al these sorts of social capital and networks

should have contributed to Pingwu and Wenchuan respondents' cohesion and their eventual decision to stay in their original place.

Besides social cohesion, the situations in Pingwu and Wenchuan also reflected the impact of historical cohesion, in particular ancestors' footprints, on post-disaster relocation in China.

Relocation is not simply moving people from one place to another, and not just involving a social network, but is relocating a collective way of life, especially if the ancestors' established the original place (Boen *et al.* 2001).

In Pingwu, for example, majority of the Han respondents were from Xinjian village, which is part of Jiangyouguan area. Jiangyouguan has been an important military fortress and historic landmark since the late Han dynasty (B.C.202 - A.D.220). People there have long been proud of its ancient civilisation and historical background. Even during the time the research was conducted, Han flags were hanged prominently in the township centre and historical monuments were displayed (Figure 6.5). Most of the Xinjian villagers were Hans and it is very possible that they possessed a strong cultural identity and historical affiliation regarding their place. This may explain why they were less likely to move after the quake.

Figure 6.5
Han flags and historical monuments in Nanba Township centre
(Left) Han flag hangs on the landmark in Jiangyouguan area where Xinjian village is located.
(Middle and right) Monuments and stelae illustrating the history and civilisations of the area since Han Dynasty are displayed at Nanba Township Centre.



Photos by Rhea Leung, July 2016.

The other study area Wenchuan is located in the Aba Tibetan (Zang) and Qiang Autonomous Prefecture where a great number of Tibetan and Qiang population accommodate, and has a long history of human settlement of more than 5,000

years (NEAC 2022a). Sichuan Tibetan Autonomous Region was established there in 1952, then changed to Aba Tibetan Autonomous Prefecture in 1955, and further developed to include the Qiangs in 1987 (Abazhou 2023). With such a long history of establishment, residents living in Wenchuan could have possessed a sense of affiliation and historical cohesion of the place, which in turn made them less likely to relocate elsewhere after the 2008 earthquake.

In contrary, those who had a bigger chance to move elsewhere in Pingwu and Wenchuan could dislike, feel inferior of or even be depressed by their risky communities in the mountains, as in the situation of post Chuetsu earthquake in Japan (Iuchi 2010), where the embedded inconveniences and underdevelopment were the underlying causes, with the earthquake acted as a triggering factor, for the affected population to relocate.

Neighbours

Neighbours, being part of the community, played a critical role and commonly performed as one of the first responders during post-earthquake emergency rescue and relief, such as after the 1995 Kobe earthquake in Japan (Horwich 2000; Shaw and Goda 2004), the 1999 Marmara earthquake in Turkey (Jalali 2002), the 2001 Gujarat earthquake in India (Shaw 2003) and the 2011 Tohoku earthquake tsunami in Japan (Aldrich and Meyer 2015). In practice, neighbours are considered as valuable support resources hence community members are encouraged to know their neighbours and learn how neighbours can help before, during and after an emergency (Australian Red Cross 2009). However, not all encounters with neighbours are encouraging. For instance, there was a lack of positive neighbourhood experience after Chuetsu earthquake in Japan (Iuchi 2010), where the embedded marginalisation and isolation were underlying the affected populations' relocation, with the earthquake as a triggering factor.

The characteristics and formation of neighbourhood in both the previous and new places of accommodation could therefore be a consideration of the Pingwu and Wenchuan respondents when they decided to move or not.

Sichuan is the home of different ethnic groups. In many cases, populations of the same ethnicity would like to live nearby each other and formed neighbourhoods. In

fact China has a number of autonomous regions across the country to accommodate people of the same ethnicity, such as the Aba Tibetan (Zang) and Qiang Autonomous Prefecture where Wenchuan is located. The Qiangs neighbourhood, in particular, was found inherited a Dunkirk spirit (Xiong and Ding 2007) and this could probably connected to the post-earthquake relocation decision making of residents in the two study areas.

Family

Consideration of family also influenced respondents' post-earthquake moving decisions.

"Blood is thicker than water" is a European proverb indicating the importance of kinship (Cambridge Dictionary 2022b). Anthropologist David Schneider (1984) argued that kinship is privileged, more binding than and prioritised over other bonds simply because the fundamental assumption and root of the idea of kinship is the physical fact of blood relation and that blood is thicker than water. In China, a study on political history even demonstrated this proverb by revealing that kinship networks facilitate state building (Wang 2022).

It is logical that family members are among the first to offer support and assistance during emergencies and difficult times. Family ties are crucial in providing support in different stages of the disaster cycle, including during recovery when resources are limited (Sim and Dominelli 2017). The important role of family and relative ties during evacuation was established (Drabek and Boggs 1968). People having networks with a higher percentage of kin could receive more assistance in both disaster preparation and recovery phases (Hurlbert *et al.* 2000). Family ties were noticeable during disaster, and dependence on kin were more preferred than formal community social capital networks (Meyer 2013). Family members are always supportive, especially between parent and child (Wellman and Wortley 1990). Relatives and friends, was trusted most for hazard information (Haynes *et al.* 2008). The concept of family resilience proposed by Walsh (1996, 2003, 2016) viewed family as a functional unit or a system having the ability to resist and recover from adversity. Strengthening families can therefore reduce disaster impact (Garrison and Sasser 2009). In terms of model application, family and social

networks to tackle debris flow are considered as coping capacities in alleviating vulnerability in the BBC framework (Bogardi and Birkmann 2004; Cardona 1999).

Instead of revealing how family members would assist each other or testing the trust in families during various stages of the disaster cycle, the importance of family ties in this research is reflected in villagers' reply on their consideration of whether the new residing place had sufficient land to accommodate their family members.

In China, the traditional concept of "home" (or "jia" in Chinese) means family members live together in a room (Xinhua 2022) and implies a household (Joniak-Lüthi 2013). Particularly parents have the obligation to take care of their children and provide housing accommodation, while vice versa when the children grown up (Wang *et al.* 2020). When one chooses a place to reside or to move to, whether the place has sufficient land to accommodate his or her family members can be very important.

Social and Historical cohesion, Family, Neighbourhood and Ethnical factors

The specific contents of the sub-variables in this cultural construct, including some China-specific ones, were not proposed or studied in existing vulnerability models. The statistical significant relation between this construct and the respondents' moving decisions therefore provides new insight about what could affect peoples' relocation decisions and potential disaster avoidance. The results can therefore contribute to existing theories.

Particularly, the empirical findings on culture established by the survey results have opened new questions. Since this topic of cultural consideration is new and are extensions to the empirical work here, as inspired by the grounded theory, an additional model or theory can be developed. It can be speculated that the potential impact of the set of cultural factors being identified in this thesis on post-disaster relocation can contribute to theoretical development and stimulate further research.

Individual economic competencies

For decades, social scientists have paid much attention to the study of factors that affect disaster recovery. Level of economic development, access to recovery funding, availability of financial resources were found crucial and contributed to the

success of reconstruction or recovery (Kates and Pijawka 1977; Hogg 1980; Alexander 1989). In China, a recent research on earthquake also suggested that external financial support was important for recovery (Wang, Chen and Li 2012).

On an individual level, the MOVE framework considered economic dimension as one of the key thematic components of susceptibility (Vinchon *et al.* 2011). Individual economic competencies, including financial support from various sources (Birkmann 2013), funding availability (Hogg 1980) or economic vulnerability (Alexander 1997), could be considered as coping capacity of an individual. Such competencies could be related to whether one decided to move after a disaster. Economically disadvantaged, a lack of funding or an unequal distribution of financial or economic resources can affect the compliance with risk reduction directives (Arnold 2006).

This research, however, gives another perspective. In both study areas, respondents' relocation decisions after the Wenchuan earthquake were found not affected by a specific set of economic reasons particularly asked in the survey which comprised of whether they had the money or subsidy to move or to build a new house somewhere else, whether moving elsewhere required them to give up their farmland, and whether the new place was nearby their farmland.

This result can possibly be explained by the following. In the first three years after the quake, the huge financial support provided by the Chinese central government for rehabilitation, reconstruction and recovery amounted to RMB 220 billion, while the Communist Party's Special Fund distributed RMB 8.03 billion funding aid to Sichuan Province, within which RMB 4.7 billion were used to assist the building of houses (Guo *et al.* 2019). The Partner Assistance Model, in which selected non-Sichuan provinces or cities were assigned to assist individual Sichuan counties or towns on a one-on-one basis, was applied in the post-Wenchuan earthquake rehabilitation and resettlement (State Council 2008b; Sichuan Government 2009; World Bank 2012). Numerous non-governmental organisations (NGOs), both from China and overseas, also offered great financial and non-financial support to assist the recovery, including the rebuilt of houses, for the earthquake-affected (Xinhua 2008; Lu and Xu 2015; RJC 2018; Chan 2016).

In some earthquake-stricken areas, each household were financed by the government with around RMB 20,000 to rebuild their houses, while some of the rebuilding cost were supported by loans, NGOs or the households themselves (Tse *et al.* 2014; Li *et al.* 2019; RCSC 2011). In Wenchuan, villagers only needed to contribute about RMB 20,000 to get a new house with an area of 120 to 160 square meters (CPG 2009). All these explained why economic sources were secure for the earthquake-affected populations and financial concern was not crucial in influencing the respondents' moving decisions.

Individual/ Personal competencies (not mentioned in existing models) (Pingwu)

Capability of different people in coping with the same hazard differs, leading to variation in vulnerability (Hunter 2005).

Specifically, whether and how rural people's personal competencies influenced actual decision to move in post-earthquake rural China is underexplored, particularly those involve villagers' evaluation of their own competencies to tackle disaster risk. This research looked into a collection of these factors not mentioned in existing vulnerability models. The construct comprised of five factors asked in the survey included three self-evaluation questions on the capability of moving and tackling debris flow, and two related to the provision of government support (see Table 5.12 in the results chapter).

Results show that in Pingwu, respondents' personal competencies affected moving decisions. Those considered more about this personal competencies variable were more likely to stay after the quake. It is logical that those respondents who lacked the confidence on their own capability to move or to tackle debris flow risk, or questioned about the support provided by the government would choose to behave passively and not to move. As a result, they might not be able to comply with government's suggestion to avoid potential disaster areas.

Coping capacities influenced by government/ political institutions in the new residing place that can avoid geological risks (new from existing models) (Wenchuan)

From a vulnerability model perspective, the MOVE framework suggested that institution is one of the key thematic components of susceptibility, together with

economic, physical, environmental and cultural dimensions (Vinchon *et al.* 2011). Political influences involving government strategies and policies are important in recovery (Hogg 1980). How the government provides disaster information could affect coping capacity of the affected people (Vinchon *et al.* 2011).

After the Wenchuan earthquake, the Chinese government has spent resources on disseminating the risk of geohazards, including debris flow, to the threatened populations. The effectiveness of such knowledge transfer, including the need to avoid geohazard risk areas during rehabilitation, could depend on the interaction between the authorities who disseminated the knowledge and the target audiences.

On top of what the existing models and literatures have already addressed, this research explored the impact of what the government said about ("directives" in Hypothesis 1) and did to ("disaster risk reduction measures" in Hypothesis 1) the new residing places on villagers' decision to move to avoid geohazard risk. This involves the interaction between the government and the villagers, and would influence the villagers' vulnerability.

The survey here on Wenchuan particularly shows that respondents' decision to move or not was affected by whether the government said the new residing place was safe. Those who considered more about this variable were more likely to move. In contrast, those who did not concern about what the government said tended to stay in their original place. There was no such association in Pingwu.

This might reflect the effectiveness of what the Wolong SAR or Wenchuan government did in terms of interacting with the villagers and explaining to them the safeness of the new place. This echoes previous research finding that government was influential to evacuation decision if there were effective communications and detailed planning (West and Orr 2007). Here those who considered more about whether the government said the new place was safe probably did trust the government hence decided to move. This result reflecting public trust on government as risk information source, however, is inconsistent with findings from several other non-China empirical studies (Poortinga and Pidgeon 2003, 2004; Haynes *et al.* 2008). This sheds lights on the difference of government role in the Chinese and non-Chinese context.

Wenchuan respondents' moving decisions in this study were also affected by government's geotechnical and disaster preparedness measures. Those who considered about whether the government had introduced effective geotechnical engineering mitigation or disaster preparedness measures in the new residing place were more likely to move. In contrast, those who did not concern this variable tended to stay in their original place. There was no such association in Pingwu.

The results reveal the awareness of Wenchuan respondents on government's geotechnical engineering and disaster preparedness measures in the new location after the quake. In Xingfu village, for instance, a huge structural mitigation dam was built just uphill of the village (Figure 6.6) and it is the biggest infrastructure of its kind in the three Wenchuan villages studied. In the downstream, artificial step pools were constructed along the gully just adjacent to the village houses (Figure 6.7). They are so obvious that the villagers should be aware of their imposition to protect their lives and properties, hence increased respondents' confidence about the safety of the new location and settlements, and encouraged them to move.

(Left) Figure 6.6 A huge dam uphill of Xingfu village in Wenchuan
(Right) Figure 6.7 Artificial step pools along the gully downstream
Houses of Xingfu Village are on the right and the Panda Centre is upstream on the left.




Photos by Rhea Leung, August (left) and July (right) 2016.

6.1.4 Conclusions of Hypothesis 1 discussion

Evaluations on the application of land-use restriction measures aiming to reduce vulnerability are crucial (UNEP 2008). Relocation is considered as an intervention tool to alleviate vulnerability (Birkmann and Wisner 2006). Despite its positive impact, many still chose not to relocate after a disaster. Kates (1962) and Fordham (1992) have systematically worked out a list of reasons to explain why people

chose not to leave hazard zones, including their unawareness of the hazard and their acceptance of expected loss in return of benefits gained from staying.

This research demonstrates that, in both Pingwu and Wenchuan, residents decided not to move after the quake were also due to their lack of consideration about their hazard exposure and susceptibility, as well as their concern about the benefits they got from their cultural affiliation in the place they originally resided.

In terms of model application, the concept of wilful vulnerability proposed in Alexander's model of vulnerability types (2007) shed lights on Sichuan rural residents' sub-optimal consideration of official directives to move after the 2008 earthquake. In the two study areas, knowledge of debris flows and risk reduction, including the non-structural mitigation directives on rehabilitation site selection, was to a certain extent ignored by different reasons, such as cultural factors.

This research also distinguished the significance of ethnicity on moving decision in both Pingwu and Wenchuan echoes the use of "non-white" indicator in the revised hazards-of-place model (HOP) by Cutter and Morath (2013) in the USA. In their study, ethnicity is an origin of difference. Ethnicity, though rooted biologically or culturally on an individual level, illustrates marginality that built on bias, inequality and prejudice on a societal stratum. The Chinese situation, however, was different. In Sichuan, as noted, the policy tended to address what the ethnic minorities needed by paying special attention to their reconstruction and cultural recovery.

The element of risk amplification in Alexander's risk and vulnerability equation (Alexander 1991a, 1991b) can be referred as the non-compliance of government directives after the quake in this thesis, i.e. the percentage of populations who have not relocated as suggested by the government. The reasons behind, e.g. ethnicity, culture issues and coping capacities were considered in evaluating the relocation decisions of the populations threatened by debris flows in the study areas.

Moreover, in Pingwu, in particular, the lower educated, farmers, those who stayed in their communities for a longer time period per year and those considered more about their non-economic individual competency were more reluctant to move after

the quake. In Wenchuan, those less concerned about their coping capacities influenced by government in the new residing place were more likely to stay.

Other demographic variables, such as age and gender, considered by some vulnerability literatures as potentially relating to vulnerability (Cutter *et al.* 2000, 2003) were found having no association with Sichuan residents' decision to move.

Research on environment-related migration was limited (Bilsborrow 2002). In China, studies on disaster-related relocation still focused on people's willingness to move (Xu, D. *et al.* 2020; Zhou *et al.* 2021). The gap in exploring reasons behind the actual behaviour of moving from one place to another is filled by this research.

This research fills in some theoretical and empirical gaps regarding the demographic characteristics of those who resisted to relocate after the quake. It also provides insights on non-demographic reasons why the geohazard-affected rural population were reluctant to move.

In this process, the previous theories and models being presented in the literature review chapter situated the thesis and the empirical work. If making reference to the grounded theory, the empirical findings on certain important themes established by the survey data collected, namely culture, individual competences and governance, are identified. An investigation of their importance building on literatures were made in this section. Since these topics are new and are extensions to the empirical work here, they have opened new questions. An additional model is generated. The potential impacts of these new factors being highlighted here on post-disaster relocation can contribute to theoretical development and inspire further research.

From a practical point of view, based on the survey results, governments can learn what factors could facilitate or discourage which group of disaster-affected people from moving or staying, so that more resources can be input to appropriately manipulate such factors in order to achieve the goal of encouraging people to relocate to safer places without resistance in the future.

6.2 Hypothesis 2

6.2.1 Introduction

Despite some scholars conducted comprehensive evaluation of landslide risks perception (Salvati *et al.* 2014; Thiene *et al.* 2017), research conducted on this topic, in particular debris flow risk perception, has been insufficient. Literature on the debris flow risk perception of rural residents in mountainous regions in China is particularly limited. But this started to draw the attention of researchers in recent years. It is hope that the findings here can further fill in empirical gaps regarding factors affecting debris flow risk perception in the existing disaster studies.

Hypothesis 2 of this study evaluates the effectiveness of government disaster risk reduction measures in shaping debris flow risk perception in marginalised communities in remote mountainous regions.

6.2.2 Results from Pingwu and Wenchuan

Some independent variables only affected debris flow risk perception in one of the two study areas, but five influenced both places.

- **Pingwu**

Survey analysis shows that Pingwu respondent's debris flow risk perception could possibly be affected by three demographic, four non-demographic and awareness of two categories of government measures variables (Figure 6.8 and Table 6.1).

Among the twelve demographic variables, age, occupation after Wenchuan earthquake and ethnicity could have affected Pingwu respondents' risk perceptions. Those aged 65 or above, non-farmers and Qiangs had lower debris flow risk perceptions.

As for non-demographic variables, perception of community remoteness probably also affected Pingwu respondents' risk perceptions. Those who did not perceive their communities as remote had lower debris flow risk perceptions.

Village affiliation also had impact on Pingwu where Niufei villagers were more inclined to perceive lower debris flow risk. Those with no debris flow experience or perceived substantial debris flow less dangerous also had lower risk perceptions.

With regard to government measures, those Pingwu respondents who were aware of geotechnical mitigation measures perceived lower risk. Awareness of four community early warning tools, namely website, phone, shout and gong, as different forms of government disaster response measures or facilities, caused higher risk perception.

- **Wenchuan**

Wenchuan respondents' debris flow risk perception was related to fewer factors. One demographic, three non-demographic and awareness of two categories of government measures variables appeared to be influential (Figure 6.8).

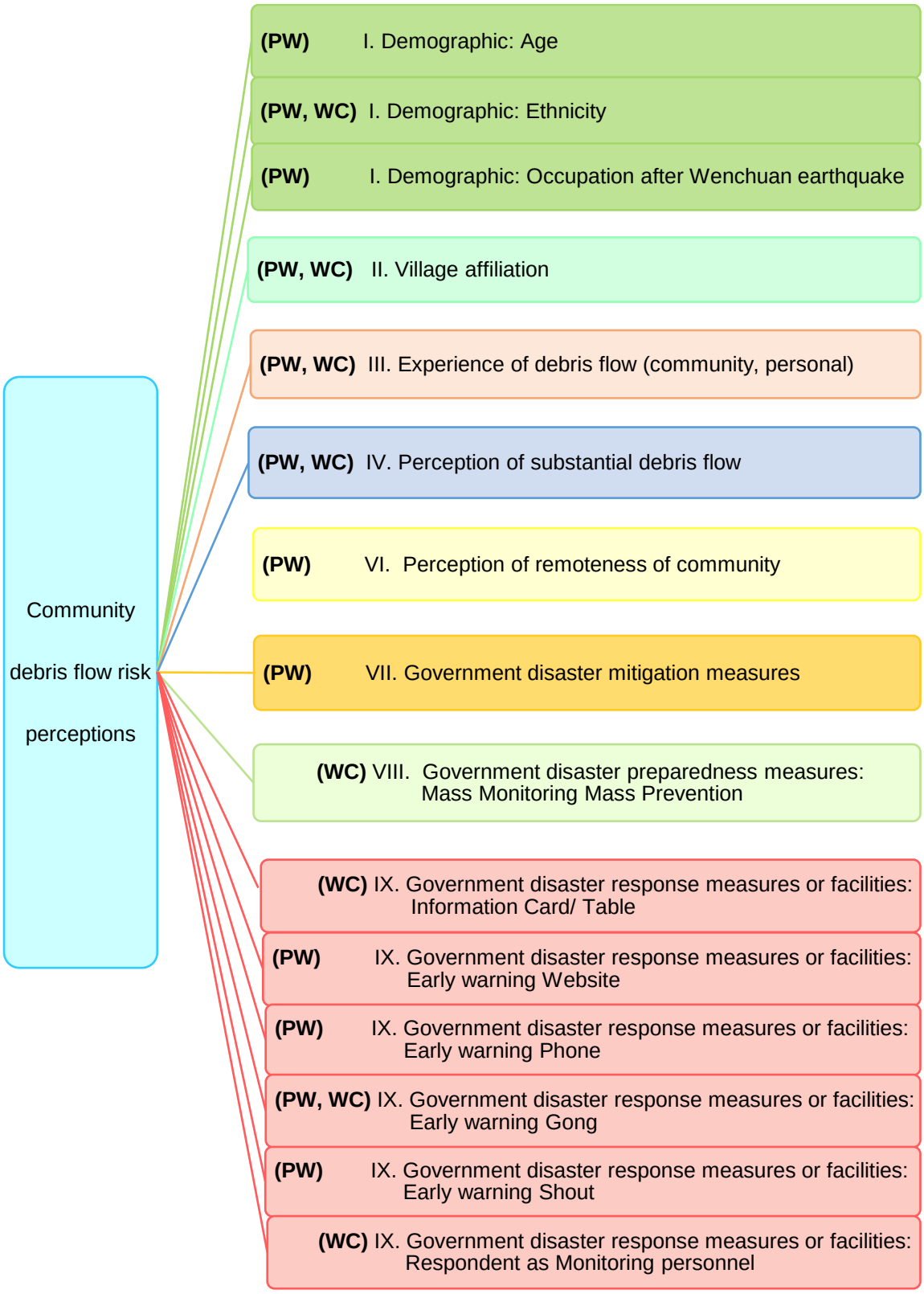
Ethnicity is the only demographic factor appears to impact Wenchuan respondents' risk perception. The Hans were more likely to perceive higher debris flow risk.

For non-demographic variables, village affiliation influenced risk perception in Wenchuan where Xingfu villagers were more inclined to perceive lower debris flow risk. Those with no debris flow experience or perceived substantial debris flow less dangerous also had lower risk perception.

In terms of government disaster preparedness measures, those who had heard of Mass Monitoring and Mass Prevention (MMMP) were more likely to perceive higher debris flow risk. As for government disaster response measures in Wenchuan, those had accessed government information card or table or aware of gong as early warning tool, or the monitoring personnel perceived higher debris flow risk.

Figure 6.8

Factors that could affect respondents' existing community debris flow risk perceptions



PW = Pingwu
WC = Wenchuan

Table 6.1

Factors that could positively or negatively affect existing community debris flow risk perceptions in Pingwu and Wenchuan

	Pingwu		Wenchuan	
	Lower risk perception	**Higher risk perception**	**Lower risk perception**	**Higher risk perception**
Age	Aged 65 or above	Aged 18 to 64		
Ethnicity	Qiang	Han	Hui, Qiang	Tibetan, Han
Occupation after earthquake	Non-farmer	Farmer		
Village affiliation	Niufei	Xinjian	Xingfu	Longtan
Experience in debris flow	No experience	More experience	No experience	More experience
Substantial debris flow	Perceived less dangerous	Perceived more dangerous	Perceived less dangerous	Perceived more dangerous
Communities remote	Not perceived	Perceived		
Government mitigation engineering measures	Aware of	Not aware of		
Government disaster preparedness measures: Mass Monitoring and Mass Prevention			Not heard of	Heard of
Government disaster response measures - Card/ Table			Not accessed	Accessed
- Early warning tool: Website	Not aware of	Aware of		
- Early warning tool: Phone	Not aware of	Aware of		
- Early warning tool: Gong	Not aware of	Aware of	Not aware of	Aware of
- Early warning tool: Shout	Not aware of	Aware of		
- Monitoring personnel: Respondent			Those who were not	Those who were

- **Comparison of results from the two counties**

In both study areas, ethnicity is the only demographic variable appears to affect debris flow risk perception. The Qiangs tended to perceive lower debris flow risk. The Hans were more likely to have higher debris flow risk perception.

For non-demographic variables, village affiliation influenced risk perception. The Niufei and Xingfu villagers were more inclined to perceive lower debris flow risk. Those with no debris flow experience or perceived substantial debris flow less dangerous also had lower debris flow risk perception in both study areas.

Among the 29 government risk reduction measures, awareness of gong as a community early warning tool was the only one affecting risk perception in both Pingwu and Wenchuan. Those who were aware of gong were more likely to perceive higher risk.

Some other factors, however, only influenced respondents' debris flow risk perception in one study area but not the other. Age, occupation after earthquake, community remoteness perception, awareness of government mitigation engineering measures, as well as website, phone and shout as early warning tool affected risk perception in Pingwu only. Heard of MMMP as a government disaster preparedness measure, awareness of card or table as a government disaster response measure, and also respondents as monitoring personnel were found only impactful in Wenchuan.

6.2.3 Discussion of the results

Demographic variables

According to existing vulnerability models, socioeconomic characteristic is one of the major aspects contributing to vulnerability (BBC by Bogardi and Birkmann 2004 and Cardona 1999; HOP by Cutter and Solecki 1989; PAR by Blaikie *et al.* 1994 and Wisner *et al.* 2004; MOVE by Vinchon *et al.* 2011). However, not all socioeconomic aspects mentioned in these models can be applied to the post-Wenchuan earthquake situation. In the study areas, survey results show that only age, ethnicity and occupation after Wenchuan earthquake were related to debris flow risk perception, which in turn would affect vulnerability. Among these three

socioeconomic variables, only ethnicity is statistically significantly associated with and affected risk perception in both Pingwu and Wenchuan.

Ethnicity (Pingwu and Wenchuan)

In both Pingwu and Wenchuan, respondents' risk perception was related to their ethnicity. The ethnic majority Hans, had statistically significantly higher debris flow risk perception than the Qiang minority. The Hans were more agreed that their communities were threatened by existing debris flow while the Qiangs were less agreed. Interestingly, this result is inconsistent with suggestions of existing social vulnerability model such as the hazards-of-place model (Cutter and Solecki 1989; Cutter 1996; Cutter *et al.* 2000, 2003) and literatures that ethnic minorities perceived higher disaster risks (West and Orr 2007) or simply at higher risk (Morrow 1999). The Pingwu and Wenchuan survey results also do not echo another China study on Yunnan Province where small variation of risk perception was found among different ethnic groups (Huang *et al.* 2020).

To explain the possible impact of ethnicity on risk perception found in Pingwu and Wenchuan, traditional wisdom of both the Hans and the Qiangs could be referred to.

Traditionally, the Hans in China were mainly farmers (CPG 2006; CC 2003). For centuries, they have put much efforts in enhancing their agricultural techniques in face of various types of disasters in order to raise their productivity (Hsu 1980). The experience or knowledge of the Han ancestors regarding their living environment might contribute to their sensitivity and alertness to surrounding risk affecting their farmland, and in turn influence how the Hans respondents perceived existing community debris flow threat.

But this did not mean the Qiangs do not have their traditional wisdom. In fact, as mentioned, the Qiangs have a long nomadic history and are mountain dwellers. It is therefore possible that the Qiang respondents did get used to geohazards attacks, especially those occur on hillslopes, such as debris flow, and did not perceive the surrounding debris flow risk as threatening.

Secondly, the Qiangs are described as a “marginalised” ethnic group in China (Zhang 2018). Being an ethnic minority, the Qiangs are get used to living in less protected mountainous and open environments. They therefore might have adapted to facing and tackling various forms of geohazard, causing them to perceive less danger caused by debris flow.

Thirdly, as noted in Hypothesis 1, the Qiangs were more likely to move after the Wenchuan earthquake. One possible major reason was because their original homes or residing place were destructed during the earthquake. Their relocation probably implies that they have moved to a safer place. It is therefore not difficult to understand that the Qiangs, when comparing their old and new communities, tended not to perceive their current newly resided communities were at risk.

Fourthly, it is possible that the correlation between ethnicity and debris flow risk perception is linked to which village the respondents belonged to. This is particularly evident in Pingwu where the Qiangs were more likely to affiliate to Niufei Village while the Hans were more likely to reside in Xinjian Village. In Wenchuan, a great majority of the responding villagers in Longtan and Wolongguan were Tibetans.

The results chapter noted a statistical significant relationship between debris flow risk perception and village affiliation. In Pingwu, perception of debris flow risk of Xinjian respondents was statistically significantly higher than Niufei villagers. In Wenchuan, Longtan villagers had highest risk perception, followed by Wolongguan villagers while those living in Xingfu had the lowest. The reasons explaining the association between risk perception and village affiliation can therefore be of reference here to explain why the Hans had a higher risk perception than the Qiangs in Pingwu, and why the Tibetans had a higher risk perception in Wenchuan.

Risk perception is difficult to measure and assess (Purchase and Slovic 1999; Alexander 2012b). How the villagers in the study areas perceived debris flow risk and their relations with ethnicity is explored in this section. However, the question of how ethnicity influenced risk perception is not fully resolved. Alexander (2000, 2012b) considered risk perception as closely related to cultural factors and influence of ideologies. Culture and ethnicity, though two different concepts, are

closely connected in many instances. Therefore it would be sensible and useful to further investigate in the future how the cultural characteristics of the Tibetans and the Qiangs might have affected their debris flow risk perceptions.

Age (Pingwu)

This research reveals that the elderly persons aged 65 or above tended to have lower debris flow risk perception in both Pingwu and Wenchuan. This echoes the Yunnan research in China that rural younger residents were more likely to perceive bigger landslide threat than the elderly persons (Huang *et al.* 2020). The survey result, however, is inconsistent with two post-Wenchuan earthquake studies. A qualitative study revealed that continuous fear of repeated occurrence of debris flow, especially in rainy seasons, was a major psychosocial problem among the rural elderly interviewees (Cui and Sim 2017). Fearfulness can be connected to risk perception. Elderly persons who were aware of occurrence of past debris flow in their place, but less capable in tackling the risk effectively, could easily develop higher risk perception. Huang *et al.* (2022) who studied secondary geohazard risk perception after the 2008 earthquake found that the middle-age group perceived a significantly higher risk. However, the impact of age on disaster risk perception was only statistically significant in Pingwu but not Wenchuan. This discrepancy echoes the inconclusive findings of existing literatures. On one hand, an Italy survey revealed that landslide risk perception of different age groups did not differ much (Salvati *et al.* 2014). Conversely, age was found influenced or related to geohazard risk perception in Myanmar (Fernandez *et al.* 2018), Yunnan (Huang *et al.* 2020) and Italy (Miceli *et al.* 2008). Nevertheless, the finding in this research that the elderly persons tended to perceive lower risk can have the following explanations.

Firstly, the elderly persons might be less educated, less literate or not good at Putonghua, making them having less access to debris flow information and unable to learn the existing risk in their communities, leading to their lower risk perception.

In fact, age has been considered as an important demographic variable that might relate to and affect vulnerability. For instance, the hazards-of-place model (HOP) (Cutter *et al.* 2000, 2003) suggested people of different ages can have differential access to resources, leading to disparities in vulnerability. This might apply here, where it was possible that the elderly persons tended to receive fewer disaster risk

resources, particularly in the form of information, than the younger ones. This can be particularly true with technological advancement when more disaster information has been disseminated through electronic means rather than traditional word-of-mouth or printed materials. This might have caused the elderly persons to have lower debris flow risk perception and increased their vulnerability.

Secondly, many elderly persons in Pingwu had resided in their village for most of the year. Many had also lived there for many years and longer than the non-elderly group. They should be more familiar with their place and had accumulated knowledge of their living environment. They might trust their own judgement and hence perceived their surrounding existing debris flow threat as lower.

As in the case of relocation, however, if the survey was conducted at a different time of the year, interviewees of a different age distribution might have been generated, and the results could have changed. Despite the possible bias that might have incurred by the date of survey, the ultimate respondents could indeed better represent the actual age groups residing in rural mountainous areas in China for most of the year and who would need to rely on themselves during rainy summer when debris flows are active.

Occupation after Wenchuan earthquake (Pingwu)

Risk perception of people with different occupations can differ. However, risk perception of rural residents with different occupations, particularly those in China, was seldom studied.

This study shows that Pingwu farmers had a statistically significantly higher debris flow risk perception than the non-farmers. The farmers were more agreed that their communities were threatened by existing debris flow. The non-farmers were less agreed that their communities were at risk.

There are at least two possible explanations. Firstly, farmers in Pingwu County mainly cultivated in the village, if not the community, they resided. Since they spent most of the time working and living in the same place, they should be familiar with the surrounding environment, including disaster threats around induced by the 2008 earthquake, when compared to the non-farmers who probably worked

somewhere else and spent less time in their communities. Non-farmers therefore had a lower perception of existing threat.

Secondly, since the survey targeted rural populations in mountainous regions, many responding farmers cultivated their farmlands along mountain slopes (Figure 6.9). Any earthquake-induced debris flow risk in their surrounding environment, especially those along the slopes, would easily get their attention, hence farmers had a higher risk perception. This is particularly evident in Pingwu than in Wenchuan because the land available for cultivation in Pingwu was especially limited so the farmers there were having closer connections with the slopes and gullies around.

Figure 6.9

Farmlands on slopes in Pingwu



Existing vulnerability models may further help explain why farmers had a higher debris flow risk perception. According to HOP model (Cutter *et al.* 2003) and BBC framework (Birkmann and Wisner 2006), occupation is an indicator of vulnerability. Disasters can damage production means, causing occupation loss and economic vulnerability (Alexander 1997). Livelihoods would be at risk as noted in the PAR model (Blaikie *et al.* 1994; Wisner *et al.* 2004). The worse is that, disaster can cause unemployment and resulting in financial deprivation as a form of

socioeconomic vulnerability, according to the MOVE framework (Vinchon *et al.* 2011).

When applying these to this research, farmers heavily relied their livelihoods on their farmland might worry their place would be hit by debris flow. Their worries could reasonably be higher than the non-farmers because they were afraid to become unemployed and fall into financial deprivation once their farmland is destroyed. Fearfulness can be connected to higher risk perception. This explanation, again, should only be more applied to Pingwu. In Wenchuan, although farmers were found to have higher risk perceptions as well, such relation was not statistically significant.

Village affiliation (Pingwu and Wenchuan)

In both Pingwu and Wenchuan, respondents' village affiliation was statistically significantly associated with their existing community debris flow risk perception. There can be a number of possible explanations.

Firstly, different villages should have different debris flow exposure. Such exposure could directly affect risk perception of respective villagers. However, exact level or extent of debris flow risk exposure of each of the five villages were not covered in this research. Such information was even not available or at least not disclosed by the government. What is known from government records and site surveys is that all five villages were threatened by debris flow risk, and in various extent.

Secondly, village affiliation can be connected with proximity to debris flow threat, which is closely linked to risk exposure. Impact of geographical or risk proximity and location on vulnerability is recognised by previous literatures (Palm and Hodgson 1992; Alexander 1993; West and Orr 2007). The five villages in this study are located in different geophysical settings and environments, although all are in remote mountainous regions. Their proximity to debris flows also vary. Site visits revealed that houses of Longtan Village spread across a mountain slope just next to a narrow rainwater drainage channel (Figure 4.53). Any debris flow occurs uphill can influence and spill over to the adjacent houses. This may explain why Longtan villagers perceived the highest debris flow risk among the three Wenchuan villages.

Proximity to debris flow threat can also explain the high risk perception in Wolongguan Village. On 26 July 2016, just about two weeks before the research team of this study interviewed Wolongguan villagers on 8 to 9 August, a debris flow occurred in Xiongmao Gully (also called Yingxiong Gully) just upstream of the village. This flow carried about 500,000m^3 of debris into Pitiao River (Pitiaohe) and affected the village located along the river (WCCD 2016). About 300 meters of the main road G350, houses, cultivated land and livestock were destroyed (Liu 2019). The destruction was still obvious when the survey of this research was conducted (Figure 4.70). The incident impacted some residents hence it is possible that the debris flow risk perception of Wolongguan villagers were influenced. In fact among the 121 Wolongguan villagers being interviewed in this study, 30 were from the fourth community group, Toudaoqiao Group, which is nearest to Xiongmao Gully. As high as 90% of them strongly agreed or agreed that their communities were threatened by debris flow. Only 10% were neutral or disagreed.

As for Xingfu Village, since the source of debris flow and the blockage dams were both at least a few minutes' walk far up in the mountain out of sight of the villagers (Figure 4.47), they could easily feel that debris flow risk was far away. Moreover, due to the newly-built panda centre adjacent to Xingfu Village, a wide drainage channel was constructed in the site to ensure rain water and debris from uphill could flow downhill quickly and effectively (Figure 4.47). These help explain the relatively low debris flow risk perception of Xingfu villages.

The Pingwu situation is different. Xinjian Village in Pingwu, although also protected by a huge structural mitigation measure up in the mountain out of villagers' sight (Figure 4.19) as Xingfu Village in Wenchuan, as many as about three-quarter of the Xinjian villagers still perceived existing debris flow risk, comparing to only about half of the respondents in Xingfu. This can be related to the tragic experience of Xinjian villagers during the Wenchuan earthquake which triggered a substantial debris flow at the site where the new sediment trap dam is now located. The debris flow had killed quite a number of residents in the villages nearby. Houses of Xinjian Village are still scattered on the mountains surrounding the midstream of Xingping Gully where the debris flow occurred. Therefore even though a huge sediment trap dam is now constructed to prevent future disasters, many Xinjian villagers and residents in nearby villages still perceived they were threatened by debris flow.

In Niufei Village of Pingwu, although the Huanglianshu Gully cut across the village and is close to the village houses and farmlands, the scale of debris flows induced by the Wenchuan earthquake and the casualties caused were smaller than the debris flows occurred near Xinjian Village. This helps explain why the existing community debris flow risk perception of Niufei villagers was statistically significantly lower than their Xinjian counterparts.

Thirdly, risk perception can be influenced by chats or daily conversations among villagers and neighbours. The number of villagers of each of the five villages studied in this research was only a few hundreds. Each community within a village usually only comprised of one to two hundred villagers. In such small communities, many people know all other individuals, not to say some are relatives. If someone perceived debris flow risk in the community, the news, no matter it is true or not, can be spread across the community and the village. The communication theory of The Spiral of Silence (Noelle-Neumann 1974) can be referenced here. Once a public opinion on debris flow risk is formed and become dominant in a village, people would tend to follow and express the same view, sometimes to avoid social isolation. Risk perception of those from the same village can therefore be very similar, while risk perception of people from different villages can be different.

Experience of debris flow (Pingwu and Wenchuan)

All five studied villages were attacked or threatened by debris flows. “Experience” of disaster, no matter it is in Wisner’s vulnerability and resilience list of indicators (2001), or considered as coping capacities in the BBC framework (Bogardi and Birkmann 2004; Cardona 1999), is relevant for this thesis. The MOVE framework suggested that susceptibility is indicated by the percentage of people who have experienced debris flows (Vinchon *et al.* 2011). The “experience” indicator is therefore included in the survey to see if it has any implication to risk perception.

In both Pingwu and Wenchuan, respondents who had personally experienced debris flow and their community also had debris flow occurred in the past were more likely to have higher debris flow risk perception. Those who had not experienced debris flow at all had a lower perception of existing community debris flow threat. The positive correlation was statistically significant.

Although individual studies on China and even Asia revealed that disaster experience did not necessarily imply high risk perception (CCOUC 2014), or was not so influential on risk perception or awareness (Shaw *et al.* 2004; Luo *et al.* 2014), the outcomes in Pingwu and Wenchuan are similar to the findings of a number of other studies on China (Huang *et al.* 2020), including post-Wenchuan earthquake research in Sichuan (Lo and Cheung 2015; Xu *et al.* 2019), such as a study on large scale secondary geohazard experience (Huang *et al.* 2022). All these research revealed the positive relation between disaster experience and risk perception.

Moreover, many other literatures on Asian and European countries almost consistently found that experience has positive impacts on disaster risk perception (Weinstein 1989; Bezuyen *et al.* 1998; Siegrist and Gutscher 2006; Salvati *et al.* 2014; Chaturvedi and Dutt 2015; Fernandez *et al. 2018*), as in the case of Pingwu and Wenchuan.

A possible explanation is that those experienced more debris flow might believe that the place they were residing had continued to be threatened by debris flow, hence they had a higher perception of existing community debris flow threat. Those who had less debris flow experience might feel that they were less exposed to debris flow risk, hence had a lower perception of existing threat.

The concept of susceptibility and its relation with disaster experience suggested by the MOVE framework (Vinchon *et al.* 2011) can also help explain the survey results. Those respondents in the two study areas who had experienced debris flow would find themselves more susceptible and therefore perceived higher risk. Those without debris flow experience could find themselves less susceptible and perceived lower risk.

A model of vulnerability types by Alexander (2007) helps explain the Sichuan situation from another aspect. Since the scale of the Wenchuan earthquake was unprecedented in the past decades, some debris flows induced in various sites were “newly-generated” by the worsening geological environment. Even for those places where debris flows were reactivated, their scales were much larger than the

pre-earthquake ones. In such cases, these debris flows were unexperienced hazards for the local people, hence aroused vulnerabilities.

Perception of substantial debris flow (Pingwu and Wenchuan)

Statistical analysis shows that in both Pingwu and Wenchuan, the more dangerous the respondents perceived substantial debris flow, the higher existing community debris flow risk perception they had. “Perception of substantial debris flow”, therefore, is a new factor not mentioned in existing vulnerability models, but is found influential to disaster risk perception in a China context.

A possible explanation is that those who perceived substantial debris flow as more dangerous were more concerned about the impact of debris flow on their lives and livelihoods. They might afraid even small debris flow threat can develop into substantial ones. Hence they would be more alert about existing debris flow threat in their communities and have higher risk perceptions. Those who did not perceive substantial debris flow as dangerous might pay less attention to their debris flow risk exposure, and hence perceived lower risk.

The MOVE framework suggested that susceptibility is indicated by the expected economic loss to be caused by disasters (Vinchon *et al.* 2011). Survey findings of both Pingwu and Wenchuan tends to echo this suggestion. Those respondents in the two study areas who perceived substantial debris flow as more dangerous would probably expect it would cause higher economic loss, hence they would find themselves more susceptible and perceived higher debris flow risk. On the other hand, those who perceived substantial debris flow as less dangerous could find themselves less susceptible and therefore perceived lower debris flow threat in the communities.

Perception of remoteness of community (Pingwu)

In both counties, respondents who perceived their communities as remote has a higher debris flow risk perception than those who did not. However, the relation between the two variables was statistically significant only in Pingwu, but not in Wenchuan.

“Isolation”, one of the vulnerability indicators (Wisner 2001), is particularly relevant here because this thesis focuses on studying the remote mountainous regions where people are isolated to some extent.

Vulnerable groups like elderly people and female always feared of danger caused by earthquakes (Armas 2006). The minorities, who are always the vulnerable, were also found hopeless and fear the lack of protection from disasters like earthquakes which would affect their lives and homes (West and Orr 2007). Such fearfulness of the vulnerable may also apply to those who perceive their place remote.

For those who perceived the community they reside in is remote, their risk perception could be higher because they probably would be fear that once their place is attacked by geohazard like debris flow, it would be more difficult to inform others and to seek help from outside.

In fact shortly after the Wenchuan earthquake, emergency support was difficult to access the remote mountainous earthquake-affected areas because of road blockage caused by the earthquake itself or the secondary geohazards induced. Rescue teams were unable to access certain remote areas and relief materials had to be airdropped (ADB 2008). People lived in such remote rural areas became more vulnerable. Such a background could make those respondents who perceived their communities as remote in Pingwu and Wenchuan has a higher debris flow risk perception. However, why such sense of remoteness was only statistically significantly affecting risk perception in Pingwu but not in Wenchuan can be explained by the difference in location and accessibility of the two places.

Distance from the provincial capital can be an indicator for the rural villagers to judge whether the place they reside is remote. In Pingwu, Niufei Village is 212 km from Chengdu, the provincial capital, while Xinjian Village is even 255 km away from it. In Wenchuan, however, the distance from Chengdu to the three villages, Xingfu, Longtan and Wolongguan, are only 113 km, 116 km and 140 km respectively (Google Maps 2015).

Accessibility to main road can be another factor affecting people’s perception of their communities’ remoteness. All three Wenchuan villages of this study are

located along the main road G350. But for the two Pingwu villages, although Niufei and the most accessible houses of Xinjian are situated nearby the main roads G247 and G543 respectively, the most remote community of Xinjian Village high up in the mountain is not easy to access. It is just 7 km from the main road G543, but takes an extra 21 minutes to reach. Such environmental settings help explain why more Pingwu respondents perceived their communities as remote when compared to the Wenchuan counterparts.

Awareness of government disaster mitigation (engineering) measures (Pingwu)

Imposition of geotechnical mitigation measures is considered as an intervention tool in alleviating vulnerability in the BBC framework (Birkmann and Wisner 2006).

In this research, people's awareness of the imposition of geotechnical mitigation measures was addressed. Instead of focusing on the geotechnical effectiveness of mitigation engineering measures as proposed in existing risk and vulnerability model and equation (Alexander 1991a, 1991b), the risk mitigation factor in the study areas was tested by asking the villagers whether they were aware of the measures imposition. The survey finds that there was a difference in awareness rate of geotechnical measures between the two study areas. In Pingwu, the majority (51.12%) were not aware of the measures, whereas in Wenchuan, the majority (65.29%) were aware of. This variation can be explained by the difference in the locations and prominence of such measures in the two places.

In Wenchuan, as noted, a wide drainage channel was constructed just adjacent to Xingfu Village to drain rainwater and debris from uphill. Another rainwater drainage channel is adjacent to houses in Longtan Village. Both prominent geotechnical measures should have helped arousing about two-third of all Wenchuan respondents to be aware of the geotechnical measures introduced in their communities.

In Pingwu, however, a huge structural mitigation structure comprised of sediment trap dams was constructed up in the mountain after the Wenchuan earthquake to prevent further disasters and to protect at least three villages downhill, including Xinjian Village, from Xingping Gully debris flow. Since it is built close to the source

of the debris which is far away from the villages, it is less prominent than the one in Wenchuan. It does not mean that the Pingwu government was doing less to protect her people, but since the dam is basically out of the villagers' sight, they were less aware of what the government has done to protect them. It is therefore sensible that those who were unaware of the geotechnical measures in their communities thought they were not protected. They might therefore had a higher debris flow risk perception than the actual risk they were facing.

In Niufei, the sediment trap dam and the drainage channel located almost at the periphery of the village were not so obvious to those respondents living on the other side of the village. These could contribute to the low percentage (48.88%) of awareness of geotechnical engineering measures introduced, hence higher debris flow risk perception. As a result, more Pingwu respondents were not aware of the geotechnical measures when compared to their Wenchuan counterparts.

Although there was a difference in the overall awareness level of geotechnical measures between Wenchuan and Pingwu, those who were unaware of or did not know whether their communities had introduced geotechnical engineering measures had a higher debris flow risk perception in both places. Those who were aware of such measures perceived lower risk.

One possible explanation is that those who were aware of the structural mitigation measures in their communities might develop a sense of security that they were protected, hence perceived lower risk.

Those who were unaware of or did not know whether their communities had introduced such measures might feel they were more exposed to debris flow risk without protection, hence have a higher perception of existing threat. The model of vulnerability types propounded by Alexander (2007) might explain this situation. Impact of limited or incomplete knowledge of debris flow risk reduction geotechnical measures was an indicator of vulnerability in the study areas. This is particularly true when residents living in the remote mountainous villages might not be fully accessible to knowledge of debris flow mitigation imposed by the government. Such inaccessibility can be due to isolation, literacy level, education level, language barrier as well as communication which are not uncommon in

Sichuan. However, this negative relation between geotechnical engineering measures awareness and debris flow risk perception was statistically significant only in Pingwu, not Wenchuan.

The implication of the result that there was a negative relation between geotechnical engineering measures awareness and debris flow risk perception should be noted. Numerous debris flow mitigations were adopted in different places, including China, with some best practices (Wu *et al.* 2016; Liu *et al.* 2013; Banihabib and Forghani 2017) and some failure cases (Baggio and D'Agostino 2022). An experience of debris flow hit in a Chinese province, Gansu, revealed an incomplete application of sediment trap dams built with poor quality could not serve its blocking purpose, contributed to destruction and caused casualties (Wang 2013). In Yunnan Province, some engineering measures aimed to protect the rural residents from debris flows were not operating well, not useful, had limited impacts but required much maintenance efforts (Huang *et al.* 2020).

In post-Wenchuan earthquake Sichuan, despite certain successful application of debris flow mitigation treatments (SKLGP 2019), there were a number of silted or failed engineering measures (Wang, Qi and Wang 2012; Chen *et al.* 2015). Such failures, to some extent, were contributed by huge amount of materials carried by more occurrence of debris flow after the quake (Tian *et al*. 2022).

When applied to the scenario of this research, if the structural measures which were aware of by the villagers were constructed, implemented, maintained and reinforced properly, and can really protect them from debris flow risk, then even if they perceive the existing threat as lower, their safety would not be affected inversely. However, if the geotechnical measures cannot effectively protect the residents from debris flow, their lower perceived risk might lead them to underestimate the actual threat. They might misunderstand that the structural measures could protect them, hence causing insufficient disaster preparedness or inappropriate disaster response.

According to field visit observations, during the rainy season in summer, rainwater carried debris loosened by the earthquake downstream. Due to huge amount of

debris pouring downhill, individual sediment trap dams were found filled up with debris (Figure 6.10).

Figure 6.10

A sediment trap dam filled up with debris flowed from upstream



Any failures of the first round of geotechnical mitigation measures can be related to an underestimation of risk, insufficient financial support, technical limitations, unexpected extreme weather related to estimation of occurrence, or lack of experience in tackling debris flows and related geohazards in such an unprecedented large scale in the region. In the two study areas, local authorities had monitored the dams and arranged clean-up of debris from time to time. Continuous close monitoring of the sediment trap dam situation and major reinforcement of the quality of the geotechnical measures, such as those imposed to tackle Xingping Gully Debris Flow and Xingfu Gully Debris Flow, are necessary to ensure they could function well when debris flow hit.

Government disaster preparedness measures

Heard of Mass Monitoring and Mass Prevention System (Wenchuan)

Mass Monitoring and Mass Prevention (MMMP) is an important disaster risk reduction system introduced and promoted by the Chinese government before the Wenchuan earthquake in monitoring and preventing geohazards by mobilising local manpower, resources, and even experience. Indeed, significance of

community-based disaster management in China has been recognised (ODI 2015) and positive impacts of community participation was also evident in aspects like environmental protection in Wolong (Scolobig *et al.* 2023).

The result on Wenchuan in this study echoes the findings by Zhao *et al.* (2019). Wenchuan villagers' awareness of MMMP was statistically significantly and positively affected their debris flow risk perception. Though initiated by the government, those respondents who had heard of MMMP could be more aware of people-centred disaster risk monitoring and prevention practice in their communities (IFRC 2020). They could be more alert about geohazard, such as debris flow, risk, surrounding them. They might also associate any implementation of MMMP with the existence of debris flow threat in their places. On the other hand, those who had not heard of MMMP had no idea about any use of community efforts in disaster risk monitoring and prevention. They might therefore had a lower perception on the existing community debris flow risk.

The finding is important for both the academics and policymakers. Although the statistical significant relation between MMMP awareness and risk perception was only found in Wenchuan and not Pingwu, but since MMMP is a nationwide policy, the research finding still adds value to the understanding of the relation between the two variables on a country level. If the government could invest even more resources in promoting MMMP to the vulnerable populations in different provinces, it could be foreseeable that a higher awareness of this monitoring system and hence a higher geohazard risk perception can be achieved. For the academics, the finding contributes to the current literature by introducing the importance of this China-specific geohazard risk reduction system, and improving the understanding of a widely studied topic of risk perception. The impact of MMMP awareness on debris flow risk perception found in this research can be a primary reference for future academic studies.

Government disaster response measures or facilities

Accessibility to Disaster Prevention Understanding Cards or Table of Geohazard Prevention and Protection Plan (Wenchuan)

"One Table, Two Cards" were prepared by the authorities in both Pingwu and Wenchuan annually after the geohazard inspection.

The accessibility of such table or cards among the respondents in this research was low in both Wenchuan (12.40%, 45/363), and Pingwu (7.09%, 19/268). Such rates were much lower than that found in Yunnan Province (Huang *et al.* 2020). This might reflect an ineffectiveness of using such documents to notify the villagers regarding geohazard risks in both counties.

Despite the low accessibility rate, the survey found that in Wenchuan, those who accessed the Table or Cards tended to have statistically significantly higher debris flow risk perception.

A possible explanation is that those who had seen certain Table or Cards might learnt or more alert about surrounding debris flow risk. They might associate such Table or Cards with the existence of debris flow threat in their communities. In fact, if a respondent did not simply just access the Table or Cards somewhere in the community, but had instead received it from the authorities directly, his or her house was actually identified by the government as threatened by certain geohazard risk. Therefore, they could have particularly high perceptions of existing risk. On the other hand, those who had not seen such Table or Cards before were less able to learn the existence of community debris flow risk.

The importance of distributing the Cards to the geohazard affected population to enhance their disaster prevention awareness and capability is also noted in the National Accidental Geohazard Emergency Response Plan (Central Government 2006).

Similar to the case of MMMP, although the statistically significantly positive impact of accessibility to the Table or Cards on debris flow risk perception was only found in Wenchuan and not Pingwu, such effectiveness found in certain region in Sichuan has been established. This is an important and encouraging sign for the authorities, especially the Ministry of Land and Resources (currently the Ministry of Natural Resources), which has been promoting the application of the Table and Cards for years in different parts of Sichuan, such as the epicentre of Wenchuan earthquake, Yingxiu Town (Sim *et al.* 2015). The possible effectiveness of the Table and Cards

in enhancing geohazard risk perception can be further evaluated by more throughout studies covering more places, both within and outside Sichuan.

The survey results could contribute to the current academic literature by introducing the importance of the use of “One Table, Two Cards”, that is, a China-specific geohazard risk reduction information dissemination method, in affecting risk perception. This could not only enhance the understanding of a widely studied area of risk perception, but could also shed lights on the study of risk communications.

Monitoring personnel (Wenchuan)

This study finds that perception of existing community debris flow risk of those Wenchuan respondents who were monitoring personnel was statistically significantly higher than those who were not. The two variables were positively correlated.

A possible explanation is that monitoring personnel were usually more informed about the debris flow risk in their communities, hence would have higher perception of community debris flow threat. However, those who were not monitoring personnel were relatively less informed and less knowledgeable about the threat of debris flow in their communities, hence have a lower risk perception.

In Pingwu, however, the originally threatening Huanglianshu Gully Debris Flow was taken out from the geohazard risk site list during the survey, while Xingping Gully Debris Flow was only threatening the Settlement Site of Xinjian Village. Although the monitoring personnel should have noted these geohazard information, this had no impact on their debris flow risk perception. A possible explanation is that the changing status in the two Pingwu gullies could not allow the monitoring personnel to have definite perceptions of risk.

Early warning tools awareness (Pingwu and Wenchuan)

Introduction of early warning tool is considered as an intervention in alleviating vulnerability in the BBC framework (Birkmann and Wisner 2006). The MOVE framework further suggested that coping capacity is indicated by performance of the early warning system (Vinchon *et al.* 2011).

Several types of disaster early warning tools are applied in rural China. The selection of the type of tools in a certain place could vary according to the nature of the hazard, the geo-setting, the financial and technical ability of the place, and even the characteristics and situation of the community and the people.

After the Wenchuan earthquake, most research on early warning in Sichuan focused on technological advancement of the systems (Shi *et al.* 2018; Wang *et al.* 2021; Ju *et al.* 2015; Zhao *et al.* 2021; Fan *et al.* 2019c; Xu, Q. *et al.* 2020; Sichuan Government 2016; Chen 2015). Literatures evaluating the human aspects of early warning, such as awareness of early warning tools applied by the government in debris flow-prone areas is limited.

Analysis of the effectiveness of different types of early warning tools in affecting disaster risk perception is even more minimal. This study addressed this question and fill in the empirical and theoretical gaps.

This research evaluates five types of debris flow early warning tool being applied in rural Sichuan and see whether and how each of them affected risk perception.

Based on background research, field visits and understanding from local authorities, the tools included website, siren, phone, gong and shout. Survey respondents' awareness of the imposition of each of the five tools in the two counties is listed in Table 6.2.

Table 6.2
Respondents' awareness of community imposition of the five early warning tools in the two counties

Early warning Tool / Study area	Website	Siren	Phone	Gong	Shout
Pingwu (N=268)	2 (0.75%)	28 (10.45%)	26 (9.70%)	44 (16.42%)	59 (22.01%)
Wenchuan (N=363)	3 (0.83%)	94 (25.90%)	34 (9.37%)	63 (17.36%)	187 (51.52%)

In both counties, respondents' awareness of the five early warning tools imposed on their communities were generally low. The most aware of was shout. More than one-fifth (22.01%, 59/268) of Pingwu and over half (51.52%, 187/363) of Wenchuan respondents were aware of someone in the community responsible to shout to issue debris flow early warning. This indicates the rural populations still relied on traditional and low-tech early warning method. Proportion of respondents who were aware of website, phone and gong being their communities' early warning tools were very similar in both study areas, with the most advanced website the least aware of. Siren was less aware of than gong in Pingwu, but were more aware of in Wenchuan.

The higher awareness of siren in Wenchuan was consistent with observations during site visits. More sophisticated sirens were found in Wenchuan while in Pingwu, siren mainly appeared in the form of loudspeaker. In Xinjian Village, probably owing to the widely scattering of houses, siren was not even seen during site visits.

If taking reference of the categorisation of Huang *et al.* (2020) by grouping website, siren and phone call/ messaging as automatic early warning while treating gong and shout as manual early warning, respondents in this research have higher awareness of manual early warning systems and lower awareness of the automatic ones. This result echoes the findings of Huang *et al.* (2020) in Yunnan, indicating the debris flow early warning systems carried out by humans were more established and more aware of by rural residents across at least the two Chinese provinces. The authorities can therefore utilise such manual systems in debris flow risk reduction. The consistency of the findings in Yunnan and Sichuan here in this study may also reveal that the debris flow early warning systems using more sophisticated electronic and technological devices were still in a developing stage. Either the devices themselves, like the website, siren and phone system require more investment, or the rural resident users need more technical support and training in order to receive the new forms of early warnings effectively.

Relations between each early warning tools' awareness and debris flow risk perception

Statistical analysis reveals that Pingwu respondents' debris flow risk perception were affected by their awareness of four out of five debris flow early warning tools in their communities, namely website, phone system, gong and shout. In Wenchuan, respondents' debris flow risk perception was only influenced by their awareness of gong. In other words, among the five tools, only the awareness of gong influenced survey respondents' debris flow risk perception in both counties, and in a positive way.

- **Gong (Pingwu and Wenchuan)**

Survey analysis shows that in both Pingwu and Wenchuan, those who were aware of the use of gong in issuing debris flow early warning had statistically significantly higher debris flow risk perceptions. Those who were not aware of or did not know were less agreed that their places were at risk.

In addition, among the five debris flow early warning tools revealed in this research, gong was the second most aware of in Pingwu, and the third in Wenchuan (Table 6.2).

Although gong is a low-tech traditional way to issue geohazard early warning in rural China, it is an easy-to-use and easy-to-understand method for most villagers. People do not need to be well-educated, wealthy, young or technology-literate in order to use a gong to issue early warning and to understand an early warning message issued through a gong. It is also the most economic early warning method when compared to sophisticated website, siren or phone system. The communities also do not need to invest a lot of money to buy gongs.

In fact, existence of a gong often indicates the site or its surrounding area has geohazard risk. To a certain extent, gong is an icon of geohazard threat.

Since the gongs are usually placed in or near geohazard risk zones, those who were aware of the availability of gong in their communities were probably alerted that there was debris flow threat, hence perceived higher risk.

On the other side of the coin, those who were unaware of the availability of gong in their communities for issuing debris flow early warning would be less likely to know there was debris flow risk around. Many of them therefore had a lower risk perception. Moreover, since they simply were not aware of the availability of gong, they probably would also not aware of debris flow warning issued through such channel. Therefore, they would be less likely to be aware of debris flow threat in their communities.

These results imply that if gong awareness can be increased in places with debris flow risk, risk perception can also be enhanced. The government should therefore ensure gongs to be put in all geohazard risk sites, preferably in prominent places easily seen and accessed by villagers. By doing so, the rural residents would know where the geohazard risks exist hence have higher risk perception. As a result, they can be more alert and better prepare themselves to tackle and to respond to such risks.

The key is to set rules and educate the villagers on when a gong early warning is to be issued, what exactly a warning represents, would different sounds or frequencies represent different geohazards or risk levels, and what they should do when hear such warnings.

- **Website (Pingwu)**

Although only less than 1% of the respondents in both Pingwu and Wenchuan said they were aware of website as an early warning tool impacting their communities, the potential use of website to issue early warning should not be underestimated.

In Pingwu, those who were aware of the introduction of certain website as an early warning tool in their communities has a statistically significantly much higher debris flow risk perception. The two variables were positively correlated. Those who were not aware of or did not know were much less agreed that their places were at risk. This means if more rural villagers were aware of website as a debris flow early warning tool, more would have a higher debris flow risk perception.

According to China Internet Network Information Center (CINIC), internet penetration rate in China reached 50.3% in December 2015 with 688 million of

netizens, and 90.1% of them went online through mobile phones (CINIC 2016a). As for rural areas, internet penetration rate in 2015 reached 31.6%, increased by 2.8% when compared to year 2014, and there was still room for development (CINIC 2016b). Until December 2015, the number of netizen in rural China reached 195 million, increased by 9.5% compared to the previous year; and among them, 87.1% (170 million) used mobile phones to go online.

Together with government policies to support broadband construction development in rural villages and remote areas (MIIT 2016), using website, particularly with a mobile phone version, as a debris flow early warning platform has great potential to reaching more rural populations and enhancing their awareness of community debris flow risk.

As noted in the literature review, the Chinese central government has developed a national early warning website (MNR and CMA 2022), as those official websites developed in the US and Japan (USGS 2017; JMA 2017a, 2017b). On a provincial level, however, some provinces only issue provincial early warning occasionally, without a regular sophisticated website updated daily as the one run by Sichuan (DLRSC 2016) or able to issue timely geohazard forecast as Hubei Province (Zheng *et al.* 2008). Given an expanding Chinese netizens population, application of website in each province in disseminating geohazard early warning would be useful. In addition, since the majority of netizens use mobile phones to go online, a mobile version of the geohazard early warning site would be particularly effective.

On a local level, the Sichuan Government announced that with the assistance of university scholars, a real-time geohazard early warning system through the web platform was developed for the whole section of provincial road starting from Yingxiu to Wolong (Sichuan Government 2016). This research outcome was accepted by the Sichuan Government in late 2016, which is after the conduct of survey of this study, hence its impact could not be evaluated through the survey. If this system would eventually be applied with early warning issued to Wenchuan residents, the government or related parties could evaluate its awareness rate and effectiveness in affecting risk perception. In addition, another research on southwest China has incorporated the use of website, phone text messaging, sirens or loudspeakers as part of the early warning system (Ju *et al.* 2015, 2020).

Any additional evaluation of the impact of awareness of such tools on risk perception could be valuable for future reference.

- **Phone (Pingwu)**

The survey reveals that only 9.70% and 9.37% of the Pingwu and Wenchuan respondents respectively said they were aware of using phone as an early warning tool in their communities. However, similar to the case of website, the use of phone to issue disaster early warning has great potential.

In both counties, those who were aware of the use of phone as a community early warning tool had higher debris flow risk perceptions. Those who were unaware of or did not know were less agreed that their places were at risk. This is particularly evident in Pingwu where the two variables were statistically significantly correlated in a positive direction. This is probably because the settlements in Pingwu are relatively more scattered than in Wenchuan, instant phone call or messaging should be a more effective way of communication, particularly during disaster attack.

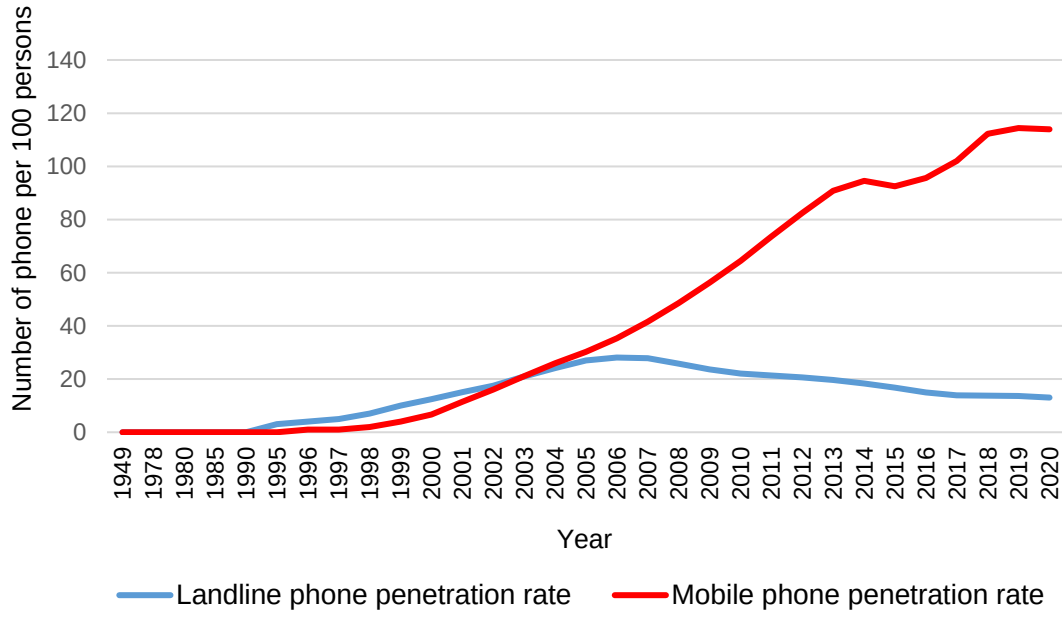
The research results further suggest that if more rural villagers would be aware of phone call or messaging as a debris flow early warning tool, more of them would have a higher debris flow risk perception.

The application of mobile phone call or messaging, including traditional SMS alerts or WhatsApp warning messages, is becoming a more common means of hazard early warning in different parts of the world, like debris flow in Italy (Arattano and Marchi 2008) and tsunami in Indonesia (Rahayu *et al.* 2020).

In China, selected loess landslide and debris flow sites in Gansu (Xu, Q. *et al.* 2020) and Sichuan (Ju *et al.* 2020) respectively have applied comprehensive early warning systems, including sophisticated monitoring and mobile text messaging through SMS and WeChat together with telephone alarms, collectively improved risk detection and helped evacuation. Although individual impact or effectiveness of phone messaging was not investigated, these studies marked the usefulness of phone as a debris flow early warning tool in rural China.

The applications of these phone messaging early warnings in these different places have something in common: the alerts were only sent to selected people, and in most cases, the authorities and/or the disaster management personnel. Phone early warning targeting the public or general residents of a community was not yet come into practice. The authorities should therefore develop phone messaging systems that can be issued to the public in need or the pool of residents threatened by debris flow. Through raising their awareness of the imposition of phone early warning, it is hoped that their debris flow risk perception can be enhanced, so they can be more alert in preparing themselves to tackle and respond to debris flow hit. According to the Chinese Ministry of Industry and Information Technology (MIIT), by the end of year 2016, total phone users in China reached 1.53 billion, within which 1.32 billion were mobile phone users (MIIT 2017), with a penetration rate of 95.6%, i.e. for every 100 persons, there were 95.6 mobile phones, increased by 3.1 compared to the previous year, and further increased to 102% in 2017, meaning on average one person owned 1.02 mobile phone (MIIT 2019). In contrary, the penetration rate of landline phone was only 15.0% with 207 million users in 2016 and continuously decreased to 13.9% in 2017 (MIIT 2019). The trends of phone penetration rates are displayed in Figure 6.11.

Figure 6.11
Development and situation of landline and mobile phones penetration rate from 1949 to 2020 in China



Sources: MIIT 2017, 2019, 2021.

On a provincial level, phone penetration rate in Sichuan continued to rise from year 2015 to 2020 (Table 6.3). In 2015, Sichuan has 68.72 million mobile phones users and the penetration rate was 82.87%. The rate exceeded 100% in 2018, i.e. on average each person owned more than one mobile phone.

As for landline phones, the situation in Sichuan was different from the nation as a whole. Both urban and rural landline phone users in Sichuan increased through the years and the penetration rate also increased steadily (NBSC 2016, 2017, 2018, 2019, 2020, 2021).

Table 6.3

Population of Sichuan and number of phone users from year 2015 to 2020

Year end	Resident population '0000	Urban landline phone users '0000	Rural landline phone users '0000	Total landline phone users '0000	Landline phone penetration rate	Mobile phone user (4G) '0000	Mobile phone user (total) '0000	Mobile phone penetration rate
2015	8196	939.1	414.4	1353.4	16.50%	--	6872.0	82.87%
2016	8251	981.3	508.8	1490.1	18.03%	--	7294.5	88.29%
2017	8289	1027.9	608.1	1636.0	19.71%	--	7693.6	92.67%
2018	8321	1041.1	679.9	1721.0	21.98%	--	9068.6	108.72%
2019	8351	--	--	1862.8 (till Nov)	22.35%	7206.5 (till Nov)	9457.7 (till Nov)	112.76%
2020	8371	--	--	1885.0	22.53%	7115.7	9124.6	109.05

With the increasing penetration rates, mobile phones have already become an inevitable part of daily lives of Sichuanese, and Chinese as a whole, and even for all humans.

Information delivered on the web through mobile phones can reach people instantly, making information flow much more efficient than ever. It is therefore not difficult to understand the effectiveness of the awareness of phone system in influencing people's debris flow risk perceptions in this research.

- **Shout (Pingwu)**

Among all five debris flow early warning tools investigated in this study, shouting was the most aware of. More than one-fifth (22.01%) of Pingwu and over half (51.52%) of Wenchuan respondents were aware of someone in the community responsible to shout to issue debris flow early warning (Table 6.2).

In Pingwu in particular, those who were aware of the use of shout as an early warning measure had a statistically significantly higher debris flow risk perception. Those who were unaware of or did not know were less agreed that their places were at risk.

Although shouting is a traditional, common and economic way of debris flow early warning in China, academic studies evaluating its impacts on disaster risk reduction or even effectiveness on saving lives and properties are limited. Individual research has at most noted people's awareness and perceived effectiveness of manual early warning system which engaged public participation and employed farmers as inspectors (Huang *et al.* 2020). However, whether the manual early warnings were issued through shouting or other means was not specified. Findings of this research provide insights regarding the positive impact of shouting awareness on debris flow risk perception.

Overall discussions on early warning tools

Earthquake early warning in China is not a pure scientific question regarding earthquake prediction, but requires the collaboration and cooperation among the government, the science community and the society (Qian 2008). Similarly, effective debris flow early warning in the two study areas also requires joint efforts

of the government which introduce and implement relevant early warning systems, the scientists who provide update scientific and technical support, as well as the residents who prepare themselves to understand how various tools would issue early warnings and how they should react appropriately to early warnings.

This section discusses the third pillar regarding villagers' awareness of five early warning tools and how such awareness affected their debris flow risk perception. Through such understanding, policymakers can follow-up and target their efforts and resources in educating the villagers on the types of early warning tool they would encounter, so as to enhance their risk perception. In parallel, the authorities should teach the villagers how to react upon receiving such early warning alerts. By doing so, disaster risk can be reduced.

Indeed, those who were aware of the introduction of early warning tools discussed might associate such measures with the actual existence of debris flow risk in their communities, hence have a higher perception of existing threat. Those who were unaware that their communities had introduced such tools might feel they were less exposed to debris flow risk, hence have a lower existing threat perception.

The early warning tools in the study areas could be considered as interventions as suggested by the BBC framework (Birkmann and Wisner 2006). Awareness of such interventions caused higher risk perception which could lead the villagers to carry out more protective or preparedness measures for themselves, and in turn could alleviate their vulnerability.

As noted by the MOVE framework, coping capacity is indicated by performance of early warning system (Vinchon *et al.* 2011). Therefore the relative efficacy of the five early warning tools should be noted. Research results show that phone call or messaging was the most effective and the best method in influencing risk perception in Pingwu, followed by gong, with shouting being the least effective among the three tools. Website was an exception as it was aware of by only two respondents and might be irrelevant for evaluation. In Wenchuan, respondents' debris flow risk perception was only related to their awareness of gong, indicating gong was the only early warning tool that was effective in affecting debris flow risk perception there.

It is worth noting that phone was the most influential early warning method while shout was the least. This may be because mobile phone usage has become more common in China. As the penetration rate of mobile phone in Sichuan was as high as 82.87% in 2015, it is sensible that the villagers would choose to make a phone call to inform other villagers about debris flow hit rather than shout in big remote mountains or using a gong as an early warning medium.

In fact, a recent literature (Zhao *et al.* 2021) explicitly noted that in summer 2020, an individual from one Sichuan village located upstream hit by debris flow made a phone call to another person in another village downstream to alert the attack. The person of the later village therefore was warned about the upcoming hazard which eventually hit a few minutes later. Although the call was not an official early warning, this case reflected the common and effective use of phone call in making debris flow alerts.

With phone penetration rate continued to rise, it is foreseeable that phone is becoming more common and effective in arousing disaster risk awareness and perception. Landslide early warning system developers, however, made an important remark that expert judgements are crucial before issuing phone alert messages (Xu, Q. *et al.* 2020). This is because even though an automated alarm is released by a sophisticated early warning program when significant deformation or displacement is detected or monitored, any false alarm may cause public disquiet and affect the reliability of the warning system.

6.2.4 Conclusions of Hypothesis 2 discussion

Factors influencing disaster risk perception

Factors affecting disaster risk perception vary in different scenarios. Previous literatures could not, to a great extent, conclude the list of factors influencing disaster risk perception.

For institutional factors, existing vulnerability models suggested various lists of intervention tools imposed by governments that would affect vulnerability (Angotti 1977; Alexander 1991a, 1991b, 2000, 2002, 2012b; Blaikie *et al.* 1994; Wisner *et al.* 2004; Birkmann and Wisner 2006). In what ways the government provides

disaster information is also crucial in impacting coping capacity and susceptibility of the vulnerable population (Vinchon *et al.* 2011). As Slovic (1986) suggested, those in charge of information delivery could influence people's perception. However, none of the existing models and their indicators could be fully applied and could explain the post-Wenchuan earthquake Sichuan situation. By selecting relevant vulnerability indicators from the existing vulnerability models, while also including selected China or Sichuan specific variables, this research discovered the list of institutional factors that could influence debris flow risk perception of the Sichuan rural residents.

To test Hypothesis 2, this thesis selects a total of 46 sub-variables of nine factors as independent variables, and see whether and how they affected risk perceptions.

Survey results reveal that among the 29 disaster risk reduction measures sub-variables imposed by the government, only one of them -- the awareness of gong as an early warning disaster response measure, was found affecting debris flow risk perception of respondents of both study areas.

Some government measures only affected debris flow risk perception in one of the two study areas. Awareness of government disaster mitigation engineering measures was found affecting only Pingwu respondents' risk perception. Awareness of one of the government disaster preparedness measures, MMMP, was influential in Wenchuan only.

Among the government disaster response measures or facilities, awareness of four early warning tools, namely website, phone, gong and shout, were found affecting Pingwu respondents' risk perception. For Wenchuan respondents, accessibility to information card or table, awareness of gong, as well as whether working as monitoring personnel were influential. However, besides the mentioned disaster risk reduction measures imposed by the government after the Wenchuan earthquake, this study shows that risk perception of the rural populations living in remote mountainous regions was also affected by several demographic and non-demographic factors.

Debris flow risk perceptions of respondents in Pingwu and Wenchuan were affected by three and one demographic variable(s) respectively. Ethnicity is the only possible influential demographic variable in both counties. Pingwu respondents' risk perception was also influenced by age and occupation after the Wenchuan earthquake.

Although gender was considered to be an influential demographic factor that affects disaster risk perception in various places (Fernandez *et al.* 2018; Tian *et al.* 2014), it was found having no statistical significant relation with debris flow risk perception in Pingwu and Wenchuan in this study. This result echoes that of some other research (Salvati *et al.* 2014; Huang *et al.* 2020).

Another demographic factor, educational attainment, is also found not statistically significantly associated with debris flow risk perception in Pingwu and Wenchuan. This result is inconsistent with many previous disaster studies, both on geohazards in China (Tian *et al.* 2014; Huang *et al.* 2022) and on other countries (Shaw *et al.* 2004; Fernandez *et al*. 2018) which suggested the contribution of education on risk perception. Moreover, the results of this study do not echo previous research which established the impacts of income or household size on risk perception (Tian *et al*. 2014; Fernandez *et al.* 2018).

As for non-demographic variables, village affiliation, experience of debris flow, perception of substantial debris flow were found all affecting debris flow risk perception of respondents of both counties in this research. Perception of remoteness of community affecting only Pingwu respondents' risk perception.

These results imply that Hypothesis 2 which states *"The rural populations living in remote mountainous areas have developed perceptions of geological risk that are now generally more advanced than the measures for disaster mitigation, preparedness and response imposed by the government since the earthquake"* is accepted. Besides the government measures, people's risk perception could also be influenced by specific demographic factor such as ethnicity or non-demographic factors such as village affiliation, experience of debris flow and perception of substantial debris flow.

Perceived risk Versus Actual risk as part of Hypothesis 2 discussion

Knowing and considering risk perception of the disaster-affected populations is important for planning, establishing and applying disaster risk management and reduction measures. However, perceived risk is influenced by a wide range of factors which might vary in different scenarios. In particular, risk perception is considered as closely related to cultural factors and influence of ideologies, and can increase or decrease vulnerability (Alexander 2000, 2012b). As individuals always develop risk perception based on personal evaluation, perceived risk can deviate from actual risk (Huang *et al.* 2022).

Therefore understanding what factors affect risk perception in different settings and making good use of such findings to adjust, influence and even manipulate risk perception to make it more align with the actual risk is important. By such alignment, both the government and the people themselves can implement the most suitable risk reduction measures that can best tackle the disaster risks. This alignment involves the control of the kind of risk-related information (the question of "what") to be appropriately provided to which disaster-affected vulnerable group (the question of "to whom") through which channels (the question of "how") in which location (the question of "where"). The identification of the influential independent variables found in Hypothesis 2 of this research, particularly those statistically significantly associated with risk perception in both Pingwu and Wenchuan, can help achieve such goal.

To whom

The discovery of demographic characteristics of those who perceived particularly high or low risk in the two study areas can give the authorities the direction on whom the debris flow risk information should be disseminated.

This research reveals that ethnicity is the demographic factor possibly affecting rural residents' debris flow risk perception in both counties. The Qiangs had the lowest debris flow risk perception among the three major ethnic groups. The Tibetans, though only represented in Wenchuan in this study, had the highest risk perception. The authorities, therefore, can target the Qiang and the Tibetan audiences and explore further why they had such perceptions. Through such understanding, the government can design and disseminate suitable debris flow

risk information to the two groups respectively. By such target audience-oriented information dissemination, it is hoped that the two ethnic groups can obtain better and more accurate knowledge about the debris flow risk threatening them, so that they can better prepare themselves to tackle future risks.

Where

Apart from ethnicity, village affiliation of respondents in both counties was statistically significantly associated with their debris flow risk perception. Xinjian villagers of Pingwu and Longtan villagers of Wenchuan had higher debris flow risk perception. The authorities and academics can further investigate whether this was related to the actual risk exposure of the two villages or there were other factors. If it was really that the two villages were exposed to higher risk, more disaster risk reduction measures including more education on the existing risk in the two villages should be introduced to the residents to alleviate vulnerability.

Interestingly, the case study chapter noted that in 2015, Huanglianshu Gully Debris Flow, which had threatened Niufei Village, was taken out from the list of government geohazard risk sites; while only two out of nine resident groups in Xinjian Village were threatened by Xingping Gully Debris Flow and a landslip respectively. Whether and in what ways did these government inspection results might have affected villagers' risk perceptions can also be investigated.

What and How

Debris flow experience are two other variables that were found to be statistically significantly associated with debris flow risk perception in both Pingwu and Wenchuan. The more debris flow experience the respondents have, the higher community debris flow risk they perceived.

Although it is possible that people having adequate experience of disaster can promptly grasp the disaster situations, some authors noted that personal experience may influence or even enhance individual perception of the possibility of being victimised (Perloff 1983; Weinstein 1989). Instead of referring to the current situation to predict the future, some people rely on their previous experience (Osberg and Shrauger 1986). However, relying on memory would affect likelihood judgments (Kahneman and Tversky 1973).

Based on all these discussions, one should be critical when interpreting the relationship between experience and risk perception. Even though disaster experience was widely found associated with and affecting disaster risk perception, as in the results shown in this research, whether such outcome risk perception was exaggerated when compared to the actual disaster risk is to be noted. This is important for the authorities who carry out disaster risk reduction measures because they need to strike a balance between adequately addressing the risk perception of the residents on one hand and imposition of measures that are appropriate and non-excessive to tackle the disaster risk on the other. From an implementation perspective, this involves the assessment and evaluation of what kind of risk-related information (the question of "what") should be provided to the actual risk-affected populations (the question of "to whom") through which channels (the question of "how"). Ultimately, it is hoped that risk perception of the disaster-affected residents can align with the actual existing risk affecting the places.

6.3 Hypothesis 3

6.3.1 Introduction

Disaster response behaviour during emergencies can be influenced by a combination of factors, including demographic and non-demographic ones. In what way a person responds when encountering a disaster hit can directly affect the chance of survival. Factors affecting disaster response behaviour, therefore, were widely explored in disaster studies (World Bank 2020; Twigg 2003).

Many academic articles on post-Wenchuan earthquake noted that debris flow is a rapid downslope movement of a mix of rock, soil and water under gravity caused by torrential rainfall flowing along pre-existed stream and can grow in size and power with the supplement of debris and soil on steep slopes and river banks as it flows downstream (Zhou *et al.* 2013). Given the rapid, explosive and devastating nature of debris flow, appropriate behaviour in response to debris flow hit is of particular important for saving lives and reducing loss.

Despite the special nature of debris flow, previous literatures still focused more on behavioural response to other disasters, in particular earthquake and tsunami,

probably because the number of people killed by a single occurrence of these disasters can be much higher (Dowling and Santi 2014; UNISDR 2018). In what ways people would behave when hit by debris flow was less explored, and only a handful investigated the factors affecting such behaviour (Luo *et al.* 2014). However, according to a global study by the former UNISDR (2018), during the period from 1998 to 2017, the number of deaths caused by debris flow together with other types of landslides, as well as the frequency of landslide occurrence, ranked the fifth among all types of disasters, whereas the number of people affected by different forms of landslides collectively ranked the sixth. It is therefore crucial to study the anticipated response behaviour of the people living in communities threatened by debris flow and the reasons behind such behaviour. Through such understanding, disaster risk reduction workers and policymakers can extract those groups of people who would behave inappropriately and educate them the correct debris flow response, so that their risk and vulnerability can be reduced.

For those encountering landslide or debris flow, despite there are some recommended response actions, there is in fact no definite answer on how to react. According to the US government, one can run away from the debris path, run to higher grounds, move to upper storeys or roof of a building, refuge in a closed room, or even climb a tree (FEMA 2022). Which action one should take depends on the scenario the affected person is situated. Watching out signs of landslide in the surrounding environment, such as be aware of any sudden change in water flow or water clarity, is also recommended (Ready 2022). Red Cross suggested people to evacuate right away, inform neighbours and the authorities if possible (American Red Cross 2022).

Academics have also proposed how to respond. Spence *et al.* (2004) suggested four directions: evacuate, stay indoors, reduce permeation and enlarge openings to tackle pyroclastic, though not debris, flow. In particular evacuation is a common disaster response (Drabek and Boggs 1968). Findings of this Sichuan research echoes these previous studies.

This research, in order to collect more accurate data about how the Chinese would anticipate their disaster response, an open question: *“In the future, what will you*

do in the first place when you are at home and see signs of debris flow?" was asked. There was no predefined answer. The collected answers were coded and categorised into four big groups as indicated in the results chapter. They can be summarised as: (1) evacuate; (2) stay or take refuge at home; (3) inform others; and (4) others. The categorisation of this dependent nominal variable, that is anticipated behavioural response, is similar to some debris flow responses recommended by governments and NGOs. In particular, the impact of government disaster risk reduction measures on behaviour was explored. As shown in the case study area chapter, since the occurrence of Wenchuan earthquake, different levels of the Chinese government have introduced various measures aiming to reduce geohazard risk threatening the people. Many involved changing their behaviour.

Hypothesis 3 of this study, therefore, determines and evaluates the effectiveness of government disaster risk reduction measures in shaping debris flow response behaviour in marginalised communities in remote mountainous regions. How the respondents would respond when see debris flow signs at home are explored. With such results, it is hoped that the anticipated behaviour, the profiles of respondents, the regularities, as well as the explanations behind can serve as references for other areas facing similar geohazard risk. These findings are useful for policymakers in targeting certain groups of rural residents for future imposition of disaster mitigation, preparedness and response measures, including education and training.

6.3.2 Results from Pingwu and Wenchuan

In the two study areas, survey respondents' anticipated behavioural responses when see debris flow signs at home could be influenced by various factors. In terms of the number of factors, residents in both counties were probably much more affected by government measures rather than their demographic characteristics.

Pingwu

Pingwu respondent's anticipated behaviour could be contributed by two demographic variables and nine non-demographic ones which were all government disaster risk reduction measures including four disaster preparedness and five disaster response measures or facilities.

Wenchuan

In Wenchuan, respondents' anticipated behaviour were affected by two demographic and 13 non-demographic variables, in which nine were government disaster risk reduction measures. The nine government measures were composed of mitigation (engineering), two preparedness and six response measures.

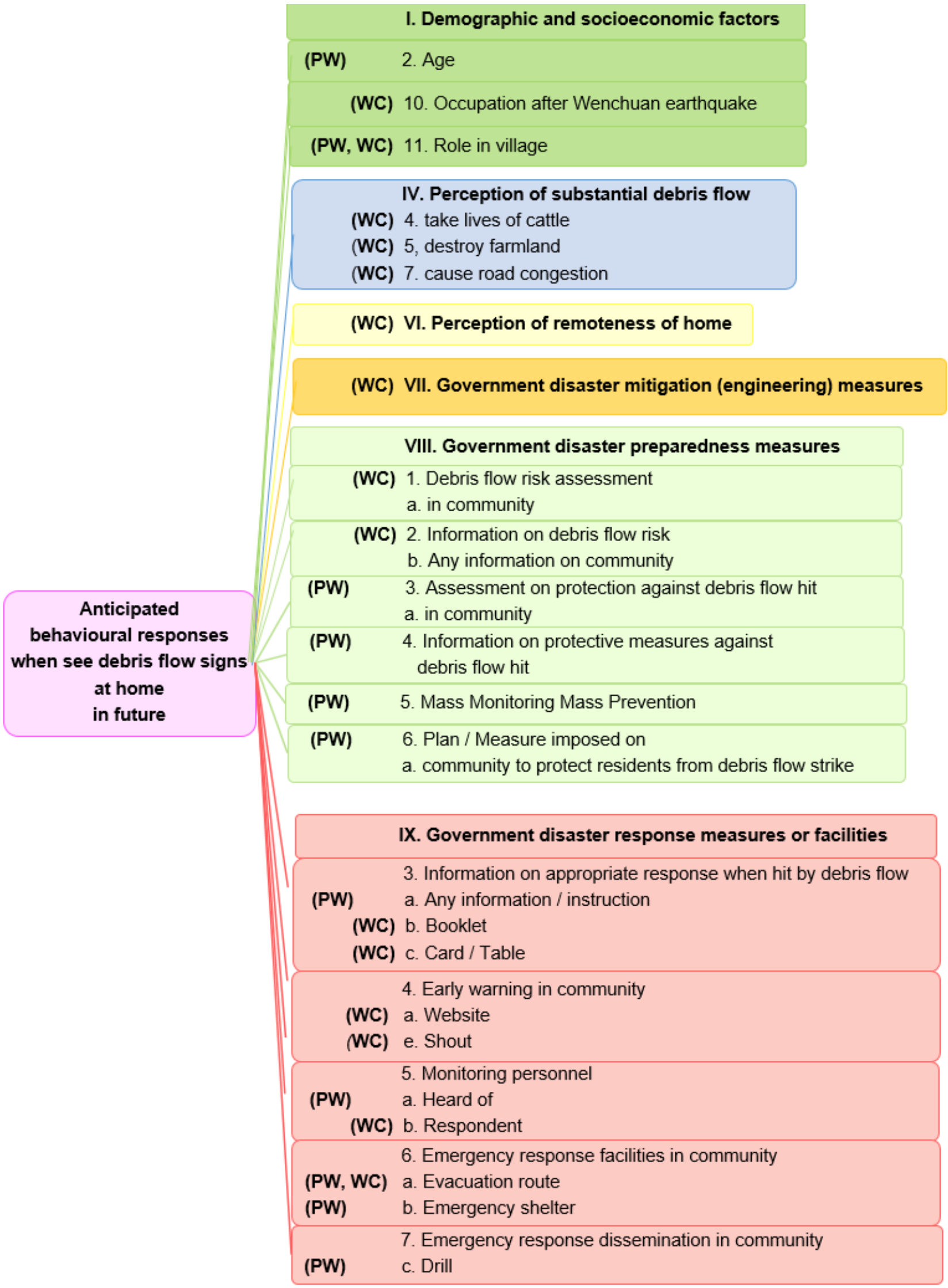
Comparison of results from the two counties

Among all factors, awareness of evacuation route was the only government measure found affecting anticipated disaster responses in both counties. Role in village is the only demographic factor influenced disaster responses in both places. Furthermore, two non-governmental and non-demographic factors, namely perception of substantial debris flow and home remoteness affected anticipated disaster responses in only one county, Wenchuan, but not Pingwu. This implies that the anticipated behaviour of the residents in Pingwu and Wenchuan were affected by very different government risk reduction measures and demographic factors. Most influential independent variables only affected anticipated behaviour in either county only.

Figure 6.12 summarises all factors affecting anticipated disaster responses in the two counties.

Figure 6.12

Factors that could affect anticipated disaster responses when see debris flow signs at home



PW = Pingwu
WC = Wenchuan

Table 6.4 further shows how the influential independent variables would impact debris flow responses in Pingwu and Wenchuan respectively. Three sets of demographic, non-demographic and government risk reduction measures regularities that would contribute to the three major anticipated behavioural responses in the two counties respectively are revealed.

In both counties, those who served certain position in the village or were aware of the evacuation route as an emergency response facility would be more likely to inform people. Those who did not serve any village role or were unaware of any evacuation route would be more likely to take either of the two opposite actions -- evacuate or take refuge at home. However, some factors affecting anticipated disaster response in Pingwu only. Elderly respondents aged 65 or above or those who did not serve, did not know or forgot if served any village position would tend to evacuate. The younger adults aged 18 to 64 or those who served certain village role would be more likely to inform others. Moreover those non-elderly adults who did not serve, did not know or forgot if served any village position would be more likely to stay at home.

Wenchuan respondents' anticipated disaster responses were affected by occupation after the 2008 earthquake, apart from their role in village. The non-farmers or those who did not serve any village position would be more likely to take either of the two opposite actions -- evacuate or take refuge at home. The farmers or those who served certain village position would tend to inform others.

Disaster responses in Wenchuan were also influenced by two non-demographic variables: perception of substantial debris flow and home remoteness. Those who agreed or strongly agreed that substantial debris flow can take lives of cattle, destroy farmland or cause road congestion, would be more likely to evacuate. Those disagreed or strongly disagreed substantial debris flow could cause such dangers or those did not perceive their homes remote tended to stay at home. Those perceived their homes remote would be more likely to inform others.

With regard to government disaster risk reduction measures, the variables affecting the two counties were very different. In Pingwu, there is no evidence that geotechnical mitigation measures awareness influenced disaster response. In

Wenchuan, however, those who were aware of such measures were more likely to stay at home or inform others while the unaware group would tend to evacuate.

For disaster preparedness, it is worth noting that the four measures that would affect Pingwu respondents' behaviour were totally different from the two impactful factors in Wenchuan.

In Pingwu, those who had accessed certain information on protective measures against general debris flow hit, had heard of MMMP, were aware of the imposition of assessment, plan or measure to protect residents from debris flow strike in the community, would be more likely to inform others.

In Wenchuan, however, those who were aware of assessment or had accessed certain information on community debris flow risk would be more likely to inform others. The unaware or non-accessed groups would tend to evacuate.

For disaster response measures and facilities, besides the awareness of community evacuation route impacting both Pingwu and Wenchuan, anticipated behaviour in the two counties would be affected by totally different measures.

In Pingwu, apart from evacuation route, respondents' awareness of another four disaster response measures or facilities would influence their anticipated disaster responses.

Those who had accessed certain information or instruction on appropriate debris flow response, had heard of monitoring personnel or emergency response dissemination through drill, or were aware of emergency shelter, would be more likely to inform others. Those who had not accessed, had not heard of, or were unaware of these measures or facilities would tend to have either one of the two opposite responses: evacuate or stay at home.

In Wenchuan, apart from evacuation route, respondents' awareness of another five disaster response measures or facilities were found influencing their anticipated disaster responses.

Those who had accessed booklet, card or table on appropriate debris flow response, were aware of website or shouting as early warning tools or the monitoring personnel, would be more likely to inform others. Those who had not accessed or were unaware of such measures, or the non-monitoring personnel, would tend to evacuate.

Table 6.4

Factors that could affect anticipated disaster responses when see debris flow signs at home – a comparison of Pingwu and Wenchuan

	Three major anticipated behavioural responses of Pingwu respondents			Three major anticipated behavioural responses of Wenchuan respondents		
	More likely to run, escape or evacuate	**More likely to stay or take refuge at home, take care of home, impose risk reduction measures or observe**	**More likely to inform family members, authorities or others**	**More likely to run, escape or evacuate**	**More likely to stay or take refuge at home, take care of home, impose risk reduction measures or observe**	**More likely to inform family members, authorities or others**
Demographic or socioeconomic factors						
- Age	Aged 65 or above	Aged 18 to 64	Aged 18 to 64			
- Occupation after Wenchuan earthquake				Non-farmers	Non-farmers	Farmers
- Role in village	Did not serve/ Did not know/ Forgot	Did not serve/ Did not know/ Forgot	Served	Did not serve/ Did not know/ Forgot/ Did not answer	Did not serve/ Did not know/ Forgot/ Did not answer	Served
Non-demographic factors						
Perception of substantial debris flow - take lives of cattle				Agreed/ Strongly agreed	Disagreed/ Strongly disagreed	Disagreed / Strongly disagreed
- destroy farmland				Agreed/ Strongly agreed	Disagreed/ Strongly disagreed	Neutral
- cause road congestion				Agreed/ Strongly agreed	Disagreed/ Strongly disagreed	Disagreed/ Strongly disagreed
Perception of remoteness of home				Both perceived and not perceived	Not perceived	Perceived
Government risk reduction measures						
Government mitigation engineering measures				Not aware of	Aware of	Aware of
Government disaster preparedness measures - Debris flow risk assessment in community				Not aware of	Not aware of	Aware of
- Accessibility to any information on debris flow risk in community				Not accessed	Accessed	Accessed
- Assessment on protection against debris flow strike in community	Not aware of	Aware of	Aware of			
- Accessibility to any information on protective measures against general debris flow hit	Not accessed	Not accessed	Accessed			
- Heard of Mass Monitoring and Mass Prevention	Heard of	Not heard of	Heard of			
- Plan/ Measure imposed on community to protect residents from debris flow strike	Not aware of	Not aware of	Aware of			
Government disaster response measures and facilities: - Accessibility to any information/ instruction on appropriate response when hit by debris flow	Not accessed	Not accessed	Accessed			
- Booklet				Not accessed	Accessed	Accessed
- Card/ Table				Not accessed	Not accessed	Accessed
- Early warning tool: Website				Not aware of	Not aware of	Aware of
- Early warning tool: Shout				Not aware of	Aware of	Aware of
- Monitoring personnel: Heard of	Not heard of	Not heard of	Heard of			
- Monitoring personnel: Respondent				Those who were not	Those who were	Those who were
- Emergency response facilities: Evacuation route	Not aware of	Not aware of	Aware of	Not aware of	Not aware of	Aware of
- Emergency response facilities: Emergency shelter	Not aware of	Not aware of	Aware of			
- Emergency response dissemination: Drill	Not heard of	Not heard of	Heard of			

6.3.3 Discussion of the results

Demographic variables

Socioeconomic characteristic is one of the major aspects contributing to vulnerability according to existing vulnerability models (BBC; HOP; PAR; MOVE). However, not all socioeconomic aspects mentioned in these models can be applied to the post-Wenchuan earthquake situation. In the study areas, only age, occupation after Wenchuan earthquake and role in village were found related to and would influence anticipated debris flow response behaviour, which could affect vulnerability (see Figure 6.12).

Role in village (Pingwu and Wenchuan)

Among the three influential socioeconomic variables, role in village is the only one found statistically significantly associated with, and would affect, respondents' anticipated behavioural responses when see debris flow signs at home in both counties.

In the two study areas, those served certain position or role in the villages were more likely to inform family members, authorities or others than those who did not serve, did not know or forgot. These village leaders might think they should take care of elderly persons, children and other villagers. This echoes another study which suggested that Sichuan village leaders were the ones to rely on in times of emergencies (Du *et al.* 2016). It would be their primary responsibility to inform others during disasters, and to help evacuation if needed. As in other places, community leaders were expected to perform special communication roles in disaster situations (Grossman 2020) and they were more capable in disseminating hazard information and early warning, bridging the institutions and residents (Rahayu *et al.* 2020). Hence village leaders would be less likely to escape in the first place when compared to other villagers. The training they received from their role could also told them not to stay or take refuge at home when debris flow hit.

In such case, the government should utilise the strength of village leaders and empower their roles during emergencies (Rahayu *et al*. 2020).

Conversely, those who did not serve any village position or did not know or forgot at all, did not have the chance to receive any on-job training regarding how to respond to debris flow hit. Therefore they were more likely to simply flee as soon as possible or take refuge at home when compared to those serving certain village role.

Age (Pingwu)

In Pingwu, age was found associated with residents' anticipated disaster response, apart from impacting risk perception as shown in the Discussions section of Hypothesis 2. The elderly respondents aged 65 or above tended to evacuate in the first place when they see debris flow signs while the younger adults aged 18 to 64 were more likely to inform others.

This could be because elderly respondents were relatively slower in receiving debris flow hit information and were less mobile, taking them more time to evacuate during emergencies. This is particularly true in Pingwu because the houses there are more scattered and the roads are more rugged. When the elderly villagers are at home and see debris flow signs, they would be more likely to simply flee as soon as possible so as to have enough time to escape. This is consistent with earlier findings which considered age as affecting disaster response (Morrow 1999), with elderly persons having fewer resources (Phifer 1990) or less access to resources (Tobin and Ollenburger 1992) and facing higher risk (Morrow 1999). This also echoes the hazards-of-place model (HOP) (Cutter *et al.* 2000, 2003) which suggested people of different ages can have differential access to resources, leading to disparities in vulnerability. The impact of age on both risk perception and disaster response in Pingwu could in turn affect respondents' vulnerability.

For those aged 18 to 64, however, besides the need to evacuate, they might also think that they should take care of the elderly persons, children and other villagers, and it would be their responsibility to inform others. Hence they would be less likely to escape when compared to the elderly group. But age had no impact on Wenchuan respondents' anticipated disaster response or risk perception because the scenario in Wenchuan was different from that in Pingwu.

Occupation after Wenchuan earthquake (Wenchuan)

Analysis showed that in Wenchuan, respondents' anticipated disaster responses were associated with their occupation after Wenchuan earthquake, Wenchuan farmers were relatively less likely to evacuate when they see debris flow signs at home. They might believe that they were familiar with their place or simply thought that their place was not that threatened by debris flow. Hence a greater portion of them thought the need to run is less urgent when compared to the non-farmers. In parallel, they would be more likely to inform others in times of debris flow emergencies. But they would also not prefer to stay at home in order to minimise their risks.

On the contrary, the non-farmers should be less familiar with their land than the farmers. When they see debris flow signs at home, many of them would only have the ability to take care of themselves by fleeing in the first place or staying at home where they thought safe, although these two responses seem opposite to each other. They might not be able to spare efforts to inform other people.

The responses of the Wenchuan farmers could be explained by existing vulnerability models. Occupation is a vulnerability indicator in the HOP model (Cutter *et al.* 2003) and BBC framework (Birkmann and Wisner 2006). Disasters could damage production means, causing occupation loss and economic vulnerability (Alexander 1997) as well as putting livelihoods at risk as noted in the PAR model (Blaikie *et al.* 1994; Wisner *et al.* 2004), and resulting in financial deprivation according to the MOVE framework (Vinchon *et al.* 2011).

In Wenchuan, many houses of the three villages studied are built in clusters and quite compact. Many farmlands were also clustered near the houses. Based on the rationale of the vulnerability models, the Wenchuan farmers who relied their livelihoods on their farmlands might worry once their land is destroyed by debris flow, they would become financially deprived. Therefore a greater portion of them would inform other villagers so that they could tackle the attacking debris flows and protect their farmlands together. Moreover, it is easier to inform other villagers in a compact accommodation area. These explanations, however, should only apply to Wenchuan because the houses and farmlands of the Pingwu respondents were

more scattered, leading to different disaster responses. There is no statistically significant relation between occupation after earthquake and disaster response in Pingwu at all.

Perception of substantial debris flow (Wenchuan)

Survey results show that those Wenchuan respondents who perceived substantial debris flow would take the lives of cattle, destroy farmland or cause road congestion were more likely to evacuate when see debris flow signs at home. This might because they would find themselves more susceptible under such circumstances. This tends to follow MOVE framework's suggestion that susceptibility is indicated by the expected economic loss to be caused by disasters (Vinchon *et al.* 2011).

On the other hand, those who strongly disagreed or disagreed with such substantial debris flow impacts could find themselves less susceptible and were more likely to stay or take refuge at home, or even to inform others.

Three aspects of perception of substantial debris flow profile were related to and could cause three different major anticipated debris flow response regularities of the Wenchuan respondents (Table 6.5).

Table 6.5

Relations between perception of substantial debris flow and anticipated disaster responses among Wenchuan respondents

	Three major anticipated behavioural responses of Wenchuan respondents when they see signs of debris flow at home		
Perception of substantial debris flow	**More likely to run, escape or evacuate**	**More likely to stay or take refuge at home, take care of home, impose risk reduction measures or observe**	**More likely to inform family members, authorities or others**
Can take the lives of cattle	Agreed/ Strongly agreed	Disagreed/ Strongly disagreed	Disagreed/ Strongly disagreed
Can destroy farmland	Agreed/ Strongly agreed	Disagreed/ Strongly disagreed	Neutral
Can cause road congestion	Agreed/ Strongly agreed	Disagreed/ Strongly disagreed	Disagreed/ Strongly disagreed

Extracted from Table 6.4.

Explanations and Discussions on the regularities

For those respondents who probably thought that substantial debris flow is destructive, the best thing to do when see debris flow signs is to flee.

Those who perceived substantial debris flow can take the lives of cattle would prefer to evacuate as soon as possible might be because if the debris flow hit is strong enough to take the lives of cattle, they could not manage to escape if they do not flee in the first place.

Some farmlands of the Wenchuan respondents were nearby their houses. If they perceived their farmlands could be destroyed by substantial debris flow, they themselves would also be at risk if they stay at home. Therefore they would rather evacuate soonest as well.

In China, there is a long history of huge-scale landslides interrupting traffic (Li 1994). In Wenchuan, those who perceived substantial debris flow can cause road congestion would prefer to evacuate as soon as possible. This is probably because if they do not flee in the first place, once the roads are blocked, they could no longer escape and would be stuck at home.

Those who did not perceive substantial debris flow can take the lives of cattle or destroy farmland would be more likely to think that substantial debris flow was less threatening. Even when they see debris flow signs, it would still be safe to stay at home, to impose risk reduction measures to protect their cattle or farmland or to observe the situation. Those who did not perceive substantial debris flow can cause road congestion might think their houses would still be accessible even if they stay at home because the roads are not blocked.

Some others who did not perceive substantial debris flow can take the lives of cattle or can cause road congestion, or those who were neutral about whether farmland can be destroyed were more likely to inform others when see debris flow signs at home. This indicates that although they believed substantial debris flow was not threatening so there is no need to flee in the first place, informing others about the

geohazard attack is still necessary, and they would be able and willing to spend time to inform others during emergencies.

Perception of remoteness of home (Wenchuan)

Those Wenchuan respondents who perceived their homes remote were much less likely to stay or take refuge at home when see debris flow signs at home. They were slightly more likely to inform others when compared to those who perceived their homes not remote.

They might think that debris flow hit would put them at higher risk because they might not be easily reached by others like the rescues. Communications with the outside world would also be easily disrupted. Staying or taking refuge at a remote home is certainly not a good choice. They would prefer informing other villagers during emergencies probably because helping each other in a remote neighbourhood is crucial to save lives during emergencies. In contrary, those who perceived their homes not remote might think it is safe to stay at home or to observe first because even if they later find themselves at risk, they can still escape or seek help. Hence they were more likely to stay home when compared to those who perceived their homes remote.

In Pingwu, no relationship was found between remoteness perception and disaster response.

Awareness of government disaster mitigation (engineering) measures (Wenchuan)

Governmental or institutional disaster risk reduction measures can be imposed on many forms which can have different impacts on disaster response. Even the same form of government measure can lead to different behaviour in different places and on different individuals, leading to variations in vulnerability. The impact of government on disaster vulnerability was addressed by vulnerability models. The MOVE framework suggested that institution is one of the key components of susceptibility, together with economic, physical, cultural and environmental dimensions (Vinchon *et al.* 2011).

In Wenchuan, those who were aware of the introduction of certain government disaster mitigation (engineering) measures in their communities were more likely to inform others or simply stay at home when they see signs of debris flow at home than those who were unaware of.

Those who were unaware of the existence of such measures were more likely to evacuate than the aware group. It was probably because they had no idea about the availability of protection provided by the engineering structures. Therefore when they see signs of debris flow at home, they would be more likely to flee in the first place. However, those who were aware of the existence of certain geotechnical measure in their communities would believe that they were protected and safe, hence it is less urgent for them to escape. As a result, they would be less likely to evacuate but rather choose to inform others or take refuge at home.

On 20 August 2019, Wenchuan County was seriously affected by heavy rain. Nine debris flows induced by this “8.20” heavy rain incident were investigated (SKLGP 2019). It was found that only three debris flows occurred in areas with large earthquake-induced material sources and frequent debris flow. This suggested that the debris flow mitigation treatments imposed on the sites had performed well and protected the residents during the heavy rain. In such case, imposition of geotechnical mitigation measures served as an intervention tool in alleviating vulnerability as suggested by the BBC framework (Birkmann and Wisner 2006). However, since there were more occurrence of debris flows after the Wenchuan earthquake and carried huge amount of materials deposited on the dams, a number of studies found that some of the structures failed and were damaged (Wang, Qi and Wang 2012; Chen *et al.* 2015).

This means if the structural measures can perform properly, even if the villagers choose to inform others or simply stay at home rather than evacuate when debris flow strike, they would still be protected. However, if the geotechnical measures are damaged and could not perform their protection function, the respondents’ non-evacuation response might put them in danger.

Government disaster preparedness measures

Survey results show that in both Pingwu and Wenchuan, respondents' awareness of government disaster preparedness measures was associated with their anticipated disaster responses. This echoes another study on Sichuan which showed that rural residents who were aware of public disaster preparedness, including government preparedness, would put more efforts in family disaster preparation (Du *et al.* 2016). However, the specific types of government disaster preparedness measure that could be influential in the two counties were totally different. The four variables related to how Pingwu respondents would behave when see debris flow signs were totally varied from the two variables in Wenchuan.

Awareness of four government disaster preparedness measures (Pingwu)

Pingwu respondents' awareness of or accessed to four disaster preparedness measures slightly or moderately associated with their anticipated debris flow response at home. Three sets of regularities in terms of knowing such four measures could contribute to three major anticipated responses. Table 6.6 summarises the three sets of profile.

Table 6.6

Relations between disaster preparedness measures awareness or accessibility and anticipated disaster responses among Pingwu respondents

	Three major anticipated behavioural responses of Pingwu respondents when they see signs of debris flow at home		
Disaster preparedness measures	**More likely to run, escape or evacuate**	**More likely to stay or take refuge at home, take care of home, impose risk reduction measures or observe**	**More likely to inform family members, authorities or others**
3a. Assessment on protection against debris flow strike in community	Not aware of	Aware of	Aware of
4. Accessibility to any information on protective measures against general debris flow hit	Not accessed	Not accessed	Accessed
5. Heard of Mass Monitoring and Mass Prevention	Heard of	Not heard of	Heard of
6a. Plan/ Measure imposed on community to protect residents from debris flow strike	Not aware of	Not aware of	Aware of

Extracted from Table 6.4.

Explanations and Discussions on the regularities

Those Pingwu respondents who were unaware of any assessment on protection against debris flow hit in the community had no idea about the protection available. Therefore when they see signs of debris flow at home, they would be more inclined to flee in the first place. However, those who were aware certain such assessment might believe that they are protected, hence they would be less likely to escape but rather choose to inform others.

Similarly, those who had not accessed any information on debris flow protective measures or were unaware of any community plan or measure to protect residents from debris flow strike, had no idea about what protective measures were available. They might simply think they were not protected from debris flow at all. Therefore when see signs of debris flow at home, they would be more likely to actively flee or have another apparently opposite while passive response: stay or take refuge at home in the first place.

In contrast, those who had accessed certain information on protective measures against general debris flow hit or were aware of such plan or measure might believe there were some general protection available in their place, they would be protected from debris flow and this could strengthen their coping capacities. Information access was not only relevant for disaster response (Lestari *et al.* 2021), but could also be considered as a coping capacity in alleviating vulnerability as noted in the BBC framework (Bogardi and Birkmann 2004; Cardona 1999). In such case, escape might not be of utmost important when debris flows hit. The respondents could instead spare efforts to inform others. Yet they only knew that there were certain measures that could protect in general situations or in the community but might not be able to protect their homes in particular, therefore they would not be likely to take refuge at home.

This explanation echoes the goal of the government and has policy implications. In terms of disaster preparedness, government of Mianyang City which administers Pingwu County indicated that they would develop websites, as well as radio and television broadcasting platforms, to promote information on disaster reduction and earthquake prevention, aiming to enhance disaster knowledge of residents (SEA

2019). As Slovic (1986) suggested, those in charge of information dissemination could influence people's behaviour. If more efforts and resources can be put into those measures, more people can access accurate risk information, so that flee would not be their only choice when they see debris flow signs. The residents can apply their disaster knowledge to assess the debris flow strike scenario before they make the most appropriate response, including inform other people and the authorities, so more lives can be saved.

In terms of MMMP, those who had heard of it would probably understand the importance of team spirit and group effort in disaster prevention. Therefore if they see debris flow signs at home, they would be more likely to inform the authorities or others. An individual case study of Chongqing, a neighbouring city of Sichuan Province, preliminarily investigated how the MMMP system enhanced populations' flood prevention risk avoidance capability (Zhao *et al.* 2019). On the other hand, those who had not heard of MMMP had no idea about what kind of prevention support during debris flow hit would be available. Therefore they would be more likely to stay or take refuge at home than those who had heard of.

In short, those who might think they were not protected from debris flow at all would tend to believe staying at home is their best choice when debris flow hit. They would also be more likely to choose evacuation as their first action. However, fleeing could actually get them into danger rather than out of it in some scenarios. Those with better knowledge on community protective measures against debris flow would probably be more eager and capable to inform other villagers during emergencies.

Awareness of two government disaster preparedness measures (Wenchuan)

Wenchuan respondents' awareness of or accessed to two disaster preparedness measures slightly to moderately associated with their anticipated debris flow response at home. Three sets of regularities in terms of knowing those two measures were found relating to three major anticipated disaster responses. Table 6.7 summarises the three sets of profile.

Table 6.7

Relations between disaster preparedness measures awareness or accessibility and anticipated disaster responses among Wenchuan respondents

	Three major anticipated behavioural responses of Wenchuan respondents when they see signs of debris flow at home		
Disaster preparedness measures	**More likely to run, escape or evacuate**	**More likely to stay or take refuge at home, take care of home, impose risk reduction measures or observe**	**More likely to inform family members, authorities or others**
1a. Debris flow risk assessment in community	Not aware of	Not aware of	Aware of
2b. Accessibility to any information on community debris flow risk	Not accessed	Accessed	Accessed

Extracted from Table 6.4.

Explanations and Discussions on the regularities

Those Wenchuan respondents who were unaware of any assessment or had not accessed any information regarding community debris flow risk had no idea about what risk was faced by their communities and were unfamiliar with the risk level. Therefore when they see signs of debris flow at home, they could not judge the risk. It would be more secure for them to evacuate in the first place.

Some others who were unaware of any risk assessment might not be able to fully grasp the debris flow risk situation, hence believed that stay or take refuge at home would be their best choice. Those who had accessed concrete information regarding community debris flow risk might judge their homes were safe enough for taking refuge when debris flows hit. However, those who were aware of the conduct of certain community debris flow risk assessment might believe that when debris flow strike, the authorities should be able to keep the situation under control, meaning the residents would be safe. Therefore they would not need to evacuate but could inform others.

Some of those who had accessed certain information on community debris flow risk might have an idea about how risky their places were, hence escape might not be of utmost important, and many would rather spare efforts to inform others. They

might also think that they knew more risk information than others, hence would be more likely to share.

These outcomes reflected those with better knowledge on community debris flow risk are more eager and capable to inform other villagers in times of emergencies. As with the case of Pingwu, information access here in Wenchuan can be considered as a coping capacity in alleviating vulnerability as noted by the BBC framework (Bogardi and Birkmann 2004; Cardona 1999).

Summary of government disaster preparedness measures that could affect anticipated behaviour in both counties

Although the anticipated behaviour of respondents from Pingwu and Wenchuan were apparently affected by two different sets of government disaster preparedness measures, the relations between the preparedness measures and the responding behaviour of the two counties are similar.

In both study areas, villagers who had accessed certain debris flow related information, or were aware of certain assessments, plan or measure, were more likely to inform family members, authorities or others when they see signs of debris flow at home. Conversely, those who had not accessed such information, or were unaware of certain assessments, plan or measure, were more likely to run, escape or evacuate.

This means those who were more knowledgeable about government disaster preparedness measures were in general more likely to inform others. Those unfamiliar with such measures were more likely to flee. This is very reasonable because those who learnt more about what disaster preparedness measures the government had imposed to alleviate debris flow risk should be more prepared to tackle debris flow strike. They should be more capable to inform others about debris flow threats. Those who were unfamiliar with such government measures would be less prepared for debris flow hit, therefore many of them would simply flee when see signs of debris flow.

Government disaster response measures or facilities

Evacuation route (Pingwu and Wenchuan)

There was one government measure statistically significantly related to the anticipated disaster responses in both counties. It is the villagers' awareness of evacuation route in their respective communities.

Those who were unaware of any debris flow evacuation route in the community were more likely to evacuate when see debris flow signs at home. Those who were aware of were much more likely to inform others than the unaware group. In Pingwu in particular, a greater portion of respondents who were unaware of certain evacuation route would choose to stay at home than those aware of the route.

A possible explanation is that those Pingwu and Wenchuan respondents who were not aware of any evacuation route in the community had no idea about how and where to evacuate when debris flow hit. Therefore when they see debris flow signs at home, many would simply flee as soon as possible. Some Pingwu respondents are therefore also more likely to stay or take refuge at home.

For those Pingwu and Wenchuan villagers who were aware of certain evacuation route in the community, besides escape, they might think they would have sufficient time to inform others before they flee. By referring to Alexander's risk and vulnerability equation (1991a, 1991b), the better implementation of evacuation plan could be reflected in higher awareness of the evacuation route among the threatened villagers, which implied lower total risk, hence influenced their disaster response. That's why the residents in both counties could spare efforts to notify others about which route to take in order to save lives, hence less likely to escape in the first place. Moreover, since they knew the evacuation route, they would rather escape than stay at home when debris flow strike.

Moreover, survey results also show that Wenchuan respondents were relatively more aware of the existence of evacuation route in their communities. Slightly more than one-third (36.36%, 132/363) of them were aware of the existence of certain such route. This percentage is more than double of 16.04% (43/268) of Pingwu.

The MOVE framework suggested that susceptibility is indicated by the percentage of people who are able to evacuate (Vinchon *et al.* 2011). Survey findings might follow this suggestion. As a much higher percentage of Wenchuan respondents said they were aware of the existence of evacuation route in their communities when compared to their Pingwu counterparts, the Wenchuan respondents should be relatively more able to escape using the evacuation route, and should be less susceptible.

The relatively high awareness of evacuation route among the Wenchuan respondents might have an institutional explanation. This involves the emphasis of evacuation route importance by the local government. In the chapter introducing the case study areas, it was noted that the information of evacuation route was added into Wolong Township Government's Geohazard Prevention Plan since 2016. Basically for each geohazard sites, specific evacuation route was briefly described (Wolong Township Government 2016d). This unique content should help explain that a better evacuation planning could affect public's disaster response behaviour.

In addition, signage of evacuation routes with simple diagrams were posted in prominent places where there were debris flow risks. The Wenchuan residents nearby the risk sites could access the proposed evacuation routes information easily, hence could contribute to their higher awareness of such routes.

Awareness of four other government disaster response measures or facilities (Pingwu)

Apart from evacuation route, Pingwu respondents' awareness of the introduction of another four government disaster response measures or facilities slightly or moderately related to their anticipated disaster responses when they see debris flow signs at home.

Three sets of regularities in terms of disaster response measures awareness or accessibility were found relating to the three major anticipated behaviour in Pingwu. Table 6.8 summarises the three sets of profile.

Table 6.8

Relations between disaster response measures awareness or accessibility and anticipated behaviour among Pingwu respondents

	Three major anticipated behavioural responses of Pingwu respondents when they see signs of debris flow at home		
Disaster response measures or facilities	**More likely to run, escape or evacuate**	**More likely to stay or take refuge at home, take care of home, impose risk reduction measures or observe**	**More likely to inform family members, authorities or others**
3a. Accessibility to any information/ instruction on appropriate response when hit by debris flow	Not accessed	Not accessed	Accessed
5a. Heard of monitoring personnel	Not heard of (slightly)	Not heard of	Heard of
6. Emergency response facilities a. Evacuation route	Not aware of	Not aware of	Aware of
6. Emergency response facilities b. Emergency shelter	Not aware of	Not aware of (slightly)	Aware of
7. Emergency response dissemination c. Drill	Not heard of	Not heard of	Heard of

Extracted from Table 6.4.

Explanations and Discussions on the regularities

When see debris flow signs at home, those who had not accessed any information or instruction on appropriate response had no idea about what to do. Similarly, those who were unaware of any emergency shelter location or had not heard of community geohazard drill probably had no idea about where to go or how to respond. Those who had not heard of monitoring personnel would not know that someone could help them when debris flows hit. Therefore the general anticipated response or reflexive action of these groups of people was to flee in the first place. However, their choice might actually get them into danger rather than out of it.

Some other residents of these groups would take refuge or stay at home, take care of home, impose risk reduction measures or observe, especially those who were unaware of emergency shelter location. They probably did not have any knowledge on how to respond at all and believed staying at home could be their best choice.

Many of those who had not heard of monitoring personnel would rely on themselves, hence would also choose to stay at home.

On the other hand, those who had accessed certain information or instruction on appropriate debris flow response probably had stronger coping capacities. Besides able to take care of themselves, they anticipated they would also be capable to inform others. Hence some of them would be less likely to escape in the first place. They might also learn that taking refuge at home is not a good choice to avoid risk in some scenarios when debris flows hit.

Those who had heard of monitoring personnel or drill might understand that contact or report to the assigned personnel is important. Hence they would be more likely to inform the authorities or others if the situation allows. The emergency shelter location aware group might think they have sufficient time to inform others before they themselves evacuate to the shelter, hence they would be less likely to escape immediately when debris flow hit.

In short, those with better knowledge on community debris flow disaster response measures or facilities could be more eager and capable to inform other villagers in times of emergencies. This Pingwu result again echoes the BBC framework (Bogardi and Birkmann 2004; Cardona 1999) which considered information access as a coping capacity to alleviate vulnerability. The gap between disaster risk reduction knowledge and behaviour noted in other scenarios (Nakano and Yamori 2021) seemed did not exist in Pingwu.

Such results in Pingwu could be attributed to government efforts. Mianyang City, in which the county is affiliated to, emphasised the promotion and education of disaster reduction (SEA 2019). It stressed the need to carry out different emergency response and risk avoidance drills, particularly on special dates like the Disaster Prevention and Reduction Day or during the Science and Technology Activity Week. All these could help strengthen the disaster coping capacities of Pingwu residents.

In fact, dissemination of information regarding government disaster response measures or facilities in the study areas could be considered as informal or public education. Apart from formal education, informal or public education specifying on disaster response should be equally important because it can affect disaster response decision (Nielsen and Lidstone 1998; Shaw *et al.* 2011).

Awareness of five other government disaster response measures or facilities (Wenchuan)

In the three Wenchuan villages studied, besides evacuation route, the respondents' awareness of another five respective government disaster response measures were slightly or moderately related to their anticipated behaviour when they see debris flow signs at home. Three sets of regularities in terms of disaster response measures or facility awareness associated with three major anticipated behaviour were found. Table 6.9 summarises the three sets of profile.

Table 6.9

Relations between disaster response measures awareness or accessibility and anticipated behaviour among Wenchuan respondents

	Three major anticipated behavioural responses of Wenchuan respondents when they see signs of debris flow at home		
Disaster response measures or facilities	**More likely to run, escape or evacuate**	**More likely to stay or take refuge at home, take care of home, impose risk reduction measures or observe**	**More likely to inform family members, authorities or others**
3b. Accessibility to booklet on appropriate response when hit by debris flow	Not accessed	Accessed	Accessed
3c. Accessibility to card/ table on appropriate response when hit by debris flow	Not accessed	Not accessed (slightly)	Accessed
4. Early warning a. Website	Not aware of	Not aware of	Aware of
4. Early warning e. Shout	Not aware of	Aware of	Aware of
5. Monitoring personnel b. Respondent	No	Yes (slightly)	Yes
6. Emergency response facilities a. Evacuation route	Not aware of	Not aware of (slightly)	Aware of

Extracted from Table 6.4.

Explanations and Discussions on the regularities

Those who had not accessed booklet, Card or Table telling appropriate debris flow response probably had no idea about what to do when encounter the hazard. Therefore many would simply flee in the first place. However, those who had accessed such booklets, Cards or Tables might learn that inform others is important, hence they would be less likely to escape.

In particular, those who had accessed such booklets would be more likely to stay at home when they see debris flow signs. This could be because the booklets have provided them with information regarding a choice of taking refuge at home in certain scenarios.

When referring to vulnerability models, the MOVE framework suggested that in what ways the government provides disaster information would affect people's coping capacity (Vinchon *et al.* 2011). Here in Wenchuan, survey results echo that disseminating debris flow information through booklets, cards or tables, with information telling the appropriate debris flow response, could indeed enhance rural residents' coping capacities. By receiving such material, apart from taking care of themselves by evacuating, some villagers were also capable of alerting others during disasters. As in Pingwu, those with better knowledge on community debris flow disaster response measures were more eager and capable to inform other villagers during emergencies.

As for early warning**,** previous comparison of different early warning systems or tools is rare (Corral *et al.* 2019; Cepeda *et al.* 2020; Huang *et al.* 2020). Analysis of the effectiveness of different early warning tools in affecting disaster response is particularly lack of.

By studying the application of various geohazards early warning tools in Sichuan, this study addresses these two questions based on the Chinese experience and fills in some empirical and theoretical gaps. First, it targets and compares five early warning tools reachable by rural villagers in their daily lives. Secondly, possible impacts of the five tools on disaster responses are analysed.

Although previous studies found that different warning methods might contribute to variation in disaster response (Mileti and Peek 2000; Rahayu *et al.* 2020), this research reveals that in Wenchuan, respondents who were aware of two different types of debris flow early warning tool, namely website or shout, were both more likely to inform others when see debris flow signs. Conversely, those who were unaware of website or shout consistently tended to evacuate. They were probably unable to receive debris flow risk information and early warning alert delivered by such online channel or traditional format when debris flows hit. Many would have no official reference to take, hence have no idea on how to respond. Therefore they would probably made their own judgement and more likely to simply flee as soon as possible.

Those who were aware of website as an early warning tool might share the latest and the least accessed debris flow information from the website with other villagers, meaning they would be more likely to inform others. Similarly, those who were aware of shout might help forward the shout message and inform those who could not hear the shout early warning. In such cases, early warning tools in the form of website and shout probably served as interventions in alleviating vulnerability as noted in the BBC framework (Birkmann and Wisner 2006). However, such positive impact of early warning tools awareness on active disaster response was not find in an urban setting (Yik *et al.* 2023).

In addition, some of those who were unaware of website might think that simply take refuge at home is also a good choice. Those who were aware of shout as an early warning tool might estimate their risk level based on the shout message and then more likely to stay at home.

Apart from early warning tools, the contents of information delivered through such hardware to those in need and at risk that could guide them to respond and protect themselves are also important (Tian *et al.* 2019). Future studies can further explore this aspect.

As for monitoring, the non-monitoring personnel should be relatively less informed and less knowledgeable on how to respond to debris flow hit. Therefore when they

see debris flow signs at home, they would be much more likely to simply escape. Yet their choice of flee might actually get them into danger rather than out of it.

In contrast, the monitoring personnel should be more capable to deal with debris flow, hence would be much more likely to inform their family members and others. It is also their responsibility to report to the officials when they see debris flow signs, therefore they would be much more likely to inform the authorities.

Summary of government disaster response measures that could affect anticipated behaviour in both counties

Although the anticipated behaviour of respondents from Pingwu and Wenchuan were apparently affected by two different sets of government disaster response measures and facilities, there are two common relations between the disaster response measures or facilities on one hand, and the responding behaviour on the other.

In the two study areas, villagers who had accessed certain disaster information, were aware of certain early warning tools or emergency response facilities, had heard of or were monitoring personnel, or had heard of certain emergency response dissemination, were more likely to inform family members, authorities or others when they see debris flow signs at home. In contrast, those who had not accessed such information, were unaware of certain early warning tools or emergency response facilities, had not heard of or not being monitoring personnel, or not heard of certain emergency response dissemination, were more likely to run, escape or evacuate.

This means those who were more knowledgeable about various government disaster response measures or facilities were in general more likely to inform others. This is very reasonable because those who learnt more about what disaster response measures or facilities the government had imposed to alleviate debris flow risk should be more prepared to tackle debris flow strike. They should be more capable to inform others about the debris flow threats.

Conversely, those who were unfamiliar with such government measures or facilities were more likely to flee because they would be less prepared for debris flow hit, and many of them would simply escape when facing the disaster.

6.3.4 Conclusions of Hypothesis 3 discussion

This research shows that in Pingwu and Wenchuan, respondents' anticipated behaviour when see signs of debris flow at home could be affected by respective demographic and non-demographic characteristics, as well as government disaster risk reduction measures. Despite the great disparities between Pingwu and Wenchuan in terms of the possible contribution of government disaster risk reduction measures on anticipated behavioural responses, it is generally found that, those who had accessed information on, or were aware of, certain government disaster risk reduction measure, were more likely to inform others about the attack of debris flow. Those who had not accessed information on, or were not aware of, such measures, were more likely to evacuate when see signs of the hazard.

In both counties, those respondents with better knowledge on debris flow in general, including its risk, protective measures, response measures or facilities imposed on their communities would be more eager and capable to inform other villagers in times of emergencies.

In particular, two variables appeared to affect anticipated disaster response in both study areas. They are respondents' role in village and their awareness of evacuation route in their places. Both are closely related to information access. As mentioned above, those who performed certain role in village were supposed to access more information related to disaster risk and risk reduction. Awareness of evacuation route also involve information access.

Information access is considered as a coping capacity in alleviating vulnerability in the BBC framework (Bogardi and Birkmann 2004; Cardona 1999). The MOVE framework also suggested that how the government provides disaster information would affect people's coping capacity (Vinchon *et al.* 2011). Part of the findings of this research supports these models. The significance of information access on anticipated disaster response is specified in five situations in this study. These

include accessibility to information in Pingwu: on debris flow protective measures and on appropriate debris flow response as well as accessibility to information in Wenchuan: on community debris flow risk and on appropriate debris flow response disseminated by booklet and Card. Most importantly, these findings contribute to the understanding of the specific kinds of government information access that could affect rural residents' coping capacities as reflected by their disaster response in the China context.

Chapter 7
Conclusions

This thesis investigates the post-2008 Wenchuan earthquake debris flow risk and subsequent directives, mitigation, preparedness and response measures introduced by the Chinese government. It evaluates the impact and the effectiveness of such disaster risk reduction measures by analysing their relations with relocation decisions, debris flow risk perceptions and anticipated disaster responses of the affected populations. The focus is on rural remote mountainous areas where secondary geohazard risks are tolerable but need to be managed after the quake. Besides governmental measures, the influences of vulnerability dimensions on residents' relocation, perception and disaster responses are explored. Variation in space are revealed by comparing two Sichuan counties: Pingwu and Wenchuan.

Both counties studied in this thesis, Pingwu and Wenchuan, are economically backward when compared with many other parts of China and the developed world. The populations in these two rural places have been exposed to various types of earthquake-induced geohazards, including debris flow. Many of them were elderly or female farmers who rely on farming to earn their living. They and even their communities have a higher economic, and particularly microeconomic, vulnerability as described by Birkmann (2013).

After the Wenchuan earthquake, the Chinese government took a proactive and leading role in disaster relief, recovery and rehabilitation, aiming at alleviating disaster risks and reduce vulnerability of her people.

With the numerous post-earthquake mass movements, land resources have become more limited and precious in the earthquake-affected mountainous regions. Securing the residents with land resources entitlement for accommodation and livelihood in areas with low geohazard risk has been a major goal of the government to alleviate the people's environmental vulnerability.

Introduction of new directives, imposition of various structural mitigation measures, as well as application of disaster preparedness and response training and promotion to reduce disaster risks, have been some of the major works of the authorities to enhance capability in tackling geohazards. During the recovery process, as noted by Alexander (2012b), participation and involvement of the people are crucial. This thesis therefore, targets the affected rural populations and evaluates the effectiveness of various government risk reduction efforts.

Both Pingwu and Wenchuan lie on the two ends of Yingxiu-Beichuan Fault of Longmenshan Fault Zone which movement had caused the Wenchuan earthquake (Wen 2011) and experienced the highest earthquake intensity (CSI 2008). However, these two study areas used for comparison vary in terms of socioeconomic conditions and disaster loss, with Pingwu much backward economically at all the county, village and individual levels than Wenchuan. Such comparison provides inspiration on two different remote China contexts affected by post-earthquake geohazards, so policymakers may plan and introduce appropriate policies and measures tailor-made for regions with different situations to tackle geohazard risk in the future.

This chapter concludes the effectiveness of government measures through the investigation of post-earthquake relocation decisions, risk perceptions and anticipated disaster responses. It explores the applicability of existing vulnerability indicators and other factors on the choices of the rural residents. With the light of these findings, implications for debris flow risk reduction is discussed and a new model is developed. Recommendations are provided. Finally, it addresses the scope and constraints of the research and offers insights for future studies.

7.1 Relocation decisions

The first hypothesis states that *"After the Wenchuan earthquake, among the rural populations there was a lack of consideration with institutional directives and disaster risk reduction measures when making relocation decisions."* It refers to conditions during the eight years that elapsed between the earthquake and the time of the survey. It is rejected in Wenchuan.

This research reveals that the driving forces that in combination created this situation of inertia were mainly ethnical, cultural, geographical, in supplement with socioeconomic, personal competency and political.

A total of three factors could explain relocation decisions of respondents from both study areas. Ethnicity is the only demographic variable involved. As for the five non-demographic constructs developed to test Hypothesis 1, cultural factors as well as exposure and susceptibility influenced residents' moving decisions in both counties.

Some other factors only associated with respondents' moving decision in one study area but not the other. Education, occupation, length of stay and individual competencies were possibly influential in Pingwu only, while respondents' coping capacities influenced by government was only impactful in Wenchuan.

When looking into the two counties separately, Pingwu respondent's post-earthquake relocation decision were possibly affected by four demographic and three non-demographic variables.

The Qiangs, the non-farmers, the higher educated ones or those who stayed in the community for a shorter period per year were more likely to move. Those more considered about their hazard exposure and susceptibility, less concerned about cultural, historical and social cohesion, family, ethnical or neighbourhood affiliation, or personal competencies were also more likely to relocate.

In contrast, the Hans, the farmers, the less educated or those residing in the community for a longer period of time per year were more likely to stay in their original place. Those less considered about their hazard exposure and susceptibility, but more concerned about cultural, social and family cohesion, or personal competencies were also more likely to stay.

In Wenchuan, respondents' relocation decisions were probably affected by fewer factors than Pingwu. One demographic and three non-demographic variables could be influential.

The Qiangs, those more considered about their hazard exposure and susceptibility or less cared about cultural, social and family affiliation were more likely to move. Those who considered more about geological risk avoidance coping capacities influenced by government in the new residing place were also more likely to relocate.

On the contrary, those more considered about cultural, social and family cohesion but less considered about their hazard exposure and susceptibility or government-impacted coping capacities in the new residing place were more likely to remain in their original location.

7.2 Debris flow risk perceptions

The second hypothesis of this research states that *"The rural populations living in remote mountainous areas have developed perceptions of geological risk that are now generally more advanced than the measures for disaster mitigation, preparedness and response imposed by the government since the earthquake."* This hypothesis is accepted in both study areas.

Risk perceptions of the rural respondents exposed to debris flow risk were found not only possibly influenced by their awareness of several government disaster risk reduction measures, but also likely to depend on vulnerability indicators like ethnicity, village affiliation, debris flow experience and perception of substantial debris flow.

Among the 46 selected sub-variables grouped under nine independent factors (I to IX), 12 and eight were found having statistical significant influence on Pingwu and Wenchuan respondents' debris flow risk perception respectively.

There are five common factors in Pingwu and Wenchuan. The awareness of using gong as an early warning tool is the only government measure appeared to be impactful in both places. On top of this, a demographic factor, ethnicity, is statistically significantly associated with risk perception in both study areas. Three non-governmental and non-demographic variables, namely village affiliation, experience of debris flow and perception of substantial debris flow, could also affect respondents' risk perception in both counties.

It is not surprising, however, differences also existed between the two counties. Inter-county comparison found that respondents from the two places had different debris flow risk perception which were related to differences in the awareness of disaster mitigation, preparedness or response measures or other factors. Four government measures, including geotechnical engineering measures and three early warning tools were impactful only in Pingwu. In Wenchuan, half of the eight statistical significant sub-variables are government measures, including three that were unique to Wenchuan. They are residents' awareness of MMMP and Card/ Table, as well as whether the respondents themselves were monitoring personnel.

Moreover, two demographic factors, age and occupation after the quake, as well as one non-demographic factor, namely perception of community remoteness were influential on debris flow risk perception only in Pingwu.

When look into the two counties separately in more detail, the survey reveals that in Pingwu, those aged 65 or above, non-farmers, the Qiangs or those who did not perceive their communities as remote had lower debris flow risk perception. Niufei villagers or those with no debris flow experience or perceived substantial debris flow less dangerous were more inclined to perceive lower debris flow risk as well.

With regard to government measures, those Pingwu respondents who were aware of geotechnical mitigation measures perceived lower risk. Awareness of four community early warning tools, namely website, phone, shout and gong, as different forms of government disaster response measures or facilities, caused higher risk perception.

In Wenchuan, the Hans were more likely to have higher debris flow risk perception. Xingfu villagers, those with no debris flow experience or perceived substantial debris flow less dangerous perceived lower debris flow risk.

In terms of government disaster preparedness measures, those who had heard of MMMP were more likely to perceive higher debris flow risk. As for disaster response measures, those had accessed government information card or table or aware of gong as an early warning tool, or the monitoring personnel perceived higher debris flow risk.

Despite all these findings, however, there is a possible perception gap between intuition and objective reality. Intuition may cause inaccurate picture of the situation while government measures involve expert judgement.

7.3 Anticipated disaster responses

The third hypothesis states that *"Disaster response behaviour of the rural populations living in remote mountainous regions of Sichuan is affected by their awareness of government disaster risk reduction measures."* "Disaster response" here means what the respondents' anticipated behaviour in the first place when they see debris flow signs at home in the future. This reflects their readiness and ability to respond to an event if it occurs.

The government had imposed a wide range of disaster risk reduction measures tending to influence, change or shape rural residents' future disaster responses. With reference to the survey results, impacts of such measures on Pingwu and Wenchuan respondents' anticipated behavioural responses implied that Hypothesis 3 is accepted in both scenarios. However, besides government measures, anticipated disaster behaviour of the respondents of the two areas were also related to demographic and other factors.

In both counties, a total of ten independent variables categorised as I to X with 54 sub-variables were tested to determine if they are associated with the anticipated behaviour when see debris flow signs at home.

Three and six independent variables, including 11 and 15 sub-variables were found to be statistically significantly associated with and would influence Pingwu and Wenchuan respondents' preparedness for debris flow response respectively.

Three sets of demographic, non-demographic and government risk reduction measures regularities that would contribute to the three major anticipated behavioural responses in the two counties respectively are revealed.

Among the various government measures or facilities, only one, namely awareness of evacuation route, was influential in both counties. Other effective government measures only impacted anticipated disaster responses of either county. In other words, the government measures that could affect the two counties were very different.

In both counties, those who were aware of the evacuation route would be more likely to inform others while the unaware group would tend to take either one of the two opposite actions -- run or take refuge at home.

Awareness of engineering measures could affect anticipated disaster responses in Wenchuan only. The aware group would be more likely to stay at home or inform others while the unaware ones would tend to evacuate. In Pingwu, there is no evidence that geotechnical measures awareness might influence disaster response.

For disaster preparedness, the four measures that would affect Pingwu respondents' anticipated disaster behaviour were totally different from the two impactful factors in Wenchuan.

Those who had accessed information on protective measures against debris flow hit, or were aware of MMMP, community assessment, plan or measure to protect residents from debris flow, would be more likely to inform others in Pingwu only. In Wenchuan, however, those who would tend to inform others were aware of the

assessment or had accessed information on community debris flow risk. The unaware or the non-accessed groups would tend to evacuate.

For government disaster response measures or facilities, besides evacuation route awareness that would be influential in both Pingwu and Wenchuan, anticipated behaviour in the two counties would probably be affected by totally different measures.

Awareness of or accessibility to four measures or facilities would be influential in Pingwu only. In Pingwu, those who had accessed information or instruction on appropriate debris flow response, had heard of monitoring personnel or drill, or were aware of emergency shelter, would be more likely to inform others. Others would tend to either evacuate or stay.

Wenchuan respondents' future behaviour were found related to another five disaster response measures or facilities. Those who had accessed booklet, card or table on appropriate debris flow response, were aware of early warning website or shouting, or the monitoring personnel, would tend to inform others. Others would tend to escape. However, apart from government measures, anticipated debris flow responses could also be influenced by non-governmental factors.

The role of a person in their village, in particular, was influential in both counties. Those who served certain village position would be more likely to inform people while others would be more likely to either run or stay at home. However, two demographic factors, age and post-earthquake occupation, would probably affect anticipated disaster response in either county only. In Pingwu, the younger adults aged 18 to 64 would be more likely to inform others or stay at home while the elderly aged 65 or above would tend to escape. In Wenchuan, the non-farmers would be more likely to take either run or stay, whereas the farmers would tend to inform others.

Non-demographic and non-governmental factors would influence future disaster response behaviour in Wenchuan only. Those who agreed or strongly perceived that substantial debris flow can take lives of cattle, destroy farmland or cause road

congestion, would be more likely to evacuate. Those disagreed or strongly disagreed with these three aspects or did not perceive their homes remote tended to stay at home. Those perceived their homes remote would tend to inform others.

7.4 Implications for debris flow risk reduction and model development

7.4.1 Impact on vulnerability study

Most of the current influential vulnerability models focused on what factors and how such factors contributed to vulnerability. Detailed relations between a series of government disaster risk reduction measures on one hand, and relocation decisions, risk perceptions and disaster responses on the other, are seldom addressed.

By testing the three hypotheses in Pingwu and Wenchuan, the applicability of the selected vulnerability indicators of the existing models is explored and examined. An all-rounded understanding of the effectiveness of a combination of government disaster risk reduction measures, together with economic, social, cultural and other factors, in relation to debris flow threatened populations' relocation decisions (Hypothesis 1), risk perceptions levels (Hypothesis 2) and yielding various disaster responses (Hypothesis 3) is revealed and explained. Relations among the variables are evaluated and regularities are found out.

Through this thesis, advances in theoretical understanding of vulnerability are achieved in two dimensions. First, the vulnerability indicators mentioned in existing models can only partially explain the post-Wenchuan earthquake relocation decisions, risk perceptions and disaster responses. Some indicators do not apply at all. Secondly, besides the existing vulnerability indicators, there are other factors in this research that can provide insights to future studies.

According to previous vulnerability models, socioeconomic characteristic is a major aspect leading to vulnerability (BBC by Bogardi and Birkmann 2004 and Cardona 1999; HOP by Cutter and Solecki 1989; PAR by Blaikie *et al.* 1994 and Wisner *et al.* 2004; MOVE by Vinchon *et al.* 2011). However, not all socioeconomic variables

mentioned in these models can be applied to the post-Wenchuan earthquake situation.

For instance, gender and age are two major vulnerability indicators in HOP (Cutter *et al.* 2000*,* 2003). But this thesis reveals no statistical significant relation between gender and post-Wenchuan earthquake relocation decisions, debris flow risk perceptions as well as disaster responses at all. These findings are inconsistent with a vast number of literatures which addressed similar topics.

Although this study finds that age was associated with both risk perceptions and disaster responses, which probably influenced vulnerability, these occurred in Pingwu only. These also do not align with the findings of many other previous literatures. Moreover, the results of this study do not echo the PAR model, the MOVE framework and some previous research which established the impacts of income (Tian *et al*. 2014; Fernandez *et al.* 2018; Morrow 1999) or household size (Fernandez *et al.* 2018) on vulnerability, relocation behaviour or risk perception. The findings in this thesis provide additional perspectives on social vulnerability.

7.4.2 This research thesis and a model to explain the China context

Based on this research on remote rural China, a new model that is capable in explaining the relations of government disaster risk reduction measures awareness, vulnerability indicators and other independent factors on one hand, and relocation decisions, risk perceptions and disaster responses on the other, is developed (Figure 7.1).

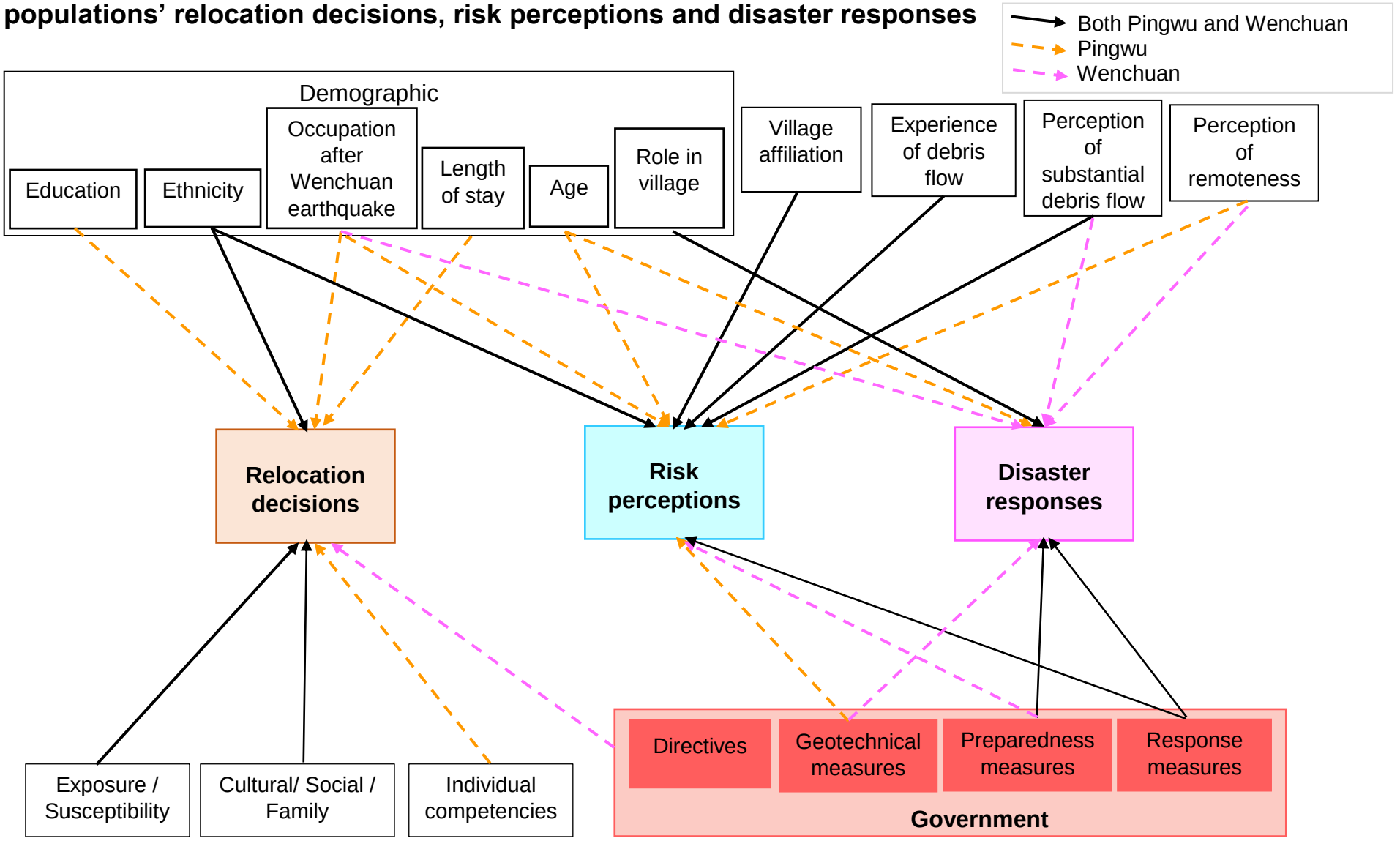
In terms of demographic factors, besides education, ethnicity, occupation and age which were commonly considered as vulnerability indicators in existing vulnerability models, this research finds that rural residents' length of stay in their communities and their role in their villages could also influence their relocation decisions and anticipated disaster responses respectively.

For factors affecting relocation decisions, besides risk exposure and susceptibility which were commonly referred to by existing models, this research also discovered

other influential factors. These involves a group of cultural, social and family factors and a particular set of individual competencies.

The key finding of this research concerns the impact of a series of government directives and measures on all three aspects of relocation decisions, risk perceptions and anticipated disaster responses. Although some of these institutional factors are influential on only one study area, the empirical results are already sufficient to tell the government measures were effective in influencing post-disaster actions and thoughts of the rural populations in Sichuan. Moreover, a number of non-demographic and non-governmental factors are also found to have possible contribution to risk perceptions and anticipated disaster responses in the two study areas on different levels. These factors are: village affiliation, experience of debris flow, perception of substantial debris flow, and perception of remoteness of the places where the rural residents were residing in.

Figure 7.1 A model on the impacts of government disaster risk reduction measures on rural populations' relocation decisions, risk perceptions and disaster responses



It is hoped that the empirical findings of this research and the new model created can contribute to the understanding of vulnerability in relation to effectiveness of government directives, disaster mitigation, preparedness and response measures, and be able to fill in some missing theoretical gaps. In practice, it is hoped that this model can be referenced or applied to other regions with similar contexts.

7.5 Recommendations

Relocation decisions, risk perceptions and anticipated disaster responses of the survey respondents in the two study areas were influenced by a wide range and different combinations of factors. As this study evaluates the effectiveness of government disaster risk reduction measures, this section proposes some key recommendations on refining the institutional initiatives and efforts, with focus on how to further influence risk perceptions and disaster responses that are crucial in reducing debris flow risk and alleviating vulnerability in the future.

7.5.1 Recommendations on influencing future risk perception and actual risk exposure

Debris flow engineering control

Awareness of government geotechnical mitigation engineering measures statistically significantly associated with debris flow risk perception among Pingwu respondents. Unawareness of such measures was significantly related to high risk perception. This implies if the existence of such measures can be made known to more Pingwu villagers, they might feel more protected from debris flow and have a higher sense of safeness about their communities.

Promoting the awareness of imposition of engineering measures is crucial. However, ensuring the quality of such geotechnical measures is of the same importance, and in fact, more important. If the residents are aware of the geotechnical measures but those measures could not actually protect them, their lower perceived risk might lead them to have insufficient disaster preparedness or inappropriate disaster response behaviour. Some technical studies on debris flows mitigation in China suggested different kinds of slope stabilisation, drainage, sediment blocking and dredging measures for controlling debris flows, evaluated their effectiveness and suggested the best practices (Wu *et al.* 2016). Optimising

the benefits of disaster mitigation facilities combinations based on debris flow simulations (Tian *et al.* 2022) and designing advanced debris flow mitigation system (Liu *et al.* 2013) were also proposed. Outside China, scholars also involved in designing check dams based on experimental findings (Armanini and Larcher 2001). These academic studies done in both the Chinese and international contexts should be seriously referred to by the Sichuan government and local authorities. By doing so, the actual risk, and probably the perceived risk as well, threatening the rural residents can be reduced.

Early warning

Several early warning tools were found related to debris flow perceptions in the two study areas. By further promote and refine the phone call or messaging system, and provide more gongs for risk sites, for example, more people can be aware of the debris flow risk threatening them. More disaster preparedness and response measures which would strengthen their coping capacities can therefore be introduced more easily.

Shout

For instance, those Pingwu respondents who were aware of the use of shout as a community early warning tool had a statistically significantly higher debris flow risk perception. The authorities could encourage more villagers to engage in such shouting when debris flow hit. By doing so, more residents could perceive the debris flow threatening them, hence facilitate the implementation of disaster preparedness and response measures.

Website

The government should invest more resources to refine, develop and promote a more accurate and precise geohazard official early warning website readable on mobile devices. Timely alerts on a county and even village or community level can be provided. More Chinese citizens and netizens, especially those living in debris flow risk areas, can therefore be more aware of the website service and be more informed about debris flow emergencies. By enhancing their risk perceptions through website awareness, they can better prepare themselves to tackle debris flow hit and reduce disaster risk.

Telephone

The government can make good use of the trends of increasing landline and mobile phones penetration rates in Sichuan to educate the public that debris flow early warning are to be issued through phone call or messaging. In particular, with the growing number of 4G and even 5G mobile phone users, the authorities can issue early warnings more timely and more precisely in terms of the location and scale of geohazard threats. References of other countries can be made. The USGS-led ShakeAlert system issues earthquake early warnings for the West Coast of the USA through mobile phones (USGS 2016), and the U.S. Federal Emergency Management Agency offers mobile apps to issue emergency alerts when tornado and flash floods are approaching (NWS 2022), are some of the examples. The Chinese government can also develop appropriate mobile apps to provide geohazard alerts for mobile phone users.

In parallel, through designing more audio-visual educational materials to teach the villagers via the phone on how to prepare and respond to debris flow, hopefully the perception of existing debris flow risk can be increased. Ultimately, disaster risk can be reduced.

Siren

Sirens are used not only as early warning tools in some places. Their multi-function might make them less effective in arousing debris flow risk awareness of villagers. Owing to insufficient resources, technology limitations or other reasons, it might be inevitable for the rural governments to use the same siren or loudspeaker machine to issue geohazard early warning and other community announcements. To avoid any confusion between early warning and other announcements, the government should clearly inform the villagers what is the sound and pattern of debris flow early warning. With such information disseminated in advance, once the villagers heard the designated siren sound, they will immediately learn that a debris flow is hitting the village. Different siren sounds or tones can be introduced to represent different types of geohazard or even other hazards. Different pitches can be used to represent different severe levels of a hazard. Such siren sound can be accompanied by verbal explanation on details of the debris flow, such as the location and scale. Emergency warning asking the villagers to evacuate can also be made through the siren and/or loudspeaker system.

Future studies can follow the direction of the Yunnan study by Huang *et al.* (2020) and this Sichuan research to investigate the awareness and performance of different types of early warning tools in different places. Although the results can be similar or different from the findings of Yunnan and Sichuan, the authorities can make reference and investigate the reasons behind and think about what they can do to refine their early warning systems to alleviate the risk of the rural populations.

In addition, to better protect the residents living in debris flow prone areas by enhancing their risk perception, the Chinese government can consider developing community emergency alert systems for the residents to sign up, like those provided by the Emergency Alert System (EAS) and National Oceanic and Atmospheric Administration (NOAA) Weather Radio in the USA. The authorities would call for evacuation when necessary (FEMA 2020).

7.5.2 Recommendations on influencing future disaster response behaviour

This research shows that government disaster risk reduction measures would impact respondents' anticipated disaster response behaviour. The two county governments can therefore put more efforts in promoting and disseminating the measures and facilities they introduced. By doing so, the debris flow affected populations can learn more about the appropriate responses in different debris flow hit scenarios, so as to change their future disaster response behaviour, reduce their risks and alleviate their vulnerability.

Recommendations on disaster preparedness information dissemination

This research finds that in Pingwu, those who had not accessed any disaster preparedness information on protective measures against debris flow hit were more likely to either run or stay at home when see debris flow signs at home, while those who had accessed were more likely to inform others. In Wenchuan, those who had not accessed to any information on community debris flow risk were more likely to escape while those who had accessed were more likely to stay or inform others.

The first thing governments should do is to visit the communities. The Pingwu authorities should evaluate whether any information on the protection of residents

from debris flow is available. The Wenchuan government should investigate whether any information on community debris flow risk is imposed.

If such disaster preparedness information is unavailable, the governments should introduce them as soon as possible. If it is available, the governments should reveal why some respondents were unaware of them. Was there an information delivery or communication problem? Or was the information too difficult for the villagers to understand? Pingwu and Wenchuan government should ensure the residents have access to comprehensive and update protection and risk information respectively. As geohazard situations might change over time, such information dissemination should be done regularly.

In this study, different villages and even different communities have varied surrounding geophysical environment and proximity to debris flow risk, and protected by different geotechnical measures, hence exposed differently to debris flow risk. If sufficient resources are available, local governments can tailor-make debris flow risk information for their respective residents based on their unique situations. Such information is not only be distributed to those exposed to the highest risk, but can also be shared with all villagers in the same village. By doing so, information possessed by all villagers in the same place can be of the same, and false information dissemination can be eliminated or even avoided.

In addition, hazard zone mapping could be a useful disaster preparedness measure the government can implement with the aid of academics and experts. Before debris flow occurs, different levels of risk zones should be precisely mapped based on detailed and scientific measurement. The map should be disseminated to all threatened residents in advance through different channels. It should also be posted in local government buildings, near and at the debris flow risk spots, and places easily accessed by the affected population.

Recommendations on disaster response information, measures and facilities dissemination

In terms of disaster response measures and facilities, those Pingwu respondents who had not accessed any information or instruction on appropriate debris flow response, had not heard of monitoring personnel or drill, or did not aware of

evacuation route or emergency shelter, would tend to have either one of the two opposite reaction when see signs of debris flow: more likely to run or to stay at home. Those who had accessed certain information or instruction on appropriate response, heard of monitoring personnel or drill, aware of evacuation route or emergency shelter, were more likely to inform others.

In Wenchuan, those respondents who had not accessed any booklet, card or table, were unaware of early warning website, shouting, or evacuation route, or the non-monitoring personnel, were more likely to run. Those who had accessed booklet on appropriate debris flow response, or were aware of early warning shouting but not website, were more likely to stay at home. Those who had accessed booklet, card or table, aware of website, shouting or evacuation route, or being a monitoring personnel, were more likely to inform others.

In both study areas, to address the need of for those who would be more likely to run or choose to stay at home, the first thing the government should do is to visit the respondents' communities and evaluate whether the mentioned information, measures and facilities that were inaccessible or unaware of by the respondents, were in fact available.

If they are not available, the governments should introduce them as soon as possible. If they are available, the governments should reveal why the respondents were not aware of them. Was there a dissemination problem? Or were the information or measures too difficult to access or too complicated for the villagers to understand? Or were the measures simply ineffective or not user friendly? In Wenchuan, for example, was it possible that the network coverage was not good enough for the residents to use their mobile devices to get such information from the website? Or was it simply that the villagers did not have a habit of going online or getting disaster information from the web? The two county governments should then find ways to let the residents aware of the availability of such disaster response information, measures and facilities.

For those who choose to escape in particular, their awareness and knowledge of these disaster response information, measures or facilities, would help them to respond more appropriately during debris flow strike, such as making better

choices on when and how to evacuate, and which evacuation route to choose. They could get a better idea of the location, direction and scale of the attacking debris flow from the information provided. In Pingwu, the residents would know how to get to the correct emergency shelter destination, and could be able to contact the appropriate monitoring personnel and report the debris flow situation. In Wenchuan, on the other hand, the villages can be more alert of early warnings issued through website or shouting. Since geohazard situations as well as the arrangements of such disaster response measures and facilities might change over time and space, such dissemination should be done regularly and to be updated from time to time.

Based on such disaster response knowledge, the residents of both counties would also be able to make choices other than just flee when see debris flow signs at home. The authorities should teach the residents under what circumstances they can escape but under what situations they should not. And in such situations, what else they should or could do, for example, whether they should stay or take refuge at home, or whether they could conduct any mitigation measures, observe or seek for help etc.

In both Pingwu and Wenchuan, people chose to stay home might because they want to secure their house and belongings, to impose risk reduction measures to their homes, or to take care of their dependents and livestock at home. Some might think taking refuge at home is safer. Others might try to observe the development of the debris flow before they take any action.

The government can educate them with better choices on what they can do at home to eliminate their debris flow risk and reduce the potential destruction, for example, imposing certain specific risk reduction measures that they can manage. However, in some cases, staying home taking refuge, observing or even taking risk reduction measures can be dangerous. The government should tell the residents under what circumstances they can stay at home but under what kind of emergency debris flow hit situations they should not take refuge at home at all but should flee or seek for help etc. If more knowledge regarding disaster response measures and facilities is available, the residents would be able to make choices other than just stay or take refuge at home when see debris flow signs.

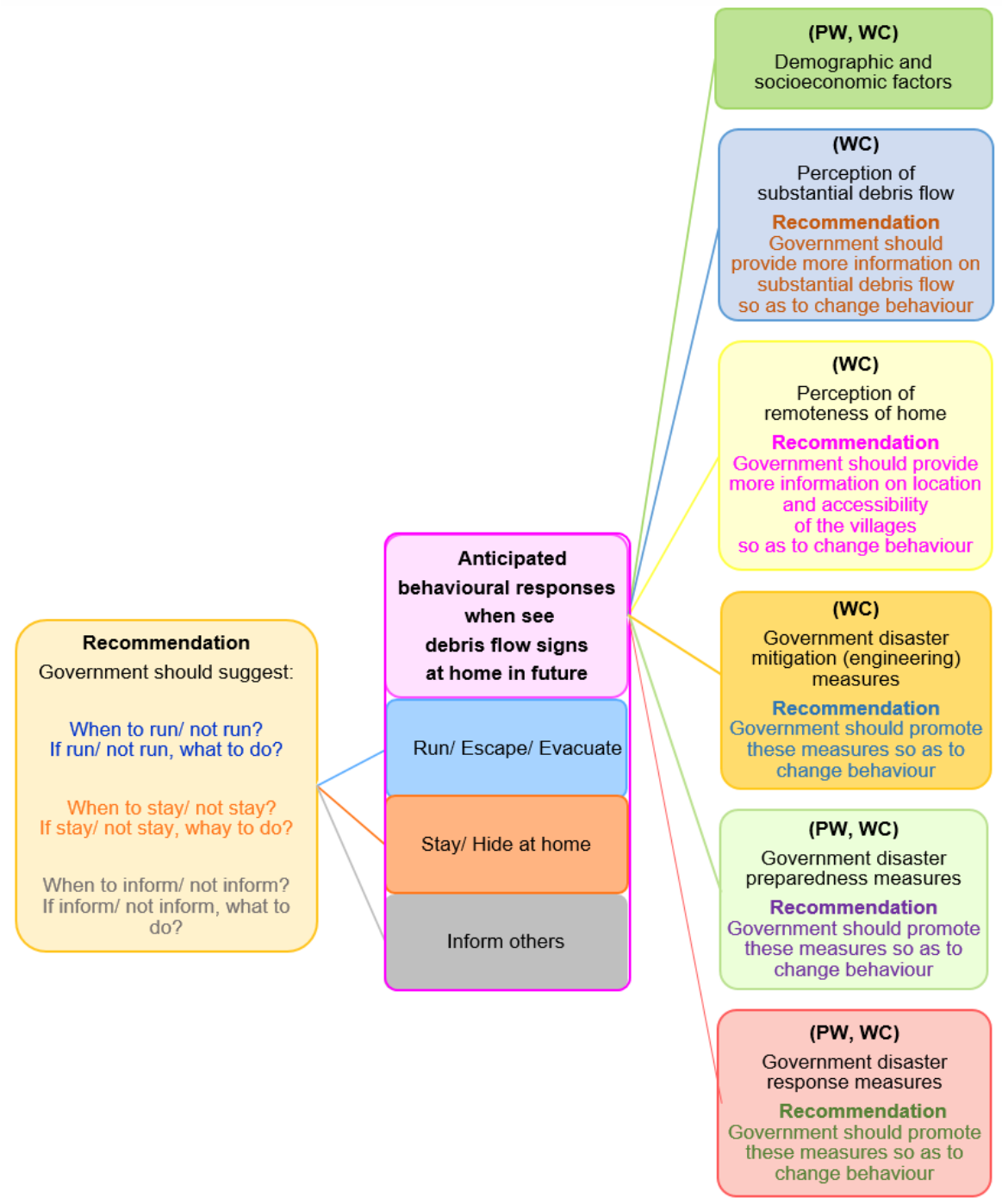
The government should also teach the villagers to pre-pack emergency bags with the most important personal and life-saving belongings, so they can flee swiftly if debris flow suddenly hit. They can also ask their neighbours or the village leaders in advance to help save their old family members or kids at home or even their livestock in times of emergencies if they themselves are incapable of evacuating their dependents or are not at home when debris flow hits.

Governments can also offer talks, presentations or trainings for the debris flow threatened populations in advance. Under what circumstances they should or should not stay at home when they see debris flow signs can be shared. Such educational materials can be presented in electronic format and posted on official websites, shared as online information or courses.

Based on the findings from the two study areas, Figure 7.2 shows a comprehensive list of recommendations on how to enhance rural residents' disaster response capacities. The recommendations cover both government and non-government factors that are found influencing anticipated disaster responses in the survey.

Figure 7.2

Recommendations on how to enhance disaster response capacities of rural residents based on the findings from the two study areas



7.5.3 Recommendations on evacuation

Evacuation is a common reaction during disaster. This research revealed that evacuation, or simply run or escape, was the most common disaster response of the respondents if debris flow strike in the future. However, whether the

respondents knew where to go when they evacuate is crucial in deciding if their lives could be saved. Interestingly, and also worrisome is that, a study found in a flood attack, all respondents did not know their destination after they flee from their homes (Bolin and Bolton 1986). Therefore the authorities should put efforts in educating and ensuring the debris flow threatened residents not only know to evacuate when appropriate, but also the correct way and where to evacuate.

7.5.4 Recommendations on emergency practices

In a broader sense, the research results can provide insights into emergency practices. In areas with people having different responses to debris flows or diverse reactions to government instructions during emergency, different practices can be imposed. The government should plan in advance how emergency responders should react to those who choose to leave and to those who do not. The authorities can even consider if some reactions may endanger the emergency workers, appropriate training should be provided to handle and mitigate such dangers.

7.6 Scope and constraints of the research

Like many other social research, particularly those focused on disaster-related scenarios, this study has its limitations. Apart from those mentioned in the methodology chapter, there are more limitations related to the sample size that can be covered by this research given the available time, resources and funding.

In particular, the survey of this research originally tended to cover a wider and more in-depth scope of questions. However, owing to insufficient sample size and also constraints of the length of this thesis, the answers to these questions are not analysed.

7.6.1 From whom, how and when did the respondents become aware of government disaster risk reduction measures?

The survey actually included some questions to explore the details of respondents' awareness of various government disaster risk reduction measures. Future study, if managed to interview more people from remote mountainous regions affected or threatened by earthquake-induced geohazards, can apply these questions to get

a more throughout understanding of residents' information source and timing of receipt regarding government disaster risk reduction measures.

1. The FROM WHOM? question

If the respondents did ever receive education or knowledge about debris flow risk and risk exposure, disaster protection and response measures, by whom was such information was delivered?

1a. The FROM WHOM? question -- government

If it was the government delivered such information on debris flow risk and risk exposure, disaster protection and response measures, which department / which level exactly from the government disseminated such knowledge?

1b. The FROM WHOM? question -- apart from government

If it was not the government delivered such information on debris flow risk and risk exposure, disaster protection and response measures, which organization/party/ individual had disseminated such knowledge to the respondents?

2. The HOW? question

How did the information of debris flow risk and risk exposure, disaster protection and response measures reach the respondents? Through what channels, dissemination or communication methods?

3. The WHEN? question

When exactly did the respondents receive such information on debris flow risk and risk exposure, disaster protection and response measures? Before or after the 2008 earthquake?

7.6.2 Perceived effectiveness of government disaster risk reduction measures

The survey also asked the rural residents' perceived effectiveness of various government disaster risk reduction measures. Future study can apply these questions and interview more people so a more throughout understanding of this aspect can be achieved.

The HOW question

The disaster mitigation, preparedness and response measures are listed out one by one. By providing several statements about evaluating each of the disaster risk reduction measures, such as their usefulness, and ability to enhance risk

awareness, the respondents were asked to judge how effective they thought the measures were by rating such statements. Any association between the perceived effectiveness on one hand, and risk perception or anticipated behaviour on the other, can be explored.

7.6.3 Impact of mitigation measures on vulnerability

According to Alexander (2002), several criteria can be adopted in evaluating the subsequent impact of a mitigation proposal to vulnerability level. The survey has made reference to this literature. Future studies can also apply Alexander's criteria to test the impact of actual rehabilitation site selection to vulnerability of the earthquake-induced geohazard affected population. Debris flow risk exposure of rural residents after rehabilitation and relocation can be revealed.

7.6.4 Effectiveness of geotechnical engineering mitigation measures

Imposition of government geotechnical measures is aimed to reduce the actual debris flow risk. A few questions aimed to explore the effectiveness of such measures in the eyes of the affected residents were included in the survey. For instance, those who recognised the imposition of certain geotechnical measures in their communities were further asked about how many debris flows had such measure stopped after the Wenchuan earthquake, whether they felt safer than before, and to what extent the imposition avoided the community from huge debris flow risk.

Answers collected from these questions can be compared to the original purpose of the governments when introducing such geotechnical measures, such as whether their imposition could actually help protect lives, properties, farmland and roads exposed to debris flow risks.

Effectiveness of the structural measures in affecting debris flow risk level can also be evaluated by looking into whether the engineering measures are appropriate and sufficient, because some geotechnical measures needed a second or third round of refinement. Therefore, how better designs and other structural mitigation methods should be introduced to further reduce debris flow risks can be explored more in future studies. Such findings could be applied not just to Sichuan, but other rural mountainous debris flow-prone regions within and outside China.

7.6.5 Other research opportunities

As noted in the methodology chapter, a quantitative social survey is the main method adopted in this thesis to acquire data from the two research sites. Given the limited resources available, conducting a survey was the appropriate and feasible method to collect data from over 600 respondents in the remote mountainous areas. However, since the inflexibility nature and lack of depth of survey could bring limitations in collecting and interpreting results (DeCarlo 2018), further research methods could be used to investigate the topics this thesis covered if resources are allowed in the future. This could involve qualitative research like interviews and focus groups, especially on residents' risk perception. A mixed methods approach might enable a greater explanatory power of the findings.

With qualitative research, new areas for future studies, in particular the interviewing of victim-survivors and emergency personnel, could be considered. When doing so, professionals with expertise in dealing with distressed people should be specifically involved to provide support.

Moreover, in light of the relationship between social vulnerability indicators and reconstruction behaviour noted in the literature review chapter, post-disaster reconstruction proposals and regulations referencing vulnerability analysis would be crucial for reducing future risks (Davis 2015). Additional research can be done to explore this aspect to achieve the goal of building back better (UNISDR 2017c).

This thesis is a comparative analysis of the two Sichuan counties in terms of relocation decisions, risk perceptions and anticipated disaster responses of the debris flow affected populations. As noted in the results chapter, however, dividing the full set of data collected into two according to the two selected counties can be a limitation leading to the missing of some analyses. If the data can be combined into one and viewed as a single set, other analyses utilising all 631 samples across different sites could be done. On the other hand, breakdown of the dataset into five sample groups according to the five villages from which the data was collected can also be used as a basis for analysis and allow other intended lines of comparison. These directions can be of reference for future research.

7.7 Insights for future research

7.7.1 More research in the light of ethnicity and cultural characteristics

This thesis finds that ethnicity could be significantly affecting relocation decisions and risk perceptions in both study areas. The importance of ethnicity could partly attributed to the selection of case study areas. However, this outcome was unexpected because ethnicity was not at all a criteria in site selection. Nonetheless, the implications of the research findings here for further studies can be in two directions. Both can be done through ethnographic research in which more participation of the rural villagers are to be involved so that in-depth insights of their views can be collected and revealed.

Firstly, more studies about Tibetans' debris flow or other geohazards risk perception can be carried out and compared to other ethnic groups to see if the Tibetans are also having higher risk perception as revealed in this study. If higher geohazard risk perception of Tibetans is established, further investigation can be done to find out the reasons behind. By doing so, the research gaps can be filled, and appropriate remedies and mitigation measures targeting the Tibetans can be imposed as policy considerations.

Secondly, more attention can be put on the Qiangs. In this study, their debris flow risk perceptions in both counties were lower than the two other major ethnic groups despite all the five villages were facing debris flow risk. Further studies can explore more reasons behind their relatively lower risk perception in the light of cultural impact. Based on the findings, the government can put more efforts to arouse the awareness of the Qiangs on the geohazard risks around. The Qiangs can also impose more preparedness measures with the aid of the government to reduce their risk and to protect their lives and properties. Tragedies and great loss of the Qiangs caused by the 2008 earthquake hopefully would not repeat itself in future.

In terms of the possible impacts of cultural consideration on relocation decision-making, more research can also be done in the future. As noted in the discussion chapter, culture, together with individual competences and governance, are identified as important themes that could influence post-earthquake moving decisions based on survey data being collected and analysed. As inspired by the

insights of the grounded theory, with the development of the new model presented in this thesis and its contribution to theoretical development, conducting further research on these topics could be the next step forward.

7.7.2 More research on governance and the role of other parties in the society in impacting vulnerability

This thesis focuses on government impact on vulnerability. Previous research noted that governance is underlying vulnerability alleviation (Ammann 2006). Alexander (2012b) elaborated that governance in a form of participatory democracy is the foundation of sustainable disaster risk reduction. However, although possible impact of the type of political system, such as capitalism and socialism, on the levels and forms of vulnerability was explored, no clear relationship was found (Cannon 1994). Furthermore, despite political dimension and state influence are inevitable in vulnerability study, other parties like the academics, NGOs and civil society (Cannon 1994; Ozerdem and Jacoby 2006) as well as the press (Cannon 2006) are also important in impacting vulnerability. Future studies can therefore investigates the impacts of the form of governance as well as influences of academics, NGOs and civil society on vulnerability.

7.7.3 More research on the impact of citizen science

The emerge of citizen science (Haklay 2013; Paul *et al.* 2018, 2019) with the advancement in mobile phones, internet as well as social media might lead to a revolutionary development in both the early warning system and the MMMP system in geohazard monitoring and early warning in China. The original top-down early warning system and the community-based MMMP system might be injected with more local participation. In what ways these changes would affect risk perception and disaster response can be a future direction for investigation.

7.8 Concluding remarks

With the completion of this thesis, it is hoped that more attention can be brought to the remote mountainous rural population in China and places with similar context in terms of their earthquake-induced debris flow risk exposure and vulnerability. In turn, more care and resources can be distributed to relevant disaster mitigation, preparedness and response measures whenever and wherever appropriate.

Appendix 1

The pilot and the main surveys

The pilot and the main surveys were very similar. The one reproduced here, therefore, is a hybrid of the two, with indications of what modifications were made to the final version used to collect the majority of the data.

+ indicates answers newly added after the pilot survey
x indicates questions or answers deleted after the pilot survey

Details of the number of people who completed the pilot survey and the sampling method through which they were chosen are given in Section 3.5.2 Conduct of the survey.

The original version is in Chinese. This is an English translated version.

Village affiliation: _____, Pingwu / Wenchuan

I. Personal accommodation information

		Before 2008 Wenchuan earthquake		**After 2008 Wenchuan earthquake and before 2013 Lushan earthquake**			**After 2013 Lushan earthquake**	**I forget how long**	**How many years in total?**
1	When did you start living in this village? For how long?	1		2			3	0	____years
2	How long have you been living here where your house is now located?	1		2			3	0	____years
		Nil	**1 member**	**2 members**	**3 members**	**4 members**	**5 members**	**Other number**	**What is/are their relationships with you?**
3	How many household members, apart from you, live in the same house here in this village?	0	1	2	3	4	5		
4	→ How many of them work outside?	0	1	2	3	4	5		
5.1	→ How many of them is/are: (a). Elderly (65 or above)	0	1	2	3	4	5		
5.2	(b). Children (18 or below)	0	1	2	3	4	5		
5.3	(c). Housewife	0	1	2	3	4	5		
5.4	(d). Disabled (physically and mentally)	0	1	2	3	4	5		

II. Demographic information

1	Gender	_____
2	Age	_____
3	Educational attainment	(1) Uneducated (2). Primary (3). Secondary (4). Tertiary/University (5). Masters (6). Doctorate
4	Occupation (before 2008 Wenchuan earthquake	(1). Farmer (2). Businessman (3). Worker (blue collar) (4). Office worker (5). Government official (6). Housewife (7). Student (8). Retired (9). Unemployed (10). Others _____
5	Occupation (after 2008 Wenchuan earthquake)	(1). Farmer (2). Businessman (3). Worker (blue collar) (4). Office worker (5). Government official (6). Housewife (7). Student (8). Retired (9). Unemployed (10). Others _____
6	Within a year, how long do you stay here in this group/community?	(1). Whole year (2). 9 months to below 12 months (3). 6 months to below 9 months (4). 3 months to below 6 months (5). Below 3 months (6). Basically not living here (0). Don't know / Not sure / Not applicable
7	What is your annual household income?	RMB _____ yuan
8	Do you know Sichuan dialect?	(1). Yes, I know (2). No, I don't know (0). Not applicable
9	Do you know Putonghua?	(1). Yes, I know (2). Able to understand but don't know how to speak + (3). No, I don't know (0). Not applicable
10	Can you read Chinese?	(1). Yes, I can (2). Partially (3). No, I can't (0). Not applicable
11	Do you perform any position or role in the village, such as village head, secretary, village officer, geohazard monitoring personnel etc.?	(1). Yes, I am _____ (2). No, I do not serve (0). Don't know / Forget / Not applicable
12	What is your ethnicity?	_____

III. About knowledge on the living place

1	Do you know what a "seismic fault zone" is?		(1). I know → What is it? _____				(0). I don't know
2	Are you living along seismic fault zone?		(1). Yes		(2). No		(0). I don't know
	Questions about "the past" (Experience of earthquake)	**Yes, before 2008 Wenchuan earthquake**	**Yes, 2008 Wenchuan earthquake to before 2013 Lushan earthquake**	**Yes, 2013 Lushan earthquake and after**	**Yes, but I forget exactly when**	**No**	**I don't know/ I forget/ Not applicable**
3	In the past, had any earthquake occurred in your group/community?	1	2	3	4	5	0
4	In the past, had your home affected by earthquake(s)?	1	2	3	4	5	0
5	Have you yourself experienced earthquake(s)?	1	2	3	4	5	0
6	How frequent is earthquake occurrence in your group/community?	(1). More than once a year	(2). Every year	(3). Once every several (less than 10) years	(4). Once every several decades	(5). Never	(0). I don't know/ I forget/ Not applicable

7	**Do you know what "debris flow" is?**		(1). I know → What is it? _____				(0). I don't know/ Not applicable
8	Are you living in a region with "debris flow"?		(1). Yes		(2). No		(0). I don't know/ Not applicable
9	Are you living in a place with "debris flow" risk spot?		(1). Yes		(2). No		(0). I don't know/ Not applicable
	Question about "the past" (Experience of debris flow)	**Yes, before 2008 Wenchuan earthquake**	**Yes, 2008 Wenchuan earthquake to before 2013 Lushan earthquake**	**Yes, 2013 Lushan earthquake and after**	**Yes, but I forget exactly when**	**No**	**I don't know/ I forget/ Not applicable**
10	In the past, had any debris flow occurred in your group/community?	1	2	3	4	5	0
11	In the past, had your home been affected by debris flow?	1	2	3	4	5	0
12	Have you yourself experienced debris flow?	1	2	3	4	5	0
13	How frequent is debris flow occurrence in your group/community?	(1). More than once a year	(2). Every year	(3). Once every several (less than 10) years	(4). Once every several decades	(5). Never	(0). I don't know/ I forget/ Not applicable
14	How frequent is debris flow affecting your home?	(1). More than once a year	(2). Every year	(3). Once every several (less than 10) years	(4). Once every several decades	(5). Never	(0). I don't know/ I forget/ Not applicable

	Questions about "now" (Perception of current earthquake/debris flow risk)	Strongly agreed	Agreed	Neutral	Disagreed	Strongly disagreed	I don't know/ I forget/ Not applicable
15	Is your group/community currently threatened by earthquake?	5	4	3	2	1	0
16	Is your group/community currently threatened by debris flow?	5	4	3	2	1	0
17	Is your home currently threatened by debris flow?	5	4	3	2	1	0
18	Is the debris flow affecting your group/community induced by the 2008 Wenchuan earthquake?	5	4	3	2 → what do you think is the cause of the debris flow affecting your group/ community: _____	1 → what do you think is the cause of the debris flow affecting your group/ community: _____	0
19	Is the debris flow affecting your group/community induced by the 2013 Lushan earthquake?	5	4	3	2→ what do you think is the cause of the debris flow affected your group/ community: _____	1→ what do you think is the cause of the debris flow affected your group/ community: _____	0
20	Can mega earthquake, such as the one occurred in 2008, induce debris flows in the next 20 to 30 years?	5	4	3	4	1	0

IV. About perception of substantial debris flow

1	What do you think constitutes to a "substantial debris flow"?	Strongly agreed	Agreed	Neutral	Disagreed	Strongly disagreed	I don't know/ I forget/ Not applicable	Who told you?	How did you know about it?
1.1	A debris flow which can take human lives.	5	4	3	2	1	0		
1.2	A debris flow which can destroy the whole village or group/ community.	5	4	3	2	1	0		
1.3	A debris flow which can damage houses.	5	4	3	2	1	0		
1.4	A debris flow which can take the lives of cattle.	5	4	3	2	1	0		
1.5	A debris flow which can destroy farmland.	5	4	3	2	1	0		
1.6	A debris flow which can cause property losses.	5	4	3	2	1	0		
1.7	A debris flow which can cause road congestion.	5	4	3	2	1	0		

V. About relocation

1	Have you moved after the 2008 earthquake?	(1). Yes, moved → Moved to _____ metres from original site		(2). No, not moved (i.e. stayed in the original site)			(0). Not applicable/ I don't know/ I forget
2	What factors did you consider when you decided whether to move or not?	**Strongly agreed**	**Agreed**	**Neutral**	**Disagreed**	**Strongly disagreed**	**Not applicable/ I don't know/ I forget**
2.1	Whether the new place would be affected by earthquake.	5	4	3	2	1	0
2.2	Whether the new place would be affected by debris flow.	5	4	3	2	1	0
2.3	The topography and landscape of the new place.	5	4	3	2	1	0
2.4	Whether the new place was nearby my farmland.	5	4	3	2	1	0
2.5	Whether the new place had sufficient land to accommodate my family members.	5	4	3	2	1	0
2.6	The government said whether the new residing place is safe.	5	4	3	2	1	0
2.7	Whether the government had introduced effective geotechnical engineering measures, including sediment trap dam, to the new residing place.	5	4	3	2	1	0
2.8	Whether the government had introduced effective disaster preparedness measures, including risk notifications, early warnings and disaster response, to the new residing place.	5	4	3	2	1	0
2.9	Whether the government would provide training for me to tackle debris flow.	5	4	3	2	1	0
2.10	Whether I could tackle debris flow risk.	5	4	3	2	1	0
2.11	Whether the government would take care of me, including the provision of accommodation if I am affected by debris flow.	5	4	3	2	1	0
2.12	Whether the place I originally lived was safe.	5	4	3	2	1	0
2.13	Whether I liked the place I originally lived and did I belong to the place.	5	4	3	2	1	0
2.14	Whether my ancestors also resided in the place I originally lived.	5	4	3	2	1	0
2.15	Whether my children studied nearby the place I originally lived.	5	4	3	2	1	0
2.16	Whether I liked the neighbours of my original home.	5	4	3	2	1	0
2.17	Whether the neighbours of my previous home were of the same ethnic group as me.	5	4	3	2	1	0
2.18	Whether the neighbours of the place I would move to were of the same ethnic group as me.	5	4	3	2	1	0
2.19	Whether I were afraid of moving to a new place.	5	4	3	2	1	0
2.20	Whether moving to somewhere else required me to give up my farmland.	5	4	3	2	1	0
2.21	Whether the moving process was too complicated for me and my family and could be handled.	5	4	3	2	1	0
2.22	Whether I had the money to move.	5	4	3	2	1	0
2.23	Whether I had sufficient money to build a new house somewhere else.	5	4	3	2	1	0
2.24	Whether there was any subsidy to move to another place.	5	4	3	2	1	0
2.25	Home's current location made me feel safer than the location before the Wenchuan earthquake.	5	4	3	2	1	0

VI. About debris flow (Knowledge of debris flows)

1	Can debris flow cause casualties?	(1). Yes, it can.	(2). No, it cannot	(0) I don't know / I forget / Not applicable
1.1	Who told you?	(1) _____		(0) I don't know / I forget / Not applicable
1.2	(If it was the government), which department?	(1) _____		(0) I don't know / I forget / Not applicable
1.3	Which level?	(1) _____		(0) I don't know / I forget / Not applicable
1.4	Through what channel, dissemination or communication method did you learn about this?	(1) _____		(0) I don't know / I forget / Not applicable
2	Can debris flow cause property losses?	(1). Yes, it can.	(2). No, it cannot	(0) I don't know/ I forget / Not applicable
2.1	Who told you?	(1) _____		(0) I don't know / I forget / Not applicable
2.2	(If it was the government), which department?	(1) _____		(0) I don't know / I forget / Not applicable
2.3	Which level?	(1) _____		(0) I don't know / I forget / Not applicable
2.4	Through what channel, dissemination or communication method did you learn about this?	(1) _____		(0) I don't know / I forget / Not applicable
3	Can debris flow cause economic consequences and losses?	(1). Yes, it can.	(2). No, it cannot	(0) I don't know / I forget / Not applicable
3.1	Who told you?	(1) _____		(0) I don't know / I forget / Not applicable
3.2	(If it was the government), which department?	(1) _____		(0) I don't know / I forget / Not applicable
3.3	Which level?	(1) _____		(0) I don't know / I forget / Not applicable
3.4	Through what channel, dissemination or communication method did you learn about this?	(1) _____		(0) I don't know / I forget / Not applicable
4	Can debris flow cause transport problem and road congestion?	(1). Yes, it can.	(2). No, it cannot	(0) I don't know/ I forget/ Not applicable
4.1	Who told you?	(1) _____		(0) I don't know / I forget / Not applicable
4.2	(If it was the government), which department?	(1) _____		(0) I don't know / I forget / Not applicable
4.3	Which level?	(1) _____		(0) I don't know / I forget / Not applicable
4.4	Through what channel, dissemination or communication method did you learn about this?	(1) _____		(0) I don't know / I forget / Not applicable

VII. About the location of the village (Perception of remoteness)

1	Do you perceive your group/community as remote?	(1). Yes	(2). No	(0). I don't know / Not applicable
2	Do you perceive your home as particularly remote?	(1). Yes	(2). No	(0). I don't know / Not applicable

VIII. About structural engineering mitigation measures

1	After the 2008 Wenchuan earthquake, has your group/community introduced the below geoengineering technical measures to resist debris flow?			**Yes (aware of)**		**No (not aware of) / I don't know / I forget / Not applicable**	
1.1	Sediment trap dam			1		0	
1.2	Drainage channel			1		0	
1.3	Artificial step-pool systems			1		0	
1.4	Others, please specify:_____			1		0	
2	Further questions for those who recognised the imposition of certain geotechnical measure in their communities:						
2.1	How many debris flows have the structural mitigation measure(s) imposed on your group/community after 2008 Wenchuan earthquake stopped?	(1). All	(2). Partial	(3). No	(4). No debris flow hit	(0). I don't know / I forget / Not applicable	
2.2	With such structural mitigation measure(s) in your group/ community, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
2..3	The imposition of structural mitigation measure in your group/community did avoid your group/community from huge debris flow risk.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

IX. Government disaster preparedness measures

1. Assessment of debris flow risk in the surrounding area

(Awareness of debris flow risk assessment (a). in community)

1.1	Has any debris flow risk assessment ever conducted in your group/community?	(1). Yes→1.1.1 (2). No (0). I don't know / I forget / Not applicable
1.1.1	When did the assessment commence?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable
1.1.2	Who did the assessment?	(1). _____ (0). I don't know / I forget / Not applicable
1.1.3	Have you received any promotion introducing the assessment result?	(1). Yes (2). No (0). I don't know / I forget / Not applicable

(Awareness of debris flow risk assessment (b). on home)

1.2	Has anyone ever assessed debris flow risk on your home?	(1). Yes→1.2.1 (2). No (0). I don't know / I forget / Not applicable
1.2.1	When did the assessment commence?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable
1.2.2	Who did the assessment?	(1). _____ (0). I don't know / I forget / Not applicable
1.2.3	Have you received any promotion introducing the assessment result?	(1). Yes (2). No (0). I don't know / I forget / Not applicable

2. Understanding of debris flow risk in the surrounding area

(Accessibility to information on debris flow risk (a). Hazard zone information on community)

2.1	Have you heard of or have you seen debris flow hazard zone map / text information about your group/community, listing the risk areas?	(1). Yes→2.1.1	(2). No	(0). I don't know / I forget / Not applicable			
2.1.1	When did the information start to be delivered?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable			
2.1.2	Who provided the information?	(1). _____		(0). I don't know / I forget / Not applicable			
2.1.3	You find this information useful.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

(Accessibility to information on debris flow risk (b1). Any information on community)

2.2	Have you ever received any information on the debris flow risk your group/community faces?	(1). Yes→2.2.1	(2). No	(0). I don't know / I forget / Not applicable			
2.2.1	When did you receive the information?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable			
2.2.2	Who provided the information?	(1). _____		(0). I don't know / I forget / Not applicable			
2.2.3	(If the answer is "government") Which department?	(1). _____		(0). I don't know / I forget / Not applicable			
2.2.4	Which level?	(1). _____		(0). I don't know / I forget / Not applicable			
2.2.5	Through what method did you access the information?	(1). _____		(0). I don't know / I forget / Not applicable			
x	Is the information received after the 2008 earthquake more detailed when compared to that before the 2008 earthquake?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
x	Is the information received after the triggering of debris flow risk by the 2008 earthquake more detailed than before?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
2.2.6	Do you understand the contents of the information?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
2.2.7	Have you retained the information?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
2.2.8	It is good to use this method to inform you about the debris flow risk your group/community faces.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
2.2.9	You find this information useful.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
2.2.10	This information enhanced your awareness of the debris flow risk your group/community faces.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
2.2.11	With this information, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

(Accessibility to information on debris flow risk (b2). Any information on home)

2.3	Have you ever received any information on the debris flow risk your home faces?	(1). Yes→2.3.1	(2). No	(0). I don't know / I forget / Not applicable			
2.3.1	When did you receive the information?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable			
2.3.2	Who provided the information?	(1). _____		(0). I don't know / I forget / Not applicable			
2.3.3	(If the answer is "government") Which department?	(1). _____		(0). I don't know / I forget / Not applicable			
2.3.4	Which level?	(1). _____		(0). I don't know / I forget / Not applicable			
2.3.5	Through what method did you access the information?	(1). _____		(0). I don't know / I forget / Not applicable			
2.3.6	Do you understand the contents of the information?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
2.3.7	Have you retained the information?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
2.3.8	It is good to use this method to inform you about the debris flow risk your home faces.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
2.3.9	You find this information useful.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
2.3.10	This information enhanced your awareness of the debris flow risk your home faces.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
2.3.11	With this information, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

3. Assessment of debris flow protective measures

(Awareness of assessment on protection against debris flow strike (a). in community)

3.1	Has any person/organisation ever assessed whether your group/community has sufficient protection against debris flow strike?	(1). Yes→3.1.1	(2). No	(0). I don't know / I forget / Not applicable
3.1.1	When was the assessment being conducted?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable
3.1.2	Who did the assessment?	(1). _____		(0). I don't know / I forget / Not applicable
3.1.3	Have you received any education or promotion about the protection assessment result?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable

(Awareness of assessment on protection against debris flow strike (b). on home)

3.2	Has any person/organisation ever assessed whether your home has sufficient protection against debris flow strike?	(1). Yes→3.2.1	(2). No	(0). I don't know / I forget / Not applicable
3.2.1	When was the assessment being conducted?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable
3.2.2	Who did the assessment?	(1). _____		(0). I don't know / I forget / Not applicable
3.2.3	Have you received any education or promotion about the protection assessment result?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable

4. Information regarding protection against general debris flow and the impact
(Accessibility to any information on protective measures against general debris flow strike)

4.1	Have you ever received any information on protective measures against general debris flow strike?	(1). Yes→4.2	(2). No	(0). I don't know / I forget / Not applicable			
4.2	When did you receive the information?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after	(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable				
4.3	Who provided the information?	(1). _____	(0). I don't know / I forget / Not applicable				
4.4	(If the answer is "government") Which department?	(1). _____	(0). I don't know / I forget / Not applicable				
4.5	Which level?	(1). _____	(0). I don't know / I forget / Not applicable				
4.6	Through what method did you access the information?	(1). _____	(0). I don't know / I forget / Not applicable				
4.7	Do you understand the contents of the information?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
4.8	Have you retained the information?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
4.9	It is good to use this method to inform you about how to protect from debris flow strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.10	You find this information useful.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.11	This information enhanced your awareness of the need of protection in advance to avoid potential debris flow strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.12	With this information, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

5. On monitoring
(Heard of Mass Monitoring and Mass Prevention)

5.1	Have you ever heard of Mass Monitoring and Mass Prevention?	(1). Yes→5.2	(2). No	(0). I don't know / I forget / Not applicable			
5.2	What is Mass Monitoring and Mass Prevention?	(1). Mass Monitoring and Mass Prevention is _____ (0). I don't know / I forget / Not applicable (***No matter whether the villagers can correctly reply what is Mass Monitoring and Mass Prevention, an explanation is to be given to them because they may simply not know about the term "Mass Monitoring and Mass Prevention, but know about the measure itself. After explanation, the following questions can continue to be asked. ***)					
5.3	When did you start to learn about this measure?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after	(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable				
5.4	Who told you about this measure?	(1). _____	(0). I don't know / I forget / Not applicable				
5.5	(If the answer is "government") Which department?	(1). _____	(0). I don't know / I forget / Not applicable				
5.6	Which level?	(1). _____	(0). I don't know / I forget / Not applicable				
5.7	Through what channel or dissemination/communication method did you learn about this measure?	(1). _____	(0). I don't know / I forget / Not applicable				
5.8	Mass Monitoring and Mass Prevention makes you more alert about debris flow.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

5.9	It is good to use Mass Monitoring and Mass Prevention to monitor and prevent debris flow.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
5.10	Mass Monitoring and Mass Prevention is useful to reduce debris flow risk.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
5.11	Mass Monitoring and Mass Prevention enhanced your awareness of the approaching of debris flow.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
5.12	Through Mass Monitoring and Mass Prevention to monitor and prevent debris flow in your group/community, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

6. Plan/Measure to protect from debris flow

(Awareness of plan/measure imposed on (a). community to protect residents from debris flow strike)

6.1	Is there any plan/measure imposed on your group/community to protect residents from debris flow strike?	(1). Yes→6.1.1	(2). No	(0). I don't know / I forget / Not applicable			
6.1.1	When did the plan/measure start to be imposed?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable			
6.1.2	What plan/measure is it?	(1). _____		(0). I don't know / I forget / Not applicable			
6.1.3	Who imposed the plan/measure?	(1). _____		(0). I don't know / I forget / Not applicable			
6.1.4	Have you received any education or promotion about the protection plan/measure?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
6.1.5	You are satisfied with the imposition of this plan/measure.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

(Awareness of plan/measure imposed on (b). home to protect family members from debris flow strike)

6.2	Is there any plan/measure imposed on your home to protect family members from debris flow strike?	(1). Yes→6.2.1	(2). No	(0). I don't know / I forget / Not applicable			
6.2.1	When did the plan/measure start to be imposed?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable			
6.2.2	What plan/measure is it?	(1). _____		(0). I don't know / I forget / Not applicable			
6.2.3	Who imposed the plan/measure?	(1). _____		(0). I don't know / I forget / Not applicable			
6.2.4	Have you received any education or promotion about the protection plan/measure?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
6.2.5	You are satisfied with the imposition of this plan/measure.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

X. Government disaster response measures and facilities

1. Assessment on capability to tackle debris flow strike

(Awareness of assessment on capability to tackle debris flow strike in community)

1.1	Has any person/organisation ever assessed whether your group/community can tackle debris flow strike?	(1). Yes→1.1.1 (2). No (0). I don't know / I forget / Not applicable
1.1.1	When was the assessment being conducted?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable
1.1.2	Who did the assessment?	(1). _____ (0). I don't know / I forget / Not applicable

2. Plan/Measure/Instruction to tackle debris flow strike

(Awareness of plan/measure/instruction to tackle debris flow strike in community)

2.1	Is there any plan/measure/instruction imposed on your group/community to tackle debris flow strike?	(1). Yes→2.1.1 (2). No (0). I don't know / I forget / Not applicable
2.1.1	When did the plan/measure/instruction start to be imposed?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable
2.1.2	What plan/measure/instruction is it?	(1). _____ (0). I don't know / I forget / Not applicable
2.1.3	Who provided the plan/measure/instruction?	(1). _____ (0). I don't know / I forget / Not applicable
2.1.4	Have you ever accessed any education or promotion about the plan/measure/instruction?	(1). Yes (2). No (0). I don't know / I forget / Not applicable

3. Information on appropriate response when debris flows strike

(Accessibility to information on appropriate response when debris flows strike)

a. Any information/instruction

3.1	Have you ever seen or received any information/instruction telling you what to do when debris flows strike?	(1). Yes→3.1.1 (2). No (0). I don't know / I forget / Not applicable
3.1.1	When did you see or receive the information/instruction?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable
3.1.2	Who provided the information/instruction?	(1). _____ (0). I don't know / I forget / Not applicable
3.1.3	(If the answer is "government") Which department? Which level?	(1). _____ (0). I don't know / I forget / Not applicable (1). _____ (0). I don't know / I forget / Not applicable
3.1.4	What kind of information/instruction had you received? That is, through what method(s) did you learn about it?	(1). _____ (0). I don't know / I forget / Not applicable
x	Is the information/instruction received after the 2008 earthquake more detailed when compared to that before the 2008 earthquake?	(1). Yes (2). No (0). I don't know / I forget / Not applicable
x	Is the information/instruction received after the triggering of debris flow risk by the 2008 earthquake more detailed than before?	(1). Yes (2). No (0). I don't know / I forget / Not applicable

3.1.5	Have you retained this information?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
3.1.6	You understand the contents of this information.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
3.1.7	You find this information/instruction useful.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
3.1.8	This information/instruction can enhance your awareness of the need to plan in advance on how to tackle debris flow strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
3.1.9	With this information/instruction, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

b. Booklet

3.2	Have you ever seen any emergency knowledge booklet telling you what to do when debris flows strike?	(1). Yes→3.2.1	(2). No	(0). I don't know / I forget / Not applicable			
3.2.1	When did you see the booklet(s)?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable			
3.2.2	Who provided the booklet(s)?	(1). _____		(0). I don't know / I forget / Not applicable			
3.2.3	(If the answer is "government") Which department? Which level?	(1). _____ (1). _____		(0). I don't know / I forget / Not applicable (0). I don't know / I forget / Not applicable			
X	Is the booklet received after the 2008 earthquake more detailed when compared to that before the 2008 earthquake?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
X	Is the booklet received after the triggering of debris flow risk by the 2008 earthquake more detailed than before?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
3.2.4	Have you retained this (these) booklet(s)?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
3.2.5	You understand the contents of this (these) booklet(s).	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
3.2.6	You find this (these) booklet(s) useful.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
3.2.7	Booklet(s) can enhance your awareness of the need to plan in advance on how to tackle debris flow strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
3.2.8	With this (these) booklet(s), you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

c. Card/Table

3.3	Have you ever seen any Disaster Prevention Work Understanding Card / Table of Geohazard Prevention and Protection Plan telling you what to do when debris flows strike?	(1). Yes→3.3.1	(2). No	(0). I don't know / I forget/ Not applicable
3.3.1	When did you see the Disaster Prevention Work Understanding Card(s) / Table(s) of Geohazard Prevention and Protection Plan?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable

3.3.2	Who provided the Disaster Prevention Work Understanding Card(s) / Table(s) of Geohazard Prevention and Protection Plan?	(1). _____ (0). I don't know / I forget / Not applicable.					
3.3.3	(If the answer is "government") Which department? Which level?	(1). _____ (0). I don't know / I forget / Not applicable (1). _____ (0). I don't know / I forget / Not applicable					
X	Is/Are the Understanding Card(s) / Table(s) of Plan received after the 2008 earthquake more detailed when compared to that before the 2008 earthquake?	(1). Yes (2). No (0). I don't know / I forget / Not applicable					
X	Is/Are the Understanding Card(s) / Table(s) of Plan received after the triggering of debris flow risk by the 2008 earthquake more detailed than before?	(1). Yes (2). No (0). I don't know / I forget / Not applicable					
3.3.4	Have you retained this (these) Understanding Card(s) / Table(s) of Plan?	(1). Yes (2). No (0). I don't know / I forget / Not applicable					
3.3.5	You understand the contents of this (these) Understanding Card(s) / Table(s) of Plan.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
3.3.6	You find this (these) Understanding Card(s) / Table(s) of Plan useful.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
3.3.7	Understanding Card(s) / Table(s) of Plan can enhance your awareness of the need to plan in advance on how to tackle debris flow strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
3.3.8	With this (these) Understanding Card(s) / Table(s) of Plan, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

4. Early warning tools

(Awareness of early warning tools in community)

a. Website

4.1	Is there any website with debris flow early warning covering the area where your group/community is located?	(1). Yes→4.1.1 (2). No (0). I don't know / I forget / Not applicable
4.1.1	When did you start to learn about this website?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable
4.1.2	Who told you about this website?	(1). _____ (0). I don't know / I forget / Not applicable
4.1.3	(If the answer is "government") Which department? Which level?	(1). _____ (0). I don't know / I forget / Not applicable (1). _____ (0). I don't know / I forget / Not applicable
4.1.4	Through what channel or dissemination/communication method did you learn about this website?	(1). _____ (0). I don't know / I forget / Not applicable
X	After the 2008 earthquake, is the debris flow early warning information provided by the website more detailed when compared to that before the 2008 earthquake?	(1). Yes (2). No (0). I don't know / I forget / Not applicable

x	After the triggering of debris flow risk by the 2008 earthquake, is the debris flow early warning information provided by the website more detailed than before?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
4.1.5	Generally speaking, it is good to use website to inform you debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.1.6	Generally speaking, a website that can issue debris flow early warning can enhance your awareness that debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.1.7	Generally speaking, if there is a website to issue debris flow early warning covering your group/community, you would feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

b. Siren

4.2	Is there any siren/loudspeaker in your group/community that can issue debris flow early warning?	(1). Yes→4.2.1	(2). No	(0). I don't know / I forget/ Not applicable			
4.2.1	When did you start to learn about the siren/loudspeaker in your group/community?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after	(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable				
4.2.2	Who told you that your group/community has siren/loudspeaker?	(1). _____	(0). I don't know / I forget / Not applicable				
4.2.3	(If the answer is "government") Which department? Which level?	(1). _____ (1). _____	(0). I don't know / I forget / Not applicable (0). I don't know / I forget / Not applicable				
4.2.4	Through what channel or dissemination/communication method did you learn about the availability of siren/loudspeaker in your group/community?	(1). _____	(0). I don't know / I forget / Not applicable				
x	After the 2008 earthquake, has the physical coverage of the siren/loudspeaker system near your home expanded?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
x	After the triggering of debris flow risk by the 2008 earthquake, has the physical coverage of the siren/loudspeaker system near your home expanded?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
4.2.5	Generally speaking, it is good to use siren/loudspeaker system to inform you debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.2.6	Generally speaking, the siren/loudspeaker system that can issue debris flow early warning can enhance your awareness that debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.2.7	Generally speaking, if there is a siren/loudspeaker system to issue debris flow early warning in your group/community, you would feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

c. Phone

4.3	Is there any debris flow early warning issued by phone in your group/community?	(1). Yes→4.3.1	(2). No	(0). I don't know / I forget / Not applicable			
4.3.1	When did you start to learn about the use of phone notification for debris flow early warning in your group/community?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after	(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable				
4.3.2	Who told you that there will be early warning issued through the phone when debris flows strike your group/community?	(1). _____	(0). I don't know / I forget / Not applicable				
4.3.3	(If the answer is "government") Which department? Which level?	(1). _____ (1). _____	(0). I don't know / I forget / Not applicable (0). I don't know / I forget / Not applicable				
4.3.4	Through what channel or dissemination/communication method did you learn about the use of phone to issue early warning when debris flows strike your group/community?	(1). _____	(0). I don't know / I forget / Not applicable				
X	After the 2008 earthquake, was the debris flow early warning information received through your phone more detailed when compared to that before the 2008 earthquake?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
X	After the triggering of debris flow risk by the 2008 earthquake, was the debris flow early warning information received through your phone more detailed than before?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
4.3.5	Generally speaking, it is good to use phone to inform you debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.3.6	Generally speaking, the use of phone to issue debris flow early warning can enhance your awareness that debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.3.7	Generally speaking, if there is a phone system to issue debris flow early warning in your group/community, you would feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

d. Gong

4.4	Are there any gongs in your group/community that can issue debris flow early warning?	(1). Yes→4.4.1	(2). No	(0). I don't know / I forget / Not applicable
4.4.1	When did you start to learn that your group/community has those gongs?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after	(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable	
4.4.2	Who told you that your group/community has gongs?	(1). _____	(0). I don't know / I forget / Not applicable	
4.4.3	(If the answer is "government") Which department? Which level?	(1). _____ (1). _____	(0). I don't know / I forget / Not applicable (0). I don't know / I forget / Not applicable	
4.4.4	Through what channel or dissemination/communication method did you learn about the availability of gongs in your group/community?	(1). _____	(0). I don't know / I forget / Not applicable	
X	After the 2008 earthquake, were there more gongs available near your home?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable

x	After the triggering of debris flow risk by the 2008 earthquake, has the physical coverage of the gongs near your home expanded?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
4.4.5	Generally speaking, it is good to use gongs to inform you debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.4.6	Generally speaking, the gongs that can issue debris flow early warning can enhance your awareness that debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.4.7	Generally speaking, if there are gongs to issue debris flow early warning in your group/community, you would feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

e. Shout

4.5	Is there someone responsible for shouting to issue debris flow early warning in your group/community?	(1). Yes→4.5.1	(2). No	(0). I don't know / I forget / Not applicable			
4.5.1	When did you start to learn about there is someone responsible for shouting to issue debris flow early warning in your group/community?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after		(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable			
4.5.2	Who told you there is someone responsible for shouting to issue debris flow early warning in your group/community?	(1). _____	(0). I don't know / I forget / Not applicable				
4.5.3	(If the answer is "government") Which department? Which level?	(1). _____ (1). _____	(0). I don't know / I forget / Not applicable (0). I don't know / I forget / Not applicable				
4.5.4	Through what channel or dissemination/communication method did you learn about there is someone responsible for shouting to issue debris flow early warning in your group/community?	(1). _____	(0). I don't know / I forget / Not applicable				
x	After the 2008 earthquake, were there more people responsible for shouting near your home?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
x	After the triggering of debris flow risk by the 2008 earthquake, were there more people responsible for shouting near your home?	(1). Yes	(2). No	(0). I don't know / I forget / Not applicable			
4.5.5	Generally speaking, it is good to use shouting to inform you debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.5.6	Generally speaking, the shouting that can issue debris flow early warning can enhance your awareness that debris flow is approaching.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
4.5.7	Generally speaking, if there is shouting to issue debris flow early warning in your group/community, you would feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

5. Communication channels

(Awareness of communication channels (a). when see debris flow signs in general situations)

5.1	In general situations, when a person sees debris flow signs, should a report be made to a certain unit or individual in the first place?	(1). Yes→5.1.1 (2). No (0). I don't know / I forget / Not applicable
5.1.1	When did you start to learn about the need to do so?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable
5.1.2	Through what channel or dissemination/communication method did you learn about this?	(1). _____ (0). I don't know / I forget / Not applicable
5.1.3	Which organisation / Who taught you?	(1). _____ (0). I don't know / I forget / Not applicable
5.1.4	(If the answer is "government") Which department? Which level?	(1). _____ (0). I don't know / I forget / Not applicable (1). _____ (0). I don't know / I forget / Not applicable

(Awareness of communication channels (b). community unit to be contacted when debris flows strike)

5.2	When debris flows strike your group/community, do you know which unit to contact in the first place?	(1). Yes→5.2.1 (0). I don't know / I forget / Not applicable
5.2.1	When did you start to learn about the need to contact this unit?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable
5.2.2	Through what channel or dissemination/communication method did you learn about the need to contact this unit?	(1). _____ (0). I don't know / I forget / Not applicable
5.2.3	Who told you to contact this unit?	(1). _____ (0). I don't know / I forget / Not applicable
5.2.4	(If the answer is "government") Which department? Which level?	(1). _____ (0). I don't know / I forget / Not applicable (1). _____ (0). I don't know / I forget / Not applicable

6. Monitoring personnel

(Awareness of monitoring personnel in community)

a. Heard of b. Respondent c. Family member

6.1	Have you ever heard of the deployment of monitoring personnel in every geohazard risk spot?	(1). Yes→6.2 (2). No (0). I don't know / I forget / Not applicable
6.2	When did you start to learn about this monitoring personnel?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable
6.3	Through what channel or dissemination/communication method did you learn about the need to contact this monitoring personnel?	(1). _____ (0). I don't know / I forget / Not applicable
6.4	Who told you about this monitoring personnel?	(1). _____ (0). I don't know / I forget / Not applicable
6.5	(If the answer is "government") Which department? Which level?	(1). _____ (0). I don't know / I forget / Not applicable (1). _____ (0). I don't know / I forget / Not applicable
6.6	Are you yourself a monitoring personnel?	(1). Yes (2). No (0). I don't know / I forget / Not applicable
6.7	Is/Are your family member(s) monitoring personnel?	(1). Yes (2). No (0). I don't know / I forget / Not applicable

7. Emergency response facilities

(Awareness of emergency response facilities in community)

a. Evacuation route

7.1.	Is there any evacuation route in your group/community during debris flows strike?	(1). Yes→7.1.1	(2). No	(0). I don't know / I forget / Not applicable			
7.1.1	When did you start to learn about this evacuation route?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after	(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable				
7.1.2	Which organisation / Who planned and designed this evacuation route?	(1). _____	(0). I don't know / I forget / Not applicable				
7.1.3	(If the answer is "government") Which department? Which level?	(1). _____ (1). _____	(0). I don't know / I forget / Not applicable (0). I don't know / I forget / Not applicable				
7.1.4	Which organisation / Who told you to evacuate this way?	(1). _____	(0). I don't know / I forget / Not applicable				
7.1.5	(If the answer is "government") Which department? Which level?	(1). _____ (1). _____	(0). I don't know / I forget / Not applicable (0). I don't know / I forget / Not applicable				
7.1.6	Through what channel or dissemination/communication method did you learn about this evacuation route?	(1). _____	(0). I don't know / I forget / Not applicable				
7.1.7	You clearly understand the route of evacuation.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
7.1.8	The route is practical and feasible.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

b. Emergency shelter

7.2	Is there any place in your group/community that can be used as emergency shelter during debris flows strike?	(1). Yes→7.2.1	(2). No	(0). I don't know / I forget / Not applicable			
7.2.1	When did you start to learn about this emergency shelter?	(1). Before 2008 Wenchuan earthquake (3). 2013 Lushan earthquake and after	(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (0). I forget exactly when / Not applicable				
7.2.2	Which organisation / Who provides this emergency shelter?	(1). _____	(0). I don't know / I forget / Not applicable				
7.2.3	(If the answer is "government") Which department? Which level?	(1). _____ (1). _____	(0). I don't know / I forget / Not applicable (0). I don't know / I forget / Not applicable				
7.2.4	Which organisation / Who told you about this emergency shelter?	(1). _____	(0). I don't know / I forget / Not applicable				
7.2.5	(If the answer is "government") Which department? Which level?	(1). _____ (1). _____	(0). I don't know / I forget / Not applicable (0). I don't know / I forget / Not applicable				
7.2.6	Through what channel or dissemination/communication method did you learn about this emergency shelter?	(1). _____	(0). I don't know / I forget / Not applicable				
7.2.7	You clearly understand the location of the emergency shelter.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
7.2.8	The place is suitable for emergency refuge.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

c. Temporary residing place

7.3	Is there any temporary residing place in your group/community that can be used for temporary accommodation during and after debris flows strike?	(1). Yes→7.3.1 (2). No (0). I don't know / I forget / Not applicable					
7.3.1	When did you start to learn about this temporary residing place?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable					
7.3.2	Which organisation / Who provides this temporary residing place?	(1). _____ (0). I don't know / I forget / Not applicable					
7.3.3	(If the answer is "government") Which department? Which level?	(1). _____ (0). I don't know / I forget / Not applicable (1). _____ (0). I don't know / I forget / Not applicable					
7.3.4	Which organisation / Who told you about this temporary residing place?	(1). _____ (0). I don't know / I forget / Not applicable					
7.3.5	(If the answer is "government") Which department? Which level?	(1). _____ (0). I don't know / I forget / Not applicable (1). _____ (0). I don't know / I forget / Not applicable					
7.3.6	Through what channel or dissemination/communication method did you learn about this temporary residing place?	(1). ___ _____ (0). I don't know / I forget / Not applicable					
7.3.7	You clearly understand the location of the temporary residing place.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
7.3.8	The place is suitable for temporary reside, including for sleep and live temporarily.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

8. Emergency response dissemination

(Awareness of emergency response dissemination in community)

a. Emergency bag

8.1	Have you ever heard of the need to prepare an "emergency bag" at home (i.e. a bag that can be taken away immediately when you encounter emergency situations), and can be used when debris flows strike your group/community?	(1). Yes→8.1.1 (2). No (0). I don't know / I forget / Not applicable					
8.1.1	When did you start to learn about the need of this emergency bag?	(1). Before 2008 Wenchuan earthquake (2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake (3). 2013 Lushan earthquake and after (0). I forget exactly when / Not applicable					
8.1.2	Which organisation / Who told you about the need to prepare an emergency bag?	(1). _____ (0). I don't know / I forget / Not applicable					
8.1.3	(If the answer is "government") Which department? Which level?	(1). _____ (0). I don't know / I forget / Not applicable (1). _____ (0). I don't know / I forget / Not applicable					
8.1.4	Through what channel or dissemination/communication method did you learn about the need of an emergency bag?	(1). _____ (0). I don't know / I forget / Not applicable					
8.1.5	The emergency bag can enhance your awareness of the need to plan in advance on how to tackle debris flow strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
8.1.6	With this emergency bag, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

b. Training

8.2	Have you ever heard of certain training course, such as first aid or mountain rescue, provided for the villagers of your group/community to prepare for tackling debris flow strike?	(1). Yes→8.2.1	(2). No	(0). I don't know / I forget / Not applicable			
8.2.1	When did you start to learn about this training course?	(1). Before 2008 Wenchuan earthquake	(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake	(3). 2013 Lushan earthquake and after	(0). I forget exactly when / Not applicable		
8.2.2	Which organisation / Who provides this training course?	(1). _____	(0). I don't know / I forget / Not applicable				
8.2.3	(If the answer is "government") Which department? Which level?	(1). _____	(0). I don't know / I forget / Not applicable (1). _____	(0). I don't know / I forget / Not applicable			
8.2.4	Which organisation / Who told you about the training course?	(1). _____	(0). I don't know / I forget / Not applicable				
8.2.5	(If the answer is "government") Which department? Which level?	(1). _____	(0). I don't know / I forget / Not applicable (1). _____	(0). I don't know / I forget / Not applicable			
8.2.6	Through what channel or dissemination/communication method did you learn about the training course?	(1). _____	(0). I don't know / I forget / Not applicable				
8.2.7	The training course(s) is (are) useful.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
8.2.8	It is good to use training course to tell you what to do when debris flows strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
8.2.9	The training can enhance your awareness of the need to plan in advance on how to tackle debris flow strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
8.2.10	With the training, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

c. Drill

8.3	Have you ever heard of certain drill provided for the villagers of your group/community to prepare for tackling the strike of debris flows and/or other geohazards?	(1). Yes→8.3.1	(2). No	(0). I don't know / I forget / Not applicable			
8.3.1	When did you start to learn about this drill?	(1) Before 2008 Wenchuan earthquake	(2). 2008 Wenchuan earthquake to before 2013 Lushan earthquake	(3). 2013 Lushan earthquake and after	(0). I forget exactly when / Not applicable		
8.3.2	Which organisation / Who arranges the drill?	(1). _____	(0). I don't know / I forget / Not applicable				
8.3.3	(If the answer is "government") Which department? Which level?	(1). _____	(0). I don't know / I forget / Not applicable (1). _____	(0). I don't know / I forget / Not applicable			
8.3.4	Which organisation / Who told you about the drill?	(1). _____	(0). I don't know / I forget / Not applicable				
8.3.5	(If the answer is "government") Which department? Which level?	(1). _____	(0). I don't know / I forget / Not applicable (1). _____	(0). I don't know / I forget / Not applicable			
8.3.6	Through what channel or dissemination/communication method did you learn about the drill?	(1). _____	(0). I don't know / I forget / Not applicable				
8.3.7	The drill is useful.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
8.3.8	It is good to use drill to tell you what to do when debris flows strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

8.3.9	The drill can enhance your awareness of the need to plan in advance on how to tackle debris flow strike.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable
8.3.10	With the drill, you feel safer than before.	(5). Strongly agreed	(4). Agreed	(3). Neutral	(2). Disagreed	(1). Strongly disagreed	(0). I don't know / I forget / Not applicable

XI. Future anticipated disaster response

1.	In the future, what will you do in the first place when you are at home and see signs of debris flow?	(1). I will _____ → Why? _____ (0). I don't know / Not applicable

~ End of survey ~

Appendix 2

Further analysis on each ethnic group and the combination of factors influencing their moving decisions

Analysis shows that ethnicity is the only demographic factor having statistical significant relation with respondents' decision to move in both Pingwu and Wenchuan.

This section would further look into each ethnic group and gives an overview of what variables affected their moving decisions.

Further statistical analysis was conducted to explore whether each ethnic group had different considerations (constructs 2A, 2B, 3A, 3B and 4) when they made their moving decision.

In short, those Pingwu respondents who decided to move after the quake, no matter they were Hans or Qiangs, had considered more about their exposure and susceptibility (construct 2A). The Qiangs who moved had considered this factor more than the Hans. Since the Qiangs in Pingwu were more likely to move after the quake, it is reasonable to relate such behaviour to their greater concern that they were more susceptible and exposed to debris flow risk.

Conversely, in both ethnic groups, those who did not move were more concerned about the socio-cultural, historical, family factors (construct 2B), and their personal competencies to move and to tackle debris flow (construct 3B). Since the Hans were found more likely to stay, it is logical that this was affected by their greater consideration of socio-cultural, historical, family factors and personal competencies.

The concerns of the Wenchuan respondents were quite different. There is no evidence that the Hans in Wenchuan had considered any of the non-demographic constructs tested when they decided to move or not after the quake. As for the Qiangs and the Tibetans, besides concerning more about exposure and susceptibility as the Pingwu respondents did, those who moved had also considered more about what the government said of or introduced in the new

residing place to avoid geological risks. This factor was not significantly considered by the Pingwu respondents.

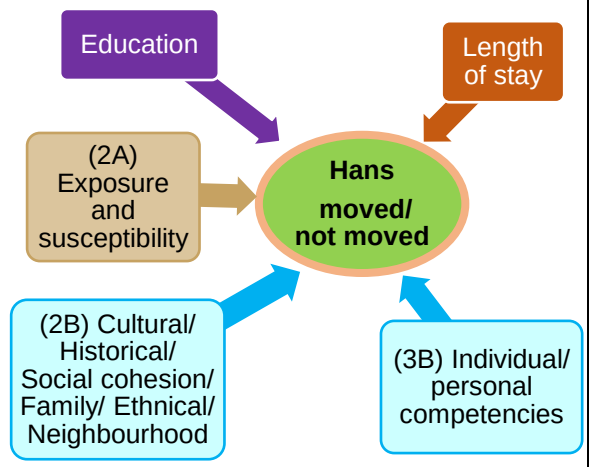
Apart from the five non-demographic constructs, based on multivariate analysis, Figure A1, A2, A3 provides a full summary of all demographic and non-demographic variables affecting the moving decision of each ethnic group, namely the Hans, the Qiangs and the Tibetans, in Pingwu and Wenchuan.

i. The Hans

The Hans' decision to move or not were affected by a combination of demographic and non-demographic factors in Pingwu (Figure A1 left chart). However, length of stay was the only variable relating to the moving decision of the Hans in Wenchuan (right chart).

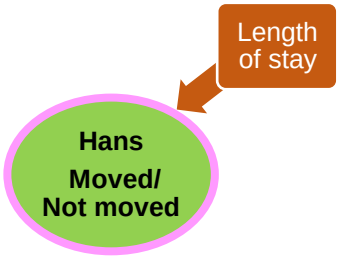
Figure A1 Variables affected Hans' moving decision

Pingwu



	More likely to move	More likely to stay
Education	Secondary	Primary
Length of stay	Shorter (<9 months)	Longer (9 months to full year)
Exposure & susceptibility	More considered	Less considered
Cultural/ Historical/ Social cohesion/ Family/ Ethnical/ Neighbourhood	Less considered	More considered
Individual/ personal competencies	Less considered	More considered

Wenchuan



	More likely to move	More likely to stay
Length of stay	Longest and shortest (9 months to full year & <3 months)	Medium (3 to <9 months)

ii. The Qiangs

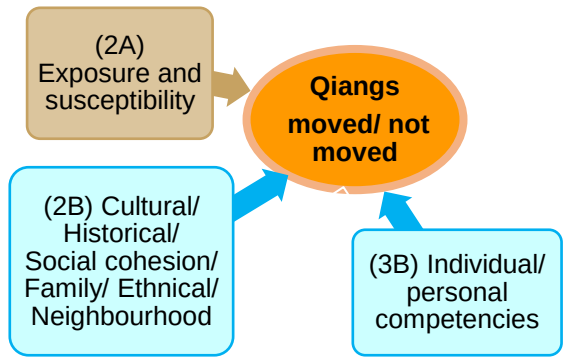
Moving decisions of the Qiangs in both Pingwu and Wenchuan, were not affected by demographic factors at all. As shown in Figure A2, they only considered non-demographic factors when they made their decision. In particular, the Qiangs in both study areas who considered more about their personal or homes' hazard exposure and susceptibility were more likely to move.

The difference between Pingwu and Wenchuan was that in Pingwu, the Qiangs' moving decision were also affected by their cultural, historical, social, family, ethnical or neighbourhood affiliation and a set of individual personal competencies. Those who were less concern about the sociocultural as well as individual competencies variable were more likely to move.

Whereas in Wenchuan, influence of government institutions on respondents' coping capacities had an impact on the Qiangs' moving decision. Those who considered more about what the government did to avoid geological risks in the new location were more likely to move.

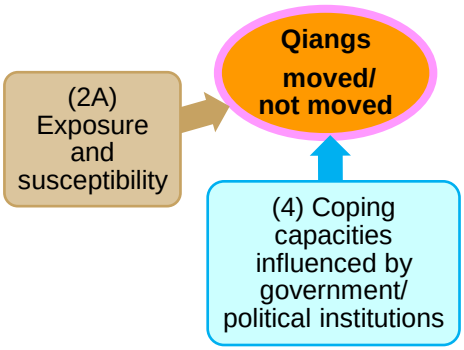
Figure A2 Variables affected Qiangs moving decision

Pingwu



	More likely to move	More likely to stay
Exposure & susceptibility	More considered	Less considered
Cultural/ Historical/ Social cohesion/ Family/ Ethnical/ Neighbourhood	Less considered	More considered
Individual/ personal competencies	Less considered	More considered

Wenchuan

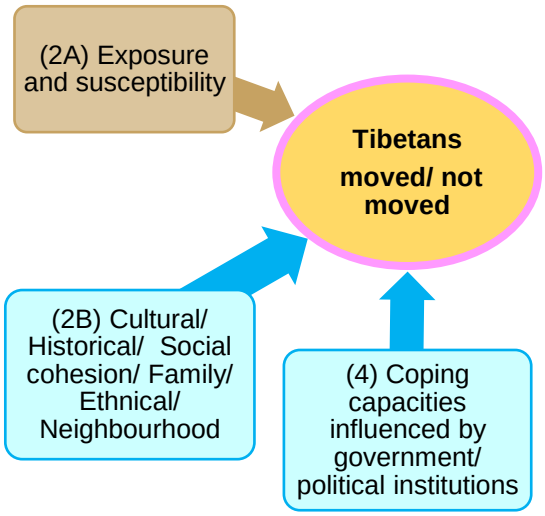


	More likely to move	More likely to stay
Exposure & susceptibility	More considered	Less considered
Coping capacities influenced by government/ political institutions	More considered	Less considered

iii. The Tibetans

Similar to the Qiangs, another ethnic minority group Tibetans, when decided to move or not, were basically affected by non-demographic considerations, as shown in Figure A3 below.

Figure A3 Variables affected Tibetans' moving decision

<table>
<tr><th>Pingwu</th><th>Wenchuan</th></tr>
<tr><td>No Tibetan respondents.</td><td> 
</td></tr>
<tr><td></td><td>
<table>
<tr><th></th><th>More likely to move</th><th>More likely to stay</th></tr>
<tr><td>Exposure & susceptibility</td><td>More considered</td><td>Less considered</td></tr>
<tr><td>Cultural/ Historical/ Social cohesion/ Family/ Ethnical/ Neighbourhood</td><td>Less considered</td><td>More considered</td></tr>
<tr><td>Coping capacities influenced by government/ political institutions</td><td>More considered</td><td>Less considered</td></tr>
</table>
</td></tr>
</table>

Same as the Qiangs in Wenchuan, those Tibetans who considered more about their personal or homes' hazard exposure and susceptibility were more likely to move.

Also similar to the Qiangs in Wenchuan, the Wenchuan Tibetan respondents' moving decision were influenced by what the government did in affecting their coping capacities. Those who considered more about what the government did to avoid geological risks in the new locations were more likely to move.

References

Abazhou. 2023. “History and Ethnicity”. *Aba Tibetan (Zang) and Qiang Autonomous Prefecture Government website.* Online. https://www.abazhou.gov.cn/abazhou/c104335/l_c.shtml Accessed on 17 June 2023. (In Chinese).

Abel, Emily K. and Nelson, Margaret K. (eds.) 1990. *Circles of Care: Work and Identity in Women’s Lives.* Albany: State University of New York.

ADB (Asian Development Bank). 2008. *People’s Republic of China: Providing Emergency Response to Sichuan Earthquake.* ADB Technical Assistance Consultant’s Report, Project Number: 42150. December 2008, 196pp.

Aldrich, Daniel P. 2010. “Fixing Recovery: Social Capital in Post-Crisis Resilience”. *Journal of Homeland Security*, June 2010, 6, p.1-10.

Aldrich, Daniel P. 2012a. “Social, not physical, infrastructure: the critical role of civil society after the 1923 Tokyo earthquake”. *Disasters,* Vol.36, Iss.3, July 2012, p.398-419.

Aldrich, Daniel P. 2012b. *Building Resilience: Social Capital in Post-Disaster Recovery*. Chicago: The University of Chicago Press. 246pp.

Aldrich, Daniel P. and Meyer, M.A. 2015. “Social Capital and Community Resilience”. *American Behavioral Scientist*, Vol.59, Iss.2, February 2015, p.254-269.

Alexander, David E. 1989. “Preserving the Identity of Small Settlements during Post-Disaster Reconstruction in Italy”. *Disasters*, Vol.13, Iss.3, September 1989, p.228-236.

Alexander, David E. 1991a. “Applied geomorphology and the impact of natural hazards on the built environment”. *Natural Hazards*, Vol.4, Iss.1, p.57-80.

Alexander, David E. 1991b. “Natural Disasters: A Framework for Research and Teaching”. *Disasters*, Vol.15, Iss.3, September 1991, p.209-226.

Alexander, David E. 1993. *Natural Disasters. London*: UCL Press. 632pp.

Alexander, David E. 1997. “The Study of Natural Disasters, 1977-97: Some Reflections on a Changing Field of Knowledge”. *Disasters*, Vol.21, Iss.4, p.284-304.

Alexander, David E. 2000*. Confronting catastrophe: new perspectives on natural disasters.* Oxford: Oxford University Press, 282pp.

Alexander, David E. 2002*. Principles of Emergency Planning and Management.* New York: Oxford University Press, 340pp.

Alexander, David E. 2007. ‘"From Rubble to Monument" Revisited: Modernised Perspectives on Recovery From Disaster’. David Alexander, Colin Henry Davidson, Andrew Fox, Cassidy Johnson and Gonzalo Lizzaralde (eds.) *Post-Disaster Reconstruction: Meeting Stakeholder Interests: Proceedings of a Conference held at the Scuola di Sanità Militare, Florence, Italy, 17-19 May 2006.* Firenze: Firenze University Press, p.xiii-xxii.

Alexander, David E. 2012a. “A tale of three cities and three earthquake disasters”. *Tafter Journal,* August 2012.

Alexander, David. E. 2012b. “Models of Social Vulnerability to Disasters”. *RCCS Annual Review. A selection from the Portuguese journal Revista Crítica de Ciências Sociais,* Iss.4, 2012, p.22-40.

Alexander, David E. and Magni, M. 2013. “Mortality in the L’Aquila (Central Italy) Earthquake of 6 April 2009”. *PLos Currents 5:e50585b8e6efd1.*

Allen, Richard M. and Melgar, D. 2019. "Earthquake Early Warning: Advances, Scientific Challenges, and Societal Needs". *Annual Review of Earth and Planetary Sciences*, 2019.

Altman, Irwin and Low, S.M. (eds.) 1992. *Place attachment.* New York: Plenum Press.

American Red Cross. 2022. “Landslide Safety & Preparedness Tips”. *American Red Cross website*. Online. https://www.redcross.org/get-help/how-to-prepare-for-emergencies/types-of-emergencies/landslide.html Accessed on 13 June 2022.

Ammann, Walter J. 2006. “Risk Concept, Integral Risk Management and Risk Governance”. Walter J. Ammann, Stephanie Dannenmann and Laurent Vulliet (eds.) *Risk 21: Coping with Risks Due to Natural Hazards in the 21st Century*. London: Taylor & Francis, p.3-23.

Angotti, Thomas. 1977. “Playing politics with disaster: the earthquake of Friuli and Belice (Italy)”. *International Journal of Urban and Regional Research,* Vol.1, No.2, p.327-331.

Ao, Yibin, Huang, K., Wang, Y., Wang, Q. and Martek, I. 2020. “Influence of built environment and risk perception on seismic evacuation behaviour: Evidence from rural areas affected by Wenchuan earthquake”. *International Journal of Disaster Risk Reduction*, Vol.46, June 2020, 101504.

Aptekar, Lewis. 1990. “A Comparison of the Bi-Coastal Disasters of 1989”. *Behavior Science Research,* Vol.24, Iss.1-4, p.73-104.

Arattano, Massimo and Marchi, L. 2008. “Systems and Sensors for Debris-flow Monitoring and Warning”. *Sensors,* Vol.8, Iss.4, April 2008, p.2436-2452.

Armanini, Aronne and Larcher, M. 2001. “Rational Criterion for Designing Opening of Silt-Check Dam”. *Journal of Hydraulic Engineering,* February 2001, p.94-104.

Armas, Iuliana 2006. “Earthquake Risk Perception in Bucharest, Romania”. *Risk Analysis*, Vol.26, No.5, p.1223-1234.

Arnold, Margaret. 2006. “Disaster Reconstruction and Risk Management for Poverty Reduction”. *Journal of International Affairs,* Vol.59, No.2, Spring/Summer 2006, The Globalization of Disaster, p.269-279.

Australian Red Cross 2009. *Emergency REDiPlan: 4 steps to plan for an emergency – Easy English 1st ed.* Carlton: Australian Red Cross, 42pp.

Baggio, Tommaso and D’Agostino, V. 2022. “Simulating the effect of check dam collapse in a debris-flow channel”. *Science of The Total Environment*, 10 April 2022, Vol.816, 151660.

Bailey, Robert G. 1971. *Landslide hazards related to land use planning in Teton National Forest*, *Northwest Wyoming.* U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, Utah, 131pp.

Banihabib, Mohammad Ebrahim and Forghani, A. 2017. "An assessment framework for the mitigation effects of check dams on debris flow". *CATENA,* May 2017, Vol.152, p.277-284.

Bankoff, Gregory. 2001. "Rendering the World Unsafe: 'Vulnerability' as Western Discourse". *Disasters*, Vol.25, Iss.1, March 2001, p.19-35.

Bankoff, Gregory, Frerks, Georg and Hilhorst, Dorothea (eds.) 2004. *Mapping vulnerability: disasters, development and people*. London: Earthscan.

Barton, Allen H. 1963. *Social organization under stress: A sociological review of disaster studies.* Disaster Study Number 17. Washington, D.C.: National Academy of Sciences – National Research Council.

BEARPC (Board of Editors for A record of Pingwu County) (ed.) 1997. *A record of Pingwu County.* Chengdu: Sichuan Science and Technology Press, 1028pp. (In Chinese).

Beggs, John J., Haines, V.A. and Hurlbert, J.S. 1996. "Situational Contingencies Surrounding the Receipt of Informal Support". *Social Forces*, September 1996, Vol.75, Iss.1, p.201-222.

Bethel, Jeffrey W., Burke, S.C. and Britt, A.F. 2013. "Disparity in disaster preparedness between racial/ethnic groups". *Disaster Health*, Apr-Dec 2013, Vol.1, No.2, p.110-116.

Bezuyen, M.J., van Duin, M.J. and Leenders, P.H.J.A. 1998. "Flood management in The Netherlands". *Australian Journal of Emergency Management*, Winter 1998, Vol.13, Iss.2, p.43-49.

Bian, Yanjie, Breiger, R., Davis, D. and Galaskiewicz, J. 2005. "Occupation, Class, and Social Networks in Urban China". *Social Forces*, June 2005, Vol.83, Iss.4, p.1443-1468.

Bilsborrow, Richard E. 2002. ''Migration, Population change, and the Rural Environment''. *Environmental Change and Security Project Report,* Summer 2002, Iss.8, p.69-94. The Woodrow Wilson Center.

Birkmann, Jörn (ed.) 2006. *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies.* Tokyo: United Nations University Press, 524pp.

Birkmann, Jörn (ed.) 2013. *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies, Second edition.* Tokyo: United Nations University Press.

Birkmann, Jörn, Cardona, O.D., Carren˜o, M.L., Barbat, A.H., Pelling, M., Schneiderbauer, S., Kienberger, S., Keiler, M., Alexander, D., Zeil, P. and Welle, T. 2013. "Framing vulnerability, risk and societal responses: the MOVE framework". *Natural Hazards*, Vol.67, p.193–211.

Birkmann, Jörn, Kienberger, Stefan, and Alexander, David. 2014. *Assessment of Vulnerability to Natural Hazards: A European Perspective.* San Diego: Elsevier.

Birkmann, Jörn and Wisner, Ben. 2006. *Measuring the Un-Measurable: The Challenge of Vulnerability.* United Nations University – Institute for Environment and Human Security (UNU-EHS), 60pp.

Blaikie, Piers, Cannon, T., Davis, I. and Wisner, B. 1994. *At Risk: Natural Hazards, People's Vulnerability, and Disasters, First edition*. London: Routledge, 320pp.

Boen, Teddy, Disah, Irinanto E., Soesanto, Marin and Hendarto. 2001. *Post Earthquake Disaster Relocation: Indonesia's Experience*, presented during APEC Workshop on Dissemination of Disaster Mitigation Technologies for Humanistic Concerns - Phase I: Earthquake Disaster, Taipei 18-21 June 2001, 15pp. Online. teddyboen.com Accessed on 17 February 2022.

Bogard, William. 1989. *The Bhopal Tragedy: Language, Logic, and Politics in the Production of a Hazard*. Boulder, Colorado: Westview Press.

Bogardi, Janos and Birkmann, J. 2004. "Vulnerability assessment: the first step towards sustainable risk reduction". Dorthe Malzahn and Tina Plapp (eds.) *Disaster and Society – From Hazard Assessment to Risk Reduction,* 2005, p.75-82. Berlin: Logos Verlag Berlin.

Bohle, Hans-Georg, Downing, T.E. and Watts, M.J. 1994. "Climate change and social vulnerability: Toward a sociology and geography of food insecurity". *Global Environmental Change*, March 1994, Vol.4, Iss.1, p.37-48.

Bolin, Robert C. and Bolton, Patricia. 1986. *Race, Religion, and Ethnicity in Disaster Recovery*. University of Colorado, Boulder.

Bolin, Robert C. and Klenow, D.J. 1988. "Older People in Disaster: A Comparison of Black and White Victims". *International Journal of Aging and Human Development*, Vol.26, No.1, p.29-43.

Bolin, Bob. 2007. "Race, Class, Ethnicity, and Disaster Vulnerability". Havidán Rodríguez, Enrico L. Quarantelli and Russell R. Dynes (eds.) *Handbook of Disaster Research*, Chapter 7, 2007. New York: Springer, p.113-129.

Broscoe, A.J. and Thomson, S. 1969. "Observations on an alpine mudflow, Steele Creek, Yukon". *Canadian Journal of Earth Sciences,* Vol.6, p.219-229. (Cited in Innes 1983).

Brunsden, Denys. 1979. "Mass movements". Clifford Embleton and John B. Thornes (eds.) *Process in geomorphology*, p.130-186. London: Edward Arnold, 436pp.

Bryman, Alan. 2012. *Social Research Methods*, *Fourth edition.* Oxford University Press.

Burroughs, Edward R., Chalfant, G.R. and Townsend, M.A. 1976. *Slope stability in road construction. A guide to the construction of stable roads in western Oregon and northern California.* U.S. Department of the Interior, Bureau of Land Management, Oregon State Office. Portland, Oregon, 102pp.

Burton, Ian, Kates, R.W. and White, G.F. 1978. *The environment as hazard*. New York: Oxford University Press, 240pp.

Burton, Ian, Kates, R.W. and White, G.F. 1993. *The environment as hazard, Second edition*. New York: Guilford Press, 290pp.

Caine, Nel. 1980. “The rainfall intensity-duration control of shallow landslides and debris flows”. *Geografiska Annaler. Series A, Physical Geography,* Vol.62, No.1/2, p.23-27.

Cambridge Dictionary. 2022a. “Culture”. *Cambridge English Dictionary*. Online. https://dictionary.cambridge.org/dictionary/english/culture Accessed on 17 February 2022.

Cambridge Dictionary. 2022b. “Blood is thicker than water”. *Cambridge English Dictionary*. Online. https://dictionary.cambridge.org/dictionary/english/blood-is-thicker-than-water Accessed on 8 February 2022.

Campbell, R.H. 1975. “Soil slips, debris flows and rainstorms in the Santa Monica Mountains and vicinity, coastal southern California”. *United States Geological Survey Professional Paper 851*, 51pp. (Cited in Innes 1983).

Cannon, Terry. 1994. “Vulnerability Analysis and the Explanation of Natural Disasters”. Ann Varley (ed.) 1994. *Disasters, development, and environment*. Chichester, England: John Wiley, p.13-30.

Cannon, Terry. 2006. “Vulnerability analysis, livelihoods and disasters”. W. Ammann, S. Dannenmann and L. Vulliet (eds.) 2006. *RISK21 - Coping with Risks due to Natural Hazards in the 21st Century - Proceedings of the RISK21 Workshop,* London: CRC Press, p.41-49.

Cannon, Terry, Twigg, John and Rowell, Jennifer. 2003. *Social Vulnerability, Sustainable Livelihoods and Disasters.* Report to DFID Conflict and Humanitarian Assistance Department (CHAD) and Sustainable Livelihoods Support Office.

Cao, Hong (ed.) 2000. *A record of physical geography of the Ya’an region.* Ya’an: Office of local record in the Ya’an Region, 291pp. (In Chinese).

Cardona, Omar D. 1999. “Environmental Management and Disaster Prevention: Two Related Topics: A Holistic Risk Assessment and Management Approach”. J. Ingleton (ed.) *Natural Disaster Management: A presentation to commemorate the International Decade for Natural Disaster Reduction (IDNDR), 1999-2000.* Leicester: Tudor Rose, p.151-153.

Cardona, Omar D. 2004. “The Need for Rethinking the Concepts of Vulnerability and Risk from a Holistic Perspective: A Necessary Review and Criticism for Effective Risk Management”. Gregory Bankoff, Georg Frerks and Dorothea Hilhorst. 2004. *Mapping vulnerability: Disasters, development and people*. London; Sterling, VA: Earthscan Publications, p.37-51.

CC (China Culture). 2003. “Han Ethnic Group”. *China Culture website*. Online. http://en/chinaculture.org/gb/en_aboutchina/2003-09/24/content_23849.htm Accessed on 6 March 2022.

CCOUC (Collaborating Centre for Oxford University and CUHK for Disaster and Medical Humanitarian Response). 2014. *The ethnic minority health project: Trip report for Hongyan, Sichuan.* Hong Kong: CCOUC. Online. http://ccouc.org/overview-2 Accessed on 3 May 2023.

CCPCO and PG (Chinese Communist Party Committee Office of Pingwu County and Pingwu Government). 2015. *Geohazard Prevention and Protection Plan of Pingwu County 2015*. Pingwu: Pingwu County Committee Office, April 2015. (In Chinese).

CCPCO and PG. 2016. *Geohazard Prevention and Protection Plan of Pingwu County 2016.* April 2016. Pingwu: Pingwu County Committee Office, 23pp. (In Chinese).

CCTV (China Central Television). 2008. "1400-year of Qiang culture was seriously hit". 2 June 2008. Original source: *Guangzhou Daily*. Online. http://news.cctv.com/china/20080602/101200.shtml Accessed on 25 January 2022. (In Chinese).

CEA (China Earthquake Administration). 2008a. *Index of M8.0 Wenchuan earthquake aftershocks of M4.0 above*. Online http://www.cea.gov.cn/manage/html/8a8587881632fa5c0116674a018300cf/_content/08_12/04/1228370745411.html Accessed on 1 July 2017. (In Chinese).

CEA. 2008b. *Distribution of M8.0 Wenchuan earthquake aftershocks of M4.0 above.* Online http://www.cea.gov.cn/manage/html/8a8587881632fa5c0116674a018300cf/sc/ Accessed on 1 July 2017. (In Chinese).

Central Government. 2006. "National Accidental Geohazard Emergency Response Plan". 13 January 2006. *The Central People's Government of the People's Republic of China website.* Online. http://www.gov.cn/yjgl/2006-01/13/content_157993.htm Accessed on 19 June 2022. (In Chinese).

Cepeda, Jose, Luca, P., Davide, T., Gaetano, P. and Michele, C. 2020. "Comparison of the performance of different Territorial Landslide Early Warning Systems". *22nd EGU General Assembly held online 4-8 May 2020 id.21648 Publication.* May 2020.

CGS (China Geological Survey). 2008. "Mass Monitoring and Mass Prevention Monitoring". *CGS website*. Online. https://www.cgs.gov.cn/ddztt/ddyw/wcdz/dzzhjc/201603/t20160309_293342.html Accessed on 23 March 2022. (In Chinese).

Chambers, Robert. 1989. "Editorial Introduction: Vulnerability, Coping and Policy". *IDS Bulletin,* Vol.20, No.2, p.1-7.

Chambers, Robert and Conway, Gordon R. 1992. *Sustainable rural livelihoods: practical concepts for the 21st century.* Institute of Development Studies Discussion Paper 296, Brighton: Institute of Development Studies IDS. Online. https://www.ids.ac.uk/publication/sustainable-rural-livelihoods-practical-concepts-for-the-21st-century Accessed on 31 December 2019.

Chamlee-Wright, Emily and Storr, V.H. 2009. ""There's No Place like New Orleans": Sense of Place and Community Recovery in the Ninth Ward after Hurricane Katrina". *Journal of Urban Affairs*, Vol.31, Iss.5, p.615-634.

Chan, Emily Ying Yang, Liu, K.S., Lee, P., Ling, K.W.K. and Wong, C.S. (eds.) 2016. *Training Manual on Health and Disaster Preparedness in Rural China*. Collaborating Centre for Oxford University and CUHK for Disaster and Medical Humanitarian Response (CCOUC) and Wu Zhi Qiao (Bridge to China) Charitable Foundation. Online. http://ccouc.org/_asset/file/public-health-manual-eng-small.pdf. Accessed on 1 July 2017.

Chan, Mo-po. 2016. "Revisiting the support of Sichuan rebuild works". *Blog of Chan Mo-po, Secretary for Development*, *Hong Kong Special Administrative Region.* 27 November 2016. Online.

https://www.news.gov.hk/tc/record/html/2016/11/20161127_110130.lin.shtml Accessed on 31 December 2019. (In Chinese).

Chaturvedi, Pratik and Dutt, V. 2015. “Evaluating the Public Perceptions of Landslide Risks in the Himalayan Mandi Town”. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Los Angeles, USA, 26-30 October 2015, p.1491-1495.

Chen, Chien-Yuan and Lee, W.C. 2012. “Damages to school infrastructure and development to disaster prevention education strategy after Typhoon Morakot in Taiwan”. *Disaster Prevention and Management*, Vol.21, Iss.5, p.541-555.

Chen, Hongxin. 2015. *Cell-based methodologies for rainfall-induced landslide and debris-flow risk assessment and early warning.* PhD Thesis. The Hong Kong University of Science and Technology. Online. https://hdl.handle.net/1783.1/74347 Accessed on 19 July 2022.

Chen, Wenfang, Cutter, S.L., Emrich, C.T. and Shi, P. 2013. “Measuring social vulnerability to natural hazards in the Yangtze River Delta region, China”. *International Journal of Disaster Risk Science,* Vol.4, p.169-181.

Chen, Xiaoqing, Cui, P., You, Y., Chen, J.G. and Li, D.J. 2015. “Engineering measures for debris flow hazard mitigation in the Wenchuan earthquake area”. *Engineering Geology,* 26 August 2015, Vol.194, p.73-85.

Chen, Yong, He, L. and Zhou, D. 2021. “Consequences of post-disaster policies and relocation approaches: two communities from rural China”. *Disaster Prevention and Management: An International Journal*, Vol.30, No.3, p.340-353.

China-UN. (Permanent Mission of the People’s Republic of China to the UN). 2008a. *China issues guidelines on post-quake reconstruction.* 4 July 2008. Online. http://www.china-un.org/eng/zt/earthquake20080512/t473615.htm Accessed on 1 July 2017.

China-UN. 2008b. *New home sought for Wolong's giant pandas.* 12 June 2008. Online. http://www.china-un.org/eng/zt/earthquake20080512/t464874.htm Accessed on 1 July 2017.

China view. 2008. *Earthquake costs China 73 bln USD: says official think tank. www.chinaview.cn 2008-06-18.* Online. http://www.china-un.org/eng/zt/earthquake20080512/t466721.htm Accessed on 1 July 2017.

CINIC (China Internet Network Information Center). 2016a. *The 37th Statistical Report on Internet Development Situation in China*. China: Cyberspace Administration of China. Online. www.cac.gov.cn/2016-01/22/c_1117858695.htm Accessed 21 March 2021. (In Chinese).

CINIC. 2016b. *Research Report on Internet Development Situation in Rural Areas 2015*. China: Cyberspace Administration of China. Online. www.cac.gov.cn/2016-08/30/c_1121534506.htm Accessed 20 March 2021. (In Chinese).

Clayton, Andrew. 1994. “IDNDR Conference: Protecting Vulnerable Communities, the Royal Society and the Institution of Civil Engineers, London, 13-15 October 1993”. *Disasters,* Vol.18, Iss.1, March 1994, p.89-90.

CLB (China Labour Bulletin). 2021. “Migrant workers and their children”. 4 May 2021. *China Labour Bulletin website*. Online. https://clb.org.hk/content/migrant-workers-and-their-children#:~:text=Skip%20to%20main,of%20your%20data Accessed on 21 February 2022.

Coburn, Andrew and Spence, Robin. 1992. *Earthquake protection*. Chichester, West Sussex: J. Wiley.

Colten, Craig E. 1988a. “Historical Questions in Hazardous Waste Management”. *The Public Historian*, Vol.10, No.1, p.7-20.

Colten, Craig E. 1988b. “Industrial Middens in Illinois: The Search for Historical Hazardous Wastes, 1870-1980”. *IA. The Journal of the Society for Industrial Archeology*, Vol.14, No.2, p.51-61.

Conway, Gordon R. 1987. “The properties of agroecosystems”. *Agricultural Systems,* Vol.24, Iss.2, p.95-117.

Corbett, Jane. 1988. “Famine and household coping strategies”. *World Development*, Vol.16, Iss.9, p.1099-1112.

Corral, Carles, Berenguer, M., Sempere-Torres, D., Poletti, L., Silvestro, F. and Rebora, N. 2019. “Comparison of two early warning systems for regional flash flood hazard forecasting”. *Journal of Hydrology*, Vol.572, p.603-619.

Costin, Cathy Lynne. 1998. “Introduction: Craft and Social Identity”. *Archaeological Papers of the American Anthropological Association*, Vol.8, Iss.1, Special Issue: Craft and Social Identity, January 1998, p.3-16.

CPG (The Central People’s Government of the People’s Republic of China). 2006. “Han ethnic group”. 17 April 2006. *CPG website*. Online. http://big5.www.gov.cn/gate/big5/www.gov.cn/test/2006-04/17/content_255850.htm Accessed on 6 March 2022. (In Chinese).

CPG. 2008a. “Opening of the Seminar on Rescue and Protect Qiangs’ ethnic and culture in Sichuan earthquake affected areas”. 30 May 2008. *CPG website*. Online. https://china.gov.cn.admin.kyber.vip/gzdt/2008-05/30/content_999866.htm Accessed on 29 December 2021. (In Chinese).

CPG. 2008b. “Sichuan Province will attract business investment of approximately RMB 10 billion for post-disaster rescue of Qiang culture”. 26 October 2008. *CPG website*. Online. http://www.gov.cn/jrzg/2008-10/26/content_1131682.htm Accessed on 27 February 2022. (In Chinese).

CPG. 2009. “Giant Panda Artificial Breeding Base Rebuild Project in Wolong, Sichuan, will commence this year”. 17 April 2009. *CPG website*. Online. http://www.gov.cn/jrzg/2009-04/17/content_1288495.htm Accessed on 3 February 2022. (In Chinese).

Crozier, Michael J. 1986. *Landslides: Causes, Consequences and Environment*. London: Routledge.

Cruden, David Milne and Varnes, D.J. 1996. “Landslide Types and Processes”. A. Keith Turner and Robert L. Schuster (eds.) 1996. *Landslides: Investigation and Mitigation.*

Transportation Research Board, U.S. National Research Council, Special Report 247, Chapter 3, p.36-75. Washington, D.C.: National Academy of Sciences.

CSI (China Seismic Information). 2008. *Earthquake intensity of the M8.0 Wenchuan earthquake in year 2008.* 1 September 2008. Online. http://www.csi.ac.cn/manage/html/4028861611c5c2ba0111c5c558b00001/_content/09_05/08/1241771246756.html Accessed on 12 May 2015. (In Chinese).

Cui, Ke, Han, Z. and Wang, D. 2018. "Resilience of an Earthquake-Stricken Rural Community in Southwest China: Correlation with Disaster Risk Reduction Efforts". *International Journal of Environmental Research and Public Health*, Vol.15, Iss.3, Number 407.

Cui, Ke, Shen, Z. and Song Y. 2023. "Scoping Review of the Impact of Post-earthquake Social Support on the Mental Health of Disaster Survivors". *Journal of Catastrophology*, July 2023, Vol.38, No.3, p.148-155 (In Chinese).

Cui, Ke and Sim, Timothy. 2015. *Local government emergency management and social work interventions in China.* Beijing: Social Sciences Academic Press (China). (In Chinese).

Cui, Ke and Sim, Timothy. 2017. "Older people's psychosocial needs in a post-disaster rural community of China: an exploratory study". *Natural Hazards*, Vol.85, No.3, February 2017.

Cui, Peng, Chen, X.Q., Zhu, Y.Y., Su, F.H., Wei, F.Q., Han, Y.S., Liu, H.J. and Zhuang, J.Q. 2011. "The Wenchuan Earthquake (May 12, 2008), Sichuan Province, China, and resulting geohazards". *Natural Hazards,* Vol.56, Iss.1, p.19-36.

Cui, Peng, Zhu, Y., Han, Y., Chen, X. and Zhuang, J. 2009. "The 12 May Wenchuan earthquake-induced landslide lakes: distribution and preliminary risk evaluation". *Landslides,* Vol.6, Iss.3, September 2009, p.209-223.

Cuny, Frederick, Abrams, Susan and Oxfam America (eds.) 1983. *Disasters and development*. New York: Oxford University Press.

Cutter, Susan Lynn. 1993. *Living with risk: The Geography of Technological Hazards*. E. Arnold, 214pp.

Cutter, Susan Lynn. 1996. "Vulnerability to environmental hazards". *Progress in Human Geography,* 20(4), p.529-539.

Cutter, Susan Lynn, Boruff, B.J. and Shirley, W.L. 2003. "Social Vulnerability to Environmental Hazards". *Social Science Quarterly,* Vol.84, Iss.2, p.242-261.

Cutter, Susan Lynn and Finch, C. 2008. "Temporal and spatial changes in social vulnerability to natural hazards". *Proceedings of the National Academy of Sciences (PNAS)*, 19 February 2008, Vol.105, No.7, p.2301-2306.

Cutter, Susan Lynn, Mitchell, J.T. and Scott, M.S. 2000. "Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina". *Annals of the Association of American Geographers*, Vol.90, Iss.4, p.713-737.

Cutter, Susan Lynn and Morath, D.P. 2013. *"The evolution of Social Vulnerability Index (SoVI)"*. Jörn Birkmann (ed.) *Measuring vulnerability to natural hazards: towards disaster resilient societies, Second edition*, p.304-321. Tokyo: United Nations University Press.

Cutter, Susan Lynn and Solecki, W.D. 1989. “The national pattern of airborne toxic releases”. *The Professional Geographer,* Vol.41, Iss.2, p.149-161.

Cutter, Susan Lynn, Tiefenbacher, J. and Solecki, W.D. 1992. “En-gendered fears: femininity and technological risk perception”. *Industrial Crisis Quarterly,* Vol.6, No.1, 1992, Special issue: Social science and risk, p.5-22.

Cvetkovich, George and Earle, T.C. 1992. “Environmental Hazards and the Public”. *Journal of Social Issues*, Vol.48, Iss.4, Winter 1992, p.1-20.

Davis, Ian (ed.) 2015. *Shelter after disaster, Second edition*. Geneva: IFRC and OCHA.

Davis, Ian and Alexander, David. 2016. *Recovery from Disaster.* Routledge Studies in Hazards, Disaster Risk and Climate Change. Oxon: Routledge.

Davis, Nancy Yaw. 1986. “Earthquake, Tsunami, Resettlement and Survival in Two North Pacific Alaskan Native Villages”. Vinson H. Sutlive *et al*. (eds.) Anthony Oliver-Smith (Guest Editor). *Natural Disasters and Cultural Responses,* p.123-154. Williamsburg, Va.: Department of Anthropology, College of William and Mary.

D’Cunha, Jean. 1997. “Engendering Disaster Preparedness and Management”. *Asian Disaster Management News,* November, Vol.3, No.3.

De Angeli, Silvia, Malamud, B.D., Rossi, L., Taylor, F.E., Trasforini, E. and Rudari, R. 2022. “A multi-hazard framework for spatial-temporal impact analysis”. *International Journal of Disaster Risk Reduction*, Vol. 73, 15 April 2022, Article 102829.

DeCarlo, Matthew. 2018. *Scientific Inquiry in Social Work.* Pressbooks.

DENR (Department of Environment and Natural Resources, The Philippines). 2017. *Geohazard Mapping and Assessment Program.* Online. http://www.denr.gov.ph/priority-programs/geo-hazard-mapping-and-assessment-program.html Accessed on 31 December 2019.

DGEM (Department of Geo-Environmental Management, Ministry of Land Resources). 2003. *Geological hazards and their control in China*. Beijing: Geological Publishing House. (In Chinese).

Dickinson, Simon Bernard. 2013. *Post-disaster mobilities: Exploring household relocation after the Canterbury earthquakes*. Master of Science thesis, Department of Geography, University of Canterbury.

Ding, HR, Li ,Y., Ni, SJ., Shao, CJ., Shi, ZM., Yan, L., Lv, LQ., Ni, T., Gong, RH., Shi, L. and Liu, YX. 2019. “The mountain torrent disasters and its effect on sediment transport after the Wenchuan earthquake”. *IOP Conference Series: Earth and Environmental Science, Vol.344*. The 5th International Conference on Water Resource and Environment (WRE 2019), 16-19 July 2019, Macao, China.

DLRSC (Department of Land and Resources of Sichuan Province). 2016. “Geohazard and meteorological risk early warning”. *Sichuan geological environment information site.* Sichuan Province Geological Environment Monitoring Station, DLRSC. Online. http://www.sczz.gov.cn/687.shtml# Accessed on 27 March 2016. (In Chinese).

DNRSC (Department of Natural Resources of Sichuan Province). 2022. “Geohazard and meteorological risk early warning”. *DNRSC website*. Online. http://dnr.sc.gov.cn/scdnr/scdzyj/iframe.shtml Accessed on 31 May 2022. (In Chinese).

Dowling, Casey A. and Santi, P.M. 2014. “Debris flows and their toll on human life: a global analysis of debris-flow fatalities from 1950 to 2011”. *Natural Hazards*, Vol.71, p.203-227.

Downing, Thomas E., Watts, M.J. and Bohle, H.G. 1996. “Climate change and food insecurity: Toward a sociology and geography of vulnerability”. Thomas E. Downing (ed.) *Climate Change and World Food Security.* Proceedings of the NATO Advanced Research Workshop “Climate Change and World Food Security” held in Oxford, U.K., July 11-15, 1993. NATO (North Atlantic Treaty Organization) ASI Series. Series I: Global Environmental Change, Vol.37, p.183-206. Berlin: Springer.

Drabek, Thomas E. 1969. "Social Processes in Disaster: Family Evacuation". *Social Problems,* Vol.16, No.3, Winter 1969, p.336-349.

Drabek, Thomas E. and Boggs, K.S. 1968. "Families in Disaster: Reactions and Relatives". *Journal of Marriage and Family*, August 1968, Vol.30, No.3, p.443-451.

Draugalis, JoLine Reierson, Coons, S.J. and Plaza, C.M. 2008. “Best Practices for Survey Research Reports: A Synopsis for Authors and Reviewers”. *American Journal of Pharmaceutical Education,* September 2008, 72(1), Article 11.

Du, Fei, Kobayashi, H., Okazaki, K. and Ochiai, C. 2016. “Research on the Disaster Coping Capability of a Historical Village in a Mountainous Area of China: Case Study in Shangli, Sichuan”. *Procedia – Social and Behavioral Sciences*, 9 May 2016, Vol.218, p.118-130.

Duan, Yonghou, Luo, Y.H. and Liu, Y. 1993. *Geological hazards in China.* Beijing: Architectural Industry Press of China. (In Chinese).

Dynes, Russell Rowe. 1970. *Organized Behavior in Disaster*. Lexington, Massachusetts: D.C. Heath.

Dynes, Russell Rowe. 2005. *Community social capital as the primary basis for resilience.* Newark: University of Delaware, Disaster Research Center.

Eisbacher, Gerhard H. and Clague, John Joseph. 1984. *Destructive mass movements in high mountains: hazard and management.* Ottawa: Geological Survey of Canada. Energy, Mines and Resources Canada. Government of Canada Publications. 230pp.

Elder, Keith, Xirasagar, S., Miller, N., Bowen, S.A., Glover, S. and Piper, C. 2007. “African Americans’ Decisions Not to Evacuate New Orleans Before Hurricane Katrina: A Qualitative Study”. *American Journal of Public Health,* Supplement 1, 2007, Vol.97, No.S1, S124-S129.

Elliott, James R. and Pais, J. 2006. “Race, class, and Hurricane Katrina: Social differences in human responses to disaster”. *Social Science Research*, Vol.35, Iss.2, June 2006, p.295-321.

Enarson, Elaine and Morrow, B.H. 1997. “A Gendered Perspective: The Voices of Women”. Walter Gillis Peacock, Betty Hearn Morrow and Hugh Gladwin (eds.) 1997.

Hurricane Andrew: Ethnicity, gender and the sociology of disasters, Chapter 7, p.116-139. Oxon: Routledge.

Enarson, Elaine. 1998. “Through Women’s Eyes: A Gendered Research Agenda for Disaster Social Science”. *Disasters*, Vol.22, Iss.2, June 1998, p.157-173.

Ersing, Robin L. and Kost, Kathleen A. (eds.) 2012. *Surviving Disaster: The Role of Social Networks*. Lyceum Series. Oxford University Press. 128pp.

Eyles, John. 1985. *Senses of place.* Warrington: Silverbrook Press. 162pp.

Falk, Monica Lindberg. 2012. “Gender, Buddhism and social resilience in the aftermath of the tsunami in Thailand”. *South East Asia Research*, Vol.20, No.2, June 2012, Special Issue, p.175-190.

Fan, Fa-ti. 2012. “Collective Monitoring, Collective Defense: Science, Earthquakes, and Politics in Communist China”. *Science in Context*, Vol.25, No.1, p.127-154.

Fan, Xuanmei, Juang, C.H., Wasowski, J., Huang, R., Xu, Q., Scaringi, G., van Westen, Cees J. and Havenith, Hans-Balder. 2018. “What we have learned from the 2008 Wenchuan Earthquake and its aftermath: A decade of research and challenges”. *Engineering Geology,* Vol.241, p.25-32.

Fan, Xuanmei, Scaringi, G., Domenech, G., Yang, F., Guo, X., Dai, L., He, C., Xu, Q. and Huang, R. 2019a. “Two multi-temporal datasets to track the enhanced landsliding after the 2008 Wenchuan earthquake”. *Journal of Earth System Science Data*, Vol.11, No.1, p.1-29.

Fan, Xuanmei, Scaringi, G., Korup, O., West, A.J., van Western, C., Tanyas, H., Hovius, N., Hales, T.C., Jibson, R.W., Allstadt, K.E., Zhang, L., Evans, S.G., Xu, C., Li, G., Pei, X., Xu, Q. and Huang, R. 2019b. “Earthquake-Induced Chains of Geologic Hazards: Patterns, Mechanisms, and Impacts”. *Reviews of Geophysics*, Vol.57, Iss.2, p.421-503.

Fan, Xuanmei, Xu, Q., Alonso-Rodriguez, A., Subramanian, S.S., Li, W., Zheng, G., Dong, X. and Huang, R. 2019c. “Successive landsliding and damming of the Jinsha River in eastern Tibet, China: prime investigation, early warning, and emergency response”. *Landslides,* Vol.16, Iss.5, May 2019, p.1003-1020.

Fathani, Teuku Faisal, Karnawati, D. and Wilopo, W. 2016. “An integrated methodology to develop a standard for landslide early warning systems”. *Natural Hazards and Earth System Sciences,* Vol.16, Iss.9, p.2123-2135.

Feld, Steven and Basso, Keith H. (eds.) 1996. *Senses of place.* Santa Fe: School of American Research Press. 310pp.

FEMA (Federal Emergency Management Agency). 2020. *Are You Ready? An In-Depth Guide to Citizen Preparedness.* P-2064, September 2020. 31pp.

FEMA. 2022. “Landslide Trapped. Phase: During”. *FEMA Community website*. Online. https://community.fema.gov/ProtectiveActions/s/article/Landslide-Trapped Accessed on 30 July 2022.

Feng, Mingcheng. 2013. “Study on the Current Situation and Countermeasures of Group Measurement and Prevention System Establishment in Chongqing”. *Journal of Institute*

of Disaster Prevention, Vol.15, Iss.3, p.90-94. (In Chinese).

Fernandez, Glenn, Tun, A.M., Okazaki, K., Zaw, S.H. and Kyaw, K. 2018. “Factors influencing fire, earthquake, and cyclone risk perception in Yangon, Myanmar”. *International Journal of Disaster Risk Reduction,* Vol.28, June 2018, p.140-149.

Finch, Christina, Emrich, C.T. and Cutter, S.L. 2010. “Disaster disparities and differential recovery in New Orleans”. *Population and Environment*, Vol.31, p.179-202.

Fleming, Robert W., Varnes, D.J. and Schuster, R.L. 1979. “Landslide Hazards and Their Reduction”. *Journal of the American Planning Association*, Vol.45, Iss.4, p.428-439.

Flynn, James, Slovic, P. and Mertz, C.K. 1994. “Gender, Race, and Perception of Environmental Health Risks”. *Risk Analysis,* Vol.14, No.6, p.1101-1108.

Fordham, Maureen Helen. 1992. *Choice and constraint in flood hazard mitigation: the environmental attitudes of floodplain residents and engineers*. Ph.D. Thesis, Middlesex Polytechnic, Enfield.

Fothergill, Alice. 2000. “Knowledge Transfer between Researchers and Practitioners”. *Natural Hazards Review*, Vol.1, No.2, p.91-98.

Fothergill, Alice, Maestas, E.G.M. and Darlington, J.D. 1999. “Race, Ethnicity and Disasters in the United States: A Review of the Literature”. *Disasters,* Vol.23, Iss.2, June 1999, p.156-173.

Friedsam, H.J. 1960, “Older Persons as Disaster Casualties”. *Journal of Health and Human Behaviour*, Vol.1, No.4, Winter 1960, p. 269-273.

Friedsam, H.J. 1961. "Reactions of Older Persons to Disaster-caused Losses: An Hypothesis of Relative Deprivation". *The Gerontologist*, March 1961, Vol.1, Iss.1, p.34-37.

Fritz, Charles E. and Mathewson, J.H. 1957. *Convergence Behavior in Disasters. A Problem In Social Control.* A Special Report Prepared for the Committee on Disaster Studies. Disaster Study Number 9. Washington D.C.: National Academy of Sciences – National Research Council.

Fussell, Elizabeth, Sastry, N. and VanLandingham, M. 2010. “Race, socioeconomic status, and return migration to New Orleans after Hurricane Katrina”. *Population and Environment,* January 2010, Vol.31, No.1/3, p.20-42.

Ganderton, Philip T. 2002. *Benefit-Cost Analysis of Disaster Mitigation: A Review.* 28pp.

Garrison, M.E. Betsy and Sasser, D.D. 2009. “Families and Disasters: Making Meaning out of Adversity”. Katie E. Cherry (ed.) *Lifespan Perspectives on Natural Disasters: Coping with Katrina, Rita, and Other Storms,* Chapter 6, p.113-130. New York: Springer.

Ge, Yonggang, Chen, X., Zhuang, J. and Zhu, X. 2014. “Characteristics, Impacts and Risks of Dammed Lakes Induced by Debris Flows at the Wenchuan Earthquake Areas”. *Journal of Water Resource and Protection,* Vol.6, No.17, p.1574-1588.

Ge, Yonggang, Cui, P., Zhang, J.Q., Zeng, C. and Su, F.H. 2015. “Catastrophic debris flows on July 10th 2013 along the Min River in areas seriously-hit by the Wenchuan earthquake”. *Journal of Mountain Science,* Vol.12, Iss.1, January 2015, p.186-206.

Geertz, Clifford. 1973. *The interpretation of cultures: selected essays.* New York: Basic Books. 478pp.

Gengda Township Government. 2016a. Information provided by Gengda Township Government in response to the first request from the researcher of this Research Degree Project. (In Chinese).

Gengda Township Government. 2016b. Information provided by Gengda Township Government in response to the second request from the researcher of this Research Degree Project. (In Chinese).

Gengda Xiang Government. 2008. *Geohazard Prevention and Protection Plan of Gengda Xiang 2008*. Gengda: Gengda Xiang People’s Government. (In Chinese).

Gengda Xiang Government. 2009. *Geohazard Prevention and Protection Plan cum Geohazard Emergency Response Plan*. Gengda: Gengda Xiang People’s Government. (In Chinese).

Gheradi, Silvia. 1998. “A Cultural Approach to Disasters”. *Journal of Contingencies and Crisis Management,* Vol.6, No.2, p.80-83.

Gill, Joel C. and Malamud, B.D. 2014. “Reviewing and visualizing the interactions of natural hazards”. *Reviews of Geophysics*, Vol.52, No.4, p.680-722.

Glade, Thomas and Nadim, F. 2014. “Early warning systems for natural hazards and risks”. *Natural Hazards,* Vol.70, p.1669-1671.

Glaser, Barney G. and Strauss, A.L. 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago: Aldine.

Google Maps. 2015.

Google Maps. 2016.

Google Maps. 2017.

Gorum, Tolga, Fan, X., van Westen, C.J., Huang, R.Q., Xu, Q., Tang, C. and Wang, G. 2011. “Distribution pattern of earthquake-induced landslides triggered by the 12 May 2008 Wenchuan earthquake”. *Geomorphology*, Vol.133, Iss.3-4, p.152-167.

Grossman, Valerie Aarne. 2020. “Leadership Essentials During a Disaster”. *Journal of Radiology Nursing*, Vol.39, Iss.3, September 2020, p.156-157.

Guo, Hongxing, Chen, X. and Gao, H. 2019. “Why China can rebuild ‘Wenchuan’ in three years”. 25 September 2019. *people.cn website.* Online. http://politics.people.com.cn/BIG5/n1/2019/0925/c429373-31371591.html Accessed on 3 February 2022. (In Chinese).

Guo, Xiaojun, Cui, P., Li, Y., Ma, L., Ge, Y. and Mahoney, W.B. 2016. “Intensity-duration threshold of rainfall-triggered debris flows in the Wenchuan Earthquake affected area, China”. *Geomorphology*, 15 January 2016, Vol.253, p.208-216.

Guo, Xiaojun, Cui, P., Marchi, L. and Ge, Y. 2017. “Characteristics of rainfall responsible for debris flows in Wenchuan Earthquake area”. *Environmental Earth Sciences*, Vol.76, Article number 596.

GZ (Guangzhou Municipal Planning and Natural Resources Bureau). 2022. “Organise training on geohazard prevention and mitigation. Enhance the level of Mass Monitoring and Mass Prevention”. 13 June 2022. *Guangzhou Municipal Planning and Natural Resources Bureau website*. Online. https://ghzyj.gz.gov.cn/gkmlpt/content/8/8333/mpost_8333627.html#941 Accessed on 17 June 2022. (In Chinese).

Haklay, Muki. 2013. “Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation”. D. Sui, S. Elwood and M. Goodchild (eds.) *Crowdsourcing Geographic Knowledge*. Dordrecht: Springer.

Hall, John R., Neitz, Mary Jo and Battani, Marshall. 2003. *Sociology on culture*. London: Routledge.

Hallegatte, Stephane. 2012. *A Cost Effective Solution to Reduce Disaster Losses in Developing Countries: Hydro-Meteorological Services, Early warning, and Evacuation.* Policy Research Working Papers. May 2012. World Bank.

Han, Guoyi, Xu, W., Liu, J. and Shi, P. 2013. “The Great Tangshan and Wenchuan Earthquakes in China: A Preliminary Comparison and Lessons Learned”. Peijun Shi, Carlo Jaeger and Qian Ye (eds.) *Integrated Risk Governance: science plan and case studies of large-scale disasters*. IHDP-Integrated Risk Governance Project Series, p.155-169. Beijing: Beijing Normal University Press and Springer-Verlag Berlin Heidelberg.

Han, Ziqiang. 2017. “Social Capital and Changes in Post-disaster Recovery Process: Observations from China after the 2008 Wenchuan earthquake”. William L. Waugh, Jr. and Ziqiang Han (eds.) *Restoring from Catastrophic Disaster in Asia*. *Community, Environment and Disaster Risk Management, Vol.18,* Chapter 2, p.15-36. Bingley: Emerald Publishing Limited.

Hanjiang Government. 2022. “Online survey about geohazard Mass Monitoring and Mass Prevention work, 3 to 30 January 2022”. *Hanjiang District Government website.* Putian City, Fujian Province, China. Online. http://www.pthj.gov.cn/gzcy/wsdc/detail.htm?id=2425 Accessed on 22 March 2022. (In Chinese).

Harris, Dale, Tuke, R., Smith, D. and Hughes, M. 2021. *Framework for evacuation routes. Waka Kotahi NZ Transport Agency research report 681.* 80pp.

Harris, Robert C., Hohenemser, C. and Kates, R.W. 1985. “Human and Nonhuman Mortality”. Robert William Kates, Christoph Hohenemser and Jeanne X. Kasperson (eds.) 1985. *Perilous progress: Managing the hazards of technology.* Westview special studies in science, technology, and public policy, p.129-155. Boulder, Colo.: Westview Press.

Harrison, Lawrence E. 2000. “Introduction – Why Culture Matters”. Lawrence E. Harrison and Samuel P. Huntington (eds.) *Culture Matters: How Values Shape Human Progress*, p.xvii-xxxiv. New York: Basic Books.

Hartman, Chester and Squires, Gregory (ed.) 2006. *There is no such thing as a natural disaster: Race, class, and Hurricane Katrina.* 30 November 2006. Routledge. 322pp.

Haynes, Katherine, Barclay, J. and Pidgeon, N. 2008. “The issue of trust and its influence on risk communication during a volcanic crisis”. *Bulletin of Volcanology*, Vol.70, Iss.5, March 2008, p.605-621.

Heijmans, Annelies. 2001. *‘Vulnerability’: A Matter of Perception. Disaster Management Working Paper 4/2001.* Benfield Greig Hazard Research Centre. University College London.

Heim, Albert. 1932. *Landslides and human lives (Bergsturz und Menchenleben).* Translated by Nigel Skermer (ed.) 1989. Vancouver, BC: Bi-Tech Publishers. 196pp.

Henry, Gary T. 1990. "Sample Selection Approaches". Gary T. Henry. *Practical Sampling*. Thousand Oaks: SAGE Publications Inc.

Hewitt, Kenneth (ed.) 1983. *Interpretations of Calamity from the Viewpoint of Human Ecology.* Mass: Allen & Unwin Inc.

Hewitt, Kenneth and Burton, Ian. 1971. *The hazardousness of a place: A regional ecology of damaging events. University of Toronto. Department of Geography. Research publications 6.* Toronto: University of Toronto Press.

HKJC (Hong Kong Jockey Club). 2014. “Wolong Administrative Authority Office and Staff Office Houses”. *Sichuan Rebuild.* Hong Kong Jockey Club. Online. http://www.512rjc.hk/tc/proj/proj_map/map_06_24_detail.htm Accessed on 1 July 2020. (In Chinese).

HKSAR (Hong Kong Special Administrative Region). 2016a. *Sichuan Rebuild, Paper for Hong Kong Legislative Council CB(1)248/16-17(01).* Online. http://www.legco.gov.hk/yr16-17/chinese/panels/dev/papers/devcb1-248-1-c.pdf Accessed on 1 July 2020. (In Chinese).

HKSAR. 2016b. “Fact Sheet – Infrastructure Projects”. *Sichuan Rebuild: HKSAR Projects.* Online. http://www.hk-sichuanrebuild.gov.hk/eng/factsheets_infra.html Accessed on 1 July 2020.

HKSAR. 2016c. *The China Conservation and Research Centre for the Giant Panda.* Online. http://www.hk4wolong.hk/en/research_center/index.html Accessed on 1 July 2020.

Hlady, W. Gary, Quenemoen, L.E., Armenia-Cope, R.R., Hurt, K.J., Malilay, J., Noji, E.K. and Wurm, G. 1994. “Use of a modified cluster sampling method to perform rapid needs assessment after Hurricane Andrew”. *Annals of Emergency Medicine,* Vol.23, Iss.4, April 1994, p.719-725.

Hochrainer-Stigler, S., Mechler, R. and Pflug, G. 2013. “Public sector fiscal vulnerability to disasters: The IIASA CATSIM model”. Jörn Birkmann (ed.) 2013. *Measuring vulnerability to natural hazards: towards disaster resilient societies, Second edition,* p.479-504. Tokyo: United Nations University Press.

Hoffmann, Roman and Blecha, D. 2020. “Education and Disaster Vulnerability in Southeast Asia: Evidence and Policy Implications”. *Sustainability* 2020, Vol.12, Iss.4, Article 1401.

Hofstede, Geert. 1991. *Cultures and Organizations: Software of the mind*. Berkshire: McGraw-Hill.

Hogg, Sarah Jane. 1980. “Reconstruction following Seismic Disaster in Venzone, Friuli”. *Disasters,* Vol.4, Iss.2, June 1980, p.173-185.

Horwich, George. 2000. “Economic Lessons of the Kobe Earthquake”. *Economic Development and Cultural Change*, Vol.48, Iss.3, p.521-542.

Hou, Zhijin, Zhou, X., Chen, J., Zhu, L., Ni, J. and Chen, S. 2014. “A research on factors affecting PTSD and PTG of secondary and primary school teachers: Pre-, during and post-disaster perspectives”. *Psychological Development and Education*, Vol.30, Iss.1, p.82-89. (In Chinese).

Hsu, Cho-Yun. 1980. “Han Agriculture: The Formation of Early Chinese Agrarian Economy, 206 B.C.-A.D.220”. Jack L. Dull (ed.) *Han Dynasty China Volume II.* Seattle: University of Washington Press. 377pp.

HTSMGEB (Hydro-engineering Team of Sichuan Metallurgical Geology and Exploration Bureau). 2010. *The fourth batch of significant geohazards in Sichuan Earthquake disaster-affected areas -- Construction graphs and design report of emergency engineering mitigation measures for Huanglianshu Gully Debris Flow in Pingtong Township, Pingwu County, Mianyang City.* June 2010. (In Chinese).

Hu, Jin and Yang, X.Z. 2013. “On Geo-Environment Deterioration Triggered by Earthquake Disaster – The Case of Anjiagou Debris Flow in Miansi Town, Wenchuan County, Sichuan Province”. *Advanced Materials Research*, Vols.610-613, p.771-776.

Hu, Jintao. 2008. “Speech on rescue works roundup”. Sun C.W. (ed.) *All Compilation of Sichuan Historical Earthquakes: Part 2, 2010,* p.484-493. Chengdu: Sichuan People Press. (In Chinese).

Hu, K.H., Cui, P. and Zhang, J.Q. 2012. “Characteristics of damage to buildings by debris flows on 7 August 2010 in Zhouqu, Western China”. *Natural Hazards and Earth System Sciences,* Vol.12, Iss.7, p.2209-2217.

Hu, Yanhong. 2010. “Social work of disaster based on gender: Take Wenchuan earthquake for example”. *Journal of Women’s Academy at Shandong,* Iss.5, p.28-33. (In Chinese).

Hu, Zewen, Zhang, X., Cui, J., Zhang, L. and Ahmed, W. 2021. “A survey-based analysis of the public’s willingness for disaster relief in China”. *Natural Hazards*, Vol.107, Iss.3, July 2021, p.2205-2225.

Huang, Huan, Wang, R., Xiao, Y., Li, Y., Zhang, Q.F. and Xiang X. 2022. “Determinants of People’s Secondary Hazards Risk Perception: A Case Study in Wenchuan Earthquake Disaster Areas of China”. *Frontiers in Earth Science.* 10:865143.

Huang, Jiangcheng, Li, X., Zhang, L., Li, Y. and Wang, P. 2020. “Risk perception and management of debris flow hazards in the upper salween valley region: Implications for disaster risk reduction in marginalized mountain communities”. *International Journal of Disaster Risk Reduction,* Vol.51, December 2020, 101856.

Huang, Runqiu and Li, W. 2014. “Post-earthquake landsliding and long-term impacts in the Wenchuan earthquake area, China”. *Engineering Geology*, Vol.182, Part B, p.111-120.

Huang, Shih-Kai, Lindell, M.K. and Prater, C.S. 2016. “Who Leaves and Who Stays? A Review and Statistical Meta-Analysis of Hurricane Evacuation Studies”. *Environment and Behavior,* Vol.48, Iss.8, October 2016, p.991-1029.

Hubl, Johannes, Suda, J., Proske, D., Kaitna R. and Scheidl, C. 2009. “Debris Flow Impact Estimation”. *Proceedings, International Symposium on Water Management and Hydraulic Engineering,* Ohrid/ Macedonia, 1-5 September 2009, Paper: A56, 12pp.

Hungr, Oldrich, Leroueil, S. and Picarelli, L. 2013. “The Varnes classification of landslide types, an update”. *Landslides*, Vol.11, Iss.2, April 2014, p.167-194.

Hunter, Lori M. 2005. “Migration and Environmental Hazards”. *Population and Environment,* Vol.26, No.4, p.273-302.

Huntington, Samuel P. 2000. “Foreword – Cultures Count”. Lawrence E. Harrison and Samuel P. Huntington (eds.) *Culture Matters: How Values Shape Human Progress*, p.xiii-xvi. New York: Basic Books.

Hurlbert, Jeanne, S., Haines, V.A. and Beggs, J.J. 2000. “Core Networks and Tie Activation: What Kinds of Routine Networks Allocate Resources in Nonroutine Situations?” *American Sociological Review*, August 2000, Vol.65, No.4, p.598-618. American Sociological Association.

Hutchinson, John Neville. 1988. “Morphological and geotechnical parameters of landslides in relation to geology and hydrogeology. General report”. C. Bonnard (ed.) *Proceedings of the 5th International Symposium on Landslides*, Lausanne, 10-15 July 1988, Vol.1, p.3-35. Publ Rotterdam: A A Balkema.

IFRC (International Federation of Red Cross and Red Crescent Societies). 2010. *A practical guide to Gender-sensitive Approaches for Disaster Management.* Geneva: IFRC.

IFRC. 2020. *Literature review on law and disaster recovery and reconstruction*. Geneva: IFRC.

IFRC and CREWS (Climate Risk and Early Warning Systems Initiative). 2020. *People Centred Early Warning Systems: Learning from National Red Cross and Red Crescent Societies*. Geneva: IFRC. Online. https://www.ifrc.org/document/people-centred-early-warning-systems Accessed on 1 July 2023.

IFRC and UNICEF. 2021. *Gender Responsive Disaster Risk Management. An analysis of gender integration in national and regional disaster risk management frameworks in Eastern and Southern Africa.* Online. https://www.unicef.org Accessed on 1 July 2022.

Innes, John L. 1983. “Debris flows”. *Progress in Physical Geography: Earth and Environment,* Vol.7, Iss.4, p.469-501.

IPCC (Intergovernmental Panel on Climate Change Core Writing Team, Pachauri, Rajendra K. and Reisinger, Andy) (eds.) 2008. *Climate Change 2007: Synthesis Report.*

Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC.

I¸sık, Özden, Özer, N., Sayın, N., Mishal, A., Gündo˘gdu, O. and Özçep, F. 2015. “Are women in Turkey both risks and resources in disaster management?” *International Journal of Environmental Research and Public Health,* Vol.12, Iss.6, June 2015, p.5758-5774.

Ishiwatari, Mikio and Sagara, Junko. 2012. *Structural Measures against Tsunamis.* Washington, DC: World Bank. Online. https://openknowledge.worldbank.org/handle/10986/16160 License: CC BY 3.0 IGO Accessed on 13 February 2023.

Iuchi, Kanako. 2010. *Redefining a Place to Live: Decisions, Planning Processes, and Outcomes of Resettlement after Disasters*. PhD dissertation. University of Illinois at Urbana-Champaign.

Iuchi, Kanako and Mutter, J. 2020. “Governing community relocation after major disasters: An analysis of three different approaches and its outcomes in Asia”. *Progress in Disaster Science,* Vol. 6, April 2020, Article 100071.

Iverson, Richard M. 1997. “The physics of debris flows”. *Reviews of Geophysics*, Vol.35, Iss.3, p.245-296.

Jalali, Rita. 2002. “Civil society and the state: Turkey after the Earthquake”. *Disasters,* Vol.26, Iss.2, June 2002, p.120-139.

Jayasuriya, Sisira, Paul Steele and Dushni Weerakoon in collaboration with Malathy Knight-John and Nisha Arunatilake. 2006. Asian Development Bank (ADB) Institute Research Paper Series, Number 71, January 2006, *Post-Tsunami Recovery: Issues and Challenges in Sri Lanka*. Tokyo: Asian Development Bank Institute Publishing. 64pp. Online. www.adbi.org Accessed on 16 February 2022.

Ji, Feng, Dai, Z. and Li, R. 2020. “A multivariate statistical method for susceptibility analysis of debris flow in southwestern China”. *Natural Hazards and Earth System Sciences*, Vol.20, Iss.5, p.1321-1334.

Jiang, Rui. 2018. “Participatory sensing framework based on open source software and the application in Mass Monitoring and Mass Prevention”. *Information Recording Materials*, Iss.11, p.63-64. (In Chinese).

JMA (Japan Meteorological Agency). 2017a. *Earthquake Information.* Online. http://www.jma.go.jp/en/quake/ Accessed on 31 December 2017.

JMA. 2017b. *Real-time Landslide Risk Map.* Online. http://www.jma.go.jp/en/doshamesh/ Accessed on 31 December 2017.

Johnson, Laurie A. and Olshansky, R.B. 2013. “The Road to Recovery. Governing Post-disaster Reconstruction”. *Land Lines*, July 2013, p.14-21. Lincoln Institute of Land Policy.

Joniak-Lüthi, A. 2013. “The Han Minzu, Fragmented Identities, and Ethnicity”. *The Journal of Asian studies*, Vol.72, No.4, p.849-871.

Ju, Nengpan, Huang, J., He, C., Van Asch, T.W.J., Huang, R., Fan, X., Xu, Q., Xiao, Y.

and Wang, J. 2020. “Landslide early warning, case studies from Southwest China”. *Engineering Geology*, Vol.279, 105917.

Ju, Nengpan, Huang, J., Huang, R.Q., He, C. and Li, Y. 2015. “A Real-time monitoring and early warning system for landslides in Southwest China”. *Journal of Mountain Science,* Vol.12, p.1219-1228.

Kahneman, Daniel and Tversky, A. 1973. “On the psychology of prediction”. *Psychological Review*, Vol.80, p.237-251.

Kaniasty, Krys and Norris, F.H. 1993. “A test of the social support deterioration model in the context of natural disaster”. *Journal of Personality and Social Psychology*, Vol.64, No.3, p.395-408.

Kasperson, Jeanne X., Kasperson, Roger E. and Turner, B.L. 1995. *Regions at Risk. Comparisons of Threatened Environments.* Tokyo: The United Nations University Press.

Kates, Robert William. 1962. *Hazard and Choice Perception in Flood Plain Management.* Research Paper No. 78, Department of Geography, University of Chicago. (Cited in Hunter 2005).

Kates, Robert William. 1976. “Experiencing the Environment as Hazard”. Seymour Wapner, Saul Cohen and Bernard Kaplan (eds.) 1976. *Experiencing the Environment*, p.133-156. New York: Plenum Press.

Kates, Robert William, Hohenemser, C. and Kasperson, J.X. 1985. “Introduction: Coping with Technological Hazards”. Robert William Kates, Christoph Hohenemser and Jeanne X. Kasperson (eds.) 1985. *Perilous progress: Managing the hazards of technology. Westview special studies in science, technology, and public policy,* p.1-19. Boulder, Colo.: Westview Press.

Kates, Robert William and Pijawka, D. 1977. “From rubble to monument: the pace of reconstruction”. John Eugene Haas, Robert William Kates and Martyn J. Bowden (eds.) *Reconstruction following disaster,* p.1-23. 1977. Cambridge, Massachusetts: MIT Press. 331pp. (Cited in Alexander 2007).

Kawasaki, Akiyuki, Ichihara, N., Ochii, Y., Acierto, R.A., Kodaka, A. and Zin. W.W. 2017. “Disaster response and river infrastructure management during the 2015 Myanmar floods: A case in the Bago River Basin”. *International Journal of Disaster Risk Reduction,* Vol.24, September 2017, p.151-159.

Keefer, David K. 1984. “Landslides caused by earthquakes”. *Geological Society of America Bulletin*, April 1984, Vol.95, Number 4, p.406-421.

Keefer, David K. 2002. “Investigating Landslides Caused by Earthquakes – A Historical Review”. *Surveys in Geophysics*, November 2002, Vol.23, Iss.6, p.473-510.

Kelman, Ilan, Mercer, J. and Gaillard, JC. 2012. “Indigenous knowledge and disaster risk reduction”. *Geography*, Vol.97, No.1, p.12-21.

Khondker, Habibul Haque. 1996. “Women and Floods in Bangladesh”*. International Journal of Mass Emergencies and Disasters,* November 1996, Vol.14, Iss.3, p.281-292.

Kingdon, John. 1984. *Agendas, Alternatives, and Public Policies*. Glenview, Ill.: Scott, Foresman.

Kingdon, John. 1995. *Agendas, Alternatives, and Public Policies, Second edition.* New York: Harper Collins College.

Kingdon, John. 2011. *Agendas, Alternatives, and Public Policies, Updated second edition.* Longman classics in political science. Boston: Longman.

Kok, Marcel T.J. and Jäger, J. Karlsson Sl. (eds.) 2007. *Vulnerability of people and the environment – challenges and opportunities.* Background Report on Chapter 7 of the Fourth Global Environment Outlook (GEO-4) assessment report. Nairobi, Kenya: United Nations Environment Programme (UNEP). Also by Netherlands Environmental Assessment Agency (PBL). July 2009.

Kok, Marcel T.J. and Jäger, J. 2013. "Archetypical patterns of vulnerability to environmental change: An approach to bridging scales. Lessons learned from UNEP's Fourth Global Environment Outlook". Jörn Birkmann (ed.) 2013. *Measuring vulnerability to natural hazards: towards disaster resilient societies, Second edition,* p.148-163. Tokyo: United Nations University Press.

Kong, Ji-ming, Fayou, A. and Wu, W. 2009. "Typical examples analysis the types of Wenchuan earthquake landslide". *Journal of Soil Water Conservation*, Vol.23, No.6, p.66-70. (In Chinese).

Kroeber, Alfred L. and Kluckhohn, Clyde. 1952. *Culture: A Critical Review of Concepts and Definitions.* Cambridge, Massachusetts: Peabody Museum Press. 247pp.

Kuhn, Ursina. 2019. *Measurement of income in surveys.* FORS Guide No. 02, Version 1.0. January 2019. Lausanne: Swiss Centre of Expertise in the Social Sciences FORS.

Lavelle, Kristen 2006. "Hurricane Katrina: The Race and Class Debate". Michael D. Yates (ed.) *Monthly Review, An Independent Socialist Magazine. Aspects of Class in the U.S.*, Vol.58, No.3, July-August 2006, p.52-66.

Lestari, Fatma, Jibiki, Y., Sasaki, D., Pelupessy, D., Zulys, A. and Imamura, F. 2021. "People's Response to Potential Natural Hazard-Triggered Technological Threats after a Sudden-Onset Earthquake in Indonesia". *International Journal of Environmental Research and Public Health,* Vol.18, No.7, 3369.

Lewis, James. 1999. *Development in Disaster-prone Places: Studies of vulnerability.* London: Intermediate Technology Publications.

Li, Qiushan, Umaier, K. and Koide, O. 2019. "Research on post-Wenchuan earthquake recovery and reconstruction implementation: A case study of housing reconstruction of Dujiangyan City". *Progress in Disaster Science*, December 2019, Vol.4, 100041.

Li, Qiuxi. 2017. *The reconstruction of the Sichuan earthquake: fieldwork observation and examination of the news coverage of the Qiang ethnic group.* Master's Thesis. Delaware: University of Delaware.

Li, Tianchi. 1994. "Landslide Disasters and Human Responses in China". *Mountain Research and Development*, November 1994, Vol.14, No.4, p.341-346.

Li, Xiaohong, Li, S., Qin, L., Luo, S., Hu, H., Pang, H., Li, L., Fan, W. and Xiao, Z. 2011. “Influence of earthquake on menstrual cycles and psychological well-being in women who lost their children in the quake and intended to conceive again”. *Journal of Practical Obstetrics and Gynecology*, Vol.27, Iss.1, p.69-72. (In Chinese).

Li, Xiuzhen and Kong, J. 2013. “Types and Characteristics of Typical Landslides Triggered by the M8.0 Wenchuan Earthquake”. Keizo Ugai, Hiroshi Yagi and Akihiko Wakai (eds.) *Earthquake-Induced Landslides.* Proceedings of the International Symposium on Earthquake-Induced Landslides, Kiryu, Japan, 2012, p.169-178. Berlin, Heidelberg: Springer-Verlag.

Li, Yong, Huang, R., Yan, L., Densmore, A.L. and Zhou, R. 2010. “Surface Rupture and Hazard of Wenchuan Ms 8.0 Earthquake, Sichuan, China”. *International Journal of Geosciences,* Vol.1, No.1, May 2010, p.21-31.

Lin, Jen-Jen and Lin, W-I. 2016. “Cultural issues in post-disaster reconstruction: the case of Typhoon Morakot in Taiwan”. *Disasters*, Vol.40, Iss.4, October 2016, p.668-692.

Lin, Nan, Cook, Karen S. and Burt, Ronald S. (ed.) 2001*. Social Capital: Theory and Research.* New York: Routledge. 333pp.

Lindell, Michael K. 2020. “Improving Hazard Map Comprehension for Protective Action Decision Making”. *Frontiers in Computer Science,* 31 July 2020.

Lindell, Michael K. and Perry, Ronald W. 2004. *Communicating Environmental Risk in Multiethnic Communities.* Thousand Oaks: Sage Publications.

Liu, Jinfeng, Nakatani, K. and Mizuyama, T. 2013. “Effect assessment of debris flow mitigation works based on numerical simulation by using Kanako 2D”. *Landslides,* Vol.10, Iss.2, April 2013, p.161-173.

Liu, Tiancai, Zhu, G. and Zhang, H. 2020. “Mass Monitoring and Mass Prevention technological system research based on WebGIS”. *Geospatial Information*, Vol.6. (In Chinese).

Liu, Zhuang. 2019. *Research on Sichuan Wolong Xiongmao Gully debris flow development features and counter measures.* Master Thesis. Geological Engineering. Chengdu Polytechnic University. (In Chinese).

Liverman, Diana M. 1990. “Drought Impacts in Mexico: Climate, Agriculture, Technology and Land Tenure in Sonora and Puebla”. *Annals of the Association of American Geographers,* Vol.80, Iss.1, p.49-72.

Lo, Alex and Cheung, L.T.O. 2015. “Seismic risk perception in the aftermath of Wenchuan earthquakes in southwestern China”. *Natural Hazards,* Vol.78, p.1979-1996.

López-Carresi, Alejandro. 2012. “Emergency Management Principles”. Ben Wisner, JC Gaillard, Ilan Kelman (ed.) *Handbook of Hazards and Disaster Risk Reduction, First edition*, Chapter 42. Routledge. 912pp.

Lovekamp William E. and Arlikatti, S. 2013. “Social Change and Empowerment”. Deborah S.K. Thomas, Brenda D. Phillips, William E. Lovekamp and Alice Fothergill (eds.) *Social Vulnerability to Disasters, Second edition*. 2013, Chapter 17, p.447-473. Boca Raton: CRC Press, Taylor & Francis Group.

Lowe, Donald R. 1979. “Sediment gravity flows: their classification and some problems of application to natural flows and deposits”. *The Society of Economic Palaeontologists and Mineralogists, Special Publication,* No. 27, August 1979, p.75-82.

Lowe, Donald R. 1982. “Sediment gravity flows: II Depositional models with special reference to the deposits of high-density turbidity currents”. *Journal of Sedimentary Petrology,* Vol.52, No.1, March 1982, p.279-297.

LRDSP (Land and Resources Department of Sichuan Province). 2010. *Local Administration on The fourth batch of significant geohazards in Sichuan Earthquake disaster-affected areas required mitigation assessments,* 23 March 2010*.* Online. www.scdlr.gov.cn Accessed on 31 December 2016. (In Chinese).

Lu, Yi and Xu, J. 2015. “NGO collaboration in community post-disaster reconstruction: field research following the 2008 Wenchuan earthquake in China”. *Disasters,* Vol.39, Iss.2, April 2015, p.258-278.

Ludy, Jessica and Kondolf, G.M. 2012. “Flood risk perception in lands “protected” by 100-year levees”. *Natural Hazards,* Vol.61, p.829-842.

Luo, Guo-Liang. 2014. “A research and defects analysis of the disaster relief system of China”. *Journal of Risk Research*, Vol.17, Iss.3, p.383-404.

Luo, Yuner, Shaw, R., Lin, H. and Joerin, J. 2014. “Assessing response behavior of debris-flows affected communities in Kaohsiung, Taiwan”. *Natural Hazards,* Vol.74, No.3, p.1429-1448.

Markwart, Henriette, Vitera, J., Lemanski, S., Kietzmann, D., Brasch, M. and Schmidt, S. 2019. “Warning messages to modify safety behavior during crisis situations: A virtual reality study”. *International Journal of Disaster Risk Reduction,* Vol.38, August 2019, 101235.

Meyer, Michelle Annette. 2013. *Social capital and collective efficacy for disaster resilience: Connecting individuals with communities and vulnerability with resilience in hurricane-prone communities in Florida.* Doctoral dissertation. Colorado State University, Fort Collins.

MGMR (Ministry of Geology & Mineral Resources, State Science & Technology Commission and State Planning Commission of the Chinese government, PRC). 1991. *Geological Hazards of China and their Prevention and Control.* Beijing: Geological Publishing House. (In Chinese).

Mianyang Government. 2011. “Post-earthquake rehabilitation and counterpart assistance”. *Mianyang Government website*. 23 August 2011. Online. http://www.mianyang.gov.cn/MYGOV/145812876978814976/20110823/585535.html Accessed on 31 December 2018. (In Chinese).

Mianyang Government. 2017. “Income of residents”. *Mianyang Municipal People’s Government website.* Online. http://www.my.gov.cn/MYGOV/145806288498982912/20160122/1571181.html Accessed on 11 October 2018. (In Chinese).

Mianyang Government. 2019. “The People’s Government of Sichuan Province on the endorsement of adjusting part of the townships administrative division of Mianyang City”. *Mianyang Government website.* Online. http://mzt.sc.gov.cn/scmzt/gsgg/2019/12/26/581d52db571e4662a9656929d1c58095.shtml Accessed on 6 June 2022. (In Chinese).

Miceli, Renato, Sotgiu, I. and Settanni, M. 2008. “Disaster preparedness and perception of flood risk: A study in an alpine valley in Italy”. *Journal of Environmental Psychology*, Vol.28, Iss.2, p.164-173.

MIIT (Ministry of Industry and Information Technology of the People’s Republic of China). 2016. *Memo by MIIT on Quality and Quantity of Telecommunication Service, Issue 1, 2016*. 5 February 2016. Beijing: MIIT. Online. https://www.miit.gov.cn/zwgk/zcwj/wjfb/tg/art/2020/art_1a22c866cbb04c9bb35765115d366ab4.html Accessed 21 March 2021. (In Chinese).

MIIT. 2017. *Communication Operation Industry Statistical Release 2016.* 22 January 2017. Beijing: MIIT. Online. https://www.miit.gov.cn/jgsj/yxj/xxfb/art/2020/art_71496a41ff2345c0934394a09a34c63e.html Accessed 21 March 2021. (In Chinese).

MIIT. 2019. *Communication Industry Statistical Release 2018*. 25 January 2019. Beijing: MIIT. Online. https://www.miit.gov.cn/gxsj/tjfx/txy/art/2020/art_f9b061284a1646498f135584d8f78757.html Accessed 21 March 2021. (In Chinese).

MIIT. 2021. *Communication Industry Statistical Release 2020.* 22 January 2021. Beijing: MIIT. Online. https://www.miit.gov.cn/jgsj/yxj/xxfb/art/2021/art_f2e9a4844b964586bfea3977c2e1baf2.html Accessed 22 March 2021. (In Chinese).

Mileti, Dennis S. and Passerini, E. 1996. “A Social Explanation of Urban Relocation after Earthquakes”. *International Journal of Mass Emergencies and Disasters*, March 1996, Vol.14, No.1, p.97-110.

Mileti, Dennis S. and Peek, L. 2000. “The social psychology of public response to warnings of a nuclear power plant accident”. *Journal of Hazardous Materials*, Vol.75, Nos.2-3, p.181-194.

Milligan, Melinda J. 1998. “Interactional Past and Potential: The Social Construction of Place Attachment”. *Symbolic Interaction*, Vol.21, Iss.1, May 1988, p.1-33.

Mizrak, Sefa and Turan, M. 2023. “Effect of individual characteristics, risk perception, self-efficacy and social support on willingness to relocate due to floods and landslides”. *Natural Hazards*, Vol.116, Iss.2, March 2023, p.1615-1637.

MLIT (Ministry of Land, Infrastructure, Transport and Tourism). 2023. *Disaster Prevention Portal.* Japan. Online. https://www.mlit.go.jp/river/bousai/olympic/en/helpful03/index.html Accessed on 14 February 2023.

MLR (Ministry of Land and Resources). 2008a. “Strengthen Mass Monitoring and Mass Prevention system development is the solid foundation and effective way to prevent geohazard”. *The Central People’s Government of the People’s Republic of China*

website. Online. http://big5.www.gov.cn/gate/big5/www.gov.cn//zxft/ft122/content_1000853.htm Accessed on 23 March 2022. (In Chinese).

MLR. 2008b. “Knowledge of geohazard prevention and mitigation (1): Disaster Prevention Plan and Understanding Card”. *The Central People’s Government of the People’s Republic of China website.* 15 May 2008. Online. http://big5.www.gov.cn/gate/big5/www.gov.cn/fwxx/kp/2008-05/15/content_975703_2.htm Accessed on 24 March 2022. (In Chinese).

MLR. 2009. “Commence the establishment of Geohazard Mass Monitoring and Mass Prevention Ten-possession counties”. *Ministry of Land and Resources Newsletter*, Vol.8. (In Chinese).

MLR. 2017. “Ministry of Land and Resources: Create an upgraded version of Geohazard Mass Monitoring and Mass Prevention System”. *The Central People’s Government of the People’s Republic of China website.* 21 January 2017. Online. http://www.gov.cn/xinwen/2017-01/21/content_5161590.htm Accessed on 23 March 2022. (In Chinese).

MNR (Ministry of Natural Resources). 2018. “Definition and categorisation of geohazards”. *Ministry of Natural Resources website*. Online. www.mlr.gov.cn/zt/dzfz/11.htm Accessed on 31 December 2021. (In Chinese).

MNR and CMA (Ministry of Natural Resources and China Meteorological Administration). 2022. “Ministry of Natural Resources and China Meteorological Administration jointly issue geohazard and meteorological risk early warning at 18:00 on 30 May (2022)”. *CMA geohazard and meteorological risk early warning website*. Online. http://weather.cma.cn/web/channel-fdb168519f08446088d6461b381b32b9.html Accessed on 30 May 2022. (In Chinese).

Molyneux, Maxine and Razavi, S. 2005. “Beijing Plus Ten: An Ambivalent Record on Gender Justice”. *Development and Change*, Vol.36, Iss.6, November 2005, p.983-1010.

Moore, Harry Estill. 1958. *Tornadoes Over Texas: A Study of Waco and San Angelo in Disaster.* Austin: University of Texas Press. 334pp.

Morrow, Betty Hearn. 1999. “Identifying and Mapping Community Vulnerability”. *Disasters*, Vol.23, Iss.1, March 1999, p.1-18.

Morrow, Betty Hearn and Enarson, E. 1996. “Hurricane Andrew Through Women’s Eyes: Issues and Recommendations”. *International Journal of Mass Emergencies and Disasters,* March 1996, Vol.14, No.1, p.5-22.

Moynihan, Donald. 2013. “A central agency is crucial for disaster response”. *Nature*, Vol.495, Iss.7439, p.7.

Mustafa, Daanish, Gioli, G., Qazi, S., Waraich, R., Rehman, A. and Zahoor, R. 2015. “Gendering flood early warning systems: the case of Pakistan”. *Environmental Hazards*, Vol.14, No.4, p.312-328.

Muttarak, Raya and Lutz, W. 2014. “Is Education a Key to Reducing Vulnerability to Natural Disasters and hence Unavoidable Climate Change?” *Ecology and Society,* Vol.19, No.1, Article 42.

Myers, Candice A., Slack, T. and Singelmann, J. 2008. “Social vulnerability and migration in the wake of disaster: the case of Hurricanes Katrina and Rita”. *Population and Environment*, Vol.29, p.271-291.

Nakagawa, Yuko and Shaw, R. 2004. “Social Capital: A Missing Link to Disaster Recovery”. *International Journal of Mass Emergencies and Disasters*, March 2004, Vol.22, No.1, p. 5-34.

Nakano, Genta and Yamori, K. 2021. “Disaster risk reduction education that enhances the proactive attitudes of learners: A bridge between knowledge and behavior”. *International Journal of Disaster Risk Reduction*, Vol.66, December 2021, 102620.

Nakaya, Naoki, Nemoto, H., Yi, C., Sato, A., Shingu, K., Shoji, T., Sato, S., Tsuchiya, N., Nakamura, T., Narita, A., Kogure, M., Sugawara, Y., Yu, Z., Gunawansa, N., Kuriyama, S., Murao, O., Sato, T., Imamura, F., Tsuji, I., Hozawa, A. and Tomita, H. 2018. “Effect of tsunami drill experience on evacuation behavior after the onset of the Great East Japan Earthquake”. *International Journal of Disaster Risk Reduction*, Vol.28, June 2018, p.206-213.

Nanba Township Government. 2015. Information provided by Nanba Township Government in response to the request from the researcher of this Research Degree Project. (In Chinese).

Nanba Township Government. 2016. Information provided by Nanba Township Government during site visits. (In Chinese).

Nanda, Serena and Warms, Richard L. 2020. *Cultural anthropology, 12th edition.* Thousand Oaks: SAGE Publications, Inc. 456pp.

NBSC (National Bureau of Statistics of China). 2001. *The new characteristics of Chinese rural floating population in year 2000.* 10 September 2001. Online. http://www.stats.gov.cn/ztjc/ztfx/fxbg/200203/t20020328_14072.html. Accessed on 11 December 2021. (In Chinese).

NBSC. 2016. *China Statistical Yearbook 2016.* Beijing: China Statistics Press, Beijing Info Press. Online. https://www.stats.gov.cn/sj/ndsj/2016/indexeh.htm Accessed 29 March 2022.

NBSC. 2017. *China Statistical Yearbook 2017*. Beijing: China Statistics Press, Beijing Info Press. Online. https://www.stats.gov.cn/sj/ndsj/2017/indexeh.htm Accessed 29 March 2022.

NBSC. 2018. *China Statistical Yearbook 2018*. Beijing: China Statistics Press, Beijing Info Press. Online. https://www.stats.gov.cn/sj/ndsj/2018/indexeh.htm Accessed 29 March 2022.

NBSC. 2019. *China Statistical Yearbook 2019*. Beijing: China Statistics Press, Beijing Info Press. Online. https://www.stats.gov.cn/sj/ndsj/2019/indexeh.htm Accessed 29 March 2022.

NBSC. 2020. *China Statistical Yearbook 2020*. Beijing: China Statistics Press, Beijing Info Press. Online. https://www.stats.gov.cn/sj/ndsj/2020/indexeh.htm Accessed 29 March 2022.

NBSC. 2021. *China Statistical Yearbook 2021.* Beijing: China Statistics Press, Beijing Info Press. Online. https://www.stats.gov.cn/sj/ndsj/2021/indexeh.htm Accessed 29 March 2022.

NEAC (National Ethnic Affairs Commission of the People's Republic of China). 2022a. *Aba Tibetan (Zang) and Qiang Autonomous Prefecture.* Online. http://www.neac.gov.cn/seac/ztzl/201207/1067792.shtml Accessed on 16 March 2022. (In Chinese).

NEAC. 2022b. *An Overview of the Qiang ethnic group.* Online. http://www.neac.gov.cn/seac/ztzl/qz/gk.shtml Accessed on 25 Jan 2022. (In Chinese).

NEAC. 2022c. *History and Origin of the Qiang ethnic group.* Online. http://www.neac.gov.cn/seac/ztzl/qz/lsyg.shtml Accessed on 25 Jan 2022. (In Chinese).

Neal, David M., Perry Jr., J.B. and Hawkins, R. 1982. "Getting Ready for Blizzards: Preparation Levels in the Winter of 1977-78"*. Sociological Focus,* Vol.15, No.1, January 1982, p.67-76.

Neal, David M. and Phillips, B. 1990. "Female-Dominated Local Social Movement Organizations in Disaster-Threat Situations". Guida West and Rhoda Blumberg (eds.) *Women and Social Protest*, p.243-255*.* New York: Oxford University Press.

Nielsen, Samuel and Lidstone, J. 1998. "Public education and disaster management: is there any guiding theory?" *The Australian Journal of Emergency Management*, Spring 1998, p.14-19.

Noelle-Neumann, Elisabeth. 1974. "The Spiral of Silence: A Theory of Public Opinion". *Journal of Communication*, Vol.24, Iss.2, p.43-51.

NPC (The National People's Congress of the People's Republic of China). 2008. *State Council report on the anti-seismic rescue and post-disaster recovery reconstruction work of Wenchuan mega-earthquake in Sichuan*. Online. www.npc.gov.cn Accessed on 1 July 2016. (In Chinese).

NTG (Nanba Township Government). 2016. *2016 Geohazard Prevention and Protection Plan of Nanba Township, Pingwu County.* (In Chinese).

NWS (National Weather Service). 2022. *Warning Systems.* Online. https://www.weather.gov/unr/Warning_Systems Accessed on 26 March 2022.

ODI (Overseas Development Institute). 2015. *Pathways to earthquake resilience in China*. London: Overseas Development Institute.

Ogawa, Yujiro, Fernandez, A.L. and Yoshimura, T. 2005. "Town Watching As A Tool For Citizen Participation In Developing Countries: Applications In Disaster Training". *International Journal of Mass Emergencies and Disasters*, August 2005, Vol.23, No.2, p.5-36.

Ogra, Anshu, Donovan, A., Adamson, G., Viswanathan, K.R. and Budimir, M. 2021. "Exploring the gap between policy and action in Disaster Risk Reduction: A case study from India". *International Journal of Disaster Risk Reduction,* Vol.63, September 2021, 102428.

O'Keefe, Phil, Westgate, K. and Wisner, B. 1976. "Taking the Naturalness out of Natural Disasters". *Nature,* 15 April 1976, Vol.260.

Oliver-Smith, Anthony. 1982. "Here There Is Life: The Social Cultural Dynamics of Success Resistance to Resettlement in Postdisaster Peru". Art Hansen and Anthony Oliver-Smith (eds.) 1982. *Involuntary Migration and Resettlement: The Problems and Responses of Dislocated People,* Chapter 6, p.85-104. Boulder, Colorado: Westview. 333pp.

Oliver-Smith, Anthony. 1991. "Successes and Failures in Post-Disaster Resettlement". *Disasters,* Vol.15, No.1, p.12-23.

Oliver-Smith, Anthony. 1996. "Anthropological Research on Hazards and Disasters". *Annual Review of Anthropology*, Vol.25, p.303-328.

Oliver-Smith, Anthony. 2020. "Postscript: Hazards of Nature, Disasters of Society". Anthony Oliver-Smith and Susanna M. Hoffman (eds.) 2020. *The Angry Earth: Disaster in Anthropological Perspective, Second edition*. Oxon: Routledge. 402pp.

Olson, R.A. and Alexander, D.E. (eds.) 1996. *Proceedings of the Second National Workshop on Modelling Earthquake Casualties for Planning and Response*. Los Altos, California, February 1996. Sacramento: Olson Associates. (Cited in Alexander 1997).

Osberg, Timothy M. and Shrauger, J.S. 1986. "Self-prediction: Exploring the parameters of accuracy". *Journal of Personality and Social Psychology*, Vol.51, Iss.5, p.1044-1057.

Oxfam. 2011. *Gender and Disaster Risk Reduction: A training pack.* Online. https://policy-practice.oxfam.org/resources/gender-and-disaster-risk-reduction-a-training-pack-136105/ Accessed on 18 January 2022.

Ozerdem, Alpaslan and Jacoby, Tim. 2006. *Disaster Management and Civil Society: Earthquake Relief in Japan, Turkey and India*. *Volume 1 of International library of postwar reconstruction and development.* New York: I.B.Tauris. 172pp.

Padavic, Irene and Reskin, Barbara. 2002. *Women and men at work, Second edition.* Thousand Oaks: Pine Forge Press.

Palm, Risa and Hodgson, Michael. 1992. *After a California earthquake: attitude and behavior change.* Chicago: University of Chicago Press.

Paltemaa, Lauri. 2017. "Researching disasters and disaster management in China: Persistent questions and emerging trends". *China Information*, Vol.31, Iss.3, p.277-283.

Parasuraman, S. 1995. "The Impact of the 1993 Latur-Osmanabad (Maharashtra) Earthquake on Lives, Livelihoods and Property". *Disasters*, Vol.19, Iss.2, June 1995, p.156-169.

Park, Hyoungseong, Cho, S., Kim, D. and Sungjin-hong. 2015. "Development of a smartphone application for disaster response". *OCEANS 2015 – MTS/IEEE Washington.* Washington, DC, USA, 2015, p.1-4.

Patankar, Archana. 2015. *The Exposure, Vulnerability, and Ability to Respond of Poor Households to Recurrent Floods in Mumbai.* Policy Research Working Paper, No.7481. Washington, DC: World Bank.

Patterson, Orlando. 2010. “The mechanisms of cultural reproduction: Explaining the puzzle of persistence”. John R. Hall, Laura Grindstaff and Ming-Cheng Lo (eds.) *Handbook of Cultural Sociology*, Chapter 13, p.139-151. Oxon: Routledge, Taylor & Francis Group. Online. https://scholar.harvard.edu/patterson/publications Access on 18 February 2022.

Paul, Jonathan D., Buytaert, W., Allen, S., Ballesteros-Canovas, J.A., Bhusal, J., Cieslik, K. *et al.* 2018. “Citizen science for hydrological risk reduction and resilience building”. *WIREs Water*, 5:e1262.

Paul, Jonathan D., Hannah, D.M. and Liu, W. 2019. “Editorial: Citizen Science: Reducing Risk and Building Resilience to Natural Hazards”. *Frontiers in Earth Science,* December 2019, Vol.7, Article 320.

Pavlides, Eleftherios and Cranz, G. 2011. “Ethnographic Methods in Support of Architectural Practice”. S. Mallory-Hill, W. Preiser and C. Watson (eds.) *Enhancing Building and Environmental Performance.* 2011. Hoboken, NJ: John Wiley. Online. https://www.academia.edu/7960600/Ethnographic_Methods_in_Support_of_Achitectural_Practice Accessed on 20 February 2022.

PDD (Platform on Disaster Displacement). 2022. “Internally Displaced People” and “Disaster Displacement”. *Key definitions, Platform on Disaster Displacement website*. Online. https://disasterdisplcement.org/the-platform/key-definitions Accessed on 2 February 2022.

PDOE (People’s Daily Overseas Edition). 2017. *China eradicating poverty “Declaration trusted, Action achieved”*. Beijing: The State Council, The People’s Republic of China. Online. www.gov.cn/xinwen/2017-02/24/content_5170443.htm Accessed on 9 March 2021. (In Chinese.)

Peacock, Walter Gillis and Girard, C. 1997. “Ethnic and Racial Inequalities in Hurricane Damage and Insurance Settlements”. Walter Gillis Peacock, Betty Hearn Morrow and Hugh Gladwin (eds.) 1997. *Hurricane Andrew: Ethnicity, gender and the sociology of disasters*, Chapter 9, p.171-190. London: Routledge.

PEDRR (Partnership for Environment and Disaster Risk Reduction). 2013. “Ecosystems, Livelihoods and Disasters”. *About PEDRR website.* Online. http://pedrr.org/about-us/ Accessed on 1 July 2016.

PEDRR. 2014. “A post 2015 world: Ecosystem management integral to climate resilient development”. *International Science-Policy Workshop website, Bogor. 2014*. Online. http://pedrr.org/training/current-event/international-science-policy-workshop-bogor-2014/ Accessed on 1 July 2016.

Pelling, Mark and Dill, K. 2008. ”Disaster politics: from social control to human security”. *Environment, Politics and Development Working Paper Series*, Paper 1. Department of Geography, King’s College London.

Pelling, Mark. 2001. “Natural Disasters?” Noel Castree and Bruce Braun (eds.) *Social Nature: Theory, Practice, and Politics*, p.170-188. London: Blackwell.

Perloff, Linda S. 1983. “Perceptions of Vulnerability to Victimization”. *Journal of Social Issues*, Vol.39, Iss.2, p.41-61.

Perry, Ronald W. and Lindell, M.K. 1991. “The Effects of Ethnicity on Evacuation Decision-Making”. *International Journal of Mass Emergencies and Disasters*, March 1991, Vol.9, No.1, p.47-68.

Perry, Ronald W. and Mushkatel, Alvin H. 1986. *Minority Citizens in Disasters.* Athens: University of Georgia Press.

Phifer, James F. 1990. “Psychological Distress and Somatic Symptoms After Natural Disaster: Differential Vulnerability Among Older Adults”. *Journal of Psychology and Aging,* Vol.5, No.3, p.412-420.

Phillips, Brenda D. 1991. “Post-Disaster Sheltering and Housing of Hispanics, the Elderly and the Homeless”. *Final Project Report to the National Science Foundation.* Dallas, Texas: Southern Methodist University Press. (Cited in Morrow 1999).

Pierson, Thomas C. 1980. “Erosion and deposition by debris flows at Mt Thomas, North Canterbury, New Zealand”. *Earth Surface Processes,* Vol.5, p.227-247.

Pierson, Thomas C. 1986. “Flow behavior of chanellized debris flows, Mount St. Helens, Washington”. A.D. Abrahams (ed.) *Hillslope Processes*, p.269-296*.* Boston: Allen and Unwin.

Pingtong Township Government. 2014. *2014 Geohazard Prevention and Mitigation Work Plan and Card of Understanding of Pingtong Township, Pingwu County.* Pingwu: Pingtong Township Government. (In Chinese).

Pingtong Township Government. 2015a. *Notice on implementation of monitoring, early warning and relocation in relation to geohazards, floodings, roads, levees and bridges: Five daily implementations.* Pingwu: Pingtong Township Government. (In Chinese).

Pingtong Township Government. 2015b. *Pingtong Township Geohazard Emergency Response Plan.* Pingwu: Pingtong Township Government. (In Chinese).

Pingtong Township Government. 2015c. *Pingtong Township Geohazard Drill Detailed Arrangements 2015.* Pingwu: Pingtong Township Government. (In Chinese).

Pingtong Township Government. 2016a. *Notice on implementation of monitoring, early warning and relocation in relation to geohazards, floodings, roads, levees and bridges: Five daily implementations.* Pingwu: Pingtong Township Government. (In Chinese).

Pingtong Township Government. 2016b. *Pingtong Township Emergency Response Plan on Tackling Flooding Risk 2016*. Pingwu: Pingtong Township Government. (In Chinese).

Pingwu County Government. 2015. Information provided by Pingwu County Government during site visits. (In Chinese).

Pingwu County Government. 2016. Information provided by Pingwu County Government during site visits. (In Chinese).

Pingwu Government. 2012a. *Nanba Township.* Online http://www.pingwu.gov.cn/contents/646/22527.html Accessed on 1 July 2017. (In Chinese).

Pingwu Government. 2012b. *Pingtong Township.* Online http://www.pingwu.gov.cn/contents/646/22504.html Accessed on 1 July 2017. (In Chinese).

Pingwu Government. 2017. *About Pingwu.* Online. http://www.pingwu.gov.cn/about/ Accessed on 1 July 2018. (In Chinese).

Poortinga, Wouter and Pidgeon, N.F. 2003. “Exploring the Dimensionality of Trust in Risk Regulation”. *Risk Analysis,* Vol.23, Iss.5, p.961-972.

Poortinga, Wouter and Pidgeon, N.F. 2004. “Trust, the Asymmetry Principle, and the Role of Prior Beliefs”. *Risk Analysis,* Vol.24, Iss.6, p.1475-1486.

Proshansky, Harold M. 1978. “The city and self-identity”. *Environment and Behaviour*, Vol.10, No.2, p.147-169.

Purchase, Iain F.H. and Slovic, P. 1999. “Quantitative Risk Assessment Breeds Fear”. *Human and Ecological Risk Assessment: An International Journal,* Vol.5, Iss.3, p.445-453.

Qi, Xiao-Hua. 2008. “Geohazard Mass Monitoring and Mass Prevention System in Guangxi and problem countermeasures”. *Nanfang Land Resource*, No.6. (In Chinese).

Qian, Gang. 2008. “An initial investigation of earthquake early warning”. *Universities Service Centre for China Studies website*. The Chinese University of Hong Kong. Online. http://ww2.usc.cuhk.edu.hk/PaperCollection/Details.aspx?id=6744 Accessed on 25 January 2022. (In Chinese).

Qian, Song. 2017. “Aging, and separation from children: The health implications of adult migration for elderly parents in rural China”. *Demographic Research*, Vol.37, p.1761-1792.

Qiu, Yue. 2016. *Performing Qiang: locality production in post-disaster Northern Sichuan, China.* Ph.D. Thesis. Hong Kong University of Science and Technology.

Rahayu, Harkunti Pertiwi, Comfort, L.K., Haigh, R., Amaratunga, D. and Khoirunnisa, D. 2020. “A study of people-centered early warning system in the face of near-field tsunami risk for Indonesian coastal cities”. *International Journal of Disaster Resilience in the Built Environment,* Vol.11, Iss.2, p.241-262.

Ranghieri, Federica and Ishiwatari, Mikio (eds.) 2014. *Learning from Megadisasters: Lessons from the Great East Japan Earthquake.* Washington, DC: World Bank. License: Creative Commons Attribution CC BY 3.0 IGO

Rapoport, Amos. 1987. “On The Cultural Responsiveness of Architecture”. *Journal of Architectural Education*, Vol.41, Iss.1, p.10-15. Taylor & Francis, Ltd., Association of Collegiate Schools of Architecture, Inc.

Rapp, Anders. 1960. “Recent development of mountain slopes in Karkevagge and surroundings, northern Scandinavia”. *Geografiska Annaler,* Vol.42, No.2/3, p.71-200.

Rapp, Anders and Stromquist, L. 1979. “Field experiments on mass movements in the Scandinavian mountains with special reference to Karkevagge, Swedish Lappland”. *Studia Geomorphologica Carpatho-Balcanica*, 13, p.23-38. (Cited in Innes 1983).

Ratnayake, R.M.G.D. and Rameezdeen, R. 2008. “Post Disaster Housing Reconstruction: Comparative Study of Donor Driven vs. Owner Driver Approach”.

Kaushal Keraminiyage, Suranga Jayasena, Dilanthi Amaratunga and Richard Haigh (eds.) *Post disaster recovery challenges in Sri Lanka*, 2008, Chapter 6, p.51-62. CIB International Conference on Building Education and Research, 11-15 February 2008 at Heritance Kandalama, Sri Lanka. Salford: The University of Salford.

RCSC (Red Cross Society of China). 2011. *Sichuan earthquake reconstruction report released. 9 May 2011.* Online. https://reliefweb.int/report/china/sichuan-earthquake-reconstruction-report-released Accessed on 4 February 2022.

Ready. 2022. "Landslides & Debris Flow: During". *Ready.gov website*. U.S. Department of Homeland Security. Online. https://www.ready.gov/landslides-debris-flow Accessed on 13 June 2022.

Relph, Edward C. 1976. *Place and placelessness.* London: Pion.

Ren, Tao, Wu, Y. and Hao, W. 2013. "Design and Implementation of 3-D GIS System of Mass Monitoring and Mass Prevention of Geological Hazard Based on InfoEarth iTelluro". *Journal of Changjiang River Scientific Research Institute*, Vol.30, No.7, p.111-116. (In Chinese).

Renaud, Fabrice G. 2013. "Environmental components of vulnerability". Jörn Birkmann (ed.) *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*, *Second edition,* p.109-123. Tokyo: United Nations University Press.

Rhodes, Alison M. and Tran, T.V. 2012. "Predictors of Posttraumatic Stress and Growth Among Black and White Survivors of Hurricane Katrina: Does Perceived Quality of the Governmental Response Matter?" *Race and Social Problems,* Vol.4, p.144-157.

Rhyner, Jakob. 2013. "Introduction". Jörn Birkmann (ed.) *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*, *Second edition,* 2013, p.1-6. Tokyo: United Nations University Press.

Rivers, J.P.W. 1982. "Women and children last: An essay on sex discrimination in disasters". *Disasters,* Vol.6, Iss.4, December 1982, p.256-267.

RJC (Reconstruction Joint Conference). 2018. "Foreword – Completion of Post-quake Reconstruction Work in Sichuan". *Sichuan Rebuild*. Online. https://www.512rjc.hk/en/home/index.html Accessed on 3 February 2022. (In Chinese).

Salvati P., Bianchi, C., Fiorucci, F., Giostrella, P., Marchesini, I. and Guzzetti, F. 2014. "Perception of flood and landslide risk in Italy: a preliminary analysis". *Natural Hazards and Earth System Sciences*, Vol.14, Iss.9, p.2589-2603.

Santha, Sunil D. 2014. "Coastal Resources, Ecosystem Services and Disaster Risk Reduction: An Analysis of Social and Environmental Vulnerability along the Coast of India". *GAR 2015 Input Papers*. UNISDR.

Sassa, Kyoji. 1985. "The Geotechnical classification of landslides". *Proceedings: 4th International Conference and Field Workshop on Landslides*, p.31-45. (Cited in Sassa 1999).

Sassa, Kyoji. 1989. "Geotechnical classification of landslides". *Landslide News*, No.3, p.21-24. (Cited in Sassa 1999).

Sassa, Kyoji. 1999. “Introduction”. Kyoji Sassa (ed.) *Landslides of the world*, p.3-18. Kyoto: Kyoto University Press.

SBS (Sichuan Bureau of Statistics). 2011. *The release of Main Figures of the 2010 Sixth Population Census of China, Sichuan Province*. 6 June 2011. Online. http://www.stats.gov.cn/tjsj/tjgb/rkpcgb/dfrkpcgb/201202/t20120228_30404.html. Accessed on 1 January 2022. (In Chinese).

SC and NBSC (Population Census Office of the State Council and National Bureau of Statistics of China) (ed.) 2010. *Tabulation on The 2010 Population Census of The People’s Republic of China.* Beijing: China Statistics Press, Beijing Info Press. Online. https://www.stats.gov.cn/sj/pcsj/rkpc/6rp/indexch.htm Accessed 24 December 2021. (In Chinese).

Scanlon, Joseph. 2007. “Unwelcome Irritant or Useful Ally? The Mass Media in Emergencies”. Havidán Rodríguez, Enrico L. Quarantelli and Russell Dynes (ed.) 2007. *Handbook of Disaster Research*, Chapter 24, p.413-429. New York: Springer.

Schaefer, Richard T. 2013. *Sociology: a brief introduction, 10th edition.* New York: McGraw-Hill.

Schein, Edgar H. with Schein, Peter A. 2016. *Organizational culture and leadership, Fifth edition.* December 2016. US: John Wiley & Sons Inc. 416pp.

Schneider, David Murray. 1984. “The Fundamental Assumption in the Study of Kinship: “Blood Is Thicker Than Water”. *A Critique of the Study of Kinship,* Chapter 14. Ann Arbor: The University of Michigan Press. 208pp.

Schuster, Robert L. and Krizek, Raymond J. (eds.) 1978. *Landslides: Analysis and Control*. Transportation Research Board, Special Report 176. Washington, D.C.: National Academy of Sciences.

SCIO (State Council Information Office). 2008. *Introduction of State Wenchuan Earthquake Expert Committee Press Conference by Official Ma Zongjin*. Online. www.scio.gov.cn Accessed on 1 July 2016. (In Chinese).

Scolobig, Anna, Linnerooth-Bayer, J., Pelling, M., Martin, J. G.C., Deubelli, T.M., Liu, W. and Oen, A. 2023. “Transformative adaptation through nature-based solutions: a comparative case study analysis in China, Italy, and Germany”. *Regional Environmental Change*, Vol.23, Iss.2, June 2023, Article 69.

Scrivenor, J.B. 1929. “The Mudstreams (’Lahars’) of Gunong Keloet in Java”. *Geological Magazine,* Vol.LXVI, No.X, October 1929, p.433-34.

SEA (Sichuan Earthquake Administration). 2019. “Chapter on the region -- Current work on earthquake prevention and disaster reduction in Mianyang, 29 April 2019”. *Sichuan Earthquake Administration website.* Online. http://www.scdzj.gov.cn/scdzsjb/dzpd_262/scfzjzxx/201904/t20190429_9985.html Accessed on 13 June 2022. (In Chinese).

Secretariat of IDNDR (International Decade for Natural Disaster Reduction). 1995. *Disaster Reduction in Urban Areas. A contribution to the preparations for the Second United Nations Conference on Human Settlements (Habitat II). Draft. July 1995.* Geneva.

Segoni, Samuele, Piciullo, L. and Gariano, S.L. 2018. “Preface: Landslide early warning systems: monitoring systems, rainfall thresholds, warning models, performance evaluation and risk perception”. *Natural Hazards and Earth System Sciences*, Vol.18, Iss.12, p.3179-3186.

Sen, Amartya. 1981. *Poverty and famines: An essay on entitlement and deprivation*. Oxford: Oxford University Press.

SGIO (Sichuan Geological Investigation Office). 2015a. *Detailed Investigative Report of Geohazards in Pingwu County, Mianyang City, Sichuan Province, in 2015*. (In Chinese).

SGIO. 2015b. *1:10,000 Geohazard Surveying and Mapping Report on Focal Investigation Regions - Appendix 8 of SGIO 2015a.* (In Chinese).

SGIO. 2015c*. Appended Report 2 of SGIO 2015a.* (In Chinese).

SGIO. 2015d*. Appended Table 2 of SGIO 2015a.* (In Chinese).

SGIO. 2015e. *Basic situation of Geohazard Risk Sites in Pingwu County, Mianyang City, Sichuan Province, in 2015 - Appended Table 1 of SGIO 2015a.* (In Chinese).

Sharp, Robert P. and Nobles, L.H. 1953. “Mudflow of 1941 at Wrightwood, Southern California”. *GSA Bulletin*, Vol.64, No.5, p.547-560.

Sharpe, Charles Farquharson Stewart. 1938. *Landslides and Related Phenomena: A Study of Mass Movements of Soil and Rock*. New York: Columbia University Press. 137pp. (Cited in Innes 1983 and Hungr *et al.* 2013).

Shaw, Rajib. 2003. “The Role of Non-governmental Organizations in Earthquake Disaster Management: An Asian Perspective”. *Regional Development Dialogue,* April 2003, Vol.24, No.1, p.117-129.

Shaw, Rajib and Goda, K. 2004. “From Disaster to Sustainable Civil Society: The Kobe Experience”. *Disasters*, Vol.28, Iss.1, March 2004, p.16-40.

Shaw, Rajib, Shiwaku, K., Kobayashi, H. and Kobayashi, M. 2004. “Linking experience, education, perception and earthquake preparedness”. *Disaster Prevention and Management*, Vol.13, No.1, p.39-49.

Shaw, Rajib, Shiwaku, K. and Takeuchi, Y. (ed.) 2011. *Disaster education. Community, Environment and Disaster Risk Management Volume 7.* Bingley: Emerald Group Publishing.

Sheko, A.I. and Krupoderov, V.S. (ed.) 1984. *Methods of permanent forecast of exogenic geological processes.* Moscow: Nedra. 188pp. (In Russian). (Cited in Hutchinson 1988).

Shepherd, Dean A. and Williams, T.A. 2014. “Local venturing as compassion organizing in the aftermath of a natural disaster: The role of localness and community in reducing suffering”. *Journal of Management Studies*, Vol.51, Iss.6, p.952-994.

Shi, Zhao, Wei, F. and Chandrasekar, V. 2018. “Radar-based quantitative precipitation estimation for the identification of debris flow occurrence over earthquake-affected regions in Sichuan, China”. *Natural Hazards and Earth System Sciences*, Vol.18, Iss.3, p.765-780.

Shiwaku, Koichi and Shaw, R. 2008. “Proactive co-learning: a new paradigm in disaster education”. *Disaster Prevention and Management: An International Journal*, Vol.17, No.2, p.183-198. Emerald Group Publishing Limited.

Sichuan Government. 2009. “Partner assistance”. *Sichuan Government website*. Online. https://www.sc.gov.cn/10462/10778/50000236/500000278/index.shtml#:~:text=%C2%A0,ICP%20%E5%A4%8705030899%E5%8F%B7 Accessed on 3 February 2022. (In Chinese).

Sichuan Government. 2010. *An overall list of geohazard risk sites in Sichuan Province in year 2010.* Sichuan Government. (In Chinese).

Sichuan Government. 2016. “Sichuan: Expert acceptance of ‘Earthquake geohazard early warning technical research, 29 December 2016’”. *Chinese Government website.* Online. http://www.gov.cn/xinwen/2016-12/29/content_5154248.htm Accessed on 13 June 2022. (In Chinese).

Sichuan Government. 2017a. “The Second Press Conference held at Mao County Frontline News Emergency Response Centre”. *Sichuan Government website.* Online. http://www.sc.gov.cn/10462/10464/10797/2017/6/24/10426325.shtml Accessed on 1 October 2017. (In Chinese).

Sichuan Government. 2017b. “Professor Xu Qiang’s analysis of the Xinmo Village landslide at The Sixth Press Conference held at Mao County Frontline News Emergency Response Centre”. *Sichuan Government website.* Online. http://www.sc.gov.cn/10462/10464/10797/2017/6/26/10426408.shtml Accessed on 1 October 2017. (In Chinese).

Sichuan Government. 2017c. “The latest aerial images of the landslide in Diexi Township, Mao County”. *Sichuan Government website.* Online. http://www.sc.gov.cn/10462/10778/14220/2017/6/24/10426297.shtml Accessed on 1 October 2017. (In Chinese).

Sichuan Government. 2017d. “Landslide with massif collapse from high grounds occurred at 6 a.m.this morning in Diexi Township, Mao County, buried over 100 people”. *Sichuan Government website.* Online. http://www.sc.gov.cn/10462/12771/2017/6/24/10426238.shtml Accessed on 1 October 2017. (In Chinese).

Sichuan Government. 2017e. *Sichuan Provincial People’s Government website.* Online. http://www.sc.gov.cn/10462/wza2012/scgk/scgk.shtml Accessed on 1 October 2017. (In Chinese).

Sichuan Government. 2022. “Overview of Sichuan”. *Sichuan Provincial People’s Government website*. Online. https://www.sc.gov.cn/10462/10758/11799/11800/2018/4/30/10300452.shtml Accessed on 18 March 2022. (In Chinese).

Siegrist, Michael and Gutscher, H. 2006. “Flooding Risks: A Comparison of Lay People’s Perceptions and Expert’s Assessments in Switzerland”. *Risk Analysis,* Vol.26, No.4, p.971-979.

Sim, Boon-wee (Shen, Wen-wei) and Huang, Y.Z. 2012. “An Analysis on Counterpart Assistance Policy for Wenchuan”. *Journal of Zhejiang Gongshang University,* Vol.115, No.4, July 2012. (In Chinese).

Sim, Boon-wee and Cui, Ke (ed.) 2017. *Pathways to earthquake resilience in China*. Beijing: Social Sciences Academic Press (China). (In Chinese).

Sim, Timothy and Dominelli, L. 2017. “When the mountains move: A Chinese post-disaster psychosocial social work model”. *Qualitative Social Work*, Vol.16, Iss.5, September 2017, p.594-611.

Sim, Timothy, Cui, K. and Yang, Y. 2015. ”Recent earthquakes in China: the case of Yingxiu Town in Sichuan Province”. John Young, Ke Cui, Lena Dominelli, Timonthy Sim, William Weizhong Chen, Ning Li, Ling Zhang, Zhao Bin, Yunxi Yang, Brian Tucker, Tony Zhang Jun, Patrick Zhang Jun, Philip England and Richard Walker. *Pathways to earthquake resilience in China.* London: Overseas Development Institute.

Sim, Timothy, Lau, J., Cui, K. and Wei, H-H. 2019. “Post-disaster Psychosocial Capacity Building for Women in a Chinese Rural Village*”. International Journal of Disaster Risk Science*, Vol.10, No.2, June 2019, p.193-203.

Sinoprobe. 2012. *The bad temper of the Earth: Geohazards*. Online. www.mlr.gov.cn/kpyd/tiki/201203/t20120331 Accessed on 1 July 2017. (In Chinese).

SKLGP (State Key Laboratory of Geohazard Prevention and Geoenvironment Protection). 2019. “Briefing on the Preliminary Investigation and Analysis of Mountain Torrents and Debris Flow Disasters Induced by Sichuan ‘8.20” Heavy Rainfall”. *SKLGP website*. Online. en.sklgp.cdut.edu.cn/sklgpen/info/1030/2320.htm Accessed on 1 July 2017.

Slovic, Paul. 1986. “Informing and Educating the Public About Risk”. *Risk Analysis*, Vol.6, No.4, p.403-415.

Sobhaninia, Saeideh. 2023. “Does social cohesion accelerate the recovery rate in communities impacted by environmental disasters in Puerto Rico? An analysis of a community survey”. *Environmental Advances,* Vol.13, October 2023, 100400.

Solecki, William D. 1990. *Acute chemical disasters and rural United States hazardscapes.* PhD dissertation. Department of Geography, Rutgers University.

Solecki, William D. and Michaels, S. 1994. “Looking Through the Postdisaster Policy Window”. *Environmental Management,* Vol.18, Iss.4, July 1994, p.587-595.

Speare, Alden Jr. 1974. “Residential satisfaction as an intervening variable in residential mobility”. *Demography*, Vol.11, No.2, p.173-188.

Spence, Robin J.S., Baxter, P.J. and Zuccaro, G. 2004. "Building vulnerability and human casualty estimation for a pyroclastic flow: a model and its application to Vesuvius". *Journal of Volcanology and Geothermal Research*, Vol.133, Iss.1-4, p.321-343.

SPPG (Sichuan Provincial People’s Government). 2010. “Press conference for the Post 5.12 Wenchuan Mega-earthquake rehabilitation, 12 May 2010”. *Sichuan Provincial People’s Government website*. Online. http://www.sc.gov.cn/hdjl/xwfbh/zhcjfbh/bqbd/201005/t20100512_952141.shtml Accessed on 31 December 2018. (In Chinese).

SSGEC (Sichuan Shutong Geotechnical Engineering Company). 2010. *Construction design report of engineering mitigation measures for Xingping Gully Debris Flow in*

Jiankan Village, Xingping Village and Xinjian Village in Nanba Township, Pingwu County, Mianyang City, April 2010. (In Chinese).

SSGEC. 2011. *Xingping Gully Construction Map Design Report Revised Version, January 2011.* (In Chinese).

Stallings, Robert A. 2007. "Methodological Issues". Havidán Rodríguez, Enrico L. Quarantelli and Russell R. Dynes (eds). *Handbook of Disaster Research.* New York: Springer.

Starominski-Uehara, Marvin. 2021. "How structural mitigation shapes risk perception and affects decision-making". *Disasters*, Vol.45, Iss.1, January 2021, p.46-66.

State Council. 2003. "Regulation on the Prevention and Control of Geological Disasters". *Order of the State Council of the People's Republic of China (No. 394).* Date issued: 24 November 2003. (In Chinese).

State Council. 2008a. "Regulations on Post-Wenchuan Earthquake Rehabilitation and Reconstruction, Article 32 and 47". *Order of the State Council of the People's Republic of China (No. 526).* Date issued: 8 June 2008. (In Chinese).

State Council. 2008b. "Post-Wenchuan Earthquake Rehabilitation and Reconstruction Partner Assistance Plan". 11 June 2008. *The Central People's Government of the People's Republic of China website*. Online. http://www.gov.cn Accessed on 16 Feb 2022. (In Chinese).

State Council. 2021a. *Major Figures on 2020 Population Census of China.* Beijing: China Statistics Press.

State Council. 2021b. *Announcement of the Seventh National Population Census.* Online. https://www.gov.cn/guoqing/2021-05/13/content_5606149.htm Accessed on 13 December 2022. (In Chinese).

Steady, Filomina Chioma. 1993. "Women, Shelter and the Environment". *Environmental Values*, Vol.2, Iss.2, May 1993, p.163-176.

Steele, Fritz. 1981. *The Sense of Place.* Boston: CBI Publishing Company. 216pp.

Stini, J. 1910. *Die Muren. Debris flows.* English translation by Jacob, M. and Skermer, N. 1997. EBA Engineering Consultants, Vancouver, Canada. 106pp.

Stokols, Daniel and Shumaker, S.A. 1981. "People in places: A transactional view of settings". John H. Harvey (ed.) *Cognition, social behaviour, and the environment.* Mahwah, NJ: Erlbaum. 608pp.

Stratton, Samuel J. 2019. "Data Sampling Strategies for Disaster and Emergency Health Research". *Prehospital and Disaster Medicine*, Vol.34, No.3, p.227-229.

Strauss, Jennifer A. and Allen, R.M. 2016. "Benefits and Costs of Earthquake Early Warning". *Seismological Research Letters,* Vol.87, Iss.3, p.765-772.

Strauss, Anselm L. and Corbin, J.M. 1998. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory, Second edition*. Thousand Oaks, CA: Sage.

Sun, Mengjie, Chen, B., Ren, J. and Chang, T. 2010. "Natural Disaster's Impact Evaluation of Rural Households' Vulnerability: The case of Wenchuan earthquake".

International Conference on Agricultural Risk and Food Security 2010. Agriculture and Agricultural Science Procedia, Vol.1, p.52-61.

Susman, Paul, O'Keefe, P. and Wisner, B. 1983. "Global disasters, a radical interpretation". Kenneth Hewitt (ed.) 1983. *Interpretations of Calamity from the Viewpoint of Human Ecology,* p.263-283. Boston: Allen & Unwin Inc.

Swidler, Ann. 1986. **"**Culture in Action: Symbols and Strategies". *American Sociological Review*, Vol.51, No.2, p.273-286. American Sociological Association, Sage Publications, Inc.

Swift, Jeremy. 1989. "Why are rural people vulnerable to famine?" *IDS Bulletin,* Vol.20, No.2, p.8-16.

Takahashi, T., Aschida, K. and Sawai, K. 1981. "Delineation of debris flow hazard areas". *Erosion and Sediment Transport in the Pacific Rim Steeplands*. Special Publication no.132. International Association of Hydrological Sciences, Washington, D.C. p.37-55.

Talbot, Jessica, Poleacovschi, C. and Hamideh, S. 2022. "Socioeconomic Vulnerabilities and Housing Reconstruction in Puerto Rico After Hurricanes Irma and Maria". *Natural Hazards*, Vol.110, Iss.3, p.2113-2140.

Tang, Chuan, Zhu, J., Li, W.L. and Liang, J.T. 2009. "Rainfall-triggered debris flows following the Wenchuan earthquake". *Bulletin of Engineering Geology and the Environment,* Vol.68, Iss.2, May 2009, p.187-194.

Tao, Qi and Yi, X. 2010. "Mass Monitoring and Mass Prevention avoids mass casualties – Laibin City Land and Resources Bureau strengthens geohazard prevention works". *Southern Region Land and Resources*, Iss.9, p.9-12. (In Chinese).

Tao, Xingyu, Liu, J. and Xiao, B. 2021. "Geohazard Mass Monitoring and Mass Prevention information system design". *Proceedings of the 12th Chinese Satellite Navigation Annual Forum – S01 Satellite Navigation Industrial Application.* (In Chinese).

Taylor, Edward Burnett, Sir. 1920. *Primitive culture: researches into the development of mythology, philosophy, religion, language, art, and custom, Volume I, Sixth edition*. London: Murray.

Terzaghi, Karl. 1950. "Mechanism of Landslides". *Application of Geology to Engineering Practice*. Berkey Volume, Sidney Paige, Chairman; Geological Society of America, p.83-123.

Thiene, Mara, Shaw, W.D. and Scarpa, R. 2017. "Perceived risks of mountain landslides in Italy: stated choices for subjective risk reductions". *Landslides,* Vol.14, Iss.3, June 2017, p.1077-1089.

Thomas, Deborah S.K., Phillips, B.D., Lovekamp, W.E. and Fothergill, A. (eds.) 2013. *Social Vulnerability to Disasters, Second edition*. Boca Raton: CRC Press, Taylor & Francis Group. 514pp.

Tian, Hongling, Yang, Z., Qiao, J. and Shi, L. 2019. "Monitoring and early warning of debris-flow in an earthquake impacted area, Baishahe catchment, southwest China". *7th International Conference on Debris-Flow Hazards Mitigation*.

Tian, Ling, Yao, P. and Jiang, S. 2014. “Perception of earthquake risk: a study of the earthquake insurance pilot area in China”. *Natural Hazards* Vol.74, Iss.3, p.1595-1611.

Tian, Shujun, Kong, J. and Li, X. 2011. “Forecast Method of Multimode System for Debris Flow Risk Assessment in Qingping Town, Sichuan Province, China”. *Journal of Mountain Science,* Vol.8, No.4, p.592-602.

Tian, Shujun, Zhang, J., Shi, B and Zhang, S. 2022. “Evaluation of the benefits of facility for disaster mitigation based on the risk of debris flow”. *Landslides*, Vol.19, p.85-97.

Tiefenbacher, John. 1992. *Pesticide drift and the hazards of place in San Joaquin County, California.* PhD dissertation. Department of Geography, Rutgers University.

Tobin, Graham A. and Ollenburger, J.C. 1992. “Natural hazards and the elderly”. *Natural Hazards Research and Applications Information Center, FMHI Publications*. University of Colorado. 16pp.

Tse, Chun-Wing, Wei, J. and Wang, Y. 2014. “Social Capital and Disaster Recovery: Evidence from Sichuan Earthquake in 2008”. October 2014. *Selected Paper prepared for presentation at the Southern Agricultural Economics Association (SAEA) Annual Meeting*, Atlanta, Georgia, January 31-February 3, 2015.

Tuan Yi-Fu. 1974. *Topophilia: A Study of Environmental Perception, Attitudes and Values.* New York: Columba University Press.

Tuan Yi-Fu. 1977. *Space and Place: The Perspective of Experience*. Minneapolis: University of Minnesota Press.

Tuladhar, Gangalal, Yatabe, R., Dahal, R.K. and Bhandary, N.P. 2015. “Disaster risk reduction knowledge of local people in Nepal”. *Geoenvironmental Disasters,* Vol.2:5.

Turner, Barry A. 1978. *Man-made disasters* (Wykeham science series). London: Wykeham.

Twigg, John. 2003. “The Human Factor in Early Warnings: Risk Perception and Appropriate Communications”. J. Zschau and A. Küppers (eds.) *Early Warning Systems for Natural Disaster Reduction.* Berlin, Heidelberg: Springer.

Uehara, Marvin Shigueiti. 2018*. Individual Risk Perception and Flood Mitigation: An Empirical Study of Protective Actions in Australia.* Doctor of Philosophy Thesis. School of Political Science and International Studies. The University of Queensland. 2017.

Uekusa, Shinya, Wynyard, M. and Matthewman, S. 2024. “Reinvestigating social vulnerability from the perspective of Critical Disaster Studies (CDS): directions, opportunities and challenges in Aotearoa disaster research”. *Kōtuitui: New Zealand Journal of Social Sciences Online*, 29 Jan 2024.

UNDP (United Nations Development Programme). 2004. *Reducing disaster risk: A challenge for development.* New York: Bureau for Crisis Prevention and Recovery.

UNDP. 2016. *Gender, adaptation and disaster risk reduction.* Online. www.undp.org/gender. Accessed on 18 January 2022.

UNDRO (United Nations Disaster Relief Organization). 1980. *Natural Disasters and Vulnerability Analysis. Report of Expert Group Meeting.* Geneva: United Nations Disaster Relief Coordinator.

UNDRR (United Nations Office for Disaster Risk Reduction). 2017. “Recovery”. *Terminology on Disaster Risk Reduction*. UNDRR. (2 February 2017).

UNDRR and WMO (United Nations Office for Disaster Risk Reduction and World Meteorological Organization). 2022. *Global status of multi-hazard early warning systems: Target G*. United Nations Office for Disaster Risk Reduction.

UNDTCD (United Nations Department of Technical Co-operation for Development and Statistical Office). 1989. *National Household Survey Capability Programme. Household income and Expenditure Surveys: A technical study*. New York.

UNEP (United Nations Environment Programme). 2008. *Assessing the Vulnerability of Local Communities to Disasters: An Interactive Guide and Methodology -- Community Risk Profile Tool (CRP).* Paris: UNEP.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 1978. *The assessment and mitigation of earthquake risk.* Paris: UNESCO.

UNESCO 2003. *Convention for the Safeguarding of the Intangible Cultural Heritage*. Online. https://ich.unesco.org/en/convention Accessed 17 February 2020.

UNHCR (United Nations High Commissioner for Refugees). 2015. *Guidance on Protecting People From Disasters and Environmental Change Through Planned Relocation (“Guidance on Planned Relocation”)*. 7 October 2015.

UNISDR (United Nations International Strategy for Disaster Reduction). 2009. *2009 UNISDR Terminology on Disaster Risk Reduction*. Geneva: United Nations International Strategy for Disaster Reduction. Online. http://www.unisdr.org/files/7817_UNISDRTerminologyEnglish.pdf Accessed on 31 December 2016.

UNISDR. 2015. *Making Development Sustainable: The Future of Disaster Risk Management. Global Assessment Report on Disaster Risk Reduction*. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction (UNISDR). Online. https://www.preventionweb.net/english/hyogo/gar/2015/en/gar-pdf/GAR2015_EN.pdf Accessed on 31 December 2016.

UNISDR. 2016. *Report of the Open-Ended Intergovernmental Expert Working Group on Indicators and Terminology Relating to Disaster Risk Reduction.* Online. https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf Accessed on 23 May 2023.

UNISDR. 2017a. *The GAR* (*Global Assessment Report) on Disaster Risk Reduction) Atlas: Unveiling Global Disaster Risk*. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction. Online. http://www.unisdr.org/files/53086_garatlaslr2.pdf Accessed on 1 July 2018.

UNISDR. 2017b. *UN Praises China’s 1.3% GDP limit on disaster losses, press release, 12 May 2017 – UNISDR 2017/6.* UNISDR Communications, Geneva.

UNISDR. 2017c. *Build Back Better in recovery, rehabilitation and reconstruction, Consultative version.* UNISDR.

UNISDR. 2018. *Economic Losses, Poverty and Disasters* 1998-2017. UNISDR. 33pp.

UNISDR, UNDP and IUCN. 2009. *Making Disaster Risk Reduction Gender-Sensitive: Policy and Practical Guidelines*. Geneva.

United Nations. 1987. *General Assembly Resolution A/RES/42/169, 11 December 1987.* International Decade for Natural Disaster Reduction. 96th plenary meeting.

United Nations. 1988a. *General Assembly A/43/723, 18 October 1988, Forty-third session, Agenda item 86: Special Economic and Disaster Relief Assistance.* International Decade for Natural Disaster Reduction. Report of the Secretary-General.

United Nations. 1988b. *General Assembly Resolution A/RES/43/202, 20 December 1988.* International Decade for Natural Disaster Reduction. 83rd plenary meeting.

United Nations. 1999. *International Decade for Natural Disaster Reduction (IDNDR) Programme Forum 1999 – proceedings.* Geneva.

USGS (United States Geological Survey). 1982. "Goals and tasks of the landslide part of a ground-failure hazards reduction program". *United States Geological Survey Circular 880*. 49pp.

USGS. 2008. *M 7.9 - eastern Sichuan, China.* Online. https://earthquake.usgs.gov/earthquakes/eventpage/usp000g650#region-info Accessed on 31 December 2015.

USGS. 2016. "ShakeAlert: An Earthquake Early Warning System for the West Coast of the United States". *ShakeAlert website.* Online. shakealert.org Accessed on 18 July 2022.

USGS 2017. *Earthquake Maps.* Online. https://earthquake.usgs.gov/earthquakes/map/?extent=24.08659,470.76416&extent=32.28713,479.20166&range=month&magnitude=significant&listOnlyShown=true&baseLayer=satellite&timeZone=utc&settings=true Accessed on 31 December 2017.

Van Maanen, John Eastin and Schein, E.H. 1977. "Toward a theory of organizational socialization". Barry Staw (ed.) *Annual review of research in organizational behavior,* Vol.1. New York: JIP Press, 1978. 89pp.

Varnes, David J. 1950. "Relation of Landslides to Sedimentary Features". *Applied Sedimentation.* P.D. Trask (ed.), p.229-246. New York: John Wiley & Sons.

Varnes, David J. 1958. "Landslide Types and Processes". Edwin B. Eckel (ed.) 1958. *Landslides and Engineering Practice*, Highway Research Board, Special Report 29, Chapter 3, p.20-47.

Varnes, David J. 1978. "Slope Movement Types and Processes". Robert L. Schuster and Raymond J. Krizek (eds.) 1978. *Landslides: Analysis and Control*. Transportation Research Board, Special Report 176, Chapter 2, p.11-33. Washington, D.C.: National Academy of Sciences.

Varnes and IAEG (Varnes, David J. and the International Association of Engineering Geology, Commission on Landslides and Other Mass Movements on Slopes). 1984. *Landslide hazard zonation: a review of principles and practice.* Paris: Darantiere, Quetigny. United Nations Educational, Scientific and Cultural Organization (UNESCO).

Vinchon, Charlotte, Carreno, M., Contreras-Mojica, D.M., Kienberger, S., Schneiderbauer, S., Alexander, D., Barbat, A.H., Cardona, O.D., Decker, B., Eidsvig, U., Papathoma-Kohle, M., Miniati, R., Pratzler-Wanczura, S., Ulbrich, T., Vangelsten, B.V. and Welle, T. 2011. *MOVE (Methods for the Improvement of Vulnerability Assessment in Europe). Assessing vulnerability to natural hazards in Europe: From Principles to Practice. A manual on concept, methodology and tools.* European Commission Research & Innovation DG. Seventh Framework Programme.

Vogel, C. 2001. "Environmental Vulnerability". Neil J. Smelser and Paul B, Baltes (eds.) *International Encyclopedia of the Social & Behavioral Sciences,* p.4675-4679.

Walker, Bridget (ed.) 1994. *Women and Emergencies.* Oxford: Oxfam.

Walsh, Froma. 1996. "The Concept of Family Resilience: Crisis and Challenge". *Family Process,* September 1996, Vol.35, Iss.3, p.261-281.

Walsh, Froma. 2003. "Family Resilience: A Framework for Clinical Practice". *Family Process,* Spring 2003, Vol.42, No.1, p.1-18.

Walsh, Froma. 2016. "Applying a Family Resilience Framework in Training, Practice, and Research: Mastering the Art of the Possible". *Family process,* Vol.55, No.4, p.616-632.

Wang, Fawu, Sun, P., Highland, L. and Cheng, Q. 2014. "Key factors influencing the mechanism of rapid and long runout landslides triggered by the 2008 Wenchuan earthquake, China". *Geoenvironmental Disasters,* Vol.1:1.

Wang, G.L. 2013. "Lessons learned from protective measures associated with the 2010 Zhouqu debris flow disaster in China". *Natural Hazards,* Vol.69, p.1835-1847.

Wang, Haojie, Zhang, L., Yin, K., Luo, H. and Li, J. 2021. "Landslide identification using machine learning". *Geoscience Frontiers*, Vol.12, Iss.1, January 2021, p.351-364.

Wang, Ying, Chen, H. and Li, J. 2012. "Factors affecting earthquake recovery: the Yao'an earthquake of China". *Natural Hazards*, Vol.64, No.1, p.37-53.

Wang, Ying, Zhu, Y. and Sui, Q. 2017. "Ethnic Groups Differences in Domestic Recovery after the Catastrophe: A Case Study of the 2008 Magnitude 7.9 Earthquake in China". *International Journal of Environmental Research and Public Health.* Vol.14, Iss.6, Number 590.

Wang, Yuhua. 2022. "Blood Is Thicker Than Water: Elite Kinship Networks and State Building in Imperial China". *American Political Science Review,* Vol.116, Iss.3, August 2022, p.896-910.

Wang, Yunxia and Prott, L.V. 2016. "Cultural revitalisation after catastrophe: the Qiang culture in A'er". *International Journal of Heritage Studies*, Vol.22, Iss.1, p.26-42.

Wang, Yuqu, Wang, Z., Zhou, C., Liu, Y. and Lui, S. 2020. "On the Settlement of the Floating Population in the Pearl River Delta: Understanding the Factors of Permanent

Settlement Intention versus Housing Purchase Actions". *Sustainability,* Vol.12, Iss.22, November-2 2020, Article 9771, 20pp.

Wang, Zhao Yin, Qi, L.J. and Wang, X.Z. 2012. "A prototype experiment of debris flow control with energy dissipation structures". *Natural Hazards,* Vol.60, p.971-989.

WCCD (West China City Daily). 2016. "Sichuan Wolong debris flow sudden attack: Panda safe, mobility difficulties for humans". *Xinhua Net.* 28 July 2016. Online. http://www.xinhuanet.com/politics/2016-07/28/c_129184536.htm Accessed on 20 March 2022.

WCED (World Commission on Environment Development). 1987. *Our common future. Report of the World Commission on Environment and Development*. Oxford: Oxford University Press. Online. http://www.un-documents.net/our-common-future.pdf and http://www.un-documents.net/wced-ocf.htm. Accessed on 31 December 2017.

Wei, Xiao-kui (ed.) 2010. *Sichuan Maps Collection (Sichuan Sheng Dituji)*. Chengdu Ditu Chubanshe, Chengdu. 125pp. (In Chinese).

Wei, Jianwen and Han, Y. 2018. "Pre-Disaster Social Capital and Disaster Recovery in Wenchuan Earthquake-Stricken Rural Communities". *Sustainability*, Vol.10, Iss.6, June 2018, Article 2046.

Wei, Rongqiang, Zeng, Q., Davies, T., Yuan, G., Wang, K., Xue, X. and Yin, Q. 2018. "Geohazard cascade and mechanism of large debris flows in Tianmo gully, SE Tibetan Plateau and implications to hazard monitoring". *Engineering Geology,* 31 January 2018, Vol.233, p.172-182.

Weichselgartner, Juergen. 2001. "Disaster Mitigation: The Concept of Vulnerability Revisited". *Disaster Prevention and Management*, Vol.10, Iss.2, p.85-94.

Weinstein, Neil D. 1989. "Effect of Personal Experience on Self-Protective Behaviour". *Psychological Bulletin*, Vol.105, No.1, p.31-50.

Welle, Torsten, Birkmann, J., Krause, D., Suarez, D. C., Setiadi, N. J. and Wolfertz, J. 2013. "The WorldRiskIndex: A concept for the assessment of risk and vulnerability at global/national scales". Jörn Birkmann (ed.) *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*, *Second edition,* p.219-250. Tokyo: United Nations University Press.

Wellman, Barry and Wortley, S. 1990. "Different Strokes from Different Folks: Community Ties and Social Support". *American Journal of Sociology*, Vol.96, No.3, November 1990, p.558-588. The University of Chicago Press.

Wen, B.P., Han, Z.Y., Wang, S.J., Wang, E.Z. and Zhang, J.M. 2005. "Recent landslide disasters in China and lessons learned for landslide risk management". Oldrich Hungr, Robin Fell, Rejean Couture and Erik Eberhardt (eds.) *Landslide Risk Managemen*t. 2005. London: Taylor & Francis Group, p.427-434.

Wen, Xiaofei, Meng, Y. and Wang, C. 2015. "The Landscape Change of Qiang's Settlements in the Upper Reaches of Minjiang River after Wenchuan Earthquake". *International Journal of Built Environment and Sustainability,* Vol.2, Iss.3, p.227-236. Faculty of Built Environment, Universiti Teknologi Malaysia.

Wen, Xue-ze. 2011. “Scientific investigation brief of Wenchuan earthquake surface rupture and structure of shaking”. *Sichuan Earthquake Information Network website.* Online. http://www.eqsc.gov.cn/manage/fileupload/statichtml/admin/5.12-1year/html/kekao/jnhd-1.html Accessed on 31 December 2018. (In Chinese*).*

West, Darrell M. and Orr, M. 2007. “Race, Gender, and Communications in Natural Disasters”. *The Policy Studies Journal,* Vol.35, No.4.

Wenchuan County Government. 2015. Information provided by Wenchuan County Government in response to the request from the researcher of this Research Degree Project. (In Chinese).

Wenchuan County Government. 2017. “Economic development situation”. *Wenchuan Government website.* Online. Wenchuan.gov.cn Accessed on 1 July 2018.

Westgate, Ken N. and O’Keefe, Phil O. 1976. *Some definitions of disaster.* University of Bradford, Disaster Research Unit, Occasional paper No.4. June 1976.

Westgate, Ken N. and O'Keefe, Phil O. 1977. "The Human and Social Implications of Earthquake Risk for Developing Countries". *Journal of Administration Overseas*, Vol.XVI, Nos.1-4, p.24-29.

White, Gilbert F. (ed.) 1974. *Natural hazards: Local, National, Global*. New York: Oxford University Press. 288pp.

Whittow, John. 1979. *Disasters: The anatomy of environmental hazards*. Athens: University of Georgia Press.

Willison, Zenaida Delica and Gaillard, JC. 2012. “Community Action and Disaster”. Ben Wisner, JC Gaillard and Ilan Kelman (ed.) 2012. *Handbook of Hazards and Disaster Risk Reduction, First edition*, Chapter 59. Routledge. 912pp.

Winsemius, Hessel C., Jongman, B., Veldkamp, T.I.E., Hallegatte, S., Bangalore, M. and Ward, P.J. 2015. *Disaster Risk, Climate Change, and Poverty: Assessing the Global Exposure of Poor People to Floods and Droughts*. Policy Research Working Paper; No. 7480. Washington, DC: World Bank. Online. https://openknowledge.worldbank.org/handle/10986/23437. License: CC BY 3.0 IGO. Accessed on 1 July 2020.

Wisner, Ben. 1978. “Does radical geography lack an approach to environmental relations?” *Antipode*, March 1978, Vol.10, Iss.1, p.84-95.

Wisner, Ben. 1993. “Disaster Vulnerability: Scale, Power and Daily Life”. *GeoJournal*, Vol.30, No.2, Vulnerability, Hunger and Famine, June 1993, p.127-140.

Wisner, Ben. 2001. *Who? What? Where? When? In an Emergency: Notes on Possible Indicators of Vulnerability and Resilience By Phase of the Disaster Management Cycle And Social Actor.* 9pp. (Unpublished manuscript.)

Wisner, Ben, Blaikie, P., Cannon, T. and Davis, I. 2004. *At Risk: Natural hazards, people’s vulnerability and disasters, Second edition.* London: Routledge. 471pp.

Wolong National Nature Reserve. 2015. *Description of the Reserve Region*. Online. http://www.chinawolong.gov.cn/wps/portal/wl/zwgk_commonDetail/!ut/p/b1/jZBLD4IwEIR_jVe7IqIeUSPIQWIaH3AxBVeCoS0pFaO_3mI8aIKPvW3mm5ltSUx2JBaszjOmcylY0eyxsw_9Mfj9EIJwYY1gsVlZ6zmlFtiOAaJXwOsFUwPYk2BAnZ7XH_7nhw_jwi__lsTvSMsFD-

BLxdKXHElkLhl-rKIOoU1SpdVZV91SKl2g7mKNQrtp81skMhK2MFweTHqd46VFZE-vQnFANcsVproFe5WXjGNVstSEduAiCymyfSo5l6IDj5btr5eUfL2Dk82SGya349W9A4r5ErQ!/#Z7_OH90H3O0JOI280IVQ2UFSS20S6 Accessed on 31 December 2018.

Wolong Township Government. 2009a. *Wolong Township Geohazard Prevention and Protection Plan 2009.* Wolong Township Government. (In Chinese).

Wolong Township Government. 2009b. *Wolong Township Geohazard Emergency Response Plan 2009.* Wolong Township Government. (In Chinese).

Wolong Township Government. 2014. *Overall Plan of Wolong Township 2014-2030, Wenchuan County.* Aba Prefecture Construction Design Limited Liability Company. Designed and published by the Wolong Township Government. (In Chinese).

Wolong Township Government. 2016a. Information provided by Wolong Township Government in response to the first request from the researcher of this Research Degree Project. (In Chinese).

Wolong Township Government. 2016b. Information provided by Wolong Township Government in response to the second request from the researcher of this Research Degree Project. (In Chinese).

Wolong Township Government. 2016c. Information provided by Wolong Township Government during site visits. (In Chinese).

Wolong Township Government. 2016d. *Wolong Township Geohazard Prevention and Protection Plan 2016.* Wolong Township Government. (In Chinese).

Wolong Township Government. 2016e. *Wolong Township Geohazard Prevention and Protection Response Plan 2016.* Wolong Township Government. (In Chinese).

World Bank. 2012. *Four years on: What China got right when rebuilding after the Sichuan earthquake.* 14 May 2012. Online. https://reliefweb.int/report/china/four-years-what-china-got-right-when-rebuilding-after-sichuan-earthquake Accessed on 4 February 2022.

World Bank. 2014. *GDP per capita (current US$)*. Online. http://data.worldbank.org/indicator/NY.GDP.PCAP.CD?end=2014&start=1960&year_high_desc=true Accessed on 1 July 2018.

World Bank. 2019. “The gender gap in the disaster risk management sector: why it matters”. *World Bank Blog*. Online. http://blogs.worldbank.org/sustainablecities/gender-gap-disaster-risk-mangement-sector-why-it-matters Accessed on 18 January 2022.

World Bank. 2020. *Using behavioral insights to improve disaster preparedness, early warning and response mechanisms in Haiti.* 48pp.

Wu, Haorui. 2014. *Post-Wenchuan earthquake rural reconstruction and recovery in Sichuan China: Memory, civic participation and government intervention.* Doctoral thesis. University of British Columbia.

Wu, Jishan, Tian, L., Kang, Z., Zhang, Y. and Liu, J. 1993. *Debris flow and its comprehensive control.* Beijing: Science Press. (In Chinese).

Wu, Kanglin, Chen, N., Hu, G., Huang, N. and Zhang, Y. 2018. “Emergency Investigation to 7.19 Landslide Disaster in Boli Village, Yanyuan County, Sichuan, China”. *Mountain Research,* 2018(05), p.806-812. (In Chinese).

Wu, Yongqiu, Liu, X., Wang, J., Liu, L. and Shi, P. 2016. “Landslide and Debris Flow Disasters in China”. Peijun Shi (ed.) *Natural Disasters in China.* Chapter 3, p.73-101. IHDP/Future Earth-Integrated Risk Governance Project Series. Beijing Normal University Press and Springer-Verlag Berlin Heidelberg.

Xie, S., Wang, J., Chen, J. and Ritakallio, V. 2017. “The effect of health on urban-settlement intention of rural-urban migrants in China”. *Health & Place*, Vol.47, p.1-11.

Xinhua. 2008. “Chinese people united for earthquake relief - Chinese from Hong Kong, Macau and Taiwan”. *Xinhua website*. Online. http://www.xinhuanet.com/politics/kzjz/gatq.htm Accessed on 3 February 2022. (In Chinese).

Xinhua. 2022. “Definition of ‘jia’ (home)”. *Xinhua Dictionary*. Online. http://xh.5156edu.com/html3/6267.html Accessed on 4 February 2022. (In Chinese).

Xiong, Kunxin and Ding, Y. 2007. “A General Review on the Qiang Ethnic Concepts”. *Journal of Xinjiang Normal University (Edition of Philosophy and Social Sciences),* Iss.3, p.34-41.

Xu, Dingde, Chen, Q., Deng, X., Yong, Z., Zhou, W. and Ma, Z. 2020. “Disaster Risk Perception, Sense of Place, Evacuation Willingness, and Relocation Willingness of Rural Households in Earthquake-Stricken Areas: Evidence from Sichuan Province, China”. *International Journal of Environmental Research and Public Health*, Vol.17, 602, 19pp.

Xu, Dingde, Li, P., Liu, S., Su, C., Wang, X. and Chen, T. 2017. “Influences of Sense of Place on Farming Households’ Relocation Willingness in Areas Threatened by Geological Disasters: Evidence from China”. *International Journal of Disaster Risk Science*, Vol.8, Iss.1, March 2017, p.16-32.

Xu, Dingde, Li, P., Su, C., Liu, S., Wang, X. and Chen, T. 2016. “Influences of mass monitoring and mass prevention systems on peasant households’ disaster risk perception in the landslide-threatened Three Gorges Reservoir area, China”. *Habitat International,* Vol.58, p.23-33, November 2016.

Xu, Dingde, Yong, Z., Deng, X., Liu, Y., Huang, K., Zhou, W., *et al.* 2019. “Financial Preparation, Disaster Experience, and Disaster Risk Perception of Rural Households in Earthquake-Stricken Areas: Evidence from the Wenchuan and Lushan Earthquakes in China’s Sichuan Province”. *International Journal of Environmental Research and Public Health,* Vol.16, Iss.18, 3345.

Xu, Qiang and Huang, R. 2008. “Kinetics characteristics of large landslides triggered by May 12th Wenchuan earthquake”. *Journal of Engineering Geology,* Vol.16, No.6, p.721-729. (In Chinese).

Xu, Qiang, Peng, D., Zhang, S., Zhu, X., He, C., Qi, X., Zhao, K., Xiu, D. and Ju, N. 2020. “Successful implementations of a real-time and intelligent early warning system for loess landslides on the Heifangtai terrace, China”. *Engineering Geology*, Vol.278.

Xue, Mengtian, Zhao, Y., Wang, Z. and Zhang, B. 2021. “Behavioural determinants of an individual's intention to adapt to climate change: Both internal and external perspectives”. *Environmental Impact Assessment Review*, Vol. 91, November 2021, Article 106672.

Yao, Shunyu, Nazir, A.B., Tang, J., Jiang, H., Yi, S., Zou, Q., Tashfain, A. and Guo, J. 2022. “Dynamic process of a typical slope debris flow: a case study of the wujia gully, Zengda, Sichuan Province, China”. *Natural Hazards*, Vol 112, Iss.1, May 2022, p.565-586.

Yik, Michelle, Pun, W.K., Kwok, F.H.C., Pho, J. and Ng, C.W.W. 2023. “Perceptions of landslide risks and warnings in Hong Kong”. *Landslides,* Vol.20, Iss.6, June 2023, p.1211-1224.

Yin, Yueping. 2009. “Features of landslides triggered by the Wenchuan earthquake”. *Journal of Engineering Geology*, Vol.17, Iss.1, p.29-38.

Yin, Yueping, Wang, F. and Sun, P. 2009a. “Landslide hazards triggered by the 2008 Wenchuan earthquake, Sichuan, China”. *Landslides,* Vol.6, Iss.2, June 2009, p.139-152.

Yin, Yueping *et al*. 2009b. *Great Wenchuan Earthquake: Seismogeology and Landslide Hazards*. Beijing: Geology Press. 142pp. (in Chinese).

Yore, Rebekah and Faure Walker, J. 2021. “Early warning systems and evacuation: rare and extreme versus frequent and small-scale tropical cyclones in the Philippines and Dominica”. *Disasters,* Vol.45, Iss.3, July 2021, p.691-716.

Yu, Bin, Wu, Y.F. and Chu, S.M. 2014. “Preliminary study of the effect of earthquakes on the rainfall threshold of debris flows”. *Engineering Geology*, Vol.182, Part B, p.130-135, 19 November 2014.

Zaman, Mohammad Q. 1988. *The Socioeconomic and Political Dynamics of Adjustment to Riverbank Erosion Hazard and Population Resettlement in the Brahmaputra-Jamuna Floodplain*. PhD Thesis. University of Manitoba.

Zaruba, Quido and Mencl, Vojtech. 1969. *Landslides and Their Control*. Prague: Elsevier and Academia. Czechoslovak Academy of Sciences. 205pp.

Zhang, Qiaoyun. 2018. “Heritage making after the earthquake. Safeguarding the intangible heritage of the Qiang people in China”. *The Newsletter,* 80, Summer 2018, International Institute for Asian Studies. Leiden, the Netherlands. Online. https://www.iias.asia/the-newsletter/article/heritage-making-after-earthquake-safeguarding-intangible-heritage-qiang. Accessed on 29 December 2022.

Zhang, Xiaojun, Zhong, Q., Zhang, R. and Zhang, M. 2020. “People-centered early warning systems in China: A bibliometric analysis of policy documents”. *International Journal of Disaster Risk Reduction*, Vol.51, December 2020, 101877.

Zhao, Bo, Zhang, H., Liao, H., Li, W., Su, L., He, W., Zeng L., Qin, H. and Dhital, M.R. 2021. “Emergency response to the reactivated Aniangzhai landslide resulting from a rainstorm-triggered debris flow, Sichuan Province, China”. *Landslides,* Vol.18, Iss.3, March 2021, p.1115-1130.

Zhao, L.Y., Qin, G. and Lu, W. 2019. “A preliminary investigation of the impact of Mass Monitoring and Mass Prevention on enhancing public awareness on flood prevention capability in Chongqing”. *Water Conservancy in China*, Vol.3. (In Chinese).

Zhao, Xiaohui. 2008. “The role of seismological observation network by the mass in protecting against and mitigating earthquake disaster work”. *Plateau Earthquake Research*, Iss.1, p.70-72. (In Chinese).

Zhao, Yandong. 2007. “Social Capital and Post-disaster Recovery: A sociological study of natural disaster”. *Sociological Study*, May 2007, p.164-187, 245.

Zhao, Yandong. 2013. “Social Networks and Reduction of Risk in Disasters: An Example of the Wenchuan Earthquake”. Wei-Jun Jean Yeung and Mui Teng Yap (ed.) *Economic Stress, Human Capital, and Families in Asia*, Chapter 10, p.171-182. Dordrecht: Springer.

Zheng, Guizhou, Chao, Y. and Xu, H. 2008. “The regional geological hazard forecast based on rainfall and WebGIS in Hubei, China”. Lin Liu, Xia Li, Kai Liu, Xinchang Zhang and Yong Lao (eds.) *Geoinformatics 2008 and Joint Conference on GIS and Built Environment: Monitoring and Assessment of Natural Resources and Environments. Proceedings of the SPIE,* Vol.7145, October 2008, article id. 714505. 9pp.

Zhou, Jia-wen, Cui, P. and Fang, H. 2013. “Dynamic process analysis for the formation of Yangjiagou landslide-dammed lake triggered by the Wenchuan earthquake, China”. *Landslides,* Vol.10, Iss.3, June 2013, p.331-342.

Zhou, Liqing. 2013. “Hangzhou City Yuhang District holds geohazard prevention and mitigation training for Mass Monitoring and Mass Prevention personnel”. *Zhejiang Land and Resources*, Vol.6. (In Chinese).

Zhou, Rong-Jun, Li, Y., Yan, L., Lei, J-C., Zhang, Y., He, Y-L., Chen, L-S. *et al.* 2010. “Surface rupture and hazard characteristics of the Wenchuan Ms 8.0 earthquake, Sichuan, China”. *Natural Science,* Vol.2, No.3, p.160-174.

Zhou, Wenfeng, Ma, Z., Guo, S., Deng, X. and Xu, D. 2021. “Livelihood capital, evacuation and relocation willingness of residents in earthquake-stricken areas of rural China”. *Safety Science,* Vol.141, September 2021, Article 105350, 10pp.

Zhu, D., Xie, X. and Gan, Y. 2011. “Information source and valence: how information credibility influences earthquake risk perception”. *Journal of Environmental Psychology*, Vol.31, Iss.2, June 2011, p.129-136.

Zhu, Tian-Yang and Li, H-D. 2018. “A brief discussion on the current status and countermeasures of the work of county-level earthquake hazard Mass Monitoring and Mass Prevention”. *Recent Developments in World Seismology*, Iss.10. (In Chinese).

Zottarelli, Lisa K. 2008. “Post-Hurricane Katrina Employment Recovery: The Interaction of Race and Place”. *Social Science Quarterly*, Vol.89, Iss.3, p.592-607.