Doctoral Thesis

Comprehensive Analysis of Population-Economy-Space Urbanization in the County-level Areas before and after Wenchuan Earthquake

July 2022

CHENG YU

The University of Kitakyushu

Faculty of Environmental Engineering

Department of Architecture

Gao Laboratory

Preface

This study focused on the urbanization development in the most severely affected area level and the county-level before and after Wenchuan earthquake. Ten worst-hit counties in the Wenchuan earthquake were selected for case study and further comprehensive analyzed at different stages. The distribution of types urbanization and interrelationship between these types of urbanization and coupling coordination state were also explored. Moreover, the difference between types of urbanization at different stages were analyzed. Our empirical results provide a certain reference for the variation of types of urbanization, their interrelationship, coordination state of destructive earthquake in the region level and county level.

ACKNOWLEDGEMENT

Time flies, three years of doctoral life will soon come to an end. It is a very valuable experience to come to Kitakyushu University in Japan and follow by Professor GAO. I will never forget this period of time. I would like to express my heartfelt thanks to all the people who helped and guided me during this period of study.

First of all, I would like to express my deep gratitude to my tutor, Professor GAO for support and encouragement for my study. In the paper writing and direction, he gave me a lot of guidance and energy. In terms of research, he also gave me a very free space to explore and learn. In addition, he has also given me a lot of help to adapt to the Japanese life. Mr. Gao is an example for me to learn from, whether he is a person or a scholar.

Also，I would also like to thank my family, whose encouragement and support enabled me to return to school after work and devote myself to study and work to successfully complete my studies.

Finally, I would like to express my gratitude to all the teachers and students of Kitakyushu University, especially to all the members of Gao Laboratory. It is your help that makes me feel the warmth of the campus. In the future study and work, I will remember the teachings of Professor Gao and classmates. At the same time, live up to expectations and continue to work hard.

Comprehensive Analysis of Population-Economy-Space Urbanization in the County-level Areas before and after Wenchuan Earthquake

ABSTRACT

Urbanization, as one of the most important indicators to evaluate the development level of city, usually means huge migrant of population from rural area into the urban area, secondary and tertiary industry replace the primary industry as the major economic industry, large land transfer into built-up area. In other words, based on the connotation of population urbanization, economy urbanization, space urbanization, we could deepen the knowledge of urbanization by comprehensive analysis. In particular, a comprehensive analysis of urbanization development under the context of destructive earthquakes is more conducive to enriching our understanding of the objective rules of urbanization development under extreme circumstances.

This study aims to explore the temporal-spatial distribution and difference of urbanization and its subsystems before and after the Wenchuan earthquake (Richter scale 8.0) in county scale. Based on the connotation of urbanization from dimension of population, economy, space, the assessment system of urbanization is proposed. Furthermore, coupling degree model and coupling coordination degree model are also proposed to evaluate interrelation between these three subsystems of urbanization and overall coordination development level of urbanization, respectively. In addition, the statistics analysis methods and triangle model are employed to test the stages difference and urbanization mode difference. The data of indicators are in the period from 2001 to 2017, which was collected from the authoritative China Statistical Yearbook. According to the time span, the whole time period is divided into three stages, pre-earthquake stage (2001 to 2007), reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017). According to official report, these most severely affected counties of the Wenchuan earthquake, Wenchuan, Shifang, Qingchuan, Pingwu, Pengzhou, Mianzhu, Maoxian, Dujiangyan, Beichuan, Anxian, are selected to show the empirical results.

In Chapter 1, ***INTRODUCATION***, the background and significance of the study are presented from followings: overview the world trend of urbanization development and sustainable development, review of previous studies, purpose and content structure.

In Chapter 2, ***METHODOLOGIES, URBANIZATION ASSESSMENT SYSTEM, EVAULATION MODELS***, data sources and statistics analysis methods are introduced. Moreover, comprehensive urbanization index system is proposed. In addition, coupling degree model, coupling and coordination degree model, and triangle model are all presented in this chapter.

In Chapter 3, ***OVERVIEW OF SOCIAL ECONOMY DEVELOPMENT AND DISASTER BACKGROUND AND POLICIES***, taking these most severely affected counties as the research

object, social economy development before the Wenchuan earthquake are introduced. Disaster loss, such as direct economy loss, population loss, houses loss, land loss, and paired-reconstruction policies are presented in this chapter.

In Chapter 4-6, ***COMPREHENSIVE ANALYSIS OF URBANIZATION IN COUNTY LEVEL,*** population urbanization, economy urbanization, space urbanization, population-economy-space urbanization are examined on temporal-spatial distribution characteristics and stage features. Furthermore, interrelationship degree between three subsystems, overall coordination of urbanization is also tested to show the relationship and quality of urbanization on time period features and stage characteristics. Moreover, to show difference before and after the Wenchuan earthquake, all these indexes are analyzed by T-test and paired T-test to show whether there is statistics difference between different periods and different stages. In addition, Moran's index was used to assessed the spatial differentiation on types of urbanization, coupling degree, and coupling coordination degree. Furthermore, urbanization-led mode variation is also evaluated. All these indexes are test both in county level and region level. At last, two dimensions evaluation model was employed to classification on types of urbanization variation for ten counties.

In Chapter 7, major conclusion of each chapter has been summarized.

CONTENTS

Research Background and Purpose of the Study.....
1.1 Introduction..... 1-1
1.2 Research background and significance..... 1-4
1.2.1 Wenchuan earthquake and post-disaster reconstruction..... 1-4
1.2.2 The effect of rapid urbanization of China..... 1-6
1.2.3 Research Significance..... 1-7
1.3 Review of previous study..... 1-8
1.3.1 Development on understanding of the urbanization..... 1-8
1.3.2 Research on the relationship among urbanization systems..... 1-10
1.3.3 Post disaster recovery and reconstruction..... 1-12
1.4 Purpose and research structure of this study..... 1-13
Reference..... 1-17
Methods and data in the research of comprehensive Population-Economy-Space urbanization.....
2.1 Introduction..... 2-1
2.2 Data..... 2-1
2.3 Evaluation Index system and Weight..... 2-1
2.4 Box and Whisker plot..... 2-4
2.5 Dynamic Coupling Degree model and Dynamic Coupling Coordination Degree model... 2-5
2.6 Spatial autocorrelation analysis..... 2-6
2.7 Triangle Model..... 2-8
2.8 Summary..... 2-9
Reference.....2-11
Overview of the study area and Wenchuan earthquake loss and reconstruction policy.....
3.1 Introduction..... 3-1
3.2 Overview of MSAA before the Wenchuan earthquake..... 3-3
3.2.1 Urbanization level..... 3-3
3.2.2 Economy level..... 3-3

3.2.3 Level of fixed asset investment 3-6
3.2.4 Public finance revenue 3-7
3.2.5 Savings deposit balance of urban and rural residents 3-8
3.3 Overview of disaster loss in the MSAA 3-10
3.3.1Economic loss 3-10
3.3.2 Population loss 3-11
3.3.3 Housing loss 3-12
3.3.4 Land loss 3-13
3.3.5 Secondary disasters 3-14
3.4 Overview of reconstruction policies of Wenchuan earthquake 3-15
3.4.1 Expanding financial input 3-15
3.4.2 Tax relief efforts 3-16
3.4.3 Increasing financial support 3-16
3.4.4 Advancing industrial support 3-16
3.4.5 Regulating the land market 3-17
3.4.6 Enhancement of social security 3-17
3.5 Overview of reconstruction modes of Wenchuan earthquake 3-17
3.5.1 Aid project module 3-21
3.5.2 Recipient project module 3-22
3.5.3 Safeguarding project module 3-22
3.6 Summary 3-22
Reference 3-25
Distribution of population-space-economy urbanization before and after the Wenchuan earthquake .....
4.1 Introduction 4-1
4.2 Temporal distribution of urbanization before and after the Wenchuan earthquake 4-1
4.2.1 Temporal distribution of urbanization for the most severely affected area 4-1
4.2.2 Temporal distribution of urbanization for ten counties 4-3
4.3 Spatial distribution of urbanization before and after the Wenchuan earthquake 4-20
4.3.1 Spatial distribution of urbanization for the most severely affected area 4-20

4.3.2 Spatial distribution of urbanization for ten counties 4-24
4.4 Summary 4-28
Reference 4-30
Distribution of Coupling and coordination degree of urbanization before and after the Wenchuan earthquake.....
5.1 Introduction 5-1
5.2 Temporal distribution of coupling and coupling coordination degree before and after the Wenchuan earthquake 5-1
5.3.1 Temporal distribution of coupling and coupling coordination degree for the most severely affected area 5-1
5.3.2 Temporal distribution of coupling and coupling coordination degree for ten counties 5-3
5.3 Spatial distribution of coupling and coupling coordination degree before and after the Wenchuan earthquake 5-28
5.3.1 Spatial distribution of coupling and coupling coordination degree for the most severely affected area 5-28
5.3.2 Spatial distribution of coupling and coupling coordination degree for ten counties.. 5-30
5.4 Summary 5-33
Reference 5-35
Comparison and Classification of comprehensive urbanization before and after the Wenchuan earthquake.....
6.1 Introduction 6-1
6.2 Differentiation on urbanization before and after Wenchuan earthquake 6-1
6.2.1 Urbanization difference of MSAA at different stages 6-1
6.2.2 Urbanization difference of Wenchuan county at different stages 6-3
6.2.3 Urbanization difference of Shifang county at different stages 6-5
6.2.4 Urbanization difference of Qingchuan county at different stages 6-7
6.2.5 Urbanization difference of Pingwu county at different stages 6-9
6.2.6 Urbanization difference of Pengzhou county at different stages.....6-11
6.2.7 Urbanization difference of Mianzhu county at different stages 6-13
6.2.8 Urbanization difference of Maoxian county at different stages 6-15
6.2.9 Urbanization difference of Dujiangyan county at different stages 6-17

6.2.10 Urbanization difference of Beichuan county at different stages 6-19
6.2.11 Urbanization difference of Anxian county at different stages 6-21
6.3 Differentiation on Coupling coordination characteristics of urbanization before and after Wenchuan earthquake 6-23
6.3.1 Coupling Coordination difference of MSAA at different stages 6-23
6.3.2 Coupling Coordination difference of Wenchuan county at different stages 6-24
6.3.3 Coupling Coordination difference of Shifang county at different stages 6-26
6.3.4 Coupling Coordination difference of Qingchuan county at different stages 6-28
6.3.5 Coupling Coordination difference of Pingwu county at different stages 6-29
6.3.6 Coupling Coordination difference of Pengzhou county at different stages 6-31
6.3.7 Coupling Coordination difference of Mianzhu county at different stages 6-32
6.3.8 Coupling Coordination difference of Maoxian county at different stages 6-34
6.3.9 Coupling Coordination difference of Dujiangyan county at different stages 6-35
6.3.10 Coupling Coordination difference of Beichuan county at different stages 6-37
6.3.11 Coupling Coordination difference of Anxian county at different stages 6-39
6.4 Spatial differentiation by counties before and after Wenchuan earthquake 6-40
6.4.1 Spatial differentiation on population urbanization by counties 6-40
6.4.2 Spatial differentiation on space urbanization by counties 6-41
6.4.3 Spatial differentiation on economy urbanization by counties 6-42
6.4.4 Spatial differentiation on population-space-economy urbanization by counties 6-42
6.4.5 Spatial differentiation on coupling degree by counties 6-43
6.4.6 Spatial differentiation on coupling coordination degree by counties 6-44
6.5 Comparative examination on variation of urbanization modes before and after Wenchuan earthquake 6-45
6.5.1 Transformation of urbanization modes for the MSAA 6-45
6.5.2 Transformation of urbanization modes for the Wenchuan county 6-46
6.5.3 Transformation of urbanization modes for the Shifang county 6-47
6.5.4 Transformation of urbanization modes for the Qingchuan county 6-48
6.5.5 Transformation of urbanization modes for the Pingwu county 6-49
6.5.6 Transformation of urbanization modes for the Pengzhou county 6-50

6.5.7 Transformation of urbanization modes for the Mianzhu county 6-51
6.5.8 Transformation of urbanization modes for the Maoxian county 6-52
6.5.9 Transformation of urbanization modes for the Dujiangyan county 6-53
6.5.10 Transformation of urbanization modes for the Beichuan county 6-54
6.5.11 Transformation of urbanization modes for the Anxian county 6-55
6.6 Classification of urbanization before and after Wenchuan earthquake 6-56
6.6.1 Classification of population urbanization before and after Wenchuan earthquake 6-56
6.6.2 Classification of space urbanization before and after Wenchuan earthquake 6-57
6.6.3 Classification of economy urbanization before and after Wenchuan earthquake..... 6-58
6.6.4 Classification of population-space-economy urbanization before and after Wenchuan earthquake 6-59
6.6.5 Classification of urbanization quality before and after Wenchuan earthquake 6-60
6.7 Summary 6-62
Reference 6-65
Conclusion .....
7.1 Conclusion 7-1

CONTENTS OF FIGURES

Fig1- 1 The world's urban and rural populations, estimated for 2050 1-1

Fig1- 2Estimated and projected urban populations of the world, the more developed regions and the less developed regions, 1950-2050 (Source: UN World Urbanization Prospects: The 2018 Revision) 1-2

Fig1- 3Percentage of population residing in urban areas by geographic region, 1950-2050 1-3

Fig1- 4Growth rates of the world's cities, 2000-2018(Source: UN World urbanization prospects:The 2018 vision) 1-3

Fig1- 5cities' risk of exposure to natural disasters. (Source: UN World urbanization prospects:The 2018 vision) 1-4

Fig1- 6 Research flow 1-14

Fig 2- 1 Box plot with percentile labels 2-4

Fig 2- 2 Schematic diagram of the urbanization process including three major dimensions of poSulation, economy and space 2-5

Fig 2- 3 The relative urbanization status based on three main constituent parts in terms of poSulation, space and economy 2-9

Fig 3- 1 Study area of the most severely affected area. (a) China region;(b) Sichuan Province; (c) Most severely affected area..... 3-2

Fig 3- 2 Resident Population in the most severely affected area from 2001 to 2007 (ten thousand people)..... 3-3

Fig 3- 3 Urbanization rates in the most severely affected area from 2001 to 2007..... 3-3

Fig 3- 4 GDP of the most severely affected area from 2001 to 2007 (ten thousand yuan) 3-4

Fig 3- 5 Total investment in urban fixed assets in the most severely affected area during 2001-2007 (ten thousand yuan) 3-7

Fig 3- 6 Growth rate of total urban fixed asset investment in the most severely affected area during 2001-2007 3-7

Fig 3- 7 Public revenues in the most severely affected area during 2001-2007 (ten thousand yuan)

..... 3-8
Fig 3- 8 Public revenues and growth rates in the most severely affected area during 2001-2007 3-8
Fig 3- 9 Savings deposit balance of urban and rural residents (yuan)..... 3-9
Fig 3- 10 Growth rate of savings deposit balance of urban and rural residents 3-10

Fig 4- 1 Temporal variation of types of urbanization for the MSAA from 2001 to 2017 4-2
Fig 4- 2 Types of Urbanization distribution by stages for the MSAA 4-3
Fig 4- 3 Temporal distribution of types of urbanization for the Wenchuan county from 2001 to 2017 4-4
Fig 4- 4 Types of Urbanization distribution by stages for the Wenchuan county 4-5
Fig 4- 5 Temporal variation of types of urbanization for the Shifang county from 2001 to 2017 4-6
Fig 4- 6 Types of Urbanization distribution by stages for the Shifang county..... 4-6
Fig 4- 7 Temporal variation of types of urbanization for the Qingchuan county from 2001 to 2017 4-8
Fig 4- 8 Types of Urbanization distribution by stages for the Qingchuan county..... 4-8
Fig 4- 9 Temporal variation of types of urbanization for the Pingwu county from 2001 to 20174-10
Fig 4- 10 Types of Urbanization distribution by stages for the Pingwu county..... 4-10
Fig 4- 11 Temporal variation of types of urbanization for the Pengzhou county from 2001 to 2017 4-11
Fig 4- 12 Types of Urbanization distribution by stages for the Pengzhou county 4-12
Fig 4- 13 Temporal variation of types of urbanization for the Mianzhu county from 2001 to 2017 4-13
Fig 4- 14 Types of Urbanization distribution by stages for the Mianzhu county..... 4-13
Fig 4- 15 Temporal variation of types of urbanization for the Maoxian county from 2001 to 2017 4-15
Fig 4- 16 Types of Urbanization distribution by stages for the Maoxian county..... 4-15
Fig 4- 17 Temporal variation of types of urbanization for the Dujiangyan county from 2001 to

2017 4-16
Fig 4- 18 Types of Urbanization distribution by stages for the Dujiangyan county..... 4-17
Fig 4- 19 Temporal variation of types of urbanization for the Beichuan county from 2001 to 2017 4-18
Fig 4- 20 Types of Urbanization distribution by stages for the Beichuan county 4-19
Fig 4- 21 Temporal variation of types of urbanization for the Anxian county from 2001 to 2017 4-20
Fig 4- 22 Types of Urbanization distribution by stages for the Anxian county..... 4-20
Fig 4- 23 Spatial distribution of Pu by stages for the MSAA 4-22
Fig 4- 24 Spatial distribution of Su by stages for the MSAA 4-23
Fig 4- 25 Spatial distribution of Eu by stages for the MSAA 4-23
Fig 4- 26 Spatial distribution of Pseu by stages for the MSAA 4-24
Fig 4- 27 Spatial distribution of Pu by stages for ten counties 4-26
Fig 4- 28 Spatial distribution of Su by stages for ten counties 4-27
Fig 4- 29 Spatial distribution of Eu by stages for ten counties 4-27
Fig 4- 30 Spatial distribution of Pseu by stages for ten counties 4-28

Fig 5- 1 Variation of dynamic coupling degree and dynamic coupling coordination degree of the most severely affected area (2001-2017) 5-3
Fig 5- 2 Box and whisker plot for the DCD and DCCD values of the MSAA in different stages 5-3
Fig 5- 3 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Wenchuan county (2001-2017) 5-5
Fig 5- 4 Box and whisker plot for the population-economy-space urbanization of the Wenchuan county in different stages 5-5
Fig 5- 5 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Shifang county (2001-2017) 5-7
Fig 5- 6 Box and whisker plot for the population-economy-space urbanization of the Shifang county in different stages 5-8
Fig 5- 7 Variation of dynamic coupling degree and dynamic coupling coordination degree of the

Qingchuan county (2001-2017) 5-10
Fig 5- 8 Box and whisker plot for the population-economy-space urbanization of the Qingchuan county in different stages 5-10
Fig 5- 9 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Pingwu county (2001-2017)..... 5-12
Fig 5- 10 Box and whisker plot for the population-economy-space urbanization of the Pingwu county in different stages 5-13
Fig 5- 11 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Pengzhou county (2001-2017) 5-15
Fig 5- 12 Box and whisker plot for the population-economy-space urbanization of the Pengzhou county in different stages 5-15
Fig 5- 13 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Mianzhu county (2001-2017)..... 5-17
Fig 5- 14 Box and whisker plot for the population-economy-space urbanization of the Mianzhu county in different stages 5-17
Fig 5- 15 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Maoxian county (2001-2017)..... 5-19
Fig 5- 16 Box and whisker plot for the population-economy-space urbanization of the Maoxian county in different stages 5-20
Fig 5- 17 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Dujiangyan county (2001-2017) 5-23
Fig 5- 18 Box and whisker plot for the population-economy-space urbanization of the Dujiangyan county in different stages 5-23
Fig 5- 19 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Beichuan county (2001-2017)..... 5-25
Fig 5- 20 Box and whisker plot for the population-economy-space urbanization of the Beichuan county in different stages 5-26
Fig 5- 21 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Aanxian county (2001-2017) 5-28
Fig 5- 22 Box and whisker plot for the population-economy-space urbanization of the Anxian

county in different stages 5-28
Fig 5- 23 Spatial distribution of DCD by stages for the MSAA 5-30
Fig 5- 24 Spatial distribution of DCCD by stages for the MSAA 5-30
Fig 5- 25 Spatial distribution of DCD by stages for ten counties 5-32
Fig 5- 26 Spatial distribution of DCCD by stages for ten counties 5-32

Fig 6- 1 Local Moran's I of Pu by stages for ten counties 6-41
Fig 6- 2 Local Moran's I of Su by stages for ten counties 6-42
Fig 6- 3 Local Moran's I of Eu by stages for ten counties 6-42
Fig 6- 4 Local Moran's I of Pseu by stages for ten counties 6-43
Fig 6- 5 Local Moran's I of DCD by stages for ten counties 6-44
Fig 6- 6 Local Moran's I of DCCD by stages for ten counties 6-45
Fig 6- 7 Conceptual model diagram for the urbanization of population, economy, and space in the MSAA 6-46
Fig 6- 8 Conceptual model diagram for the urbanization of population, economy, and space in the Wenchuan county 6-47
Fig 6- 9 Conceptual model diagram for the urbanization of population, economy, and space in the Shifang county 6-48
Fig 6- 10 Conceptual model diagram for the urbanization of population, economy, and space in the Qingchuan county 6-49
Fig 6- 11 Conceptual model diagram for the urbanization of population, economy, and space in the Pingwu county 6-50
Fig 6- 12 Conceptual model diagram for the urbanization of population, economy, and space in the Pengzhou county 6-51
Fig 6- 13 Conceptual model diagram for the urbanization of population, economy, and space in the Mianzhu county 6-52
Fig 6- 14 Conceptual model diagram for the urbanization of population, economy, and space in the Maoxian county 6-53
Fig 6- 15 Conceptual model diagram for the urbanization of population, economy, and space in the Dujiangyan county 6-54

Fig 6- 16 Conceptual model diagram for the urbanization of population, economy, and space in the Beichuan county 6-55
Fig 6- 17 Conceptual model diagram for the urbanization of population, economy, and space in the Anxian county 6-56
Fig 6- 18 Two dimensions evaluation model for classification of quality of urbanization by stages for ten counties 6-61

CONTENTS OF TABLES

Table 2- 1 Index system for urbanization and weights of indicators..... 2-3

Table 2- 2 Urbanization patterns and corresponding description of the poSulation–space-economy urbanization triangle model 2-9

Table 3- 1 Changes in the Industrial Structure of the most severely affected area during 2001-2007 3-4

Table 3- 2 Direct economic losses in the most severely affected area 3-10

Table 3- 3 Number of casualties in the most severely affected area 3-11

Table 3- 4 Number of Collapsed Houses in the most severely affected area 3-12

Table 3- 5 Area and proportion of cultivated land and ecosystem damaged by earthquake by county..... 3-13

Table 3- 6 Surface coverage area of landslides, landslides and debris flow damage in the most severely affected area..... 3-14

Table 3- 7 Paired reconstruction worksheet..... 3-18

Table 6- 1 Urbanization level differences between each stage and the whole period in specific types of urbanization..... 6-2

Table 6- 2 Urbanization level differences between stages for the MSAA 6-3

Table 6- 3 Wenchuan Urbanization level differences between each stage and the whole period in specific types of urbanization 6-3

Table 6- 4 Urbanization level differences between stages for the Wenchuan county 6-4

Table 6- 5 Shifang Urbanization level differences between each stage and the whole period in specific types of urbanization 6-5

Table 6- 6 Urbanization level differences between stages for the Shifang county..... 6-6

Table 6- 7 Qingchuan Urbanization level differences between each stage and the whole period in specific types of urbanization 6-7

Table 6- 8 Urbanization level differences between stages for the Qingchuan county..... 6-9

Table 6- 9 Pingwu Urbanization level differences between each stage and the whole period in

specific types of urbanization 6-9
Table 6- 10 Urbanization level differences between stages for the Pingwu county..... 6-10
Table 6- 11 Pengzhou Urbanization level differences between each stage and the whole period in specific types of urbanization 6-11
Table 6- 12 Urbanization level differences between stages for the Pengzhou county 6-12
Table 6- 13 Mianzhu Urbanization level differences between each stage and the whole period in specific types of urbanization 6-13
Table 6- 14 Urbanization level differences between stages for the Mianzhu county..... 6-14
Table 6- 15 Maoxian Urbanization level differences between each stage and the whole period in specific types of urbanization 6-15
Table 6- 16 Urbanization level differences between stages for the Maoxian county..... 6-16
Table 6- 17 Dujiangyan Urbanization level differences between each stage and the whole period in specific types of urbanization 6-18
Table 6- 18 Urbanization level differences between stages for the Dujiangyan county 6-18
Table 6- 19 Beichuan Urbanization level differences between each stage and the whole period in specific types of urbanization 6-19
Table 6- 20 Urbanization level differences between stages for the Beichuan county..... 6-20
Table 6- 21 Anxian Urbanization level differences between each stage and the whole period in specific types of urbanization 6-21
Table 6- 22 Urbanization level differences between stages for the Anxian county..... 6-22
Table 6- 23 Coupling and Coupling Coordination Degree differences of the MSAA 6-23
Table 6- 24 Coupling and Coupling Coordination Degree differences between stages for the MSAA..... 6-24
Table 6- 25 Coupling and Coupling Coordination Degree differences of the Wenchuan county 6-25
Table 6- 26 Coupling and Coupling Coordination Degree differences between stages for the Wenchuan county..... 6-26
Table 6- 27 Coupling and Coupling Coordination Degree differences of the Shifang county 6-26
Table 6- 28 Coupling and Coupling Coordination Degree differences between stages for the Shifang county 6-27

Table 6- 29 Coupling and Coupling Coordination Degree differences of the Qingchuan county 6-28
Table 6- 30 Coupling and Coupling Coordination Degree differences between stages for the Qingchuan county 6-29
Table 6- 31 Coupling and Coupling Coordination Degree differences of the Pingwu county 6-29
Table 6- 32 Coupling and Coupling Coordination Degree differences between stages for the Pingwu county 6-30
Table 6- 33 Coupling and Coupling Coordination Degree differences of the Pengzhou county 6-31
Table 6- 34 Coupling and Coupling Coordination Degree differences between stages for the Pengzhou county 6-32
Table 6- 35 Coupling and Coupling Coordination Degree differences of the Mianzhu count 6-32
Table 6- 36 Coupling and Coupling Coordination Degree differences between stages for the Mianzhu county 6-33
Table 6- 37 Coupling and Coupling Coordination Degree differences of the Maoxian county 6-34
Table 6- 38 Coupling and Coupling Coordination Degree differences between stages for the Maoxian county 6-35
Table 6- 39 Coupling and Coupling Coordination Degree differences of the Dujiangyan county 6-36
Table 6- 40 Coupling and Coupling Coordination Degree differences between stages for the Dujiangyan county 6-36
Table 6- 41 Coupling and Coupling Coordination Degree differences of the Beichuan county 6-37
Table 6- 42 Coupling and Coupling Coordination Degree differences between stages for the Dujiangyan county 6-38
Table 6- 43 Coupling and Coupling Coordination Degree differences of the Anxian county 6-39
Table 6- 44 Coupling and Coupling Coordination Degree differences between stages for the Anxian county 6-40
Table 6- 45 Classification of population urbanization at different stage..... 6-57

Table 6- 46 Classification of space urbanization at different stage 6-58

Table 6- 47 Classification of economy urbanization at different stage 6-58

Table 6- 48 Classification of population-space-economy urbanization at different stage..... 6-59

Table 6- 49 Classification of quality urbanization before and after Wenchuan earthquake 6-61

Chapter 1

Research Background and Purpose of the Study

CHAPTER ONE: RESEARCH BACKGROUND AND PURPOSE OF THE STUDY

Research Background and Purpose of the Study.....

1.1 Introduction..... 1-1

1.2 Research background and significance..... 1-4

1.2.1 Wenchuan earthquake and post-disaster reconstruction..... 1-4

1.2.2 The effect of rapid urbanization of China..... 1-6

1.2.3 Research Significance..... 1-7

1.3 Review of previous study..... 1-8

1.3.1 Development on understanding of the urbanization..... 1-8

1.3.2 Research on the relationship among urbanization systems..... 1-10

1.3.3 Post disaster recovery and reconstruction..... 1-12

1.4 Purpose and research structure of this study..... 1-13

Reference..... 1-17

1.1 Introduction

All around the world, urbanization is still attracting widely attention and is considered as one of the important ways to improve the economic development [1]. At present, with the continuous improvement of the world's urbanization level, more than half of the population lives in cities (Fig. 1-1) [2]. The world urban population has grown rapidly from 751 million in 1950 to 4.2 billion in 2018 [3]. In 1950 only a third of the population lived in the urban area, while the rest of them lived in the rural area. However, two-thirds of the population would be lived in the urban area by 2050. Furthermore, according to United Nations report [2] that in the future, the world's urban population will be concentrated in a few countries. Among these countries, India will add 416 million urban residents and China will increase 255 million more population who lived in the urban area [2].

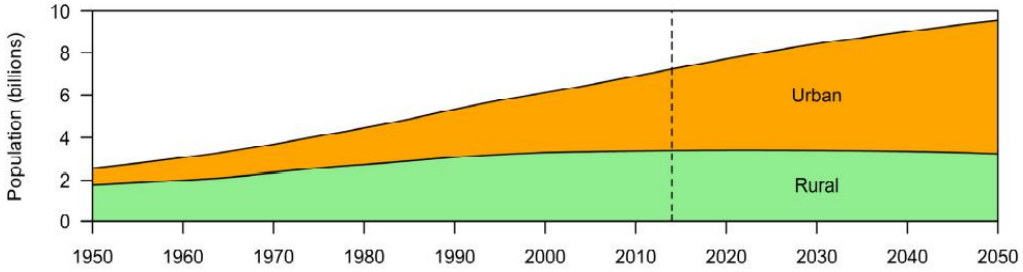


Fig1- 1 The world's urban and rural populations, estimated for 2050
(Source: UN World Urbanization Prospects: The 2014 Revision)

There is a dramatic difference in development of urbanization between more developed areas and less developed areas (Fig1-2) [4]. It could be seen that population of developed areas has remained basically stable with a slight increase. In contrast, higher growth rate on the population could be seen in less developed areas. But the proportion of their urban population is much lower than that of developed regions. Population growth in developed regions has been on an upward trend since 1950. However, it shows a different development pattern from the population growth of less developed regions. Even though the less developed regions starting from a lower level, it soon caught the population of the developed regions in 1970. And then it went into accelerating mode all the way ahead. In 2020, the population of developed regions will be only one third of that of underdeveloped countries. It is predicted that the number of people living in less developed areas will grow to 5500 million, and take up 84% of the world's population by 2050.

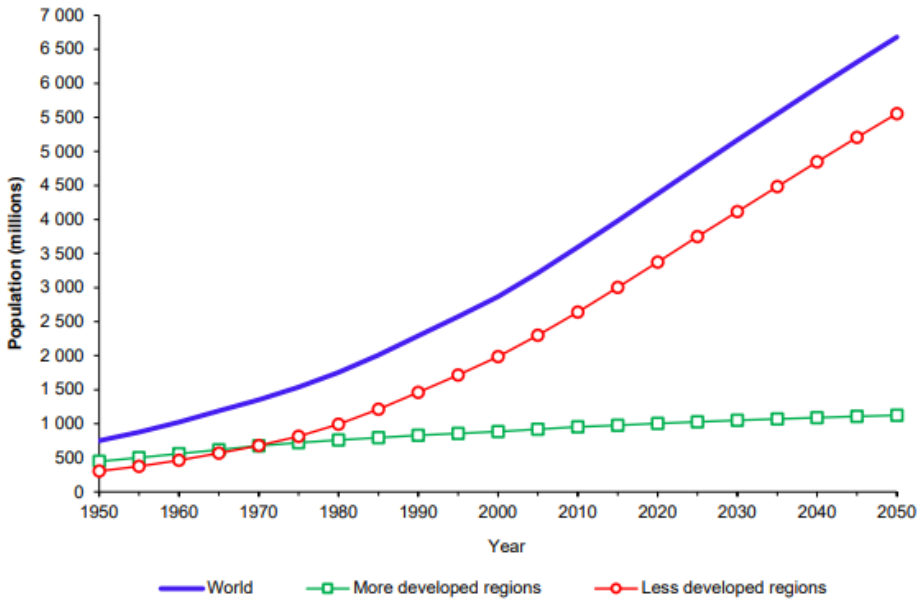


Fig1- 2Estimated and projected urban populations of the world, the more developed regions and the less developed regions, 1950-2050 (Source: UN World Urbanization Prospects: The 2018 Revision)

However, the development of the world's population varies greatly between different continents (Fig.1-3) [4]. Comparing the urbanization growth rate of the six continents, we can obviously see the differences in their development modes. There are the same trend and speed for the Asia and Africa. Even though both started late, urbanization growth rate of Asia was 19% in 1950, while urbanization growth rate of Africa was 15%, which was slightly lower than Asia and was also the lowest among the six continents. After that, all the continents have experienced rapid growth. With respect to Asia, the urbanization growth rate fluctuated from 1975 to 1990. While Africa has shown an upward trend without any fluctuation during the same time. There was a rapid growth of Asia since 1995. In 2050, the urbanization level of Asia would be 60%. While the value of Africa urbanization would be 55%, which is smaller than Asia.

In 1950, the urbanization level of North America had been exceeded over 60%. In the following decades, the level of urbanization in North America steadily increased. By 2050, North America would be the most urbanized region in the world, with the urbanization level more than 80 %. The urbanization level of Oceania was slightly lower than that of North America at the initial stage. After several years of slow development, its urbanization level declined year by year after 1975. From 2000 to 2005, the urbanization level remained basically stable. It is worth noting that its urbanization first rose, then fell and finally maintained a stable development pattern. By 2050, Oceania's urbanization rate is close to that of 1950, at 63%. In 1950, urbanization level of the Europe was 52%, which was the third highest urbanization of the world. After the rapid development of urbanization, it began to rise steadily in 1990, and gradually slowed down, and would be reached to 78% by 2050. Finally, after experienced the rapid growth during 1950-1990, the Latin America and the Caribbean had overtaken Europe and Oceania in 1990. By 2050, The urbanization level in Latin America and the Caribbean would be reached to 86%, which was the second highest in the world.

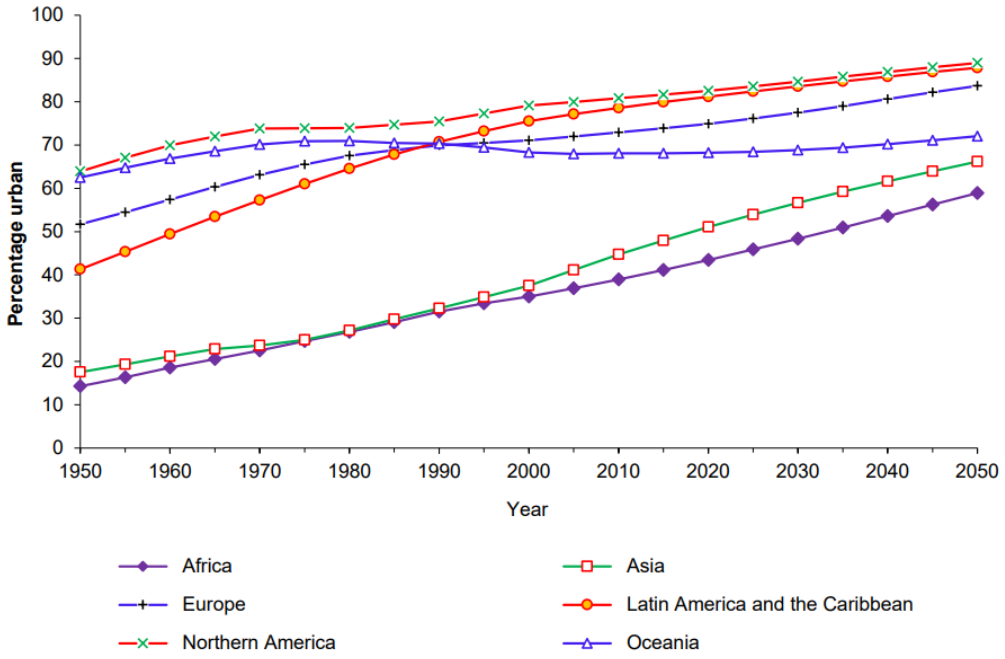


Fig1- 3Percentage of population residing in urban areas by geographic region, 1950-2050 (Source: UN World Urbanization Prospects: The 2018 Revision)

Refer to the growth rates of cities of different sizes, cities in Asia and Africa grew significantly faster and larger than those in the other four continents from 2000 to 2018(Fig1-4) [5]. The growth rate of speed and size was remarkable. As shown in Figure 1-4, majority of cities with 10 million or more distributed in the Asia. The global population of more than 500,000 people was growing at an average rate of 2.4% a year, with an annual growth rate of more than 6% in 36 cities. Among these cities, 7 cities belong to Africa and the remaining 28 cities distribute in Asia, including 17 cities locate in China [5].

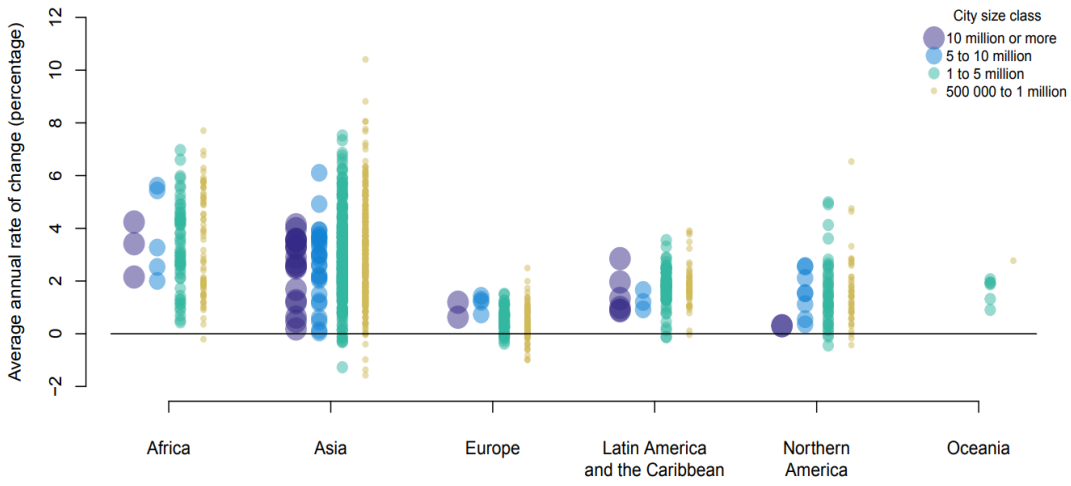


Fig1- 4Growth rates of the world's cities, 2000-2018(Source: UN World urbanization prospects: The 2018 vision)

With the rapid development of urbanization, it not only has brought a lot of development potential, especially it has brought the qualitative leap in the economic development of many cities and has

raised the income of local residents and improved their living conditions [6], but also causes many urban problems, including the aging population problem, land problem, urban expansion and ecological problems[7], especially the environmental damage and resource waste are particularly prominent in recent years[8]. Furthermore, the increasing cities are exposed to natural disasters as well (Fig1-5).

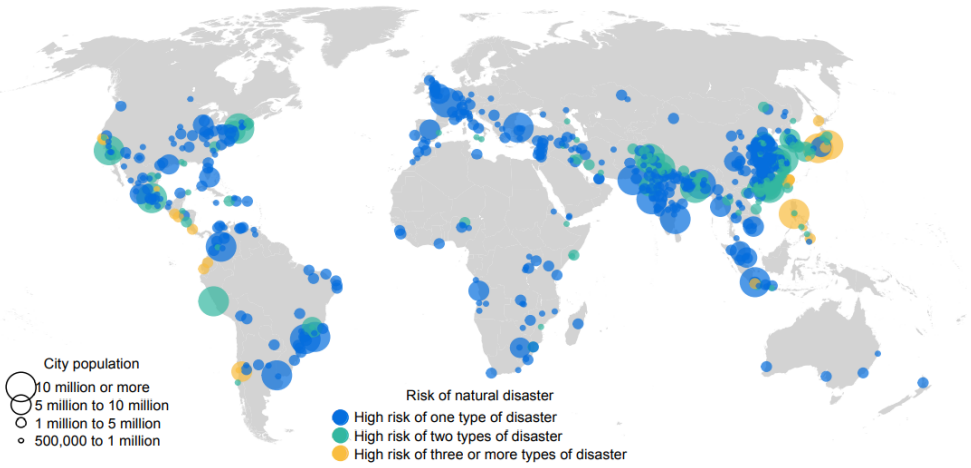


Fig1- 5cities' risk of exposure to natural disasters. (Source: UN World urbanization prospects: The 2018 vision)

In today's world, cities of all sizes are faced with different natural disasters. These disasters are mainly distributed in Asia, North America, South America, Africa and Europe. It is particular fierceness in coastal areas and island nations. Of the 1,146 cities with a population of more than 500,000, 679 (59%) cities are at high risk of at least one of six natural disasters, namely hurricanes, floods, droughts, earthquakes, landslides and volcanic eruptions4. Overall, 189 cities mostly in coastal areas were at high risk of two or more natural disasters; 26 cities, including Manila, Osaka and Tokyo, are at high risk of three or more disasters [4].

Overall, with the increasing activity of man to nature, cities are more and more exposed to natural disasters and risks. This has posed a huge challenge to the current process of urbanization development. Therefore, it is urgent necessary to study the problems faced by these cities, which can give appropriate suggestions to the government and decision makers.

1.2 Research background and significance

1.2.1 Wenchuan earthquake and post-disaster reconstruction

In recent decades, natural disasters like earthquakes, hurricanes, floods, and tsunamis have happened frequently in many parts of China and all over world [9]. Some of them are caused by the movement of the earth's own tectonic plates, and some are caused by excessive human activity and interference with nature[9]. Especially with the continuous development of urbanization, the rapid rise of economy and population, the scale of cities is also expanding, causing more and more harm to nature and resources, which further deteriorate the relationship between human and nature. Among them, earthquakes as one of the most serious damages, are devastating to the safety of local people, citizen's property as well as social development.

China is one of the countries most affected by earthquakes, which about 35 percent of the world's land earthquakes of magnitude 7 or greater occur in China [10]. On May 12th, 2008, the Wenchuan Earthquake, with a magnitude of 8.0 on the Richter scale, shoc ked China and the whole world. The earthquake was caused by the fracture of Longmenshan fault zone in the east of Qinghai-Tibet Plateau. The epicenter was located in Yingxiu Town (31.0 N, 103.4 E), Wenchuan County, Sichuan Province, southwest China, and its severely damaged area was about 500,000 square kilometers. Among them, there are 10 counties (cities) in the most severely affected areas, including: Wenchuan, Beichuan, Maoxian, Shifang, Mianzhu, Anxian, Pingwu, Pengzhou, Dujiangyan and Qingchuan, all of which are located in the Longmenshan earthquake zone in Sichuan province. There are 41 counties (cities) in the hardest hit areas and 186 counties (cities) in the general disaster areas [11]. The 5.12 Wenchuan earthquake killed 69,227 people, 17,923 people were missing, 374,643 people were injured in different degrees, and 19,930,300 people lost their homes, with a total population of 46.256 million people suffering [12]. 5.12 Wenchuan earthquake is the most destructive, widespread, disastrous and difficult earthquake since the founding of the People's Republic of China [9].

After the earthquake, the people of the whole country actively carried out disaster relief work under the leadership of the CPC Central Committee. The cadres and victims in the disaster areas also fought to save themselves, and volunteers from all corners of the country quickly Sut in their efforts to help. At the same time, the central government took immediate action to coordinate the scientific deployment of earthquake relief and post-disaster reconstruction by various social forces. On June 8, 2008, the State Council issued the Regulations on Recovery and Reconstruction [13] after Wenchuan Earthquake, and on June 18, the State Council issued the Counterpart Support Plan for Recovery and Reconstruction [14] after Wenchuan Earthquake. In the plan, the assistance mode of one province helping one of the most severely affected counties was Put forward for the first time. On September 19th, the State Council issued the Master Plan for Recovery and Reconstruction[14]after Wenchuan Earthquake. This is the central government's overall planning and design for post-disaster reconstruction, and clearly puts forward the goal of basically realizing the post-disaster recovery and reconstruction planning within three years. At the same time, it pointed out that it is important to adhere to the requirements of people-oriented, respect for nature, overall planning and scientific reconstruction.

People had to face the sudden and huge disaster, which not only destroyed the wealth created by decades of hard work of local people and turned the beautiful homes into ruins instantly, but also suspended the original urbanization process of the affected areas. After three years of post-disaster reconstruction and nearly ten years of long-term recovery and development, the reconstruction areas affected by the Wenchuan earthquake have made significant achievements. At the same time, a wealth of post-disaster reconstruction experience and development models have been accumulated. In particular, the ten most severely affected areas like Wenchuan, Beichuan, Shifang, and Mianzhu relied on government policies and benefits, material assistance, and technical guidance. Within two or three years after the earthquake, infrastructure construction, industrial restructuring, upgrading of public service facilities, and satisfaction of housing needs were rapidly completed. It can be said that the three-year post-disaster reconstruction task was successfully completed, and the economy of many disaster areas quickly returned to the pre-disaster level. At the same time, the continuous land acquisition, the expansion of urban built-up areas, as well as the transfer of a large number of

people from rural to urban households have caused significant changes in the form of post-disaster urbanization development and brought about unique problems [14]. According to the past experience of natural disaster-prone countries such as the United States and Japan, the reconstruction of major natural disasters is a long-term process. Now, although the three-year post-disaster reconstruction period led by the government has already ended, the sustainable development of economy, society and urbanization in the affected areas still needs our attention. How to construct the sustainable development of urbanization in the most severely affected areas is an unavoidable problem for the government and society. In addition, there are differences in the social-economic development levels of the ten counties in the most severely affected areas, which existed before the earthquake [15]. Whether this difference affects post-earthquake development? This is a question worth to study and considerate.

1.2.2 The effect of rapid urbanization of China

China's urbanization process

Since the reform and opening up, China's economy has developed rapidly. At the same time, urbanization has also achieved amazing development. The development of Urbanization in China was completely realized by the change of the inflow of rural population into urban population [16]. Urbanization is an important indicator to measure the level of modernization of a country or region. It took 120 years for the UK, 100 years for France, 80 years for Germany and 40 years for the US to increase the urbanization rate from 20 percent to 40 percent, but only 22 years for China [17]. It can be said that China's rapid urbanization was unprecedented in the world.

The rapid urbanization has brought unprecedented prosperity to the economy. They have improved people's living standards and living environment. However, at the same time, it has also brought negative effects, such as unlimited urban sprawl, aging, air pollution, imperfect infrastructure and insufficient energy. Especially the frequent occurrence of geological disasters directly or indirectly loss [18]. On the one hand, earthquake disasters are inevitable in the process of urbanization, and they are limited by natural conditions such as geographical conditions and climate. On the other hand, with the continuous improvement of urbanization level, the increasing population of cities and towns, and the intensive transformation of the natural environment, human beings have caused further harm to the natural environment. Serious geological disasters not only cause huge casualties and property losses, but also have a short-term or long-term impact on the development of urbanization, and even seriously restrict the development and scale of urbanization [18].

At the same time, we need to recognize that China's urbanization is both a process of continuous influx of migrant workers to the cities and the transfer of large numbers of people from the central and western parts of the country to the eastern coast. This process not only makes the urban-rural gap further widen, but also makes the development of the east and west more unbalanced [19]. The report of the 19th National Congress of the Communist Party of China in 2017 proposed to promote the development of the western region and build the urbanization road of coordinated development of towns at all levels. Not only is the population proportion and economic development in the western region different from that in the eastern coast, but the urbanization quality in the western region is also low: the scale system is not perfect, the education level is low, the industry is weak, etc. At the same time, it is limited by the geographical location and the transportation is inconvenient.

Many cities and towns in the western region are often attacked by natural disasters, making them with the lowest level of regional development, and it is difficult for urbanization to develop with high quality. Therefore, it is great guiding significance to seize the opportunity of post-disaster reconstruction, combine post-disaster reconstruction with urbanization development, so as to realize the leap-forward development of disaster-prone areas in western China.

Urban sustainable development

In 1987, the United Nations World Commission on Environment and Development (WECD) gave a comprehensive and detailed description of sustainable development for the first time in its report "Our Common Future"[20]. According to the definition and content of sustainable development, urban sustainable development refers to the realization of highly developed urbanization and modernization with long-term sustainable urban growth and structural evolution on a certain time and space scale, so as to meet the realistic needs of contemporary urban development and the needs of future urban development [21]. The idea of "sustainable development" provides a guiding ideology for the long-term development of mankind in the future. The Rio Declaration on Environment and Development in 1992 stated that "human beings must survive, the earth must be saved, and the environment and development must be synchronized and coordinated", and closely linked sustainable development with Agenda 21 to form a complete scientific development theory.

"Sustainable development theory", as a general program to guide the development of human beings and cities, has important connotation and practical role. It mainly includes the sustainable development of society, economy and environment. For the sustainable development of urban system, environmental sustainability is the foundation, economic sustainability is the condition. The coordinated development of these three is the key to sustainable development [22]. In addition, sustainable development involves not only the development of man and society, the harmonious coexistence of man and man, but also emphasizes the coordinated development of human and nature[23].

China is a country with frequent natural disasters. Preventing and mitigating the damage of natural disasters to human life and promoting the sustainable development of cities have become difficult problems that human society must solve[18]. At the same time, in cities that have experienced serious natural disasters, how to recover and rebuild after the disaster to make the operation of each subsystem of the city return to normal and better realize sustainable development is also worthy of attention and consideration.

1.2.3 Research Significance

Now, with nature disasters occurring all over the world, it has become a challenge to urbanization with rapid socio-economy development, especially for the disaster-prone area. Nature disasters could render huge casualties and property losses, posing a great threat to urbanization and limiting the socio-economy development to a large extent [24-25]. As one of the disasters with great destructive power, heavy casualties and economic losses, the impact of the earthquake cannot be negligible [26]. Since the reform and opening up in 1978, China’s urbanization process has developed rapidly. At the same time, frequent earthquakes and various natural disasters have posed significant obstacles to the high-quality development of China's urbanization.

In recent years, many scholars have carried out research on urbanization from various fields, and

have made fruitful achievements. However, there is relatively little concern about the impact of major disasters on urbanization. The development of urbanization is not only influenced by man-made, but also interfered by natural disasters. For the areas that have experienced major natural disasters, what changes will urbanization have, and will it have a long-term impact on the development of urbanization in the affected areas? There are still few discussions on urbanization under this special situation.

Cities and counties are a complete system. More importantly, the sustainable development of cities and counties can promote the sustainable development of human society. Therefore, comprehensive analysis of urbanization changes before and after earthquakes on the county scale is an indispensable part of urban and rural planning and development. China is urbanizing rapidly. There are obvious differences between urban and rural areas in China's urbanization process, especially in counties in western China. In the process of rapid urbanization of county-level units, the conflicts among economy, population and space are more intense and complex than those of cities with higher urbanization level. After experiencing a major natural disaster, how does the coordination relationship between different components of the urbanization system (such as population, economy and space) change? Will this destructive earthquake change the pattern of local urbanization? These problems play an important reference and guiding significance for the sustainable development of urbanization of county-level units and the leap-forward development of post-disaster reconstruction areas.

Wenchuan earthquake in 2008 was the most destructive earthquake since the founding of China in 1949, which caused the most damage and spread. Compared with the general disaster areas, the worst-hit areas suffer deeper and stronger disasters, resulting in heavy casualties and economic losses, serious damage to infrastructure such as transportation, It is worth noting that these ten extremely hard-hit areas are all at the county level in terms of administrative division and are very representative of the affected areas. The devastating earthquake undoubtedly brought greater challenges to the urbanization development of the underdeveloped areas. However, after a series of earthquake relief and policy support, post-disaster reconstruction has also brought new development opportunities to urbanization in disaster areas.

This paper reviews and studies the urbanization development of 10 most severely affected counties for nearly 20 years before and after the Wenchuan earthquake, and deeply discusses and analyzes the short-term recovery and reconstruction as well as long-term development stages of counties with severe earthquake from the perspective of urban subsystem coupling. It is helpful to consolidate and develop the achievements of post-disaster reconstruction, provide policy guidance and countermeasures for improving the sustainable development ability of disaster-stricken counties, realizing the comprehensive revitalization and development of county economy and society in disaster-stricken areas, and further enrich the theory of urbanization development of post-disaster counties.

1.3 Review of previous study

1.3.1 Development on understanding of the urbanization

The term urbanization was first put forward by Spanish architect Amsterdam (1867) in "Basic Concepts of Urbanization". Urbanization came into being with the rise and development of

industrialization, and its essence is the process of rural population migrating to urban population [27]. R. H. Rossi believes that urbanization is "a process in which cities constantly influence rural areas and spread urban culture [28]. E.H. Permchenko comprehensively explains that urbanization is a global demographic, social and economic evolution process which is composed of multiple fields, including the concentration of productive forces, the rapid development of social communication and the convergence of urban lifestyle [29]. Japanese scholar Yamaga Seiji pointed out that modern urbanization should include four aspects: "Redevelopment and reuse of the original urban areas; Expansion of new urban areas; the emergence of city circle between cities; and the formation of metropolitan areas" [30].

Comprehensive studies show that urbanization is an objective rule of social and economic development, and the process of urbanization will inevitably begin when social and economic development reaches a certain stage. It includes many aspects such as population transfer, economic development, social and cultural development, etc. Scholars in different fields have different interpretations of the definition of urbanization: From the perspective of demography, urbanization is defined as the process of transforming agricultural population into non-agricultural population. This part of researchers think that urbanization is basically equivalent to population urbanization. Wilson understood urbanization as a phenomenon that the proportion of population living in urban areas increased and the proportion of rural population decreased [31]. Chinese scholars Zhang Chunyuan divided urbanization into two aspects: dynamic and static, and dynamic urbanization refers to the process of rural population constantly transferring to urban population. Static urbanization means that the proportion of urban population in a region or country exceeds that of rural population [32].

From an economic point of view, it is more emphasized that urbanization is the result of the adjustment and transformation of industrial structure, which is fundamentally the promotion of productivity to promote the development of urbanization. The agricultural population shifts to non-agricultural production sectors, and farmers who used to work in the primary industry gradually turn to cities to work in the secondary and tertiary industries. Simon Kuznets [33] believed that urbanization was the product of economic growth and technological change, and technological innovation made large-scale production possible. At the same time, it attracted farmers engaged in agricultural labor to enter cities to engage in non-agricultural industries, thus promoting the economic growth of cities. Chinese scholars Feng Lanrui and others also believe that population transfer is only the manifestation of urbanization, and the agglomeration of production factors is the core of urbanization [34].

Geographers study the change of urbanization from the perspective of space, and think that cities are the center of human activities, and that urbanization is the process of the scope of urban space gradually expanding to rural areas. Gao Peiyi[35] and Xu Xueqiang et al.[36] believes that the non-agricultural population and non-agricultural economic activities are constantly concentrated in the urban space and gradually transformed into the economic elements of the city. Chen Fenggui believes that the process of urbanization is the spatial change of land, accompanied by the optimization of land structure and the high-level characteristics of land input and output [37].

Although there are some differences in the definitions of urbanization in different disciplines, the concept of urbanization includes at least population mobility, social agglomeration, economic

development rapidly, urban space expansion and so on.

1.3.2 Research on the relationship among urbanization systems

Many scholars also study urbanization from different dimensions and fields. Mainly focus on the following aspects: (1) Study on the relationship between population urbanization and land urbanization; (2) Research on the relationship between population urbanization and economic urbanization; (3) Study on the relationship between land urbanization and economic development; (4) Study on the multidimensional development relationship of urbanization subsystem.

Study on the Relationship between Population Urbanization and Land Urbanization

The process of population urbanization cannot be simply understood as the process of transforming rural population into urban population, but should be understood from multiple angles and disciplines [38]. With the rapid development of society, it not only brings about the improvement of urban functions, but also leads to the emergence of urban diseases. In terms of the crowded urban space, expanding the scale of the city has become the most effective means. Scholars at home and abroad through the establishment of comprehensive index system, using coupling coordination model, econometric methods, regression analysis, grey relational analysis and other methods to determine whether population urbanization and land urbanization coordinated development and influence factors. Yang Ren [39]and Guo Shihong et al. [40] through the different regions as cases, found that the urbanization of land in regions are obviously faster than the urbanization of population. After analyzing the coupling situation of land and population in the Yangtze River Delta, Zhou Yan et al. found that the land expansion rate is higher than the population growth rate as a whole, the coupling relationship between man and land is constantly changing in time and space, and the coordination degree of cities is at a low level of development [41]. Yuan Fangcheng et al. believe that urbanization development is the result of the flow and agglomeration of population, land as well as finance, and that the expansion of land elements can be restrained through financial elements [42]. Zhao Qinghai believes that population urbanization not only includes the transformation of population employment mode, but also provides people with supporting infrastructure and public service facilities, which greatly improves the quality of life [43].

Research on the Relationship between Population Urbanization and Economic Urbanization

Population urbanization and economic development promote each other. Early studies only described the geographical distribution of population and the spatial distribution of economy statistically. In recent years, due to the uncoordinated spatial distribution of population and economy, the regional development gap has widened. Scholars have gradually paid attention to the coordinated development of the two aspects, and established simple evaluation indicators to reflect the coordinated level of population and economy. Such as population and economic concentration index, population and economic consistency index [44]. Or construct the index system of population-economy system [45] and use coupling and grey correlation method [46]to explore its coupling and coordinated development. Oskar Nordstrom Skans studies the influence of population structure on regional productivity, and proposes that population unemployment rate has a positive effect on productivity [47]. Feng Zhiming et al. analyzed the spatial distribution and changes of population and economy in Fujian Province, and pointed out that there are obvious differences in

the distribution of population and economy in counties, which are in a state of continuous coordination on the whole [48] Jiang Xiaojun's research shows that the coordinated development of economy and society is positively correlated with the city scale and economic development level [49]. Zhao Jing et al. analyzed the direct, intermediary and regulatory effects of population urbanization on regional economic growth, and pointed out that simply adjusting household registration will not directly promote economic growth, but population urbanization will stimulate economic growth by promoting industrialization process, material capital investment, and human capital accumulation as well as innovation ability [50]. Peng Jiahui pointed out that from the perspective of population and economic situation alone, it is not enough to reflect the real state of regional internal development, and the regional industrial structure and employment structure should be considered [51].

Research on the Relationship between Spatial Urbanization and Economic Development

Land urbanization is the process of expansion of urban land-the expansion. At the same time, it is accompanied by the improvement of land economic value. In the research on the relationship between land urbanization and economic development, scholars focus on the action mechanism and reaction mechanism. Brueckner found that the main factors affecting urban scale expansion are population, economic income, transportation cost, land rent, etc. Restraining the rapid development of land urbanization, it can be alleviated by regulating rent and transportation cost [52]. Zhangyan et al. believed that development of the secondary and tertiary industries requires a certain scale of geographical agglomeration. For the pursuit of economic benefits, each enterprise makes the land with the same function tend to gather, and at the same time, it realizes the reorganization "concentration" trend of urban spatial economic structure while pursuing scale effect[53]. Dmovsck and Kovacic belive that the flattening of urban spatial form restricts the exertion of urban functions, affects the agglomeration of urban economy, and will eventually lead to the development of urban production and economy [54].

Research on Multi-dimensional Development Relationship of Urbanization Subsystem

In view of the coordinated development of population, economy, space and social urbanization, scholars have studied from different scales and directions. By analyzing the spatial autocorrelation of population-space-industrial urbanization in the middle reaches of the Yangtze River from 2008 to 2013 and the spatial-temporal coupling characteristics between systems, Chen Linxin and others found that the coupling coordination degree between population-space-industrial urbanization in cities (counties) in the middle reaches of the Yangtze River is obviously polarized [55]. Gao Baodi and others also started from the three dimensions of population-economy-spatial urbanization of urbanization development, and used the cross-sectional data of Shandong Province in 2006 and 2013 to sum up that the urbanization process in Shandong Province is developing rapidly as a whole, but there is a big gap in the development of different cities [56].

In addition to the research on the coupling and coordination between the internal subsystems of urbanization, the relationship between urbanization and external systems has also attracted scholars' attention, especially in terms of the relationship between urbanization and resources, environment, ecology, and disasters. Wang Shujia and others studied the temporal and spatial evolution and driving factors of the coordinated development of ecological environment, economic development and new urbanization in Beijing-Tianjin-Hebei urban agglomeration. The results show that the

spatial and temporal differences of the development of the three places are obvious [57]. Taking 31 provinces in China as examples, Zhou Lei and others studied the coupling coordination degree of tourism industry system, new urbanization system and ecological environment system, and pointed out that the overall coordination degree of the whole country is not high, and the space shows the difference between high in the east and low in the west [58]. Duan Haiyan and others predicted the coordinated development degree of population-economy-energy environment coupling in Jilin Province in 2030. The results show that it is more difficult to realize the coordinated development degree of population-economy-energy environment coupling under the scenario of ineffective improvement of energy environment [59]. Suo Zhilin and others constructed the evaluation index system of industrialization-urbanization-agricultural modernization of Chengdu-Chongqing urban agglomeration, and discussed the spatial distribution of the coordination stage types of "three transformations"[60].

1.3.3 Post disaster recovery and reconstruction

With the continuous advancement of urbanization, natural disasters are increasingly frequent, and post-disaster reconstruction has been widely concerned. Post-disaster reconstruction was first discussed by Hass in 1970s, and it was divided into four stages: emergency period, recovery period, replacement period, improvement and development period. Since the Northridge earthquake in the United States and Kobe earthquake in Japan occurred one after another at the end of the 20th century, post-disaster reconstruction began to study natural disasters as an important research field, involving sociology, political science, economics and other disciplines. Post-disaster reconstruction is also called post-disaster recovery and reconstruction [61]. Quarantelli believes that recovery and reconstruction is not to reach the pre-disaster level, but to restore the people in the disaster area to meet the basic living and production needs [62]. In China, since the Wenchuan earthquake in 2008, the research on post-disaster reconstruction based on Wenchuan earthquake has also increased rapidly, especially in 2011, when the post-disaster reconstruction was completed. The research on post-disaster reconstruction involves the theory and practice of post-disaster reconstruction planning, planning system evaluation, aid construction mode and experience summary, etc.

Post-disaster reconstruction is a complex system involving natural ecology, regional economy, geological engineering, cultural history and other fields. Yan Bo and others believe that the post-disaster reconstruction planning of affected towns should solve the contradiction between short-term emergency reconstruction and long-term planning. He Put forward constructive suggestions from the aspects of urban spatial layout, coordinated development of nature and towns, and planning and design of disaster prevention and mitigation. It also emphasizes that the key issues such as population distribution, industrial structure adjustment and productivity layout should be planned for a long time in post-disaster reconstruction [63]. Xu Jiuping believes that post-disaster reconstruction is a series of processes of taking emergency rescue, disaster management measures, post-disaster planning, evaluation and reconstruction after a sudden disaster [64]. After Wenchuan earthquake, Chinese scholars generally agree that post-disaster reconstruction must follow the law of harmonious development between man and nature, and increase the theoretical guidance for post-disaster planning and reconstruction in earthquake-stricken areas [65]. Frequent disaster areas, such as the United States and Japan, have rich experience in post-disaster reconstruction and have formed a sound post-disaster reconstruction model. These experiences and achievements have provided a good reference for China's post-disaster reconstruction. Xu Shusheng and Wu Yinze pointed out that

post-disaster reconstruction is an opportunity for industrial adjustment and urban development from the perspective of urban development. Binku Prefecture, Japan seized the opportunity of post-disaster reconstruction to vigorously adjust its industrial structure, upgrade and transform, and increase a large number of jobs for the victims. At the same time, the original industrial, residential mixed areas and low-density residential areas have been improved, and "compact" towns have been built to promote the development of urbanization [66]. On the basis of analyzing the experience of post-earthquake reconstruction in Japan, Chou Baoxing thinks that Japan pays attention to the difference between post-disaster reconstruction in mountainous rural areas and urban restoration and reconstruction, based on the rural resources to be nearby. On-site and decentralized reconstruction is the principle, with villagers living and working in peace and contentment, urban population returning home for sightseeing, beautiful scenery and vibrant rural villages as the reconstruction goal. And put forward that China's post-disaster reconstruction should pay attention to the combination with the construction of new socialist countryside, and the combination of direction and stage. Although he did not directly talk about the relationship between post-disaster reconstruction and urbanization, it can be seen indirectly that post-disaster reconstruction should be based on the current situation of regional development, distinguish rural areas from cities, "divide and rule", develop rural industries and upgrade modernization, improve public service system, and indirectly promote urbanization [67].

Post-disaster reconstruction is a complex giant system composed of many influencing factors. Its formulation and implementation must be based on the scientific concept of development, and it has both short-term and long-term characteristics. It is a process of policy support and material assistance experienced by cities after the disaster. Urbanization is a big background of China's economic and social development, and it is also the only way. With the development of time and further research, some scholars Put forward that post-disaster reconstruction and urbanization do not exist in isolation, but have certain correlation and intersection, and have certain differences. When a major disaster suddenly occurs, it will definitely stop or even cause the local urbanization to regress. In the post-disaster reconstruction and recovery stage, benefiting from a large number of policies and funds, urbanization will be rapidly promoted. When the post-earthquake period and short-term post-disaster reconstruction are completed, how will local urbanization develop in the long-term stage? There is still a lack of relevant research on these problems. Therefore, it is important to study urbanization development in the broader context of earthquake impacts, further explore the post-disaster reconstruction path, optimize policy support, and achieve sustainable development goals.

1.4 Purpose and research structure of this study

This paper conducts a quantitative study by combining temporal-spatial relationships change based on the coupling of population-economy-spatial urbanization in the ten most severely affected areas in 2008 Wenchuan earthquake. The changes in urbanization development before and after the earthquake are compared in county-level cities. Furthermore, it puts forward some suggestions on post-disaster urban reconstruction to adapt to the disaster-prone cities in China, and provides decision-making reference for realizing regional sustainable development (SDG) and high-quality urbanization development.

The specific contents are as follows:

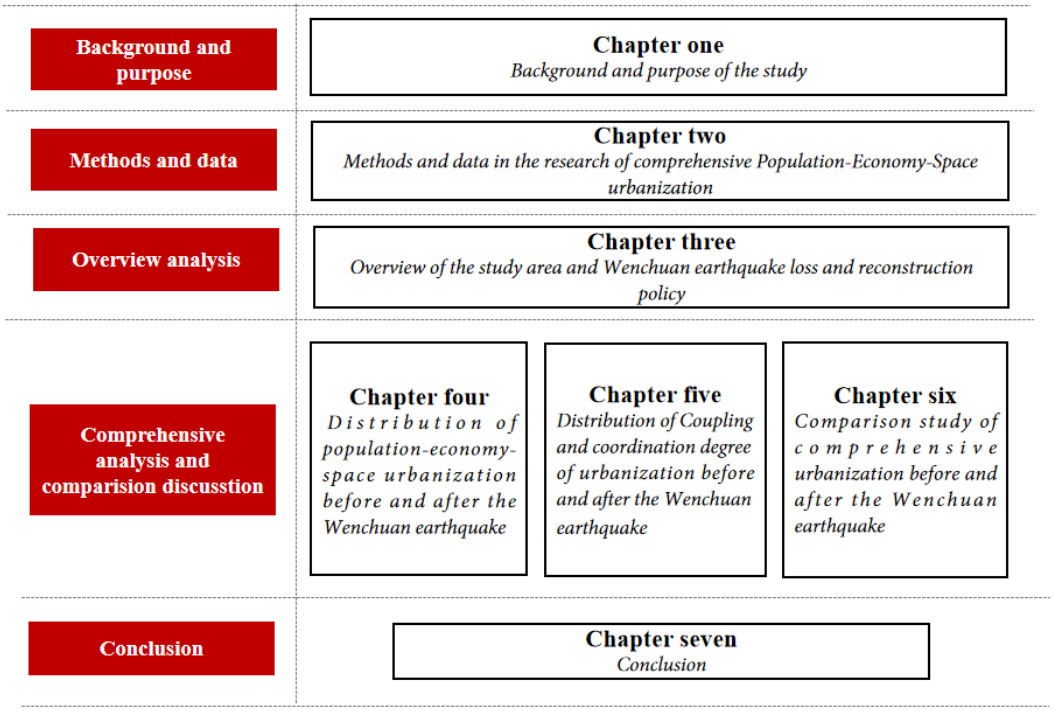


Fig1- 6 Research flow

(1) Analyzed the temporal-spatial change of urbanization in ten most severely affected areas.

(2) Constructed the coupling relationship model of urbanization in the ten most severely affected areas.

(3) Compared and summarized the development and changes of ten most severely affected areas, and analyzed the dominant patterns of their development.

Through the method optimization, the quantitative analysis method was determined, and the urbanization index system was constructed from the aspects of population, economy and spatial urbanization; Quantitative analysis of the population-economy-space coupling relationship were conducted, and the coupling relationship of the three dimensions was evaluated from the ten severely affected areas, and the change trend of the coupling coordination relationship was analyzed in detail from the specific perspective of each ten most severely affected counties, and then put forward specific working countermeasures as well as development suggestions.

In Chapter1, research background and purpose of the study:

However, as one of the important indicators to the development level of cities, the distribution of urbanization before and after the natural disaster, especially there is reconstruction period got little attention. Furthermore, the interrelationship and quality of urbanization are also valuable to study to deepen our understanding on city development in the same period. Moreover, the distribution of urbanization itself, urbanization interrelationship, quality of urbanization whether produce statistic significant differences between these periods would be worth to examine to design useful reconstruction policies to recover and redevelop cities after the natural disaster hit. In addition, most of previous studies focus on the country, province, region level, county level attracts little attention from the scholars and decision makers. Therefore, after presented the research background,

especially on the most dramatic urbanization development around the world in China, development on understanding of urbanization, research on the relationship among urbanization system, were reviewed. The purpose is to clarify the content of the study and the necessity of provide guidance to fix the miss patch of urbanization development under the context of natural disaster threaten, and to assist design useful reconstruction policies to rebuilt more sustainable cities.

In Chapter 2, methods and data in the research of comprehensive Population-Economy-Space urbanization:

Taking the Wenchuan earthquake which is the most impact earthquake since 1949 in China, the data sources and process are presented. After that, comprehensive evaluation of urbanization system has been proposed, which was built from population urbanization, space urbanization and economy urbanization dimensions. In the meanwhile, the entropy method is introduced to calculate the weight of this index system. The box plot is presented to show the distribution of urbanization itself, urbanization relationship, urbanization quality on pre-earthquake stage, reconstruction stage, post-earthquake stage. Moreover, dynamic coupling degree model to test the interrelationship of urbanization and dynamic coupling coordination degree model are introduced. To examine whether there is stages differences, T-test and paired T-test are employed to show these statistic results. At last, the triangle model is presented detailed to show the mode variation during these stages. The purpose is to further study the urbanization development features under the natural disaster hit and provide guidance to many cities which are distributed in natural disaster-prone area in China and other cities which are similar on the size of city around the world.

In Chapter 3, overview of the study area and Wenchuan earthquake loss and reconstruction policy:

Overview work is presented from the economic development, city development, personal income of research area before the Wenchuan earthquake. In addition, economy, population, houses, and land loss are reviewed in the research area. Specifically, reconstruction policy and mode of the Wenchuan earthquake are detailed presented, especially on the paired reconstruction policy. The purpose shows the basic overview of the research area before the Wenchuan earthquake and detailed data on the loss of the Wenchuan earthquake.

In Chapter 4, distribution of population-economy-space urbanization before and after the Wenchuan earthquake:

Population urbanization, economy urbanization, space urbanization, are examined on temporal-spatial distribution characteristics and stage features in the whole most severely affected areas and each county. It includes urbanization system and sub-system. Time span from 2001to 2017.

In Chapter 5, distribution of coupling and coordination degree of urbanization before and after the Wenchuan earthquake:

Interrelationship degree between three subsystems, overall coordination of urbanization was tested to show the relationship and quality of urbanization on temporal-spatial features and stage characteristics in the whole most severely affected areas and each county.

In Chapter 6, comparison and classification of comprehensive urbanization before and after the Wenchuan earthquake:

All these indexes were analyzed by T-test and paired T-test, urbanization-led mode variation was also evaluated. At last, according to the two-dimensions model, the ten most severely affected counties were classified. Corresponding recommendations were presented.

In Chapter 7, conclusion:

This part summarized the research of previous chapters.

Reference

[1] Pradhan R, Arvin M, Nair M. Urbanization, transportation infrastructure, ICT, and economic growth: A temporal causal analysis. Cities 2021; 115:103213.https://doi.org/10.1016/j.cities.2021.103213.

[2] Nations, U. World Urbanization Prospects: The 2014 Revision. Data Booklet

[3] Saborido R, Alba E. Software systems from smart city vendors. Cities 2020; 101:102690. https://doi.org/10.1016/j.cities.2020.102690

[4] Nations, U. World Urbanization Prospects: The 2018 Revision. Data Booklet

[5] Hitcher H, Loser M. Urbanization. Our world in data 2018

[6] Al-mulali U, Binti Che Sab CN, Fereidouni HG. Exploring the bi-directional long run relationship between urbanization, energy consumption, and carbon dioxide emission. Energy 2012; 46(1):156-167. https://doi.org/10.1016/j.energy.2012.08.043

[7] Zhang D, Chen Y. Evaluation on urban environmental sustainability and coupling coordination among its dimensions: A case study of Shandong Province, China. Sustainable Cities and Society 2021; 75:103351. https://doi.org/10.1016/j.scs.2021.103351

[8] Lin B, Zhu J. Impact of China's new-type urbanization on energy intensity: A city-level analysis. Energy Economics 2021; 99:105292. https://doi.org/10.1016/j.eneco.2021.105292.

[9] Yang X, Wang Y, Sun M, Wang R, Zheng P. Exploring the environmental pressures in urban sectors: An energy-water-carbon nexus perspective. Applied Energy 2018; 228:2298-2307. https://doi.org/10.1016/j.apenergy.2018.07.090

[10] Li Y, Huang RQ, Alexander L D, Zhou R, Cao S. Basic Features and Research Progress of Wenchuan Ms 8.0 Earthquake. Advanced Engineering Sciences 2009; 41:7-25.

[11] The Wenchuan Earthquake Sichuan Earthquake Relief Chronicle Compilation Committee. Wenchuan earthquake Sichuan earthquake relief history · general history of major events. Chengdu: Sichuan People's publishing House ,2017:1,6-35.

[12] Chen Y, Booth, D. (2011). The Wenchuan earthquake of 2008: anatomy of a disaster. Beijing: Science Press in Cooperation with Springer.

[13] The Wenchuan Earthquake Sichuan Earthquake Relief Chronicle Compilation Committee. Wenchuan earthquake Sichuan earthquake relief history · general history of major events.

[14] Zhou D, Zhan X. Post Disaster Urbanization--A Research on the Reconstruction after the May 12th Earthquake. National journal 2015, 6(2): 26-33, 95-98.

[15] Chen P, Zou X, Zhong Y, Wang L, Zheng X. Evaluation of Post-earthquake Economic Development of the Most Severely Affected Areas in Wenchuan Earthquake. Journal of Chengdu Normal University 2021; 37:116-124.

[16] John R. L, Zhu Y. Interpreting the challenges of China’s rapid urbanization. Landscape Architecture Frontiers 2015;3(05):12-25.

[17] Lu D, Yao S, Li G, et al. Comprehensive Analysis of the Urbanization Process based on China’s Conditions. Economic Geography 2007;(06):883-887.

[18] Zhang Z, Li Y. Coupling coordination and spatiotemporal dynamic evolution between urbanization and geological hazards–A case study from China. Science of The Total

Environment 2020; 728:138825. https://doi.org/10.1016/j.scitotenv.2020.138825

[19] He X. Regional differences and the future of Urbanization in China. Journal of Beijing University of Technology (Social Sciences Edition) 2022

[20] WCED. Our Common Future. Oxford：Oxford University Press, 1987.

[21] Luo H, Huo YG, Hu YH, Pang WB. The theory review of sustainable development. Journal of Northwest A&F University (Social Science Edition) 2004;(01):35-38.

[22] Haegeti D, Wang D, Wang L, et al. The Comprehensive Evaluation Method of Urban Sustainable Development. China Population, Resources and Environment 1997(02):46-50.

[23] Cao L, Wang H. A study on the principle and method of installation of sustainable development assessment index. Acta Scientiae Circumstantian 1998;18(05):526-531.

[24] Li H, Xu E, Zhang H. Examining the coupling relationship between urbanization and natural disasters: A case study of the Pearl River Delta, China. International Journal of Disaster Risk Reduction 2021; 55:102057. https://doi.org/10.1016/j.ijdrr.2021.102057.

[25] Ager P, Eriksson V K, Hansen CW, Lonstrup L. How the 1906 San Francisco earthquake shaped economic activity in the American West. Explorations in Economic History 2020; 77:101342. https://doi.org/10.1016/j.eeh.2020.101342.

[26] Zarghami S A, Dumrak J, A system dynamics model for social vulnerability to natural disasters: Disaster risk assessment of an Australian city. International Journal of Disaster Risk Reduction 2021; 60:102258. https://doi.org/10.1016/j.ijdrr.2021.102258.

[27] Qin H. Thinking about the scientific connotation of urbanization. Probe. 2001, (06): 76-78.

[28] Cheng M, Ye C, Zhou Y. Urbanization rate and its policy implications: Discussion and development of Northam's curve. Geographical Research 2011,30(08):1499-1507.

[29] Perchenko E. H, Ji X. New trends in the world's urbanization. Urban Planning International 1992(03):35-38.

[30] Masaru Yamaga, translated by Zhu D. Urban Geography. Hubei Education Press 1986:106.

[31] Wilson C. The Dictionary of Demography. Oxford: Basil Blackwell Ltd.; 1987:255.

[32] Zhang C, Wu Z. History of Marxist Population Thought. Peking University Press 1986:331.

[33] Kuznets S. Economic Growth of Nations: Total Output and Production Structure. Beijing: The Commercial Press.2017.

[34] Feng L. What is urbanization? Comparative Economic & Social Systems,2001(04):6-10.

[35] Gao P. Urbanization in developing countries. Tianjin Social Sciences,1991(02):23-27+59. DOI: 10.16240/j.cnki.1002-3976.1991.02.005.

[36] Xu X, Yao H. Revise and new progresses in China urban geographical studies since 1900. Economic Geography,2009,29(09):1412-1420.

[37] Chen G, Zhang H, Chen W. Affecting factors and driving mechanism of demand for construction land in Guangdong province. Territory & Natural Resources Study,2012(01):26-28. DOI: 10.16202/j.cnki.tnrs.2012.01.009.

[38] Gu J, Ma L, et al. Research Group of Chinese and Development Research Center. China's Urbanization Strategy. 2012, 36(3): 3-13.

[39] Yang R, Liu Y, Long H. The study on non-agricultural transformation co-evolution characteristics of "population-land-industry": Case study of the Bohai Rim in China.

Geographical Research 2015,34(03):475-486.

[40] Guo S, Wang F, Gao M. Spatial-Temporal Coupled Coordination between Population Urbanization and Land Urbanization in Shandong Peninsula. Economic Geography 2014,34(03):72-78.

[41] Zhou Y, Huang X, Xu G, Li J. The coupling and driving forces between urban land expansion and population growth in Yangtze River Delta. Geographical Research,2016,35(02):313-324.

[42] Yuan F, Chen Z. New urbanization towards balanced development -an analysis coupling coordination model of population-land-fiancé. Journal of Central China Normal University (Humanities and Social Sciences), 2018,57(03):1-16.

[43] Zhao Q, Liu H. Study on strategies for coordination land-use urbanization and population urbanization in Shandong province. Journal of University of Electronic Science and Technology of China (Social Sciences Edition), 2018, 20(6): 16-23.

[44] Jiang Z，Fan J，Chen D. Analysis of spatial agglomeration and equilibrium characteristic for population and economic in China duing2001-2010.Economic Geography 2014,34(05):9-13+82. DOI: 10.15957/j.cnki.jjdl.2014.05.004.

[45] Wang L, Duan X, Tian F, Qin X. Study on the relationship between population and economic spatial distribution in Yangz river delta. Economic Geography,2009,29(10):1619-1623.

[46] He H，Tu J，Su X，Wang N，Lin X . Grey relation analysis of population structure and economic structure coupling in China. Journal of Southwest University (Natural Science Edition) 2013,35(10): 140-145. DOI: 10.13718/j.cnki.xdzk.2013.10.020.

[47] Skans O N. How does the age structure affect regional productivity? Applied Economics Letters, 2008,15(10):787-790.

[48] Feng Z，Liu X. Multi-scale studies on the space consistency between population distribution and economic development in China. Population & Economics，2013（2）:3-11.

[49] Jiang X, Yang Q, Liu J, Shen F, Liu J. Multi-scale and multi-mechanism research of regional economic Differences in the three provinces of northeast China. Scientia Geographica Sinica,2020,40(03): 383-392. DOI: 10.13249/j.cnki.sgs.2020.03.006.

[50] Zhao J, Dang X, Wang X. The evolution of urban agglomeration spatial structure: Empirical evidence from western China. Economic Review,2009(04): 27-34.DOI:10.19361/j.er.2009.04.004.

[51] Peng J, Cao Y. Coordination of Spatial Relationship between population and economy in Yili prefecture in Xinjiang. Journal of Southwest University (Natural Science Edition),2022,44(03): 183-193. DOI: 10.13718/j.cnki.xdzk.2022.03.021.

[52] Brueckner J K, Fansler D A. The Economics of Urban Sprawl: Theory and Evidence on the Spatial Sizes of Cities. Review of Economics & Statistics, 1983, 65(3):479-482.

[53] Zhang Y, Liu L．Economic agglomeration and economic growth: an empirical analysis based on urban data in China .World Economic Papers，2007，01：48-56

[54] Dmovsck M, Kovacic. Why Slovenia Lags in National Competitiveness[J]. Development, Economic and Business Review, 2003, 5(3):183-201.

[55] Chen X, He Y, Xu X. Spatio-temporal coupling characteristics of population-spatio-industrial urbanization in the middle Reaches of the Yangtze River Statistics & Decision,2017(12):129-133.

[56] Gao B, Wang C, Cui X. Population-economic-space perspective of space-time evolution of urbanization in Shandong province. Economic Geography,2016,36(05):79-84.

[57] Wang S, Ren L, Kong W, Tang S. A study on the coordinated development of ecological environment-economy-new urbanization in Beijing-Tianjin-Hebei region. East China Economic Management:1-9[2018-10-18]. ttps://doi.org/10.19629/j.cnki.34-1014/f.171114013.

[58] Ren L, Cui E, Sun H. Temporal and spatial variations in the relationship between urbanization and water quality[J]. Environmental Science and Pollution Research, 2014, 21(23): 13646-13655.

[59] Duan H, Xiao Y, Ding Z, Wang X. A study on the scenario prediction on population- economy and energy-environment coordinated development of Jilin province in 2030.Population Journal,2017,39(02):47-56.

[60] Suo Z, Wang D, Zhang X. Coupling and coordination development of industrialization, urbanization and agricultural modernization in Chengdu-Chongqing urban agglomeration-from view of 3D global trend and 2D plane interpolation. Jiangsu Agricultural Sciences,2018,46(12): 284-290. DOI: 10.15889/j.issn.1002-1302.2018.12.067.

[61] J Eugene Haas, Robert W Kates, Martyn J Bowden, Reconstruction Following Disaster. Boston. The MIT Press. 1977, 177-179.

[62] Tao P, Tong X. Disaster Chain, Crisis politics and institutional change of Disaster Management. Social Sciences in Heilongjiang,2013(05):115-119.

[63] Yan B, Tan W, Chen W. Thoughts on reconstruction planning after Wenchuan earthquake.

[64] Journal of Chongqing University (Social Science Edition),2009,15(04):124-129.

[65] Xu K, Wang H, The integrated model of reconstruction system after earthquake disaster. Systems Engineering-Theory & Practice, 2008(07):1-16.

[66] Li Y. The practice of earthquake protection and disaster reduction in the process of Urbanization in Japan and its enlightenment. Journal of Southwest Minzu University (Humanities and Social Science,2017,38(08):21-27.

[67] Xu S, Wu S, Lu Y, Yu L. Experience and enlightenment of post-disaster reconstruction at home and abroad. Environmental Protection,2008(13):39-45.

Chapter 2

Methods and data in the research of comprehensive Population-Economy-Space urbanization

CHAPTER TWO: METHODS AND DATA IN THE RESEARCH OF COMPREHENSIVE POPULATION-ECONOMY-SPACE URBANIZATION

Methods and data in the research of comprehensive Population-Economy-Space urbanization .....

2.1 Introduction..... 2-1

2.2 Data..... 2-1

2.3 Evaluation Index system and Weight..... 2-1

2.4 Box and Whisker plot..... 2-4

2.5 Dynamic Coupling Degree model and Dynamic Coupling Coordination Degree model ... 2-5

2.6 Spatial autocorrelation analysis..... 2-6

2.7 Triangle Model..... 2-8

2.8 Summary..... 2-9

Reference 2-11

2.1 Introduction

As one of the most complex phenomena in human society [1], the measurement of urbanization level naturally results in different methods. According to previous studies, these dimensions, such as population migration [2], land transformation [3], economic structure transformation [4], are commonly considered as the main components of urbanization. How to assess these element's comprehensive effects? What is the relationship between these elements, the degree of connection, and the degree of order? Specifically, whether these questions mentioned above would be varied under extraordinary conditions, such as natural disaster, are worth to explore.

In this Chapter, methods and data in the research of comprehensive Population-Economy-Space urbanization are presented. Data sources and process are introduced first. Then a comprehensive assessment index systems are proposed, which are based on these elements. To show the distribution of types of urbanization, degree of interrelationship, degree of order between these subsystems, Box and Whisker is used to show their stages features. Furthermore, to evaluate the degree interrelationship between these three subsystems and order state of them, coupling model and coupling coordination model are introduced. In addition, triangle model which was used to categorize the soil filed are also introduced detailed to test which one of them is the major system leading the comprehensive development of urbanization.

2.2 Data

Most data were collected from Sichuan Statistical Yearbook Series and China County Statistical Yearbook Series, which were published by authoritative Provincial Bureau of Statistics of Sichuan (2001- 2017) and authoritative National Bureau of Statistics of China (2001-2017), respectively. All data come from above books are original value without calculate. While some indicators were simply processed, such as number of beds per thousand people in health institutions, fixed asset investment per land, secondary industry added value per person, and etc. In addition, cultivated land area and county built-up area were collected from Annual Change Data of Land Use in China which was released by Ministry of Natural Resources of the People's Republic of China. Some indicators based on these two data in this paper were also calculated.

2.3 Evaluation Index system and Weight

Considering the difference in the dimensions and units of the evaluation indicators, we adopted the min-max standardization method to normalize the indicators as dimensionless pure values to ensure the rationality in the determination of urbanization index [5-7]. A comprehensive index system of the urbanization was constructed, including target level, first-level indicators and second-level indicators. The factors that exhibit direct causal relationships with the urbanization are population, economy and space. Aggregation and development of the three indices are core values embodied in benefits of the urbanization for the scales of city or county. Therefore, population-economy-space are selected as the three major factors to evaluate the urbanization of the severely affected area in county scale in this work. The target level contains three dimensions in terms of population, economy and space, while the first-level and second-level indicators are composed of 7 indicators and 16 basic indicators, respectively. It is known that different basic indicators have

different impacts on the urbanization indexes. The functional contribution of u_{ij} was analyzed by equation (1)-(2). Indicators with positive effects are determined by equation (1), while indicators with negative effects are calculated by equation (2).

$$u_{ij} = \frac{\left(x_{ij} - x_{j\min}\right)}{\left(x_{j\max} - x_{j\min}\right)}, u_{ij} \in [0,1] \quad (1)$$

$$u_{ij} = \frac{\left(x_{j\max} - x_{ij}\right)}{\left(x_{j\max} - x_{j\min}\right)}, u_{ij} \in [0,1] \quad (2)$$

where u_{ij} is the degree of functional contribution, which reflects the degree of satisfaction of each index reaching the target; $u_{ij} = 0$ and $u_{ij} = 1$ mean the most dissatisfied and the most satisfied, respectively; j represents the index number; i means the year of study; x_{ij} is the original value; $x_{j\max}$ and $x_{j\min}$ represent the maximum and minimum values of the j^{th} index, respectively.

To overcome the shortcomings of the artificial assignment of weight of a factor, we used an entropy method to calculate the weight of different indicators in this article. The proportion of the index in the i^{th} year under the j^{th} index (w_{ij}) was calculated as:

$$w_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (3)$$

The entropy of the j^{th} index (e_j) was determined as:

$$e_j = -k\sum_{i=1}^{n} w_{ij} \ln w_{ij}, k = \left(\ln n\right)^{-1} \quad (4)$$

The information entropy redundancy (d_j) was calculated as:

$$d_j = 1 - e_j \quad (5)$$

The weight of the j^{th} index (w_j) was determined as:

$$w_j = \frac{d_j}{\sum_{i=1}^{n} d_j} \quad (6)$$

Based on these equations, the weight of the three target levels (population, economy and space) were determined and presented in Table 2-1.

Table 2- 1 Index system for urbanization and weights of indicators

Dimensions	Weight	First-level indicators	Second-level indicators	Affect	Weight
Population urbanization	0.335	Population composition	Proportion of employees in secondary and tertiary industries (%)	+	0.209
		Life index	Savings deposit balances of urban and rural residents (yuan)	+	0.178
			Number of beds per thousand people in health institutions (pieces per thousand people)	+	0.199
			Number of students in ordinary high schools (persons per thousand people)	+	0.209
			Number of Mobile phone users (household per thousand people)	+	0.205
Space urbanization	0.336	Land structure	Proportion of built-up area to regional area (%)	+	0.130
			Per-person cultivated land area (HA per people)	-	0.160
		Land input	Fixed asset investment per land (ten thousand yuan/square kilometers)	+	0.146
			Average fiscal expenditure (ten thousand yuan/square kilometers)	+	0.130
			Number of employees per area (person/square kilometers)	+	0.135
		Land output	Average economy output of secondary and tertiary industries (ten thousand yuan/square kilometers)	+	0.152
			Average fiscal revenue (ten thousand yuan/square kilometers)	+	0.147
Economy urbanization	0.329	Industrial structure	The proportion of the economy output of the primary industries in GDP (%)	-	0.262
			The proportion of general fiscal budget revenue in GDP (%)	+	0.256
		Industrial quality	GDP Per capita (person/ ten thousand yuan)	+	0.242
			Secondary industry added value per person (person/ ten thousand yuan)	+	0.240

To calculate the population urbanization quality, economy urbanization quality, and space urbanization quality of the severely affected area counties from 2001 to 2017, the linear weighting method was used in this article, which is calculated as:

$$P_i = \sum_{j=1}^{5} w_j \times u_{ij}, (i = 1, 2, \ldots..., 17) \quad (7)$$

$$E_{\mathrm{i}} = \sum_{j=13}^{4} w_j \times u_{ij}, (i = 1, 2, \ldots, 17) \qquad (8)$$

$$S_{\mathrm{i}} = \sum_{j=7}^{7} w_j \times u_{ij}, (i = 1, 2, \ldots\ldots, 17) \qquad (9)$$

where u_{ij} is the functional contribution of index j in the i^{th} year to the system and w_j is the weight of index j.

2.4 Box and Whisker plot

Box and Whisker plot, also called box plot, is one of the types of graphical methods which shows the variation of the data in the dataset [8]. It is useful for indicating whether a distribution is skewed and whether there are potential unusual observations in the data set. After creating side-by-side box plots, we could also find differences between data set groups. In the Box Plot, there is the center line in the box to show the median for the datasets, which means half of the data is above this value, and half is below. There is also the interquartile range (IQR) to show the length of the box, which means the bottom and top of the box show the 25th and 75th quantiles. In addition, there are lines to represent the expected variation of the dataset, which are also called whiskers (Fig 2-1). As a case study in this work, we used the Box and Whisker plot to compare the differences on population, economic and spatial urbanization between pre-earthquake, reconstruction and post-earthquake stages. Furthermore, coupling degree and coupling coordination degree were also analyzed by this tool.

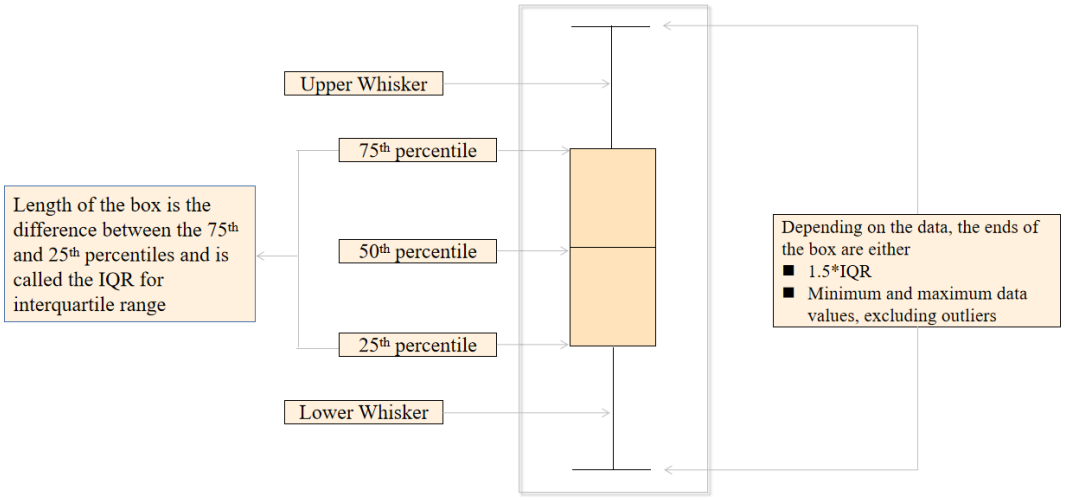


Fig 2- 1 Box plot with percentile labels

2.5 Dynamic Coupling Degree model and Dynamic Coupling Coordination Degree model

Coupling is a notion derived from physics to describe two or more systems interacting with each other via complex mutual interactions that changed over time [9]. There have been various previous works assessing such interaction by quantitatively analyzing the coupling coordination degree model between eco-environment and urbanization at urban scale [10-12]. With the development of urban industries, a large number of non-agricultural jobs have been created, attracting a large number of rural people to immigrate to cities. The immigration of a large number of people from the rural areas to cities could provide more labor for the development of the urban economy. The development of the urban economy and the expansion of the urban population inevitably leads to a requirement for more urban land, which then triggers the expansion of urban space. In the urbanization system, people are the main body of behavior, while economy is the driving force and space is the carrier [13-14]. Therefore, urbanization is an integrated process, including the three major dimensions of population, economy, and space (Fig 2-2). The coupling coordination of the three dimensions is key to achieve sustainable urbanization development.

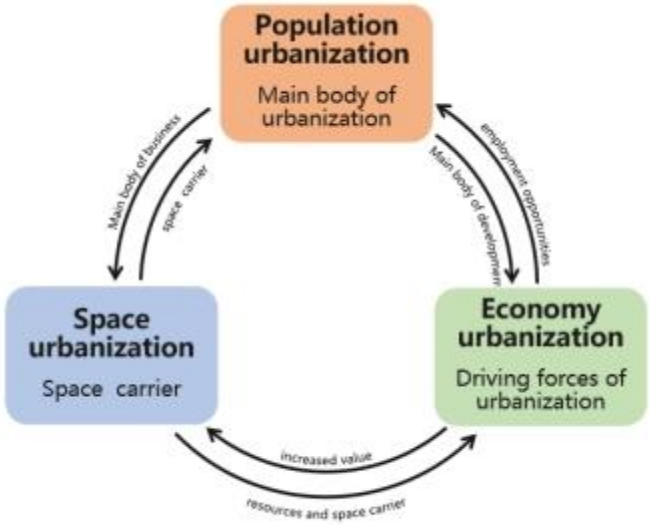


Fig 2- 2 Schematic diagram of the urbanization process including three major dimensions of population, economy and space

The conventional coupling degree model (CCD) can handle the system in the space dimension, but the impacts in temporal dimension could not be considered [15]. To extend the CCD in temporal dimensions, we applied a dynamic coupling degree model (DCD) to measure the urbanization of the severely affected area counties before and after the 2008 Wenchuan earthquake, which is described by following formulas:

$$C_i = \left\{ (P_i \times E_i \times S_i) / \prod_{i=1}^{3} (P_i + E_i + S_i) \right\}^{1/3}, C_i \in [0,1] \qquad (10)$$

whereP_i, E_i, and S_i represent the population urbanization quality, economy urbanization quality, and space urbanization quality of the ith year, respectively. C_i means the degree of coupling. DCD represent the strength of the degree of interaction between the three subsystems.

We further constructed a dynamic coupling coordination degree model (DCCD) to evaluate the degree of the interaction between the three dimensions of population, economy and space urbanization for the Dujiangyan county, which is performed by the following formulas.

$$D_i = \sqrt{C_i \times T_i}, D_i \in (0,1] \tag{11}$$

$$T_i = \alpha P_i + \beta E_i + \gamma S_i, (\alpha + \beta + \gamma = 1) \tag{12}$$

Where D_i and T_i are the coupling coordination degree and coordination indices in the ith year, respectively. α, β, and γ are undetermined coefficients, which represent the contribution shares of the three dimensions. According to the calculated objective weight of each dimension in the target layer, we took the value of $\alpha = 0.335$, $\beta = 0.336$, and $\gamma = 0.329$. Based on literature [16-17], D_i can be divided into four categories in terms of low-level coordination coupling stage ($D_i \in (0,0.4]$), antagonistic stage ($D_i \in (0.4,0.5]$), running-in stage ($D_i \in (0.5,0.8]$), and extremely coordinated coupling stage ($D_i \in (0.8,1]$).

2.6 Spatial autocorrelation analysis

Spatial autocorrelation refers to the correlation between the values of a particular attribute of the object of study at a geospatial location. It is an important indicator to test whether a phenomenon is significantly associated with its neighboring spatial units of the same kind, it includes global spatial autocorrelation and local spatial autocorrelation. This paper mainly uses spatial autocorrelation analysis to analyze the spatial dependence of urbanization scores and coupling coordination degrees of ten extremely affected counties, as well as to identify the degree of aggregation, and tries to discover the spatial and temporal evolution characteristics and patterns of urbanization scores and coordination degrees of extremely affected counties.

Global spatial autocorrelation mainly reflects the overall spatial effect, It is generally characterized by the global Moran index, but he cannot effectively test for the spatial heterogeneity present in the local area.

In terms of global spatial autocorrelation analysis, global Moran's I is usually used to measure the spatial effects. The value I of Moan is between -1 to 1. When global Moran's index >0, it means there is a positive autocorrelation relationship. In other words, High values are adjacent to high values, and low values are adjacent to low values. In opposite, when global Moran's index <0, it means there is negative autocorrelation relationship. In other words, High values are adjacent to low values. Furthermore, when the global Moran's index =0, it represents that there is no autocorrelation relationship, which means all the values are distribute randomly. The global Moran's index (GMI) is shown in the equation:

$$GMI = \frac{\mathrm{n}}{\sum_{\mathrm{i=1}}^{\mathrm{n}}\sum_{\mathrm{i\neq j}}^{\mathrm{n}} W_{\mathrm{ij}}} * \frac{\sum_{\mathrm{i=1}}^{\mathrm{n}}\sum_{\mathrm{i\neq j}}^{\mathrm{n}} W_{\mathrm{ij}}(X_i - X^*)\ (X_i - X^*)}{\sum_{\mathrm{i=1}}^{\mathrm{n}}(X_i - X^*)^2} \qquad (13)$$

where X_i represents the relative value of urbanization index in county i, X^* shows the mean value of x, n stands for the number of counties, and W_{ij} represents the spatial weight matrix.

Local spatial autocorrelation is often used to test the spatial heterogeneity that exists between local regions, which can compensate for the lack of global spatial autocorrelation. With respect to local autocorrelation evaluation, local Moran's index is another effective way to analyze the spatial relationship. The value of local Moran's index shows the similar meaning as global Moran's index. The local Moran's index (LMI) could be calculated as follows:

$$LMI = \frac{(X_i - X^*)}{\frac{1}{n}\sum_{\mathrm{i=1}}^{\mathrm{n}}(X_i - X^*)} \sum_{\mathrm{i=1}}^{\mathrm{n}}\sum_{\mathrm{i\neq j}}^{\mathrm{n}} W_{\mathrm{ij}} \frac{1}{n}\sum_{\mathrm{i=1}}^{\mathrm{n}}(X_i - X^*) \qquad (14)$$

where X_i, X^*, W_{ij} reflect the same meaning as global Moran's index.

Moran's scatter chart mainly shows the different spatial connection types between the study area and the adjacent areas through four quadrants, the first quadrant is of type HH (high), the second quadrant is of type LH (low-high), the third quadrant is of type LL (low-low), and the fourth quadrant is of type HL (high-low). Their spatial meanings can be described as follows respectively.

HH type cities are located in the first quadrant, showed a significant positive correlation, called "diffuse" cities, it is regional "hot spots".

LH type cities are located in the second quadrant, this means that the value of a certain attribute of the city is relatively low, while the value of the attribute of the surrounding area is relatively high, and there is a large spatial difference between the regions; at this time, the spatially negative correlation characteristic of low center and high periphery is shown, and it is called a "sink-type" city.

LL type cities are located in the third quadrant, which means that the value of an attribute of the city and the surrounding region are relatively low, and the difference between the regions is small, showing a significant positive correlation; it is called a "contagious" city, that is, a regional "cold spot".

HL type cities are located in the fourth quadrant, which means that the value of a certain attribute of the city is relatively high, while the value of the attribute of the surrounding cities is relatively low, and the geographical areas show a negative correlation; a spatial pattern of high center and low surrounding appears, which is called "polarized" cities.

2.7 Triangle Model

The triangle method is constructed based on the mathematical properties of triangles. It is first utilized by the United States Department of Agriculture to analyze the content of sand–silt and sand–clay for determining the soil type [18]. As an intuitive platform, the triangle method is an efficient analytical management tool by virtue of simplicity and flexibility. It has been successfully used in public health, environmental science, and regional economy [19-21]. As a case study in this work, we used the triangle approach to evaluate how urbanization status of severely affected area counties vary before and after the 2008 Wenchuan earthquake. Two criterions are required for selecting the right elements for establishing the Triangle model: a. All the indices should belong to equal parallel relationships; b. There exist the mutual influence and interaction among the three aggregated indices [22]. As such, the urbanization status of severely affected area counties can be evaluated through a triangle as the basic visual representation of population, economy and space interactions. This paper established a triangle model to describe the interrelationships among the three sets of indices of population urbanization quality (P), economy urbanization quality (E), and space urbanization quality (S). The final form of the triangle designed for this target is illustrated in Figure 2-3. It can be seen that the urbanization triangle has an equilateral shape, demonstrating relative percentage combinations of the three pillars, including population, economy and space. The X-, Y- and Z-axis values corresponding to the levels of the population element, the space element and the economy element, respectively. Each axis goes in an anticlockwise direction ranging from 0 to 1. Besides, each axis is equally divided into five parts in terms of "very low" (0-0.2), "low" (0.2-0.4), "middle" (0.4-0.6), "high" (0.6-0.8), and "very high" (0.8-1.0). The triangle area can be further divided into six regions (I, II, III, IV, V, and VI) by the three heights of the three axes, representing six different urbanization trends (Table 2-2). Variations in the relative position of the three main constituent parts (population, space, economy) in different regions over different years could lead to changes in the corresponding urbanization patterns of the severely affected area counties.

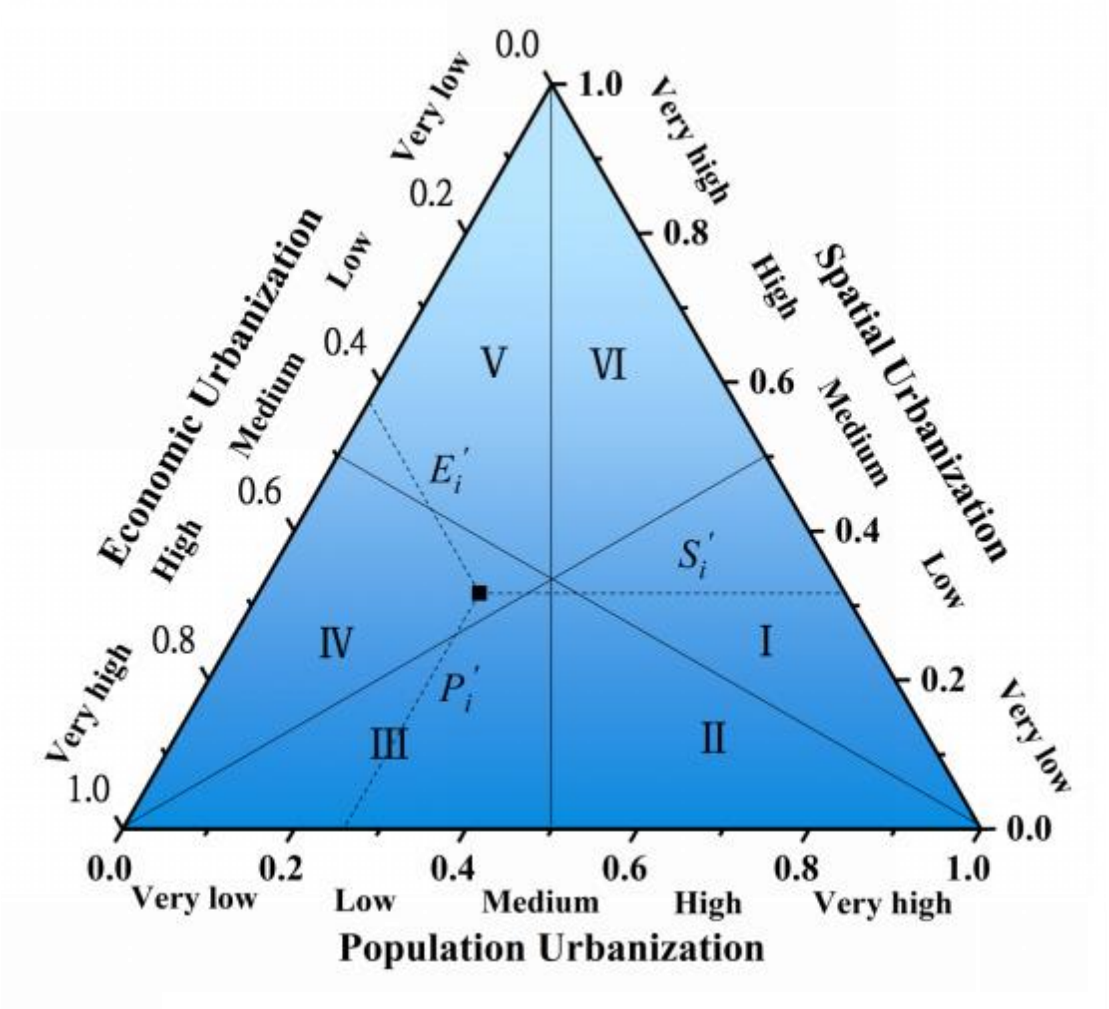


Fig 2- 3 The relative urbanization status based on three main constituent parts in terms of population, space and economy

Table 2- 2 Urbanization patterns and corresponding description of the population–space-economy urbanization triangle model

Pattern	Description
Ⅰ	Population quality > Space quality > Economy quality
Ⅱ	Population quality > Economy quality >Space quality
Ⅲ	Economy quality > Population quality > Space quality
Ⅳ	Economy quality > Space quality > Population quality
Ⅴ	Space quality > Economy quality > Population quality
Ⅵ	Space quality > Population quality > Economy quality

2.8 Summary

In this chapter, after briefly reviewed literature on the effects of extreme disaster events on urbanization and the counter effects, models, statistical tests, and empirical cases studies were summarized as the major methods to analyze the relationship between destructive earthquake and urbanization. In terms of our work, followings methods were introduced: (1) proposing dynamic coupling degree model and dynamic coupling coordination degree model to evaluate the interrelationship between destructive earthquake and urbanization in the severely affected area in

the Wenchuan earthquake; (2) adopting triangle model to analyze the pattern of urbanization in different stages; (3) designing the urbanization indicator system based on population-space-economy urbanization comprehensive contributions; (4) applying traditional statistic tests, such as Box and Whisker plot and Boston Matrix, to show the changes of urbanization in different stages and classify counties in the severely affected areas into different groups, respectively; (5) evaluating the spatial relationship between counties within the severely affected areas by spatial statistic tests.

Reference

[1] Knox P. Urbanization. International Encyclopedia of Human Geography 2009;140:112-118. https://doi.org/10.1016/B978-008044910-4.01108-1.

[2] Marzluff J.M. Worldwide urbanization and its effects on birds. In: Marzluff, J.M., Bowman, R., Donnelly, R. (eds) Avian Ecology and Conservation in an Urbanizing World. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-1531-9_2

[3] Tang F, Wang L, Guo YY, Fu M, Huang N, Duan W, Luo M, Zhang J, Li W, Song W. Spatio-temporal variation and coupling coordination relationship between urbanization and habitat quality in the Grand Canal, China. Land Use Policy 2022;117:106-119. https://doi.org/10.1016/j.landusepol.2022.106119.

[4] Laumas PS, Williams M. Urbanization and economic development. East Econ J 1984;10(3):325-32.

[5] Amico GD, Taddeo, Shi l, Yigitcanlar T, Ioppolo G. Ecological indicators of smart urban metabolism: a review of the literature on international standards. Ecol. Indic 2020; 118:106808.

[6] Zhou Y, Chen M, Tang Z, Mei Z. Urbanization, land use change, and carbon emissions: quantitative assessments for city-level carbon emissions in Beijing-Tianjin-Hebei region. Sustain. Cities Soc 2021;66:102701.

[7] Chakraborty S, Maity I, Patel PP, Dadashpoor H, Pramanik S, Follmann A, Novotny J., Roy U. Spatio-temporal patterns of urbanization in the Kolkata urban agglomeration: a dynamic spatial territory-based approach. Sustain. Cities Soc 2021;67:102715.

[8] Salkind NJ. Encyclopedia of research design (Vols. 1-0). Thousand Oaks, CA: SAGE publications, Inc. doi: 10.4135/9781412961288

[9] Cui D, Liu, H, Xiao Y, Cui, N Liu, J, Wu D. Spatiotemporal evolution and the driving

[10] forces of the coupling coordination degree between urbanization and urban resident's livelihood level in Mongolia. Sustainability 2019;11(3):781.

[11] Wang Y, Fang C, Wang Z. The study on comprehensive evaluation and urbanization division at county level in China. Geograph. Res 2012;31:1305–1316.

[12] Liao W, Heijungs R, Huppes G. Thermodynamic analysis of human-environment systems: a review focused on industrial ecology. Ecol. modell. 2012;228:76-88.

[13] Iannella M, Liberatore L, Biondi, M. The effects of a sudden urbanization on micromammal communities: a case study of post-earthquake L'Aquila (Abruzzi Region, Italy). Ital. J. Zool 2016;83:255-262.

[14] Sun P, Ding S, Xiu C. Analysis of the coordination of population-economy-space in Beijing. City Plan. Rev 2012;36:38-45.

[15] Sun P, Ding S, Xiu, C Wei, Z. Study on the population-economy-spatial urbanization and hierarchical structure of Hubei province. Resour. Environ. Yangtze Basin 2011;20:172-1179.

[16] Liu Y, Li R, Song X. Analysis of coupling degrees of urbanization and ecological environment in China. J. Nat. Resour 2005;1:105-112.

[17] Liu X, Song X. Coupling degree model and its forecasting model of urbanization and ecological environment. J. China. Univ. Min. Technol. 2005;1:94-99.

[18] Zhang R, Jiao H. Coupling and coordination between urbanization and ecological environment

in China. J. Arid. Land Resour. Environ 2015;29:12-17.

Chapter 3

Overview of the study area and Wenchuan earthquake loss and reconstruction policy

CHAPTER THREE: OVERVIEW OF THE STUDY AREA AND WENCHU AN EARTHQUAKE LOSS AND RECONSTRUCTION POLICY

Overview of the study area and Wenchuan earthquake loss and reconstruction policy.....
3.1 Introduction..... 3-1
3.2 Overview of MSAA before the Wenchuan earthquake..... 3-3
3.2.1 Urbanization level..... 3-3
3.2.2 Economy level..... 3-3
3.2.3 Level of fixed asset investment..... 3-6
3.2.4 Public finance revenue..... 3-7
3.2.5 Savings deposit balance of urban and rural residents..... 3-8
3.3 Overview of disaster loss in the MSAA..... 3-10
3.3.1Economic loss..... 3-10
3.3.2 Population loss.....3-11
3.3.3 Housing loss..... 3-12
3.3.4 Land loss..... 3-13
3.3.5 Secondary disasters..... 3-14
3.4 Overview of reconstruction policies of Wenchuan earthquake..... 3-15
3.4.1 Expanding financial input..... 3-15
3.4.2 Tax relief efforts..... 3-16
3.4.3 Increasing financial support..... 3-16
3.4.4 Advancing industrial support..... 3-16
3.4.5 Regulating the land market..... 3-17
3.4.6 Enhancement of social security..... 3-17
3.5 Overview of reconstruction modes of Wenchuan earthquake..... 3-17
3.5.1 Aid project module..... 3-21
3.5.2 Recipient project module..... 3-22
3.5.3 Safeguarding project module..... 3-22
3.6 Summary..... 3-22
Reference..... 3-25

3.1 Introduction

The 5.12 Wenchuan earthquake occurred on May 12, 2008, the epicenter of which was Yingxiu Town, Wenchuan County, Aba Tibetan and Qiang Autonomous Prefecture, Sichuan Province, with a surface wave magnitude of 8.0 and a source depth of less than 20km, making it the most destructive, widest-reaching, most costly and difficult earthquake since the founding of New China [1]. The earthquake severely damaged an area of about 500,000km² and particularly severely damaged an area of more than 100,000km², of which Wenchuan County and Maoxian County in Aba Tibetan and Qiang Autonomous Prefecture, Beichuan County, Anxian County and Pingwu County in Mianyang City, Mianzhu County and Shifang County in Deyang City, Dujiangyan County and Pengzhou County in Chengdu City and Qingchuan County in Guangyuan City were extremely severely affected [2]. According to the Wenchuan Earthquake Disaster Scope Assessment Report, the above 10 counties (cities) were classified as most severely affected area. The most severely affected area is located in the northern part of the Chengdu Plain in Sichuan, China, between longitudes 102°51′ and 105°38′ East and latitudes 30°44′ and 33°02′ North, showing an overall southwest-northeast oriented belt, involving an administrative area of 26,123 km²[3] (as shown in Figure 3-1).

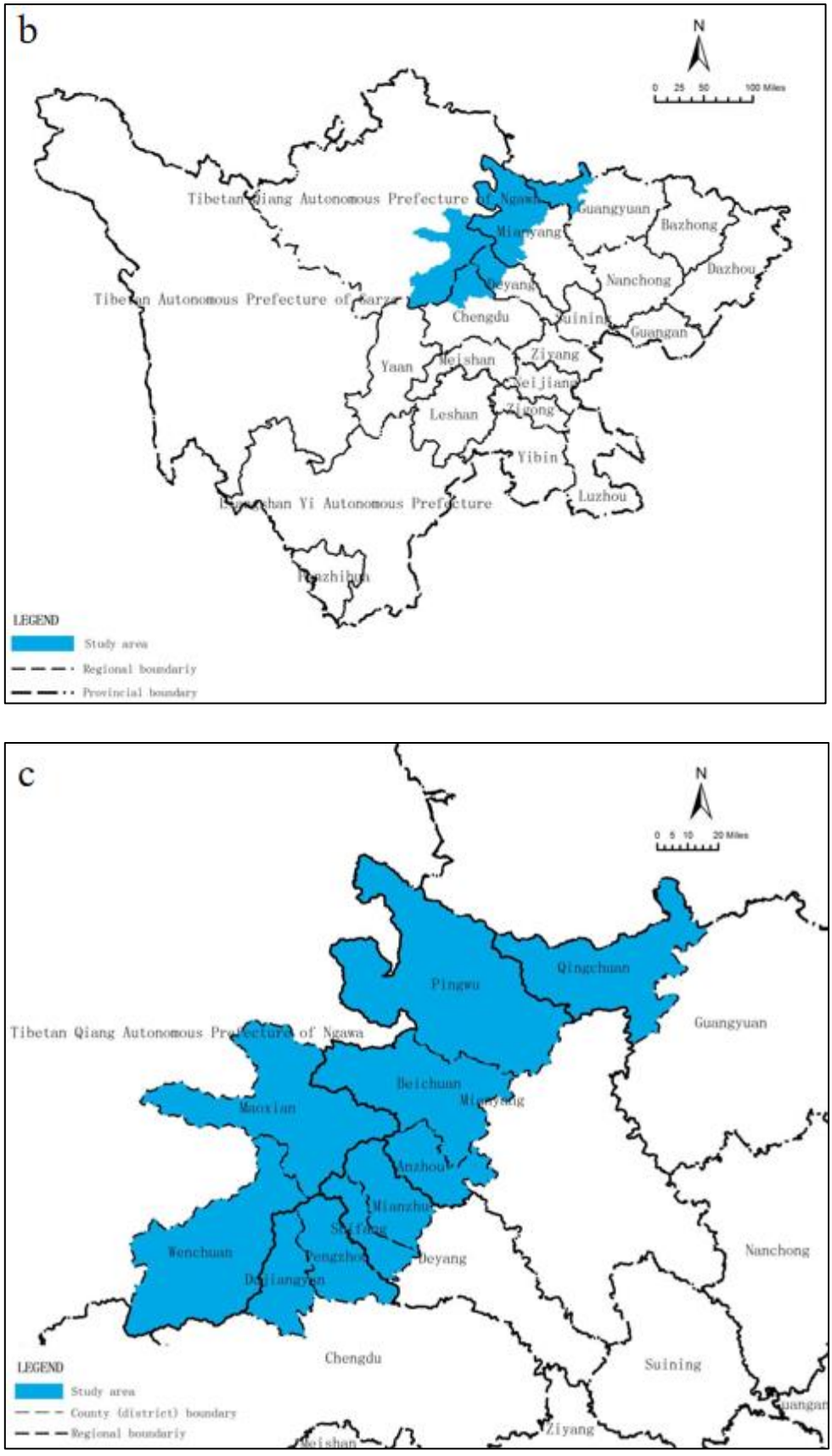


Fig 3- 1 Study area of the most severely affected area. (a) China region;(b) Sichuan Province; (c) Most severely affected area

3.2 Overview of MSAA before the Wenchuan earthquake

3.2.1 Urbanization level

As shown in Figures 3-2 and 3-3, the overall urbanization level of the most severely affected area showed a slow upward trend. Except for Maoxian County and Pengzhou County, the urbanization rates of all other districts and counties showed decreases in individual years, among which, the resident population and urbanization rate of Maoxian County, which had the largest increase, increased by 10 and 81.82 percentage points respectively; As of 2007, with the highest urbanization rate in Dujiangyan County at 37.72% and the lowest in Beichuan County at nearly 13.13%. Only Dujiangyan, Wenchuan, Pengzhou have an urbanization rate of over 30%; Shifang and Mianzhu have an urbanization rate of 20%-30%; Maoxian, Anxian, Pingwu, Pengzhou and Qingchuan have an urbanization rate of 10%-20%.

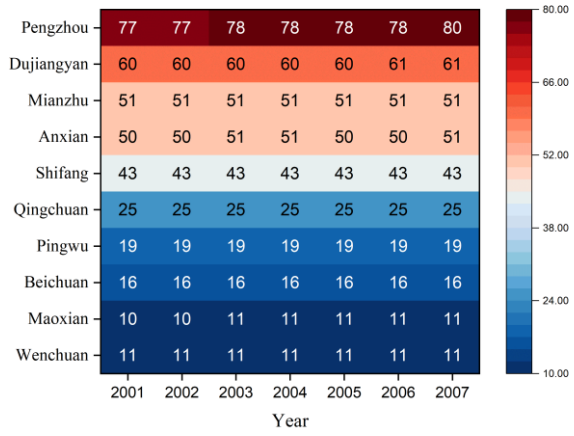


Fig 3- 2 Resident Population in the most severely affected area from 2001 to 2007 (ten thousand people)

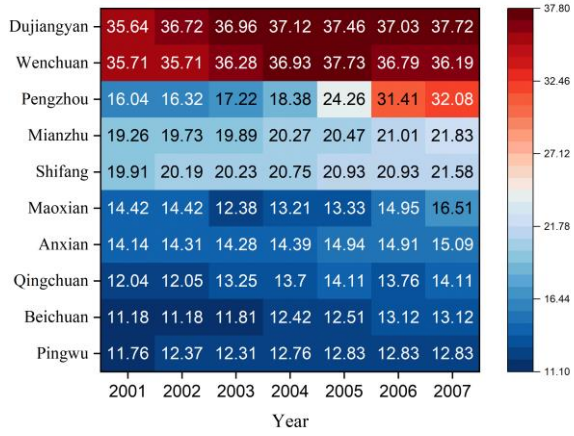


Fig 3- 3 Urbanization rates in the most severely affected area from 2001 to 2007

3.2.2 Economy level

As shown in Figure 3-4, the GDP of each county in the most severely affected area grew by

different amounts between 2001 and 2007, with some disparity between counties. The overall GDP of the 10 counties increased by 34.5 billion yuan, and the growth multiplier was between 1.9 and 2.8, among which, Pingwu County and Maoxian County had the largest growth rate of about 2.8 times, with growth rates of 184.17% and 180.56% respectively.

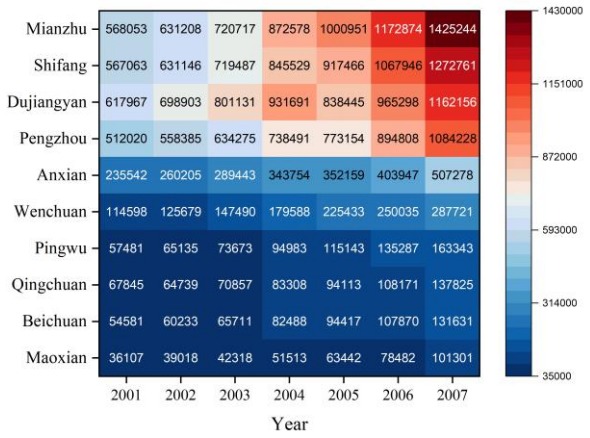


Fig 3- 4 GDP of the most severely affected area from 2001 to 2007 (ten thousand yuan)

As shown in Table 3-1, in terms of industrial structure, between 2001 and 2007, there were more obvious changes in the industrial structure of the 10 most severely affected area, with the following characteristics: First, the ratio of primary industry output value to total outset value in all counties showed a downward trend, with an average decrease of 6.7% of the ratio, and the decline value in more than one-third of the counties exceeded the average level of the 10 counties, of which Pingwu county declined the most, by 16.4%, while Dujiangyan county declined the least, with its ratio of primary industry to total industry declining by only 2.6%; second, the ratio of secondary industry to total industry output value in districts and counties other than Dujiangyan county showed an overall growth trend, with the growth value ranging from 3.8% to 21.4%, among which Pingwu county showed the largest growth of 21.4%, while Wenchuan showed the least growth of 3.8%. The proportion of secondary industry value to total output value in Dujiangyan county tended to decrease between 2001 and 2007, by 1.7%; third, the ratio of tertiary industry to total output value in most counties showed a downward trend, with the proportion of decline ranging from 1.9% to 16.0%, among which, Pengzhou county showed the largest decline of 16.0%, while Shifang county showed the least decline of 1.9%. The proportion of tertiary industry to total industry output value in Wenchuan county and Dujiangyan county increased by 0.03% and 4.3%, respectively. As of 2007, only Qingchuan County was dominated by the primary industry; the counties dominated by the secondary industry included Wenchuan County, Maoxian County, Beichuan County, Anxian County, Pingwu County, Mianzhu County, Shifang County and Pengzhou County; the only county dominated by the tertiary industry was Dujiangyan County.

Table 3- 1 Changes in the Industrial Structure of the most severely affected area during 2001-2007

County	Structure	2001	2002	2003	2004	2005	2006	2007	Leading Industry
Wenchuan	Primary Industry	10.1%	9.4%	8.5%	7.9%	6.6%	6.1%	6.3%	Secondary Industry
	Secondary Industry	73.3%	73.6%	76.2%	78.1%	77.7%	77.3%	77.1%	
	Tertiary Industry	16.5%	17.0%	15.4%	14.0%	15.7%	16.6%	16.6%	
Maoxian	Primary Industry	27.9%	27.6%	25.7%	24.3%	21.0%	16.8%	16.4%	Secondary Industry
	Secondary Industry	38.6%	40.5%	37.3%	41.8%	40.3%	48.5%	52.8%	
	Tertiary Industry	33.5%	40.0%	36.9%	33.8%	38.7%	34.7%	30.8%	
Beichuan	Primary Industry	44.8%	46.8%	41.2%	38.5%	37.1%	32.3%	32.8%	Secondary Industry
	Secondary Industry	26.7%	29.9%	29.1%	33.8%	36.4%	40.9%	42.1%	
	Tertiary Industry	28.5%	33.6%	29.7%	27.6%	26.5%	26.8%	25.1%	
Anxian	Primary Industry	39.4%	41.8%	35.6%	36.3%	39.2%	36.1%	35.5%	Secondary Industry
	Secondary Industry	32.7%	37.0%	35.2%	36.2%	33.9%	36.7%	39.4%	
	Tertiary Industry	28.0%	31.7%	29.2%	27.5%	26.8%	27.2%	25.0%	
Pingwu	Primary Industry	47.0%	49.5%	41.0%	37.7%	33.6%	30.2%	30.6%	Secondary Industry
	Secondary Industry	24.4%	32.2%	31.5%	38.0%	40.7%	44.9%	45.7%	
	Tertiary Industry	28.6%	31.6%	27.4%	24.3%	25.6%	25.0%	23.7%	
Mianzhu	Primary Industry	18.3%	19.3%	16.2%	15.6%	14.7%	12.9%	11.6%	Secondary Industry
	Secondary Industry	50.1%	54.5%	52.0%	55.8%	61.6%	64.8%	68.6%	
	Tertiary Industry	31.7%	37.3%	31.8%	28.7%	23.8%	22.4%	19.8%	
Shifang	Primary Industry	14.8%	15.7%	13.4%	13.8%	13.3%	12.5%	12.0%	Secondary Industry
	Secondary Industry	59.7%	67.2%	61.1%	61.3%	63.6%	64.0%	64.5%	
	Tertiary Industry	25.4%	28.4%	25.5%	24.9%	23.1%	23.5%	23.5%	

County	Structure	2001	2002	2003	2004	2005	2006	2007	Leading Industry
Dujiangyan	Primary Industry	15.8 %	16.5 %	12.5 %	11.8 %	13.9 %	13.0 %	13.3 %	Tertiary Industry
	Secondary Industry	38.6 %	46.9 %	44.1 %	31.6 %	35.6 %	36.4 %	36.9 %	
	Tertiary Industry	45.6 %	49.7 %	43.4 %	56.6 %	50.4 %	50.6 %	49.8 %	
Pengzhou	Primary Industry	26.1 %	27.9 %	23.6 %	21.9 %	24.6 %	22.9 %	22.8 %	Secondary Industry
	Secondary Industry	26.5 %	29.4 %	30.3 %	33.1 %	41.6 %	44.1 %	45.8 %	
	Tertiary Industry	47.4 %	51.7 %	46.0 %	45.0 %	33.9 %	33.0 %	31.4 %	
Qingchuan	Primary Industry	45.8 %	48.7 %	49.1 %	48.4 %	45.7 %	41.2 %	41.2 %	Primary Industry
	Secondary Industry	21.8 %	11.5 %	14.5 %	17.4 %	19.7 %	24.9 %	28.4 %	
	Tertiary Industry	32.5 %	35.2 %	36.4 %	34.2 %	34.6 %	33.9 %	30.4 %	

3.2.3 Level of fixed asset investment

As shown in Figures 3-5 and 3-6, between 2001 and 2007, urban fixed asset investment in the most severely affected counties maintained a steady growth, with only a few counties showing a decline in individual years. Overall, the level of urban fixed asset investment in the ten counties increased by 26.24illion yuan in seven years, a growth rate of 18.45%. Compared with 2001, all counties showed substantial growth in urban fixed asset investment in 2007, with one-half of the counties having a growth rate of more than 1000%, of which Shifang county had the fastest growth rate of 1.87billion yuan and a growth rate of 8963.04%, while Wenchuan county had the lowest growth rate of only 915.24 million yuan and 157.49%. On the other hand, the maximum growth rate of each county is concentrated in 2002, with the highest growth rate of urban fixed asset investment in Maoxian county, Pingwu county, Mianzhu county and Shifang county in that year; followed by 2005, with the highest growth rate of urban fixed asset investment in Anxian county, Dujiangyan county and Pengzhou county in that year; followed by the highest growth rate of Wenchuan and Beichuan in 2003; and finally in 2004, with the highest growth rate of urban fixed asset investment only in Qingchuan county in that year. As of 2007, the range of urban fixed asset investment levels are maintained between 730.56 - 10777.15 million yuan, with a large gap between counties, of which the highest level of urban fixed asset investment is in Dujiangyan county, reaching 10.78 billion yuan, and the lowest is in Qingchuan County, with only 730.56 million yuan. The counties where the level of urban fixed asset investment exceeded 10 billion yuan were Dujiangyan, the only county where the level of urban fixed asset investment was 5-10 billion yuan were Pengzhou, and the counties where the level of urban fixed asset investment was between 1-5 billion yuan included: Wenchuan, Maoxian, Beichuan, Anxian, Pingwu, Mianzhu and Shifang; the counties where the level of urban fixed asset investment was less than 1 billion yuan were Beichuan and Qingchuan.

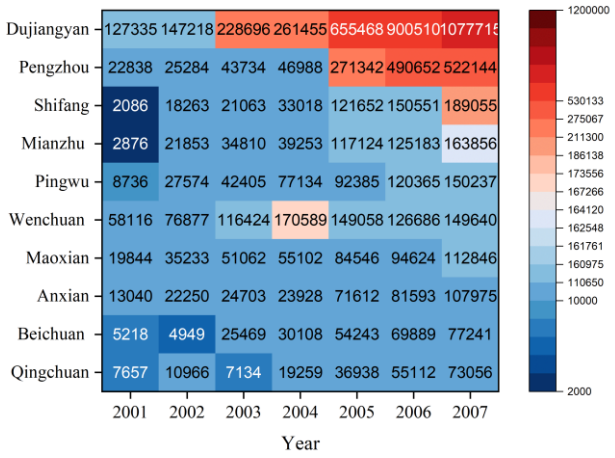


Fig 3- 5 Total investment in urban fixed assets in the most severely affected area during 2001-2007 (ten thousand yuan)

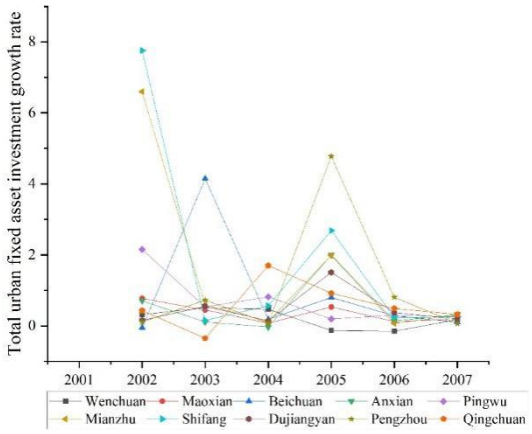


Fig 3- 6 Growth rate of total urban fixed asset investment in the most severely affected area during 2001-2007

3.2.4 Public finance revenue

As shown in Figures 3-7 and 3-8, among the public finance revenues between 2001 and 2007, most of the counties in the most severely affected area maintained a stable growth trend, with Maoxian, Beichuan, Anxian, Mianzhu, Shifang, Pengzhou and Qingchuan showing decreases in individual years. Overall, the level of public revenue in the 10 counties increased by 2.74 billion yuan in seven years, a growth rate of 36.56%. Compared with 2001, all counties had positive growth in pubic revenue in 2007, with more than two-thirds of the counties having growth rates of more than 100%, of which Dujiangyan had the fastest growth rate, with an increase of 557.23 million yuan and a growth rate of 227.16%, while Qingchuan had the lowest growth rate, with an increase of only 3.97 million yuan and 23.11%. On the other hand, the maximum growth rates of each county were mostly concentrated in 2005, when Wenchuan, Beichuan, Pingwu and Dujiangyan had the highest growth rates of public revenue; followed by 2002 and 2007, when Anxian County, Qingchuan County, Shifang County and Pengzhou County had the highest growth rates of public finance revenue; and finally, 2003 and 2006, when Mianzhu and Maoxian had the highest growth rates of public finance revenue respectively. As of 2007, the range of public revenue of all counties

remained between 21.15 and 758.28 million yuan, with a large gap between counties, where the highest public finance revenue was from Dujiangyan, reaching 758.28 million yuan, and the lowest was from Qingchuan, with only 21.15 million yuan. Counties with public finance revenues of more than 500 million yuan include Mianzhu, Shifang, Dujiangyan and Pengzhou; Counties with public finance revenues between 100-500 million yuan include Wenchuan and Anxian; Counties with public finance revenue levels less than 100 million yuan include Maoxian, Beichuan, Pingwu and Qingchuan.

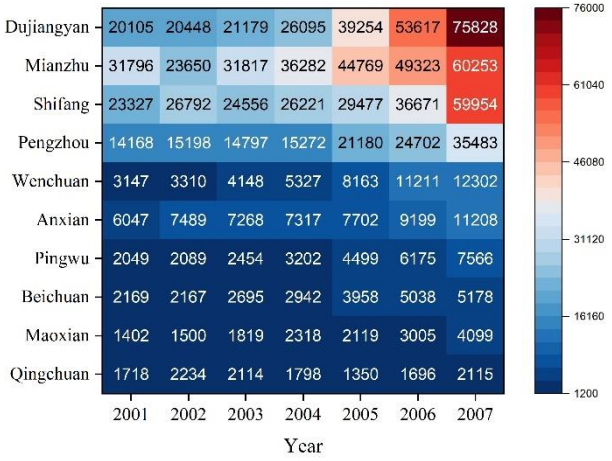


Fig 3- 7 Public revenues in the most severely affected area during 2001-2007 (ten thousand yuan)

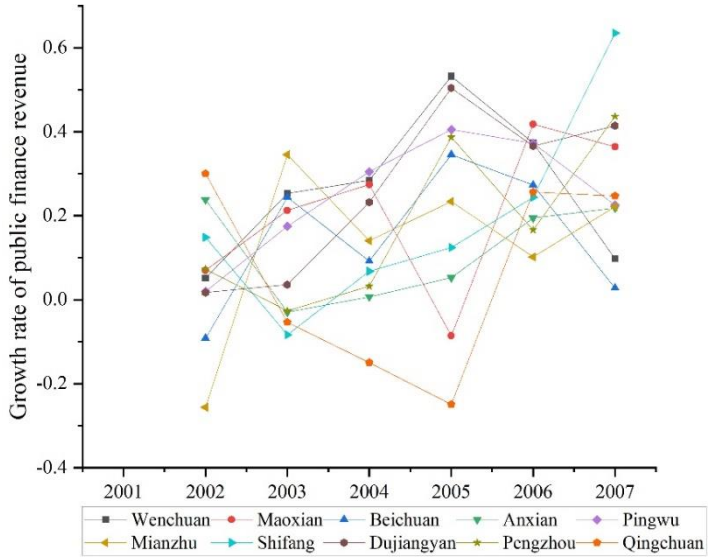


Fig 3- 8 Public revenues and growth rates in the most severely affected area during 2001-2007

3.2.5 Savings deposit balance of urban and rural residents

As shown in Figures 3-9 and 3-10, during 2001-2007, the savings deposit balances of urban and rural residents in each county of the most severely affected area maintained a steady growth trend.

Overall, the savings deposit balance of urban and rural residents in the 10 counties increased by 3,200,768 yuan in 7 years, with a growth rate of 131.99%. Compared with 2001, all districts and counties had positive growth of urban and rural residents' savings deposit balance in 2007, except for Wenchuan county, the growth rate of all districts and counties exceeded 100%, among which, Maoxian had the fastest growth rate, with an increase of 32,565 yuan and a growth rate of 175.97%, while Wenchuan County had the lowest growth amount and growth rate of only 41,433 yuan and 87.29%. On the other hand, the maximum growth rate of each county was concentrated in 2007, when Beichuan, Anxian and Shifang reached the highest growth rate of urban and rural residents' savings deposit balance. As of 2007, the range of urban and rural residents' savings deposit balances in all counties were maintained between 51,071-893,490 yuan, with the highest district and county being Dujiangyan county, reaching 893,490 yuan, while the lowest was Maoxian county, with only 51,071 yuan. The counties with urban and rural residents' savings deposit balances exceeding 500,000 yuan include Dujiangyan and Pengzhou, those between 100,000-500,000 yuan include Anxian, Mianzhu and Shifang, and those between 50,000-100,000 yuan include Wenchuan, Maoxian, Beichuan, Pingwu and Qingchuan. There was a large gap between urban and rural residents' savings deposit balances during the seven years.

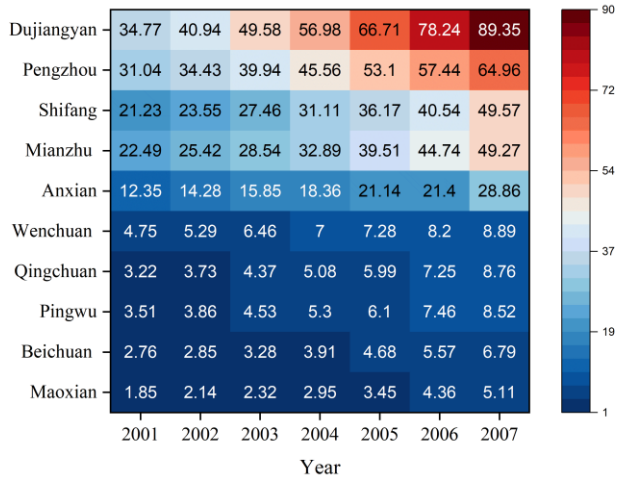


Fig 3- 9 Savings deposit balance of urban and rural residents (yuan)

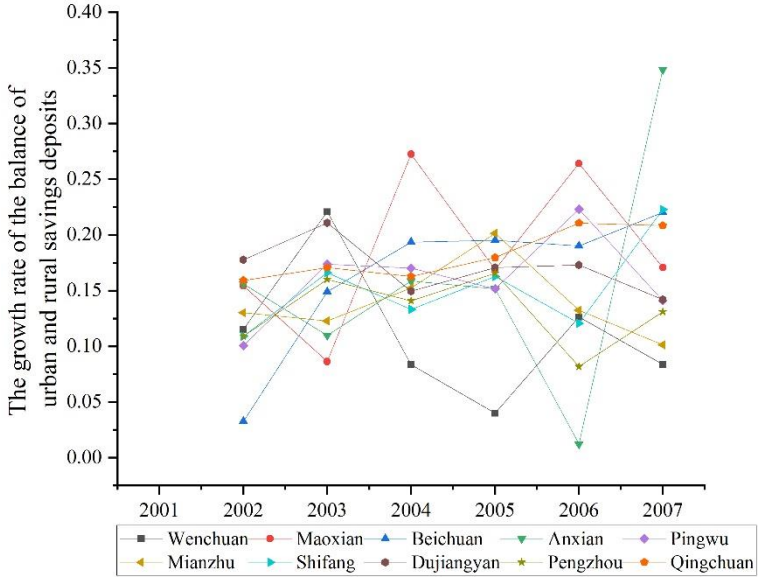


Fig 3- 10 Growth rate of savings deposit balance of urban and rural residents

3.3 Overview of disaster loss in the MSAA

The 5.12 Wenchuan earthquake was the most devastating and costly disaster since the founding of the People's Republic of China, and was felt in China and most countries in Asia. The earthquake damage area reached 500,000km², involving 186 counties (cities) in the most severely affected area, hard-hit area and general hard-hit area, respectively, of which the most severely affected area involved 212 townships totaling 26,123km² [3]. The direct and secondary disasters caused huge damage in terms of casualties, economic losses, house collapses, public facilities, arable land and ecosystems, and caused extremely serious losses in terms of population, economy and society. Among them, Wenchuan and Beichuan counties were more seriously affected, with greater losses in terms of population and secondary disaster impacts, followed by Shifang and Mianzhu, whose house collapse, land area and direct economic losses were more serious among the most severely affected area.

3.3.1Economic loss

The Wenchuan earthquake caused historically unprecedented damage to public buildings such as housing, hospitals, schools, and infrastructure such as bridges, roads, and cables. As of September 2008, the direct economic losses caused by the earthquake amounted to 845.2 billion yuan, most of which were concentrated in Sichuan, accounting for 91.3% of the total losses, while the most severely affected area accounted for 69.68%, resulting in a total loss of 588.95 billion yuan [4]. Among them, Mianzhu and Shifang had the largest economic losses, accounting for more than 10% of the overall economic losses, reaching 142.3 billion yuan and 88.9 billion yuan respectively; Pengzhou suffered less direct economic losses, 27.3 billion yuan, accounting for 3.23% of the total economic losses; Wenchuan County, the epicenter of the earthquake, ranked high among the most severely affected area, with direct economic losses reaching 64.25 billion yuan, accounting for 7.6% of the total economic loss. For details, see Table 3-2.

Table 3- 2 Direct economic losses in the most severely affected area

County	Direct economic loss （Billion）	Proportion
Wenchuan	642.5	7.60%
Beichuan	585.7	6.93%
Mianzhu	1423	16.84%
Shifang	889	10.52%
Qingchuan	500.4	5.92%
Maoxian	260	3.08%
Anxian	430.4	5.09%
Dujianyan	537	6.35%
Pingwu	348.5	4.12%
Pengzhou	273	3.23%
Total	5889.5	69.68%
Wenchuan earthquake affected area	8452	100%

3.3.2 Population loss

As of 12:00 on September 25, 2008, 69,227 people had been death, 17,995 people were missing, 374,644 people have been injured to varying degrees, and 19,930,300 people have lost their homes, bringing the total number of people affected to 46,256,000 [5]. Among the most severely affected area, Wenchuan and Beichuan counties were the most affected, with 45.6%, 65.0% and 16.4% of the total population in the most severely affected area death, missing and injured respectively. Pengzhou county was affected by the least number of people, the number of dead, missing and injured were 956, 35 and 5775, accounting for 1.4%, 0.2% and 1.5% of the total population affected in the most severely affected area; while other counties had different degrees of population loss, of which, Mianzhu county was more strongly affected by the earthquake, with the number of dead and injured exceeding 10,000, and the number of injured people in most of the counties was about 10,000-40,000, with the largest number of injured people in Anxian county, reaching 88,623. For details, see Table 3-3.

Table 3- 3 Number of casualties in the most severely affected area

County	Death	Injured	Missing	Percentage of death	Percentage of injured	Percentage of missing
Wenchuan	15941	34583	7295	23.0%	9.2%	40.5%
Beichuan	15645	26915	4412	22.6%	7.2%	24.5%
Mianzhu	11117	37208	258	16.0%	9.9%	1.4%
Shifang	5924	33075	198	8.6%	8.8%	1.1%
Qingchuan	4695	15453	124	6.8%	4.1%	0.7%
Maoxian	4016	8183	72	5.8%	2.2%	0.4%
Anxian	2640	88623	655	3.8%	23.7%	3.6%
Dujianyan	3091	10560	193	4.5%	2.8%	1.1%
Pingwu	3014	32193	2647	4.4%	8.6%	14.7%

County	Death	Injured	Missing	Percentage of death	Percentage of injured	Percentage of missing
Pengzhou	956	5775	35	1.4%	1.5%	0.2%
Total	67039	292568	15889	96.8%	78.1%	88.3%
Wenchuan earthquake affected area	69277	374644	17995	100%	100%	100%

3.3.3 Housing loss

The Wenchuan earthquake caused extremely serious damage to urban and rural housing in the most severely affected areas, including Beichuan county, which was directly turned into ruins, and Yingxiu Town in Wenchuan county, where all houses were destroyed and public facilities such as houses, schools, hospitals and office buildings were damaged to varying degrees. According to statistics, the earthquake caused a total of 15,680,646 houses destroyed, of which, the most severely affected area reached 6,726,997, accounting for 42.9% of the total number of houses collapsed in Wenchuan earthquake [5]. According to statistics, the earthquake caused a total of 15,680,646 houses destroyed, of which, the most severely affected area reached 6,726,997, accounting for 42.9% of the total number of houses collapsed in Wenchuan earthquake [6]. The remaining counties had the number of damaged houses between 290,000 and 800,000, among which, Pingwu county was relatively less affected, with the least number of collapsed houses, 299,557, accounting for 1.91% of all damaged houses; while Wenchuan county, the epicenter of the earthquake, ranked top in the rate of collapsed houses for 10,000 people, reaching 55,291, much higher than other affected counties. See Table 3-4 for details.

Table 3- 4 Number of Collapsed Houses in the most severely affected area

County	Number of collapsed houses	Proportion	Housing collapse rate per 10,000 people
Wenchuan	608198	3.88%	55291
Beichuan	347856	2.22%	21741
Mianzhu	1397925	8.91%	27410
Shifang	1006921	6.42%	23417
Qingchuan	714084	4.55%	28563
Maoxian	300229	1.91%	27294
Anxian	774896	4.94%	15498
Dujianyan	655265	4.18%	10742
Pingwu	299557	1.91%	15766
Pengzhou	622066	3.97%	7975
Total	6726997	42.90%	36283

County	Number of collapsed houses	Proportion	Housing collapse rate per 10,000 people
Wenchuan earthquake affected area	15680646	100%	

3.3.4 Land loss

The Wenchuan earthquake and its secondary disasters such as landslides, avalanches and mudslides have directly or indirectly caused extremely serious damage to land resources, with a surface coverage destruction area of 77,311hm^2 and different degrees of damage or loss of arable land and forest land, posing a huge challenge to national food security and ecological protection [5]. Simultaneously, the surface cover was damaged, resulting in serious damage to ecosystem functions in the most affected area and thus in terms of biodiversity conservation. According to statistics, the earthquake caused a total of 13,351hm^2 of arable land damage, accounting for 1.87% of the total arable land area in the region, of which, Wenchuan County, the epicenter of the earthquake, suffered the most serious damage to arable land due to the extremely strong earthquake damage, with a damaged area of 3,264hm^2, accounting for 14.1% of the total arable land area in the district, exceeding the sum of the damaged arable land areas of other counties, thus opening a huge gap with other counties [7-8]. The damaged arable land in Dujiangyan was smaller, with 118hm^2, accounting for 0.2% of the total arable land area in the district. Meanwhile, due to the complex topographical conditions in the most severely affected area, the restoration of damaged arable land is difficult to be carried out, thus its restoration rate is low, and there are very few arable land resources that can be developed in the reserve. Therefore, for some counties in the most severely affected area, the damage to arable land caused by the earthquake is permanent and causes great difficulties for the agricultural development in the area. On the other hand, the earthquake also caused serious damage to the ecosystem function, with the 10 most severely affected counties suffering from ecosystem damage reaching 63,200hm^2, accounting for 3.37% of the total regional ecosystem area. According to statistics, the spatial distribution of ecosystem damage area is highly correlated with the earthquake intensity, and the areas with earthquake intensity above X degree are severely damaged. Wenchuan County had the largest damaged ecosystem area, reaching 24,714hm^2, about three times the next largest county in terms of ecosystem damage, with a large gap to other districts and counties; among the remaining districts and counties, Shifang, Mianzhu and Pengzhou were the most severely damaged, with the proportion of ecosystem damage to the total area before damage all exceeding 10%, reaching 17.27%, 16.36%, and 11.7%. For details, see Tables 3-5.

Table 3- 5 Area and proportion of cultivated land and ecosystem damaged by earthquake by county

County	Cultivated area（hm^2）	Damaged area（hm^2）	Percentage of damaged area	Ecosystem area（hm^2）	Ecosystem affected area（hm^2）	Damaged percentage
Wenchuan	23167	3264	14.10%	385091	24714	6.42%

County	Cultivated area（hm^2）	Damaged area（hm^2）	Percentage of damaged area	Ecosystem area（hm^2）	Ecosystem affected area（hm^2）	Damaged percentage
Beichuan	57980	1940	3.3%	228031	4274	1.87%
Mianzhu	70850	1994	2.8%	51507	8425	16.36%
Shifang	49772	608	1.2%	30264	5227	17.27%
Qingchuan	137908	732	0.5%	181316	1424	0.79%
Maoxian	47340	393	0.8%	342226	5789	1.69%
Anxian	96653	2547	2.6%	41626	2112	5.07%
Dujianyan	62510	118	0.2%	54913	3505	6.38%
Pingwu	84866	1523	1.8%	508830	1679	0.33%
Pengzhou	81507	232	0.3%	53196	6051	11.37%
Total	712553	13351	1.87%	1877000	63200	3.37%

3.3.5 Secondary disasters

After the Wenchuan earthquake, frequent aftershocks led to widespread and extensive secondary geological disasters (mudslides, landslides, avalanches, etc.) for a period of time after the earthquake, resulting not only in extensive vegetation destruction and increased soil erosion, but also generating a large number of new geological disaster potential sites, further deteriorating the environment of the disaster area and seriously threatening the lives and properties of people [9]. The most severely affected area of the earthquake are in the mountainous regions of southwestern China with fragile ecological environments, and the massive secondary disasters have further damaged the surface of the affected areas, among which sedimentation has caused serious pollution of the water bodies and degraded their ecological functions, posing a serious threat to the water security and ecological security of the Chengdu Plain and even the entire middle and lower reaches of the Yangtze River. According to statistics, the area damaged by secondary disasters in the 10 most severely affected counties totaled 76,641hm^2, accounting for 39.95% of the total regional land area, among which, Wenchuan and Mianzhu had the largest disaster area, both exceeding 10,000hm^2, accounting for 6.86% and 8.37% of the district's land area respectively; although the damage area of Shifang County was medium among the ten most severely affected area, the damage area of the secondary disaster on the surface accounted for a relatively large area of 7.15% of the county's land area, which ranked high among the most severely affected area. For details, see Tables 3-6.

Table 3- 6 Surface coverage area of landslides, landslides and debris flow damage in the most severely affected area

County	National Land area（hm2）	Earthquake damage area（hm2）	Percentage
Wenchuan	408258	27979	6.86%

County	National Land area （hm2）	Earthquake damage area （hm2）	Percentage
Beichuan	286205	6225	2.17%
Mianzhu	124558	10420	8.37%
Shifang	81990	5862	7.15%
Qingchuan	320574	2165	0.68%
Maoxian	389566	2505	0.64%
Anxian	139898	8336	5.96%
Dujianyan	120665	3623	3%
Pingwu	594615	3244	0.55%
Pengzhou	137367	6282	4.57%
Total	2603696	76641	39.95%

3.4 Overview of reconstruction policies of Wenchuan earthquake

The Wenchuan earthquake caused serious damage to the population, economy, society and land, and caused significant losses to the lives and property safety of people in the earthquake-affected areas, while the suddenness and severity of the disaster caused great difficulties in the recovery of the national economy. In order to enable the people in the affected areas to effectively carry out self-help, actively rebuild their homes and realize the rapid restoration of normal production and living order in the affected areas, the state has carried out orderly reconstruction work in the affected areas in terms of financial investment, tax relief, industrial support and employment guarantee [10].

3.4.1 Expanding financial input

For rapid reconstruction of the earthquake-stricken areas, the Chinese government has established a post-disaster recovery and reconstruction fund to provide different levels of expenditure and assistance for the recovery and reconstruction of housing, public services, infrastructure, industrial and commercial enterprises, agriculture and forestry. In terms of housing, financial support such as housing subsidies, project subsidies and housing purchase subsidies have been established for rural and urban areas respectively. With respect to public service facilities, funds for the restoration and reconstruction of facilities such as education, medical care and grassroots power are borne by the central and local finances in proportion to each other, while funds supported and donated by society are prioritized for the reconstruction of public service facilities such as education and medical care. With regard to infrastructure, policies of investment subsidies and loan subsidies to help non-operating and operating urban municipal facilities projects are given respectively, while policies of loan subsidies or investment subsidies of different degrees are given for transportation infrastructure, reservoirs, etc. As for restoration and reconstruction of industrial and commercial enterprises, the State-owned Assets Supervision and Administration Commission (SASAC) or the central military enterprises and institutions gave project investment subsidies or loan subsidies, while for local industrial and commercial, tourism and other enterprises, the strategy of "giving loan subsidies to key industries and implementing other restoration and reconstruction responsibilities to local

governments" was followed; in terms of restoration and reconstruction of agriculture and forestry, the central government took the form of project investment subsidies and loan subsidies to support the affected areas.

3.4.2 Tax relief efforts

In order to put the production and life of people in the affected areas on the right track as soon as possible, the central government has established different tax relief policies for enterprises, individuals and social construction. Firstly, the policy of expanding the scope of VAT deduction was implemented for the severely affected areas, and enterprises with severe losses in the severely affected areas and those related to earthquake relief were exempted from corporate income tax, while enterprises in the affected areas or those supporting the affected areas and aiding post-disaster reconstruction materials and equipment were exempted from import tax for three years; secondly, individuals in the affected areas were exempted from personal income tax on disaster relief payments issued by the government or donations received, as well as income from subsidies related to earthquake relief. Regarding social construction, the government has formulated tax exemption policies with different rules for post-disaster reconstruction housing, farmers' reconstruction housing, construction and installation, sales, and damaged residential housing with unpaid deeds. Finally, in order to encourage the community to support and help the disaster-stricken areas, the government has granted a tax exemption system for units, enterprises and individuals who offered free donations to the disaster areas under different conditions according to their different categories of donated materials.

3.4.3 Increasing financial support

In order to promote the rapid recovery of economic construction in the affected areas and meet the production and living requirements of the people, the national government has developed a series of policies for the construction of financial institutions, capital and insurance markets and credit environment: on the one hand, it has increased the recovery and reconstruction work of financial institutions' outlets in the affected areas, encouraged banks and financial institutions to invest credit in the affected areas and supported the affected people to resume their living and production. On the other hand, it has actively promoted the construction of credit system in the affected areas, protected the legitimate rights and interests of people and enterprises in the affected areas, and maintained the financial order and security in the affected areas.

3.4.4 Advancing industrial support

In order to promote the rapid recovery of social production and national economy in the affected areas, the national government has requested to adjust the industrial structure with regional characteristics, eliminating high energy consumption, high pollution and enterprises that do not comply with national industrial policies and safe production conditions, and restoring and rebuilding local industries with special advantages, focusing on agriculture and animal husbandry, agricultural by-product processing industry and the production of agricultural production materials such as fertilizers, pesticides and feed. The national government requires the promotion of direct grain subsidies and comprehensive direct agricultural subsidies and other funds to the affected areas to ensure the basic security of food, while appropriately increasing the supply of central and local grain reserves in the affected areas to maintain market stability.

3.4.5 Regulating the land market

In order to facilitate the resettlement of people in the affected areas and the restoration and construction work in an orderly manner, the Chinese government has provided policy support to the affected areas in terms of land use fees, land concession fees, the possibility of land allocation, land price setting and the increase of the retention of mineral resources compensation fees. First of all, the affected areas have newly built resettlement housing for the affected residents, rebuilt or newly built administrative organs, schools and other institutions, and all kinds of enterprises, people's organizations and other units can be exempted from new construction land reimbursement fees and land concession income and other fees. Second, the relevant policies have been formulated in terms of land supply, and land allocation can be implemented in the following cases, namely, the construction of non-commercial residential land for affected residents through government investment, social donations and self-financing, the construction of operational infrastructure and public welfare facilities in the form of BOT and TOT, or the planning of easy land, the reconstruction of villages that really need land, the need to relocate the whole according to the plan and the recovery of their original land for industrial and commercial enterprises. Finally, for land for large industrial or commercial facilities that play an obvious role in promoting the economic development of the affected areas, the land price can be reduced according to the actual situation; and for mining enterprises in severely affected areas, the central government will no longer collect compensation fees for mineral resources, royalties for prospecting and mining rights, and income from the price of mining rights, etc., instead, all of them will be retained locally to support the accelerated recovery of production work of mining enterprises in severely affected areas.

3.4.6 Enhancement of social security

In order to promote the re-employment of people in the affected areas and improve the post-disaster self-help ability of residents, the national government has introduced relevant policies according to the employment difficulties and reopened enterprises as well as different categories of employment difficulties to step up the employment assistance to the affected areas, including the provision of implementation of jobs for employment difficulties and employment difficulties involved in post-disaster reconstruction, the granting of corresponding social insurance subsidies and other assistance measures, while for the construction of "partner assistance reconstruction" projects, priority has been given to absorbing the local affected people.

3.5 Overview of reconstruction modes of Wenchuan earthquake

The occurrence of major natural disasters has caused huge losses to society, economy, life and property, and after the occurrence of disasters, "post-disaster recovery and reconstruction" has become a topic of multidisciplinary concern, forming a more nature system in terms of concept, model and path. After the Wenchuan earthquake, the Chinese government proposed the "paired assistance reconstruction" with Chinese characteristics through system innovation and institutional innovation based on partner assistance, taking into account the special characteristics of the earthquake and the social system [11]. In other words, according to the principle of "one province assisting one disaster-stricken county", a construction pattern has been formed in which a certain economically developed province (city) supports a certain earthquake-stricken area (county), with the provincial (city) government coordinating the planning, decomposing the tasks, and

implementing the responsibilities to specific townships (streets) and villages. According to this model, the Chinese government has developed a tripartite recovery and reconstruction system of "10 most severely affected areas, 10 departments directly under Sichuan Province and 10 aid provinces (cities)", in which 10 departments directly under Sichuan Province act as a "bridge" between 10 extremely affected areas and 10 aid provinces (cities), mainly coordinating and managing the aid work between them. The three are interconnected and interact with each other, forming a subsystem of partner assistance reconstruction in the most severely affected areas. The partner assistance reconstruction worksheet for the Wenchuan earthquake is shown in Table 3-7.

Table 3- 7 Paired reconstruction worksheet

Serial No.	Most severely affected area	Departments directly under Sichuan Province	Paired Province
1	Wenchuan	Department of Transportation of Sichuan Province	Guangdong Province
2	Beichuan	Sichuan Provincial development and reform commission	Shandong Province
3	Mianzhu	Sichuan Provincial Economic and Information Department	Jiangsu Province
4	Shifang	State-owned Assets Supervision and Administration Commission of Sichuan Province	Beijing
5	Qingchuan	Department of Housing and Urban-Rural Development of Sichuan Province	Zhejiang Province
6	Maoxian	Sichuan Provincial Water Resources Department	Shanxi Province
7	Anxian	Sichuan Provincial Finance Department	Liaoning Province
8	Dujianyan	Sichuan Provincial Department of Education	Shanghai
9	Pingwu	Sichuan Provincial Department of Civil Affairs	Hebei Province

Serial No.	Most severely affected area	Departments directly under Sichuan Province	Paired Province
10	Pengzhou	of Province Department of Human Resources and Social Security of Sichuan Province	Fujian Province

Among them, Wenchuan County was assisted by Guangdong Province. According to the layout of the county system of "one center, two corridors and four districts", Guangdong Province not only solved the short-term housing, infrastructure and public service facilities construction, but also integrated the long-term development and ecological environment of Wenchuan, formulating the post-disaster reconstruction master plan and special plans for urban and rural housing construction and infrastructure construction for all 13 townships in the county. It combined post-disaster reconstruction with the promotion of economic development, seizing the opportunity of policy and financial support to promote industrial upgrading and transformation; it also vigorously developed new industries, high-quality agriculture, and tapped tourism resources to achieve rapid economic and social development after post-disaster reconstruction. Beichuan County received assistance from Shandong Province. Shandong provincial government focused on people's livelihood in the aid work, to achieve the "road infrastructure priority, urban housing projects priority, and public facilities priority". It also focused on industrial development, earnestly studying the advantages and potential of development in Beichuan County; grasped the speed and quality of project construction and carried out various forms of follow-up services; meanwhile, insisting on the policy of merging material support with spiritual aid, it actively carried out psychological lectures and counseling, launching psychological intervention for key people and families. Mianzhu County received assistance from Jiangsu Province. Jiangsu Province, in the process of construction assistance, fully propelled the six major projects of "mass settlement, public services, infrastructure construction, industrial revitalization, intellectual support and employment assistance", to accelerate the construction of urban and rural housing assistance, and quickly restore public service facilities and infrastructure. Jiangsu Province has also made efforts to promote industrial revitalization, in which the two cities have jointly built the Jiangsu Industrial Park and the Hanwang Wuxi Industrial Park to make Mianzhu County the " Hometown of Chinese New Year Paintings". Beijing gave top priority to the most urgent livelihood issues of the people in the disaster area of Shifang County, highlighting the principles of public service construction, infrastructure construction and livelihood projects in terms of aid funds and construction timeline. As a construction aid provider, Beijing combined the capital's resource advantages with industrial investment, park construction, and talent training and exchange to establish a long-term cooperation mechanism with Shifang County to facilitate the post-quake sustainable development of Shifang County. For the assistance to Qingchuan County, Zhejiang Province actively focused on the policy of accelerating "home reconstruction, facility reconstruction and industry reconstruction", and firstly organized the preparation of "town system and township planning of Qingchuan County", which provided scientific guidance for the post-disaster reconstruction and recovery of Qingchuan County, and also laid the foundation for the long-term development of Qingchuan County. At the same time, Zhejiang

Province also invested funds to vigorously build housing, schools, medical care, roads and bridges in the disaster area, and took advantage of Zhejiang Province's industrial development to drive the construction of the Sichuan-Zhejiang Cooperation Industrial Park, develop agricultural specialty industries and build an agricultural specialty industrial base. In the process of partner assistance reconstruction, the Maoxian County government was the main one, and Shanxi Province mainly undertook technical, survey, supervision, construction and other related work, so that the subjective initiative of both sides was given full play. Shanxi Province helped some special villages in Maoxian County to develop rural tourism, integrating them into minority culture to increase farmers' income. They also implemented the development model of "two village committees + company + farm households", with the village committee taking the lead and the whole village farm households voluntarily taking shares with land and housing, so as to come out of a road of agricultural industry characteristics. Anxian County employed a combination of government subsidies, mass self-financing, financial loans, and friends and relatives to solve the financial problems of agricultural housing reconstruction, giving priority to providing people in the disaster area with living assistance, road access, students resuming classes, and enterprises resuming work, and fully carrying out post-disaster reconstruction work after people in the disaster area have received basic protection for their lives and production. In terms of industrial support, Liaoning Province guided the enterprises in Anxian County to resume production under the "one factory, one policy" approach, investing in the establishment of Liaoning Industrial Park to provide more jobs for the disaster area. Dujiangyan County received assistance from Shanghai. In the post-disaster reconstruction planning, the two places actively combined with the regional sustainable development strategy, making the post-disaster reconstruction master plan of "concentrating industry to the park, concentrating land to the scale operation, concentrating farmers to the town", to create idyllic tourist areas and special agricultural gathering areas, and strive to promote high-end production through scientific planning of "three lines and nine towns" construction. For the assistance to Pingwu, Hebei Province, under the guidance of the overall requirement that "the three-year reconstruction task will be basically completed within two years", focused on the development of industrial construction, specifically as follows: in industry, with emphasis on hydropower development, speed up the recovery and reconstruction of the Industrial Complex; in tourism, restore and improve the infrastructure of scenic spots, improve the quality and reception level of In tourism, restore and improve the infrastructure of scenic spots, to enhance the quality and reception level of tourism scenic spots; actively carry out investment attraction, and develop local copper and iron ore resources industry by combining with the Hebei Province aid platform. Second, vigorously build transportation and water conservancy projects, electricity, educational facilities and medical facilities. For the aid to Pengzhou County, Fujian Province adhered to the policy of "combining the current and long-term", providing human, material and financial support to the disaster area, encouraging and guiding Fujian enterprises to invest and set up factories in Pengzhou County to promote local development; at the same time, the process of aid construction was also viewed as a process of establishing cooperation, focusing on the establishment of a long-term cooperation mechanism.

According to the requirements of the State Council's Wenchuan Post-Earthquake Rehabilitation and Reconstruction Master Plan, partner assistance reconstructions were carried out by the degree of damage and the characteristics of the disaster in the most severely affected areas, including housing construction, facility construction, industrial construction, ecological construction and spiritual construction projects, covering such aspects as "clothing, food, housing and transportation".

The duration of partner assistance reconstruction was three years. In accordance with the urgency of post-disaster reconstruction work, specific assistance reconstruction work was conducted over time. Firstly, a phased construction work plan was formulated, such as housing construction as the primary task at the initial stage of assistance construction, and the strategy of "building temporary housing first as a transition for people in the disaster area, and then building permanent housing as a follow-up supplement" was implemented. Meanwhile, the construction of infrastructure and public service facilities was also incorporated into the initial construction of the reconstruction assistance; while industrial construction, public service construction and spiritual construction were incorporated into the key tasks of the construction of facilities as the main tasks in the middle and later stages of the reconstruction assistance.

Overall, the "partner assistance reconstruction" model was led by the central government and coordinated by Sichuan's subordinate departments, with three major modules, namely: the aid construction module composed by the aid province (city), the aid recipient module composed by the most severely affected areas, and the guarantee project module.

3.5.1 Aid project module

The module of assisted construction includes housing construction, facility construction, industrial construction, spiritual construction, and ecological construction. First of all, housing construction consists of temporary housing construction and permanent housing construction, where temporary housing can be used as a temporary facility to resettle victims in case of disasters, with the characteristics of rapidity and ease of operation. At the same time, combined with the disaster situation in different areas, temporary housing has gone through the stage of tents and transitional shelters, which are widely used because some severely affected areas are trapped by terrain conditions or shortage of materials, temporary use of tents and transitional shelters are used as a transition, which are characterized by ease of use, less difficult to build and can quickly solve the resettlement problem of affected residents. Second, industrial construction, as a key task in the middle and late stages of aid construction, mainly covers the restoration and reconstruction of agriculture, industry and commerce, etc., with the following advantages: in agriculture, repairing damaged agricultural production facilities, placing emphasis on enhancing agricultural modernization capabilities and raising farmers' income levels; in industry, optimizing industrial structure and layout, developing green industry, combining industrial development with urbanization construction and information construction, and taking the path of sustainable development; in commerce, stressing the restoration of commercial outlets in the affected areas, and enhancing commercial service capabilities on the basis of meeting the daily supply of goods and materials for affected residents. With regard to spiritual construction, the aid work is divided into psychological relief and cultural construction, with the following advantages: through professional psychological relief measures, the stressful psychological disorders such as anxiety and depression of the affected people after the disaster are soothed; the reconstruction of various cultural facilities destroyed by the earthquake stabilizes the unity of the disaster area to a certain extent and maintains social harmony and stability. Finally, in terms of ecological construction, as the earthquake has caused great damage to woodland resources and water resources in the Longmen Mountains region of China, posing a serious threat to the stability of the ecosystem, ecological construction was precisely to strengthen ecological restoration and environmental management on the basis of respecting the laws of nature, thus promoting the harmonious development of man and nature.

3.5.2 Recipient project module

The recipient project module refers to the docking part of the aid project, consisting mainly of organization building, counterpart linkage network, project management and aid atmosphere creation system. First of all, the organization building is composed of the recipient leadership working group and the aid construction leadership working group, constituted by the departments directly under Sichuan Province and the governments of the most severely affected counties. Second, project management mainly refers to the effective planning and systematic management of the entire aid work. After the recipient unit makes an effective assessment of the specific disaster situation, the aid unit, according to the conditions of human, financial and material resources, negotiates with the recipient unit, scientifically plans the various matters of aid construction, clarifies the mechanisms of aid construction, explores the mode of aid construction suitable for local conditions, and ensures the orderly implementation of the aid construction project. Finally, in terms of creating a cultural atmosphere for aid construction, in order to promote the smooth development of post-disaster reconstruction work, the aid construction work is promoted by means of slogans, inscriptions, meetings, literary associations and reports, which can not only express the gratitude of the people in the disaster area to the aid construction units and personnel, but also inspire the people in the disaster area to devote themselves to the aid construction work to a great extent and build confidence in reentering their homes.

3.5.3 Safeguarding project module

Safeguarding project module refers to the support platform to ensure the orderly implementation of rescue work, specifically in five major areas: scientific planning, overall coordination, legal policy, public supervision, and organizational management. First of all, scientific planning means that the aid projects should be based on the principle of government-led, expert preparation and mass participation, the planning of the partner aid projects should be formulated to ensure the scientific rationality and local feasibility of the aid work. Second, overall coordination refers to the roles and responsibilities of the central government, the government of the supporting province (city), the government of the disaster area county (city), social institutions, NGOs, experts and technicians, people in the disaster area, and the general public in the recovery and reconstruction work in a coordinated and reasonable manner. The recovery and reconstruction work are actively promoted through the central government's formulation of general rules and the governments of the supporting provinces (cities) and various social institutions providing assistance in terms of human, material and financial resources to the disaster areas. Finally, the correspondence between organizational management and organizational construction refers to the mutual articulation between the recipient leadership working group set up by the county (city) governments in earthquake-affected areas and the aid leading working group set up by the aid provincial (city) governments, which are jointly responsible for all matters of the rescue work and provide organizational system protection for the aid work.

3.6 Summary

The Wenchuan earthquake, as the most destructive, the most extensive, the heaviest damage and the most difficult to rescue after the founding of New China, caused great damage to the affected

areas. In this chapter, the basic overview of the Wenchuan earthquake was reviewed; the socio-economic development of the 10 most severely affected counties before the earthquake was analyzed in five aspects: urban development, economic development, fixed asset investment, fiscal revenue, and the balance of residents' savings deposits; the economic, population, housing, land loss, and secondary disasters caused by the Wenchuan earthquake in the 10 most severely affected counties were introduced in detail in five aspects, respectively; finally, the post-disaster reconstruction policies and aid models were introduced in detail. The specific conclusions were as follows.

The overall level of the 10 counties in the most severely affected area was not high before the earthquake, with huge differences between districts and counties. In terms of urbanization level, the highest urbanization level in the most severely affected area did not exceed 40%. In terms of economic development level, the overall level of the 10 districts and counties was not high, with huge differences, as shown by the large difference in GDP growth rates of the 10 counties on the one hand, and the different leading types of economic development on the other hand, of which, the primary industry-led district and county was Qingchuan County, the secondary industry-led district and county included Wenchuan County, Maoxian County, Beichuan County, Anxian County, Pingwu County, Mianzhu County, Shifang County and Pengzhou County, and the tertiary industry-led district and county was only Dujiangyan County. In terms of the level of fixed asset investment, the 10 counties also varied widely, of which, only Dujiangyan County had a level of urban fixed asset investment exceeding 10 billion yuan, only Pengzhou County was in the 5 - 10-billion-yuan range, the counties between 1-5 billion yuan included Wenchuan, Maoxian County, Beichuan County, Anxian County, Pingwu County, Mianzhu County and Shifang County, and only Beichuan County and Qingchuan County were less than 1 billion yuan. The same differentiated results were also reflected in the public revenue of the 10 counties, where the districts and counties with public revenue over 500 million yuan included Mianzhu, Shifang, Dujiangyan and Pengzhou County, those in the range of 100-500 million yuan included Wenchuan and Anxian County, and those less than 100 million yuan included Maoxian, Beichuan, Pingwu and Qingchuan counties. In addition, in terms of urban and rural residents' savings deposit balance, the 10 counties and cities also varied greatly, among which the ones with urban and rural residents' savings deposit balance over 500,000 yuan included Dujiangyan and Pengzhou County, the ones between 100,000-500,000 yuan included Anxian County, Mianzhu County and Shifang County, and the ones between 50,000-100,000 yuan included Wenchuan County, Maoxian County, Beichuan County, Pingwu County and Qingchuan County.

The 10 counties and cities in the most severely affected area were greatly affected by the Wenchuan earthquake, with large differences between counties. In terms of economic losses, the direct economic losses of Mianzhu and Shifang reached 142.3 and 8.9 billion yuan respectively, accounting for more than 10% of the entire earthquake-affected area; the direct economic losses of the remaining eight districts and counties were less than 10%. In terms of population loss, the counties with more than 20% of deaths were Wenchuan and Beichuan counties, between 10% and 20% were Mianzhu, and the remaining counties had less than 10% of deaths. In terms of housing losses, only Mianzhu and Shifang were the only districts and counties where the proportion of housing collapse was higher than 5%, while the remaining 8 counties were below 5%. In terms of land loss, only Wenchuan County lost more than 10% of its arable land, while the rest of the counties

were less than 10%. In terms of secondary disasters, counties with more than 5% of earthquake damage included Wenchuan, Mianzhu, Shifang and Anxian County, while the rest of the counties were affected by more than 5% of the area.

As far as post-disaster reconstruction is concerned, the Chinese government, in accordance with the social system and taking into account the special characteristics and actual situation of the Wenchuan earthquake, quickly introduced a series of post-disaster reconstruction policies in terms of financial investment, tax relief, financial support, industrial support, land market and social security to support the post-disaster reconstruction work during the reconstruction period (2008 to 2010). Simultaneously, via system innovation and institutional innovation, the Chinese government came up with the "partner assistance construction" post-disaster reconstruction model with Chinese characteristics, forming a pattern of "one province helping one hardest-hit county", constructing three major project modules of aid construction, aid recipients and safeguard, and carrying out aid construction work in five major areas: housing construction, facility construction, industrial construction, spiritual construction and ecological construction for the most severely affected areas.

Reference

[1] Sichuan Earthquake Relief Chronicle Compilation Committee. Sichuan Earthquake Relief Chronicle of Wenchuan Earthquake General Memorabilia. Sichuan People's Publishing House, Chengdu, Sichuan.

[2] Cui P, Chen XQ, Zhu YY. The Wenchuan Earthquake (May 12, 2008), Sichuan Province, China, and resulting geohazards. Nat Hazards 2011;56:19–36. https://doi.org/10.1007/s11069-009-9392-1.

[3] National Development and Reform Committee (2008) The overall planning for post-Wenchuan earthquake restoration and reconstruction.

[4] Yuan YF. Impact of intensity and loss assessment following the great Wenchuan earthquake. Earthq Eng Eng Vib 2008;7:247–254. https://doi:10.1007/s11803-008-0893-9.

[5] Du Q. 5.12 Research on the sustainable development of the county economy in the severely hit Wenchuan earthquake. Science Press: Beijing, 2020.

[6] Lei LP, Liu LY, Zhang Y, Bi JT, Wu YH, Jiao QJ, and Zhang WJ. Spatial variations of the house collapse and afflicted population by aerial images in the Wenchuan earthquake, Proc. SPIE 7841, Sixth International Symposium on Digital Earth: Data Processing and Applications, 78411H (3 November 2010); https://doi.org/10.1117/12.873270

[7] Li RR, Wang M, Liu K. A decadal evolution of landslides and debris flows after the Wenchuan earthquake. Geomorphology 2018;323:1-12.

[8] Yin Y, Wang F, Sun P. Landslide hazards triggered by the 2008 Wenchuan earthquake, Sichuan, China. Landslides 2009;6:139–152. https://doi.org/10.1007/s10346-009-0148-5

[9] Ren D, Wang J, Fu R, Karoly DJ, Hong Y, Leslie LM, Fu C, Huang G. Mudslide-caused ecosystem degradation following Wenchuan earthquake 2008, Geophys. Res. Lett 2009;36: L05401. https://doi:10.1029/2008GL036702.

[10] Dunford M, Li L.Earthquake reconstruction in Wenchuan: Assessing the state overall plan and addressing the ‘forgotten phase’. Applied Geography 2011;31(3):998-1009. https://doi.org/10.1016/j.apgeog.2011.01.001.

[11] Deng SH. A Study on the Transformation of Wenchuan Earthquake and Disaster Relief System. Southwestern University of Finance and Economics Press: Chengdu, 2020.

Chapter 4

Distribution of population-space-economy urbanization before and after the Wenchuan earthquake

CHAPTER FOUR: DISTRIBUTION OF POPULATION-ECONOMY-SPACE URBANIZATION BEFORE AND AFTER THE WENCHUAN EARTHQUAKE

Distribution of population-space-economy urbanization before and after the Wenchuan earthquake

4.1 Introduction 4-1

4.2 Temporal distribution of urbanization before and after the Wenchuan earthquake 4-1

4.2.1 Temporal distribution of urbanization for the most severely affected area 4-1

4.2.2 Temporal distribution of urbanization for ten counties 4-3

4.3 Spatial distribution of urbanization before and after the Wenchuan earthquake 4-20

4.3.1 Spatial distribution of urbanization for the most severely affected area 4-20

4.3.2 Spatial distribution of urbanization for ten counties 4-24

4.4 Summary 4-28

Reference 4-30

4.1 Introduction

As the transition area from the Chengdu Plain to the Qinghai-Tibet Plateau, this area is easily affected by geological disasters. According to the history records, this region has diverse topography and land-forms, and the level of urbanization varies greatly among counties [1-2].

In this chapter, the MSAA (the ten of the most severely affected area) and these ten most severely affected counties which were destroyed by the Wenchuan earthquake and reconstructed after the earthquake was analyzed to find the impact of the destructive earthquake on the Population-Economy-Space Urbanization. The variation of the urbanization for the ten most affected counties before and after the Wenchuan earthquake (from 2001 to 2017) was studied through data measured by the urbanization index system, including population urbanization level (Pu), spatial urbanization level (Su), economic urbanization level (Eu) and population-space-economy urbanization level (Pseu). Moreover, stage characteristics are also examined by divided the whole period (2001 to 2017) into three stages, including pre-earthquake stage (2001-2007), reconstruction stage (2008-2010), and post-earthquake stage (2010-2017).

4.2 Temporal distribution of urbanization before and after the Wenchuan earthquake

4.2.1 Temporal distribution of urbanization for the most severely affected area

According to the urbanization index system mentioned above, all evaluation scores for 10 c According to the urbanization index system mentioned above, all evaluation scores for 10 counties of the MSAA in 2001 to 2017 were obtained. The scattered plots chart in Figure 4-1 shows the change of index of Pu, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the MSAA increased overall from 2001 to 2017. Specifically, the value of Pu, Su, Eu, Pseu all increased from 2001 to 2007. However, this increasing trend was interrupted in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu, Eu, and Pseu were all decreased to 0.296 (80.44% of 2007), 0.307 (88.31% of 2007), and 0.307 (92.72% of 2007), respectively. The results apparently showed that the Wenchuan earthquake played the negative effects on the development of Pu, Eu, and Pseu for the Wenchuan county. However, the value of Su conversely increased to 0.337 (109.32% of 2007) in the same year, indicating that the Su developed so well before the Wenchuan earthquake, so that the same negative effect of Wenchuan earthquake showed a lag phenomenon. This could also be shown from the fact that the value of Su dropped to the value 0.297 in 2009. Even benefiting from the reconstruction measures, the Su still declined to the lowest point (among 2001 to 2017) in 2009. In contrast, the value of Pu, Eu, and Pseu raised to 0.333 (112.77% of 2008), 0.320 (104.41% of 2008), and 0.312 (101.60% of 2008) in 2009, respectively. Then the Pu, Su, Eu, and Pseu all increased in 2010. However, different results were shown in 2011. Specifically, the Su declined to 0.293 (79.07% of 2010) in 2011. The results indicated that Su lost development power after the end of reconstruction measures. Conversely, Pu, Eu and Pseu still increased in 2011, suggesting that under the help of post-earthquake reconstruction measures, Pu, Eu and Pseu had completed the transformation from external to internal power, resulting in sustained growth not only in 2011, but also in the rest of years. In addition, the value distribution of Su was like a U-shape from 2008 to 2010. In terms of annual growth rate, index of Pu, Su, Eu and Pseu are all positive in the period 2001 to 2017. Among them, index of Eu experienced the fastest annual

growth rate (6.95%). In contrast, the lowest annual growth is index of Su with value 4.75%, which is maybe caused by the terrain of MSAA. In addition, the annual growth rate of index of Pu and Pseu are 5.77% and 6.16%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the MSAA in different stages was presented in Figure 4-2. Within each box, the horizontal line represents the median value while the cross line means the average value. The lower edge of the box denotes the 25th percentile while the upper edge of the box represents the 75th percentile. The average value of Pu, Eu, and Pseu increased stages by stages, while that of Su increased from pre-earthquake stage to reconstruction stage then decreased from reconstruction stage and post-earthquake stage. In a word, there were stage characteristics on Pu, Su, Eu and Pseu for the MSAA from 2001 to 2017. Furthermore, the stage characteristic of Su was different to the Pu, Eu and Pseu at the post-earthquake stage, indicating that without the external resources, such as reconstruction measures, the Su declined dramatically.

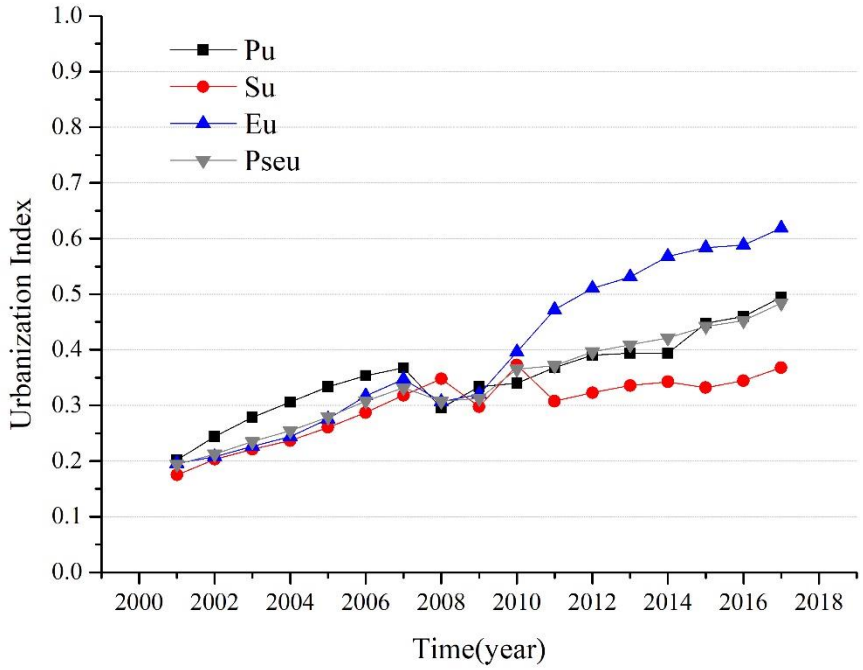


Fig 4- 1 Temporal variation of types of urbanization for the MSAA from 2001 to 2017

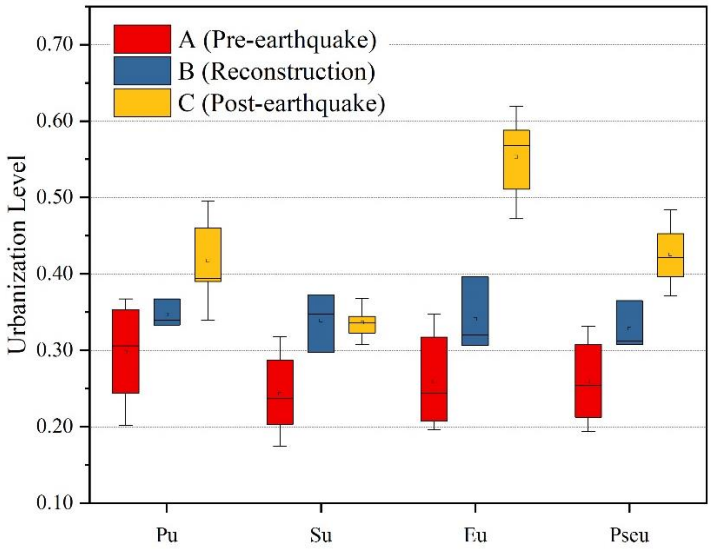


Fig 4- 2 Types of Urbanization distribution by stages for the MSAA

4.2.2 Temporal distribution of urbanization for ten counties

According to the urbanization index system mentioned above, all evaluation scores for Wenchuan county from 2001 to 2017 were obtained. The scattered plots chart in Figure 4-3 shows the change of index of Pu, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the Wenchuan county increased overall from 2001 to 2017. Specifically, the value of Pu, Su, Eu, Pseu all increased from 2001 to 2007. However, this increasing trend was interrupted in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu decreased to 0.402 (77.40% of 2007) in 2008. The results apparently showed that the Wenchuan earthquake played the negative effects immediately on the development of Su for the Wenchuan county. However, the value of Su, Eu, and Pseu conversely increased to 0.457 (129.56% of 2007), 0.655 (125.95% of 2007), 0.505 (108.75% of 2007) in the same year, respectively. The results indicated that the Su, Eu, and Pseu developed so well before the Wenchuan earthquake, so that there were lag effects of the Wenchuan earthquake on these types of urbanization. This could also be shown from the fact, negative effects were driven from the Wenchuan earthquake, that the value of Pu, Eu, and Pseu all dropped to its lowest value in 2009. Furthermore, benefiting from the reconstruction measures, the Pu, Su, Eu, and Pseu all increased to 0.392 (103.30% of 2009), 0.522 (149.67% of 2009), 0.605 (126.72% of 2009), 0.506 (125.99% of 2009) in 2010, respectively. However, different results were shown in 2011. Specifically, the Su and Pseu declined to 0.325 (62.23% of 2010) and 0.489 (96.46% of 2010) in 2011, respectively. The results indicated that Su and Pseu lost development power after the end of reconstruction measures. Under this context, reconstruction policies and measures for the Wenchuan county should be extended the execution time to help Su and Pseu recover and develop in time. Conversely, Pu and Eu still increased to 0.451 (115.09% of 2010) and 0.605 (126.72% of 2010) in 2011, suggesting that under the help of post-earthquake reconstruction measures, Pu and Eu had completed the transformation from external to internal power, resulting in sustained growth not only in 2011, but also in the rest of years. Similar results were also shown for the Su and Pseu from 2011 to 2017. In addition, the value distribution of Pu, Eu, Su and Pseu was like a U-shape from 2008 to 2010. In terms of annual growth rate, index of Pu, Su, Eu and Pseu are all positive in the period 2001 to 2017. Among them, index of Eu experienced the fastest average annual growth rate (5.19%).

In contrast, the lowest annual growth is index of Su with value 2.64%, which is maybe caused by the terrain of MSAA. In addition, the annual growth rate of index of Pu and Pseu are 3.98% and 4.19%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the Wenchuan county at different stages was shown in Figure 4-4. The average value of Pseu and Eu increased stages by stages, while that of Su increased from pre-earthquake stage to reconstruction stage and decreased from reconstruction stage and post-earthquake stage. However, the mean value of Pu showed totally different result, which declined at the reconstruction stage and raised from the reconstruction stage to post-earthquake stage. In a word, there were stage characteristics on Pu, Su, Eu and Pseu for the Wenchuan county from 2001 to 2017. Moreover, the stage characteristic of Pu was different to the Eu and Pseu at the reconstruction stage, indicating that the Pu received the negative effects by the Wenchuan earthquake. In addition, compared to other types of urbanization, Su showed different stages characteristic at the post-earthquake stage. The result suggested that the without the external resources, such as reconstruction measures, the Su declined dramatically.

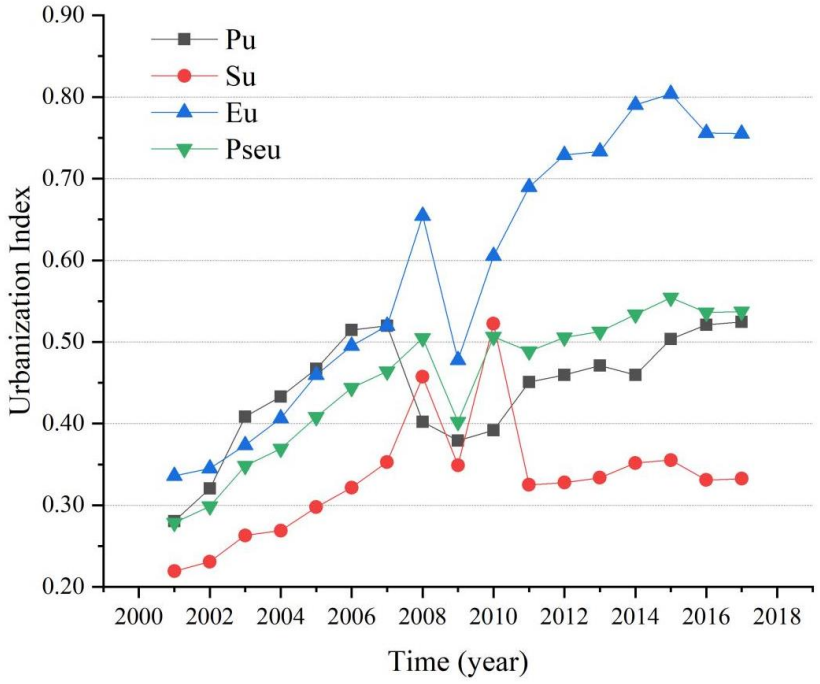


Fig 4- 3 Temporal distribution of types of urbanization for the Wenchuan county from 2001 to 2017

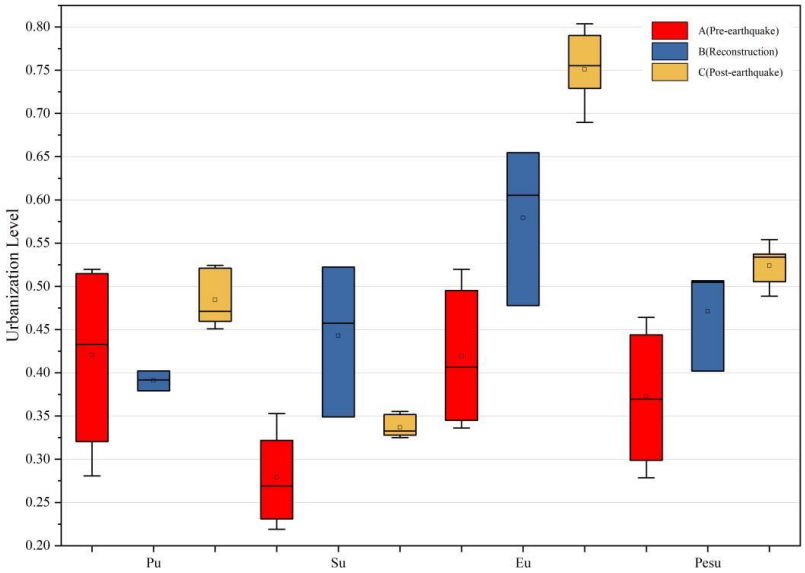


Fig 4- 4 Types of Urbanization distribution by stages for the Wenchuan county

According to the urbanization index system mentioned above, all evaluation scores for Shifang county from 2001 to 2017 were obtained. The scattered plots chart in Figure 4-5 shows the change of index of Pu, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the Shifang increased overall from 2001 to 2017. Specifically, the value of Pu, Su, Eu, Pseu all increased from 2001 to 2007. However, this increasing trend was interrupted in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu, Su, Eu, and Pseu all decreased to 0.455 (89.50% of 2007), 0.326 (97.58% of 2007), 0.441 (88.01% of 2007), 0.407 (90.95% of 2007) in 2008, respectively. The results apparently showed that the Wenchuan earthquake played the negative effects immediately on types of urbanization for the Shifang county. Even under the assistant of reconstruction measures, the Pu, Su, Eu, and Pseu still decreased to the lowest value (2001 to 2017) in 2009. However, under the combined effects of reconstruction measures and self-recovery and development, the value of Pu, Su, Eu, and Pseu conversely increased to 0.437 (108.84% of 2009), 0.388 (132.74% of 2009), 0.435 (145.48% of 2009), 0.420 (126.92% of 2009) in 2010, respectively. Furthermore, the value of Pu, Su, Eu, and Pseu keeping increased from 2011 to 2017, suggesting that under the help of post-earthquake reconstruction measures, all types of urbanization had completed the transformation from external to internal power, resulting in sustained growth not only in 2011, but also in the rest of years. In addition, the value distribution of Pu, Eu, Su and Pseu was like a U-shape from 2008 to 2010. In terms of annual growth rate, index of Pu, Su, Eu and Pseu are all positive in the period 2001 to 2017. Among them, index of Eu experienced the fastest average annual growth rate (5.09%). In contrast, the lowest annual growth is index of Pu with value 2.84%, which may be caused by the huge loss on population who settled in the built-up area of Shifang. In addition, the annual growth rate of index of Su and Pseu are 3.90% and 4.03%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the Shifang county at different stages was shown in Figure 4-4. The average value of Su, Eu, and Pseu increased stages by stages, while that of Pu decreased from pre-earthquake stage to reconstruction stage and increased from reconstruction stage and post-earthquake stage. In a word, there were stage characteristics on Pu, Su, Eu and Pseu for the Shifang county from 2001 to 2017. Furthermore, the stage characteristic of Pu was different to the Su, Eu and Pseu at the reconstruction stage, indicating that the Pu received the negative effects

by the Wenchuan earthquake and played the negative role on the development of Pseu of Shifang county.

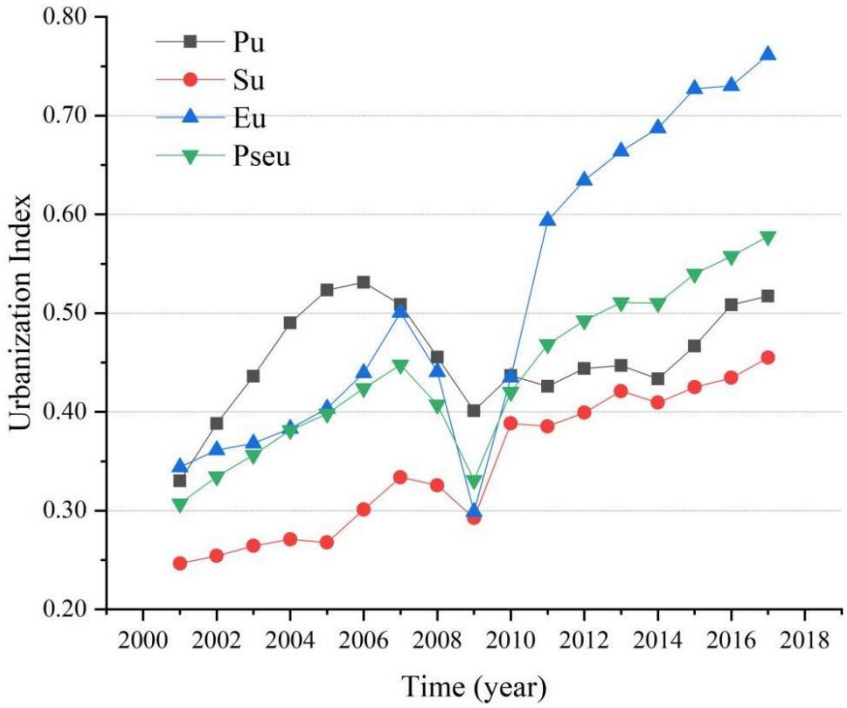


Fig 4- 5 Temporal variation of types of urbanization for the Shifang county from 2001 to 2017

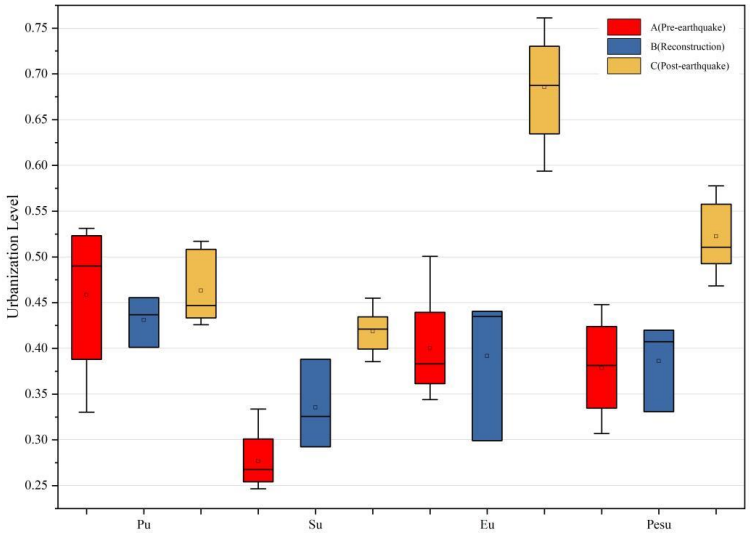


Fig 4- 6 Types of Urbanization distribution by stages for the Shifang county

According to the urbanization index system mentioned above, all evaluation scores for Qingchuan county from 2001 to 2017 were obtained. The scattered plots chart in Figure 4-7 shows the change of index of Pu, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the Qingchuan county increased overall from 2001 to 2017. However, this increasing trend was interrupted in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu and Eu declined to 0.182 (81.53% of 2007) and 0.079 (93.18% of 2007) in 2008, respectively. The results apparently showed that the Wenchuan earthquake played the negative effects immediately on the

development of Pu and Eu for the Qingchuan county. However, the value of Su and Pseu conversely increased to 0.238 (136.38% of 2007), 0.166 (103.14% of 2007) in the same year, respectively. The results indicated that the Su and Pseu developed so well before the Wenchuan earthquake, so that there was a lag effect of the Wenchuan earthquake on these two types of urbanization. Different to the Wenchuan county and Shifang county, there was an increasing trend for Qingchuan county from 2008 to 2010, while the previous two counties were shown like a U-shape in the same period. The value of Pu, Su, Eu, and Pseu all increased to 0.223, 0.428, 0.272, 0.308 in 2010, respectively. The result suggested that reconstruction measures boosted the recover and development of these types of urbanization, especially for the county like Qingchuan, which the value of Pseu was smaller than 0.2 before the Wenchuan earthquake. According to this result, reconstruction measures should be paid more attention for these counties that the Pseu was smaller than 0.4 before the natural disaster hit. After the end of reconstruction measures, the Pu, Su, Eu, and Pseu instantly showed the different results in 2011. Among them, Su, Eu, and Pseu all declined to 0.189 (44.17% of 2010), 0.246 (90.23% of 2010), 0.236 (76.73% of 2010), while Su still increased to 0.273 (122.74% of 2010) in 2011. The results indicated that Su, Eu, and Pseu lost development power after the end of reconstruction measures. Similar as Wenchuan county, the validity period of the post-disaster reconstruction policy should be extended on these types of urbanization for Qingchuan county. Different to Su, Eu, Pseu, the Pu still increased in 2011, suggesting that the special paired reconstruction measures, “one town one school, one town one hospital,” from Zhejiang Province produced prolongation effect on Pu. However, with the improvement of infrastructure, the acceleration of the overall urbanization of Sichuan Province, and the significant improvement in the teaching quality of Mianyang junior and senior high schools, a large number of school-age students have moved out of Qingchuan County, resulting in a rapid decline in the Pu value from 2012 to 2014. After this school-age student migrant wave, the Pu progressively recovered from 2015 to 2017. Similar gradually increasing trend was also found on Su, Eu, Pseu for the Qingchuan county from 2012 to 2017. In addition, different to the Wenchuan county and Shifang county, the value distribution of Pu, Eu, Su and Pseu was like a slash-shape from 2008 to 2010. In terms of annual growth rate, index of Pu, Su, Eu and Pseu are all positive in the period 2001 to 2017. Among them, index of Eu experienced the fastest average annual growth rate (11.38%). In contrast, the lowest annual growth is index of Pu with value 4.94%, which may be caused by the school-age student migrant of Qingchuan. In addition, the annual growth rate of index of Su and Pseu are 7.94% and 7.88%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the Qingchuan county at different stages was shown in Figure 4-6. The average value of Pu, Eu, and Pseu increased stages by stages, while that of Su decreased from reconstruction stage to post-earthquake stage. In a word, there were stage characteristics on Pu, Su, Eu and Pseu for the Qingchuan county from 2001 to 2017. Furthermore, the stage characteristic of Su was different to the Pu, Eu and Pseu at the post-earthquake stage, suggesting that the Su of Qingchuan was weaken on itself development. It declined so much immediately since the end of reconstruction measures.

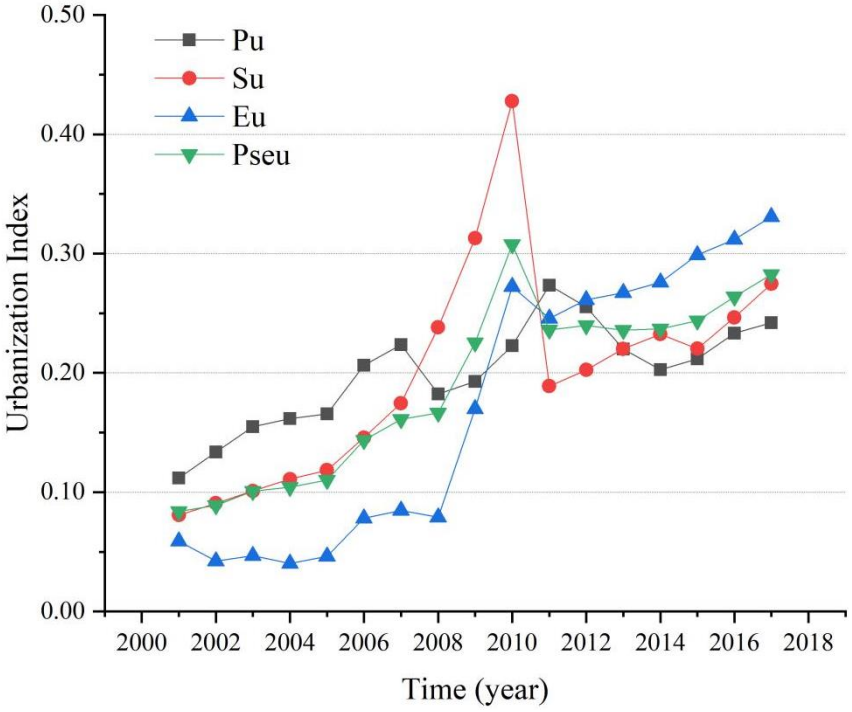


Fig 4- 7 Temporal variation of types of urbanization for the Qingchuan county from 2001 to 2017

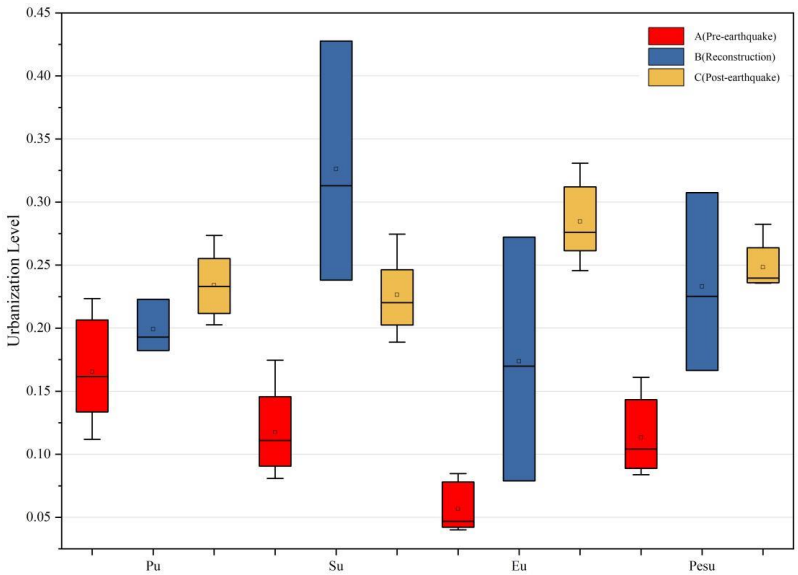


Fig 4- 8 Types of Urbanization distribution by stages for the Qingchuan county

According to the urbanization index system mentioned above, all evaluation scores for Wenchuan county from 2001 to 2017 were obtained. The scattered plots chart in Figure 4-9 shows the change of index of Pu, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the Pingwu county increased overall from 2001 to 2017. Specifically, the value of Pu, Su, Eu, Pseu all increased from 2001 to 2007. However, this increasing trend was interrupted in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu, Eu, Pseu decreased to 0.229 (90.26% of 2007), 0.196 (88.24% of 2007), 0.288 (95.86% of 2007) in 2008, respectively. The results apparently showed that the Wenchuan earthquake played the negative effects immediately on the development of Pu, Eu, Pseu for the Pingwu county. However, the value of Su conversely increased

to 0.441 (103.14% of 2007) in the same year, suggesting that the Su developed so well before the Wenchuan earthquake, so that there were lag effects of the Wenchuan earthquake on this type of urbanization. This could also be shown from the fact, negative effects were driven from the Wenchuan earthquake, that the value of Su dropped to its lowest value in 2009. Furthermore, benefiting from the reconstruction measures, the Pu, Su, Eu, and Pseu all increased to 0.225 (101.50% of 2009), 0.526 (133.70% of 2009), 0.304 (113.08% of 2009), 0352 (119.36% of 2009) in 2010, respectively. However, different results were shown in 2011. Specifically, the Pu, Su, Pseu declined to 0.203 (90.33% of 2010), 0.187 (35.95% of 2010), 0.243 (69.16% of 2010) in 2011, respectively. The results indicated that Pu, Su, Pseu lost development power after the end of reconstruction measures. Under this context, reconstruction policies and measures for the Pingwu county should be extended the execution time to help Pu, Su, Pseu recover and develop in time. Conversely, the Eu still increased to 0.339 (111.56% of 2010) in 2011, suggesting that under the help of post-earthquake reconstruction measures, Eu had completed the transformation from external to internal power, resulting in sustained growth not only in 2011, but also in the rest of years. Similar results were also shown for the Su and Pseu from 2011 to 2017. In the same period, different result was shown on Su. Due to the relative smaller increasing of secondary industry (average value was below 10% from 2013- 2014), less jobs were provided which resulting in the Pu fluctuated in the same period. In addition, the value distribution of Pu and Su was like a U-shape, while Eu and Pseu was more like a slash-shape from 2008 to 2010. In terms of annual growth rate, index of Pu, Su, Eu and Pseu are all positive in the period 2001 to 2017. Among them, index of Eu experienced the fastest average annual growth rate (11.47%). In contrast, the lowest annual growth is index of Su with value 2.12%, which would be reflected from the lots of dammed lakes were distributed in Pingwu county [3-4]. In addition, the annual growth rate of index of Pu and Pseu are 4.39% and 5.76%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the Qingchuan county at different stages was shown in Figure 4-10. The average value of Pu, Su, and Pseu increased from pre-earthquake stage to reconstruction stage and decreased from reconstruction stage to post-earthquake stage, while that of Eu increased stages by stages. In a word, there were stage characteristics on Pu, Su, Eu and Pseu for the Pingwu county from 2001 to 2017. Furthermore, the stage characteristic of Eu was different to the Pu, Su and Pseu at the post-earthquake stage, suggesting that the Eu of Pingwu had been transferred from external driven into internal driven, while Pu, Su, Pseu did not.

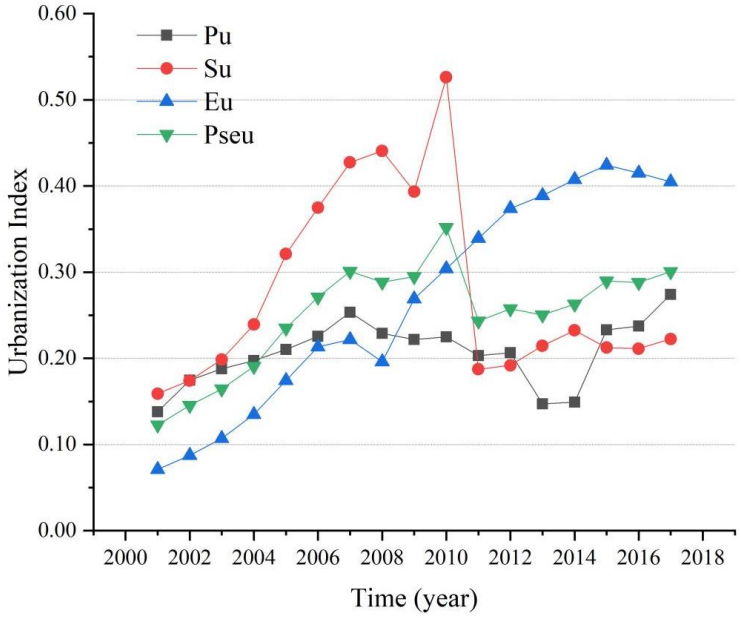


Fig 4- 9 Temporal variation of types of urbanization for the Pingwu county from 2001 to 2017

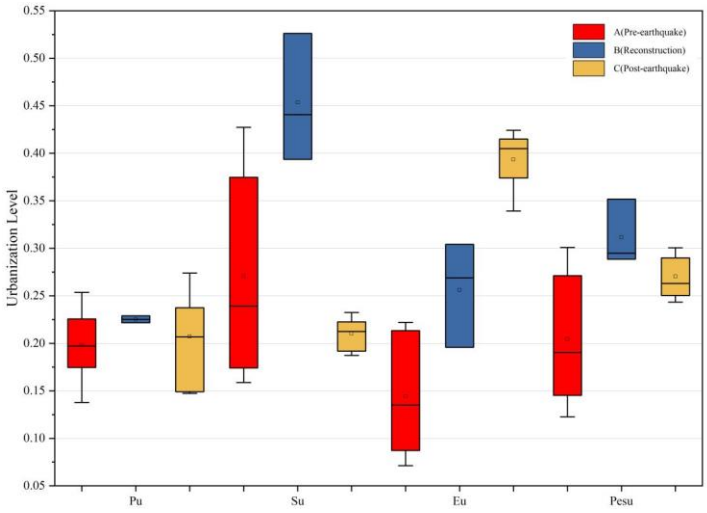


Fig 4- 10 Types of Urbanization distribution by stages for the Pingwu county

According to the urbanization index system mentioned above, all evaluation scores for Pengzhou county from 2001 to 2017 were obtained. The scattered plots chart in Figure 4-11 shows the change of index of Su, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the Pengzhou county increased overall from 2001 to 2017. Specifically, the value of Pu, Su, Eu, Pseu all increased from 2001 to 2007. However, this increasing trend was interrupted on Pu in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu declined to 0.330 (96.58% of 2007) in 2008. The results apparently showed that the Wenchuan earthquake played the negative effects immediately on the development of Su for the Pengzhou county. However, the value of Su, Eu, Pseu conversely increased to 0.257 (102.18% of 2007), 0.295 (106.95% of 2007), 0.294 (101.50% of 2007) in the same year, respectively. The results indicated that the Su, Eu, Pseu developed so well before the Wenchuan earthquake, so that there was a lag effect of the Wenchuan earthquake on these three types of urbanization. Similar as Qingchuan county, there was an increasing trend of

urbanization for Pengzhou county from 2008 to 2010. The value of Pu, Su, Eu, and Pseu all increased to 0.365, 0.322, 0.397, 0.361 in 2010, respectively. The result suggested that reconstruction measures boosted the recover and development of these types of urbanization, especially for the county like Pengzhou, which the value of Pseu was smaller than 0.3 before the Wenchuan earthquake. According to this result, reconstruction measures should be paid more attention for these counties that the Pseu was smaller than 0.3 before the natural disaster hit. Furthermore, the value of Pu, Su, Eu, and Pseu keeping increased from 2011 to 2017, suggesting that under the help of post-earthquake reconstruction measures, all types of urbanization had completed the transformation from external to internal power, resulting in sustained growth not only in 2011, but also in the rest of years. In addition, the value distribution of Pu, Eu, Su and Pseu was like a Chair-shape from 2008 to 2010. In terms of annual growth rate, index of Pu, Su, Eu and Pseu are all positive in the period 2001 to 2017. Among them, index of Eu experienced the fastest average annual growth rate (8.18%). In contrast, the lowest annual growth is index of Su with value 4.79%, which may be caused by the relative smaller of the built-up area of Pengzhou. In addition, the annual growth rate of index of Pu and Pseu are 5.50% and 6.24%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the Pengzhou county at different stages was shown in Figure 4-12. The average value of Pu, Su, Eu, and Pseu increased from pre-earthquake stage to reconstruction stage then raised from reconstruction stage to post-earthquake stage. In a word, there were stage characteristics on Pu, Su, Eu and Pseu for the Pengzhou county from 2001 to 2017. Furthermore, it is interesting to found that Pu, Su, Eu and Pseu had the same stage characteristics for Pengzhou county, suggesting that the receiving the assistant of reconstruction measures, four types of urbanization did not affect by the Wenchuan earthquake, but keep the increasing at all stages.

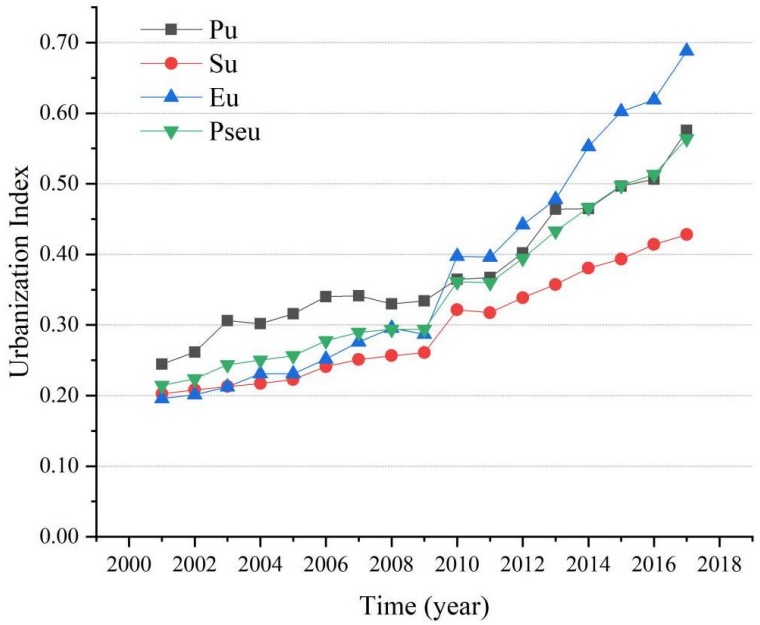


Fig 4- 11 Temporal variation of types of urbanization for the Pengzhou county from 2001 to 2017

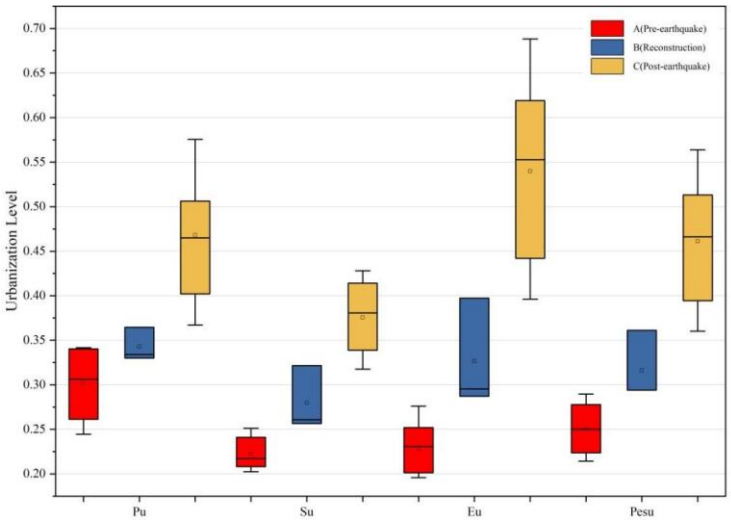


Fig 4- 12 Types of Urbanization distribution by stages for the Pengzhou county

According to the urbanization index system mentioned above, all evaluation scores for Mianzhu county from 2001 to 2017 were obtained. The scattered plots chart in Figure 4-13 shows the change of index of Pu, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the Mianzhu increased overall from 2001 to 2017. Specifically, the value of Pu, Su, Eu, Pseu all increased from 2001 to 2007. However, this increasing trend was interrupted in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu, Su, Eu, and Pseu all decreased to 0.365 (86.05% of 2007), 0.304 (95.83% of 2007), 0.430 (87.91% of 2007), 0.363 (89.34% of 2007) in 2008, respectively. The results apparently showed that the Wenchuan earthquake played the negative effects immediately on these types of urbanization for the Mianzhu county. Even under the assistant of reconstruction measures, the Pu, Su, Eu, and Pseu still decreased to the lowest value (2001 to 2017) in 2009. However, under the combined effects of reconstruction measures and self-recovery and development, the value of Pu, Su, Eu, and Pseu conversely increased to 0.365 (114.54% of 2009), 0.295 (104.68% of 2009), 0.426 (105.13% of 2009), 0.362 (107.99% of 2009) in 2010, respectively. Furthermore, the value of Pu, Su, Eu, and Pseu keeping increased from 2011 to 2017, suggesting that under the help of post-earthquake reconstruction measures, all types of urbanization had completed the transformation from external to internal power, resulting in sustained growth not only in 2011, but also in the rest of years. In addition, the value distribution of Pu, Eu, Su and Pseu for the Mianzhu county was like a U-shape from 2008 to 2010. In terms of annual growth rate, index of Pu, Su, Eu and Pseu for the Mianzhu county are all positive in the period 2001 to 2017. Among them, index of Su experienced the fastest average annual growth rate (5.46%). In contrast, the lowest annual growth is index of Pu with value 3.65%, which is majorly caused by the school-age student migrant of Mianzhu, where more convenient transportation conditions and closer location to the regional center of Mianyang. In addition, the annual growth rate of index of Eu and Pseu are 5.12% and 4.72%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the Mianzhu county at different stages was shown in Figure 4-14. The average value of Su, Eu, and Pseu increased from pre-earthquake stage to reconstruction stage then raised from reconstruction stage to post-earthquake stage. However, the mean value of Pu decreased from pre-earthquake stage to reconstruction stage, then increased from reconstruction stage to post-earthquake stage. In a word, there were stage characteristics on Pu, Su,

Eu and Pseu for the Mianzhu county from 2001 to 2017. But the stage pattern was different between Pu and the rest of types of urbanization. Furthermore, it is interesting to found that Su, Eu and Pseu had the same stage characteristics for Mianzhu county, indicating that these types of urbanization did not impact by the Wenchuan earthquake, but improved stages by stages. However, the stage features of Pu were shown in different result. The result suggested that the Pu of Mianzhu county destructive affected its development at the reconstruction stage, while recover and redevelopment at the post-earthquake stage.

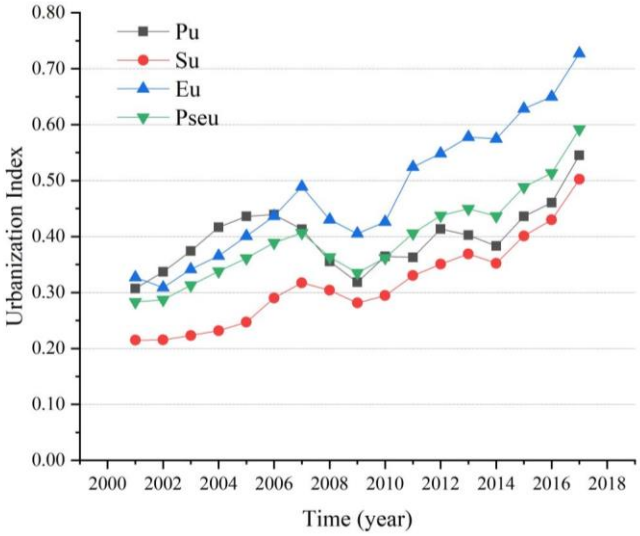


Fig 4- 13 Temporal variation of types of urbanization for the Mianzhu county from 2001 to 2017

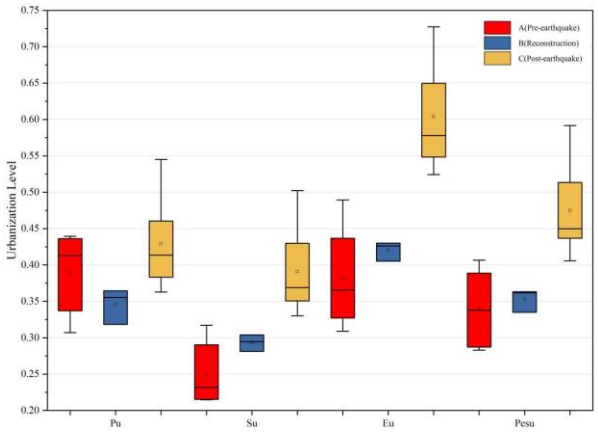


Fig 4- 14 Types of Urbanization distribution by stages for the Mianzhu county

According to the urbanization index system mentioned above, all evaluation scores for Maoxian county from 2001 to 2017 were obtained. The scattered plots chart in Figure 4-15 shows the change of index of Su, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the Maoxian county increased overall from 2001 to 2017. Specifically, the value of Su, Eu, Pseu all increased from 2001 to 2007, while Su increased from 2001 to 2005 then decreased since 2006. The result was due to the huge expansion of built-up area (2.11 times of 2005) with relative less growth on GDP (1.24 times of 2005), public expenditure (1.14 times of 2005) and etc. However, this

increasing trend was interrupted in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu, Eu, Pseu decreased to 0.322 (91.97% of 2007), 0.272 (90.53% of 2007), 0.254 (93.21% of 2007) in 2008, respectively. The results apparently showed that the Wenchuan earthquake played the negative effects immediately on the development of Pu, Eu, Pseu for the Maoxian county. However, the value of Su conversely increased to 0.168 (100.60% of 2007) in the same year, suggesting that there was a lag effect of the Wenchuan earthquake on this type of urbanization. During 2009 to 2010, the distribution of Pu, Su, Eu, Pseu was shown in different result. Among them, benefiting from the reconstruction measures, the Su, Eu, and Pseu all increased to 0.255 (151.35% of 2008), 0.398 (143.22% of 2008), 0.315 (123.89% of 2008) in 2010, respectively. However, the Pu slightly declined to 0.300 (93.18% of 2008) in 2010, which was caused by the insufficient of middle school (only one middle school rebuilt in Maoxian county) [5]. In 2011, Su decreased to 0.203 (79.86% of 2010), indicating that Su lost development power after the end of reconstruction measures. Under this context, reconstruction policies and measures for the Maoxian county should be extended the execution time to help Su recover and develop in time. Conversely, the Pu, Eu, Pseu still increased to 0.320 (106.71% of 2010), 0.446 (114.63% of 2010), 0.323 (102.73% of 2010) in 2011, suggesting that under the help of post-earthquake reconstruction measures, Pu, Eu, Pseu had completed the transformation from external to internal power, resulting in sustained growth not only in 2011, but also in the rest of years. Similar results were also shown for the Su from 2011 to 2017. In addition, the value distribution of Su, Eu, Pseu was like a slash-shape, while Pu showed like a reverse slash-shape from 2008 to 2010. In terms of annual growth rate, index of Pu, Su, Eu and Pseu are all positive in the period 2001 to 2017. Among them, index of Eu experienced the fastest average annual growth rate (6.90%). In contrast, the lowest annual growth is index of Su with value 2.43%, which may be caused by the terrain of MSAA. In addition, the annual growth rate of index of Pu and Pseu are 6.50% and 5.62%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the Maoxian county at different stages was shown in Figure 4-16. The average value of Pu, Su, Eu, and Pseu increased from pre-earthquake stage to reconstruction stage, then raised from reconstruction stage to post-earthquake stage. In a word, there were stage characteristics on Pu, Su, Eu and Pseu for the Maoxian county from 2001 to 2017. Moreover, it is interesting to found that Pu, Su, Eu and Pseu had the same stage characteristics for Maoxian county, suggesting that the receiving the assistant of reconstruction measures, four types of urbanization did not affect by the Wenchuan earthquake, but keep the increasing at all stages. However, compared to the mean value of Su at the reconstruction stage, that of Su at post-earthquake increased just little, indicating that reconstruction measures were effective assistant to Maoxian county.

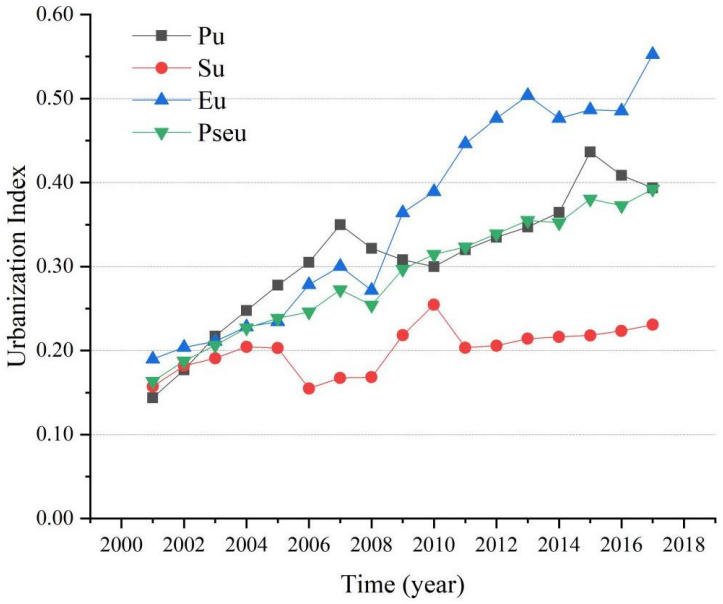


Fig 4- 15 Temporal variation of types of urbanization for the Maoxian county from 2001 to 2017

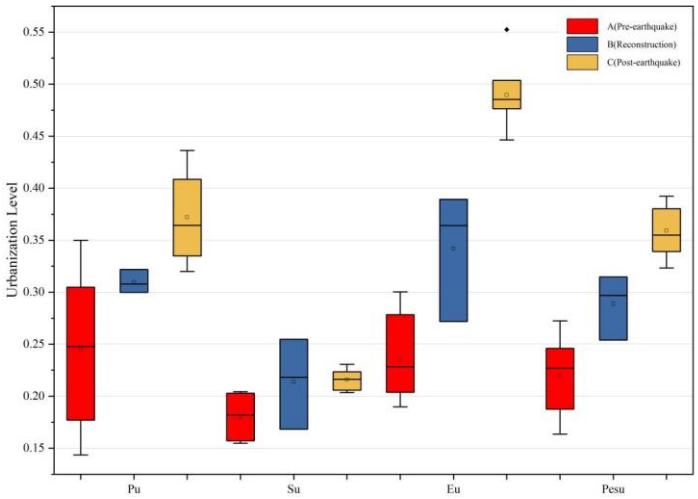


Fig 4- 16 Types of Urbanization distribution by stages for the Maoxian county

Temporal variation in the comprehensive levels of the urbanization system for the Dujiangyan county before and after the 2008 Wenchuan earthquake was shown in Figure 4-17. The comprehensive level of urbanization for the Dujiangyan county followed a gradual upward trend during the period of 2001 to 2017. The temporal variation in the urbanization of the Dujiangyan county can be obviously divided into three stages, including (i) pre-earthquake stage from 2001 to 2007, (ii) reconstruction stage from 2008-2010, and (iii) post-earthquake stage from 2011 to 2017. Space urbanization had a higher comprehensive level of urbanization than that of population urbanization before the 2008 Wenchuan earthquake, while reverse trend was observed since the end of reconstruction measures (2010). It was mainly due to the support of post-disaster reconstruction measures. The construction of a large number of infrastructure and public facilities attracted a large number of people into the city. The tertiary industry was accelerated by such policies and measures to increase employment and financial revenue.

It should be noted that the three dimensions at 2008 had lower urbanization level than 2007, and population–economy–space urbanization at 2008 decreased rapidly compared to the last year. It clearly indicated that the geological hazard rendered a low level of urbanization for the county region in a certain stage, but such inhibit effect diminished soon. This is because a series of measures and policies were implemented after the 2008 Wenchuan earthquake to reconstruct Dujiangyan county and mitigate geological hazards. For example, to ensure basic living conditions and revitalize economy, the State Council ratified Overall Planning for Post-Wenchuan Earthquake Restoration and Reconstruction State Council. Shanghai City provided substantial assistance in residential housing, infrastructure construction and public services for the post-disaster reconstruction of Dujiangyan county. By the end of 2010, Shanghai had offered relief funds of $1.26 billion for 117 post-disaster reconstruction projects in Dujiangyan county [6]. The total amount of investment and the area of geological disaster treatment both have been increased. With the aforementioned policies and measures, the comprehensive level of urbanization in Dujiangyan county increased rapidly by 34.49% after the Wenchuan earthquake (2008-2017), accompanied by the increase of built-up area for 12 square kilometers [7].

Box and whisker plot for the population-economy-space urbanization of the Dujiangyan county in different stages was presented in Figure 4-18. Within each box, the horizontal line represents the median value while the cross line means the average value. The lower edge of the box denotes the 25th percentile while the upper edge of the box represents the 75th percentile. It demonstrated that the urbanization level of population, economy and space all increased greatly after the earthquake, contributing to the increase of average value of the population-economy-space urbanization level. The results indicated that the urbanization process at the scale of county had obvious phase characteristics before and after the natural disasters.

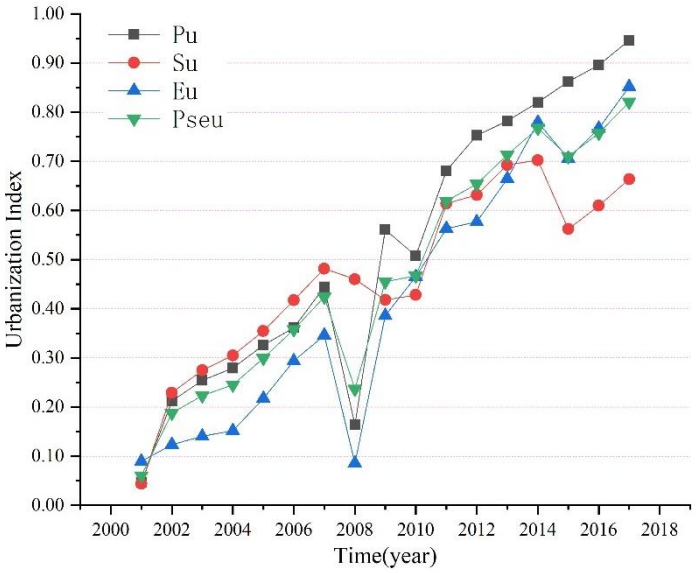


Fig 4- 17 Temporal variation of types of urbanization for the Dujiangyan county from 2001 to 2017

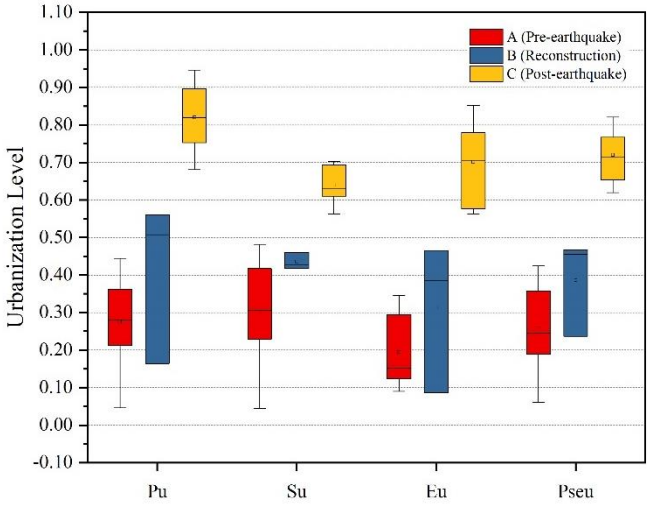


Fig 4- 18 Types of Urbanization distribution by stages for the Dujiangyan county

According to the urbanization index system mentioned above, all evaluation scores for Beichuan county from 2001 to 2017 were obtained. The scattered plots chart in Figure 4-19 shows the change of index of Pu, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the Beichuan county increased overall from 2001 to 2017. Specifically, the value of Pu, Su, Eu, Pseu all increased from 2001 to 2007. While Eu slightly declined to 0.194 from 2006 to 2007. However, this increasing trend varied in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu decreased to 0.280 (88.49% of 2007) in 2008. The results apparently showed that the Wenchuan earthquake played the negative effects immediately on the development of Pu for the Beichuan county. However, the value of Su, Eu, Pseu conversely increased to 0.561 (126.84% of 2007), 0.202 (104.43% of 2007), 0.348 (109.55% of 2007) in the same year, suggesting that the Su, Eu, Pseu developed so well before the Wenchuan earthquake, so that there were lag effects of the Wenchuan earthquake on these types of urbanization. In 2009, the Pu, Su, Pseu all decreased to the lowest point from 2001 to 2017, while Eu still increased in the same year. Especially, due to the rebuilt the downtown of Beichuan in another place, we could see that the Su declined dramatically from 0.561 in 2008 to 0.287 in 2010. Rebuilt a new county would inevitably lead to a large amount of investment in fixed assets, which lead to the Eu still increased in 2009. Furthermore, benefiting from the reconstruction measures, the Pu, Su, Eu, and Pseu all increased to 0.285 (105.34% of 2009), 0.287 (133.76% of 2009), 0.306 (126.91% of 2009), 0.292 (120.90% of 2009) in 2010, respectively. Moreover, although there was a fluctuation wave from 2011 to 2017, the value of Pu, Su, Eu, Pseu still increased in the same period. The results suggested that under the help of post-earthquake reconstruction measures, especially rebuilt the downtown in another place, Pu, Su, Eu, Pseu had got so much power to achieve the sustained growth in the rest of years. As the only one county, which was rebuilt in another place, special and continuous attentions should be paid to explore what happen on urbanization development in future research. The findings would greatly help to evaluate advantages and disadvantages between rebuilt in old place and that in another place. In addition, the value distribution of Pu, Su, Pseu was like a U-shape, while Eu was more like a slash-shape from 2008 to 2010. In terms of annual growth rate, index of Pu, Su, Eu and Pseu are all positive in the period 2001 to 2017. Among them, index of Eu experienced the fastest average annual growth rate (9.87%). In contrast, the lowest annual growth is index of Su with value 1.37%, which was the

results that the downtown was rebuilt in another place [8]. In addition, the annual growth rate of index of Pu and Pseu are 5.90% and 5.26%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the Beichuan county at different stages was shown in Figure 4-20. The average value of Pu, Eu, and Pseu increased from pre-earthquake stage to reconstruction stage then raised from reconstruction stage to post-earthquake stage. While the mean value of Su decreased from pre-earthquake stage to reconstruction stage, then declined from reconstruction stage to post-earthquake stage. In a word, there were stage characteristics on Pu, Su, Eu and Pseu for the Beichuan county from 2001 to 2017. Furthermore, it is interesting to found that Pu, Eu and Pseu had the same stage characteristics for Beichuan county, indicating that the receiving the assistant of reconstruction measures, these types of urbanization did not affect by the Wenchuan earthquake, but keep the improving stages by stages. However, the stage pattern of Su declined from pre-earthquake stage to reconstruction stage, till to post-earthquake stage, which was induced by the replace rebuilt the built-up area of Beichuan county.

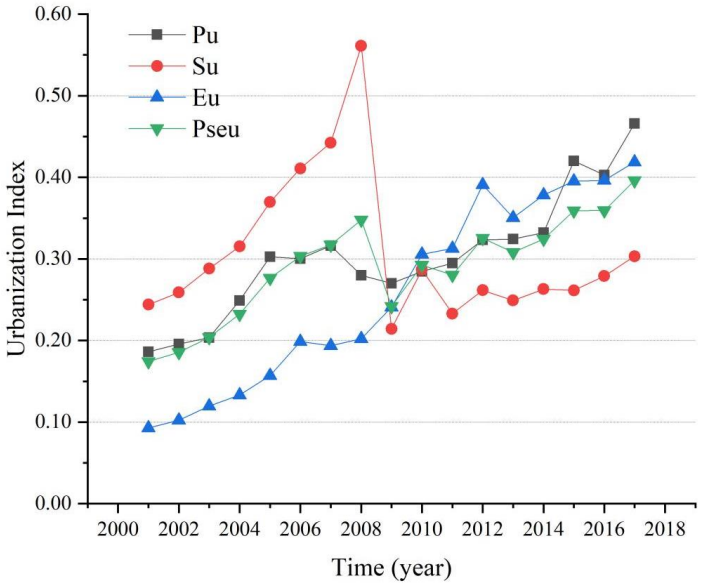


Fig 4- 19 Temporal variation of types of urbanization for the Beichuan county from 2001 to 2017

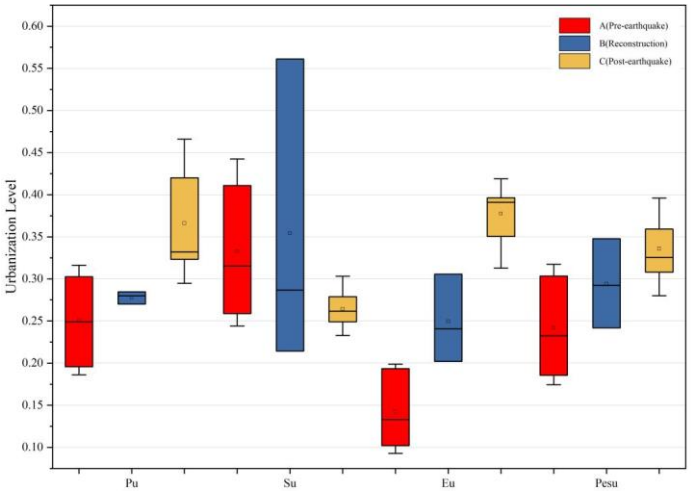


Fig 4- 20 Types of Urbanization distribution by stages for the Beichuan county

According to the urbanization index system mentioned above, all evaluation scores for Anxian county from 2001 to 2017 were obtained. The scattered plots chart in Figure 4-21 shows the change of index of Pu, Su, Eu, and Pseu, respectively. It is shown that index of Pu, Su, Eu and Pseu of the Anxian increased overall from 2001 to 2017. Specifically, the value of Pu, Su, Eu, Pseu all increased from 2001 to 2007. While there was a fluctuated point of Eu in 2005, which was caused by the suddenly increasing of primary industry. However, this increasing trend was varied in 2008, which was the year that the Wenchuan earthquake hit. The value of Pu, Eu, and Pseu all decreased to 0.236 (77.78% of 2007), 0.137 (86.16% of 2007), 0.212 (91.45% of 2007) in 2008, respectively. The results apparently showed that the Wenchuan earthquake played the negative effects immediately on types of urbanization for the Anxian county. However, the value of Su conversely increased to 0.264 (112.81% of 2007) in the same year, suggesting that the Su developed so well before the Wenchuan earthquake, so that there were lag effects of the Wenchuan earthquake on this type of urbanization. This could also be shown from the fact, negative effects were driven from the Wenchuan earthquake, that the value of Su dropped to its lowest value in 2009. Under the combined effects of reconstruction measures and self-recovery and development, the value of Su, Eu, and Pseu increased to 0.272 (115.49% of 2009), 0.232 (142.67% of 2009), 0.268 (108.10% of 2009) in 2010, respectively. However, the Pu increased to 0.347 in 2009 then decreased to 0.302 in 2010, which was result in the 24 hospitals rebuilt projects. Furthermore, the value of Pu, Eu, and Pseu keeping increased from 2010 to 2017, suggesting that under the help of post-earthquake reconstruction measures, all types of urbanization had completed the transformation from external to internal power even since the second reconstruction year. While Su increased from 2010 to 2012, then decreased from 2013 to 2017. The result was caused by the suddenly shortage of fixed asset investment. In addition, the value distribution of Eu and Pseu was like a slash-shape from 2008 to 2010, while Su showed like a U-shape and Pu showed like a reverse U-shape. In terms of annual growth rate, index of Pu, Su, Eu and Pseu are all positive in the period 2001 to 2017. Among them, index of Eu experienced the fastest average annual growth rate (8.67%). In contrast, the lowest annual growth is index of Su with value 2.33%, which was result in the location constraint that Anxian county adjacent the Mianyang downtown. In addition, the annual growth rate of index of Pu and Pseu are 4.50% and 5.01%, respectively.

Box and whisker plot for the Pu, Su, Eu and Pseu of the Anxian county at different stages was

shown in Figure 4-22. The average value of Pu, Su, Eu, and Pseu increased from pre-earthquake stage to reconstruction stage then raised from reconstruction stage to post-earthquake stage. In a word, there were stage characteristics on Pu, Su, Eu and Pseu for the Anxian county from 2001 to 2017. Furthermore, it is interesting to found that Pu, Su, Eu and Pseu had the same stage characteristics for Anxian county, suggesting that the receiving the assistant of reconstruction measures, four types of urbanization did not affect by the Wenchuan earthquake, but still keep the ameliorating stages by stages.

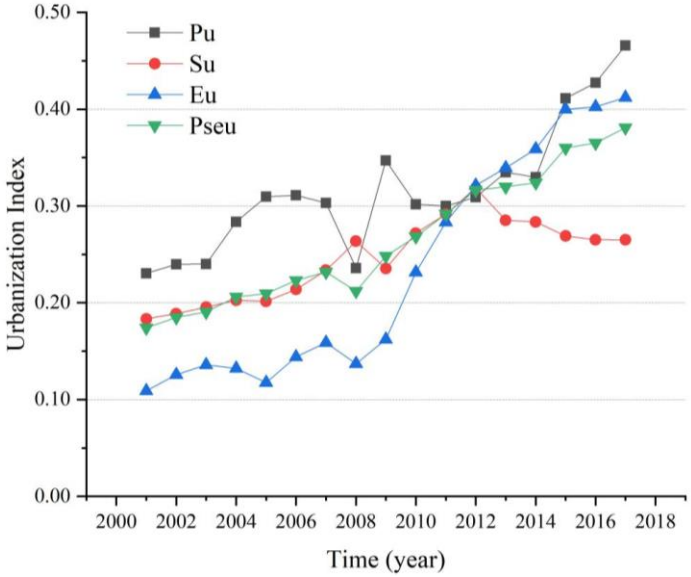


Fig 4- 21 Temporal variation of types of urbanization for the Anxian county from 2001 to 2017

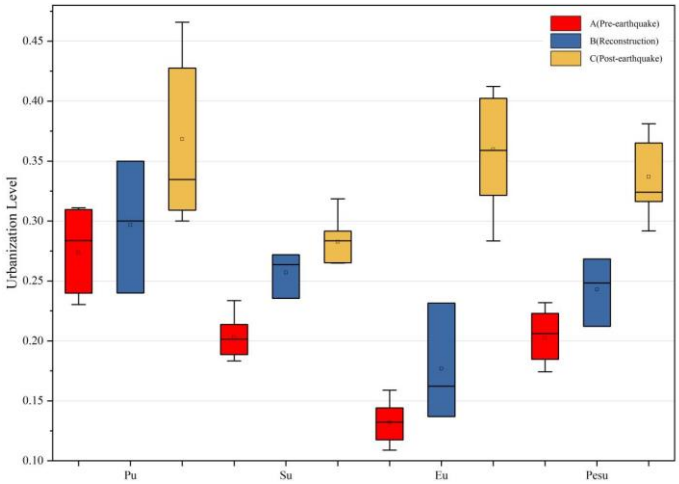


Fig 4- 22 Types of Urbanization distribution by stages or the Anxian county

4.3 Spatial distribution of urbanization before and after the Wenchuan earthquake

4.3.1 Spatial distribution of urbanization for the most severely affected area

After examine the temporal distribution of urbanization for MSAA, we also tested the spatial distribution at the regional scale. To show the spatial distribution of MSAA before and after the Wenchuan earthquake, we evaluated the variation of urbanization by Chengdu, Deyang, Mianyang,

Guangyuan and MSAA. In our cases, different counties were deducted from their respective prefecture-level cities.

To show the spatial distribution of population urbanization (Pu), we divided these prefecture-level cities, Chengdu, Deyang, Mianyang, Guangyuan, MSAA, into low-level Pu group, medium-level Pu group, high-level Pu group by Nature Break. As shown in Figure 4-23, the mean values of Pu for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Chengdu and MSAA were evaluated as the high-level Pu group. While Mianyang was classified as medium-level Pu group. Deyang and Guangyuan were grouped as low-level Pu group. The results indicated that the level of Pu for the MSAA and Chengdu were higher than Deyang, Mianyang and Guangyuan before the Wenchuan earthquake. At the reconstruction stage, the high-level Pu group only left Chengdu. MSAA and Mianyang were classified as medium-level group, while Deyang and Guangyuan did not change their Pu level. The results showing that the Wenchuan earthquake weakened the Pu level of MSAA. At the post-earthquake stage, MSAA did not change its Pu level, indicating that reconstruction measures played positive effects on Pu level. In a word, after the Wenchuan earthquake hit, the Pu level of MSAA had declined from high-level Pu group into medium-level Pu group.

Similarly, we also tested space urbanization (Su) among these prefecture-level cities by Natural Break. As shown in Figure 4-24, the mean values of Su for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Deyang was the only prefecture-level city that evaluated as the high-level Su group. While MSAA was assessed as low-level Su group. At the reconstruction stage, MSAA did not affect by the Wenchuan earthquake for its Su level group still kept in the low-level Su group. At the same time, Mianyang degraded into low-level Su group, while Guangyuan upgraded into medium-level group. At the post-earthquake stage, MSAA upgraded into medium-level Su group for huge external reconstruction investment. Chengdu also showed the same result. The results showing that the Wenchuan earthquake indirectly strengthened the Su level of MSAA by the reconstruction measures. In a word, after the Wenchuan earthquake hit, the Su level of MSAA had upgraded from low-level Su group into medium-level Su group.

In terms of economy urbanization (Eu), spatial distribution at the prefecture-level cities were also presented. As shown in Figure 4-25, the mean values of Eu for pre-earthquake stage, reconstruction stage, post-earthquake stage were shown. At the pre-earthquake stage, MSAA and Chengdu were the prefecture-level cities that evaluated as the high-level Eu group. At the reconstruction stage, MSAA degraded into medium-level Eu group and Mianyang fell into low-level Eu group. The results indicated that the Wenchuan earthquake weakened the Eu level of MSAA. At the post-earthquake stage, MSAA keeping degraded into low-level Eu group, indicating that even received external reconstruction resources, Eu level of MSAA still degenerated after the Wenchuan earthquake. In a word, after the Wenchuan earthquake hit, the Eu level of MSAA had degraded from high-level Eu group into low-level Eu group.

With respect to population-space-economy urbanization (Pseu), spatial distribution at the prefecture-level cities were also presented. As shown in Figure 4-26, the mean values of Pseu for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Chengdu was the only prefecture-level city that evaluated as the high-level Pseu

group. While MSAA was assessed as medium-level Pseu group. At the reconstruction stage, MSAA did not affect by the Wenchuan earthquake for its Pseu level group still keep in the medium-level Pseu group. At the same time, Mianyang degraded into low-level Pseu group. At the post-earthquake stage, MSAA keeping degraded into low-level Pseu group, indicating that even received external reconstruction resources, Pseu level of MSAA still degenerated after the Wenchuan earthquake. In a word, after the Wenchuan earthquake hit, the Pseu level of MSAA had degraded from medium-level Pseu group into low-level Pseu group.

Table 4- 1 Classification of urbanization for MSAA

Classification	Before and after the Wenchuan earthquake	Cities	Types of urbanization
Become better	Low-level Su group -Medium-level Su group	MSAA	Su
Not change	-	-	-
Become worse	High-level Pu group -Medium-level Pu group	MSAA	Pu
	High-level Eu group -Low-level Eu group	MSAA	Eu
	Medium-level Pseu group -Low-level Pseu group	MSAA	Pseu

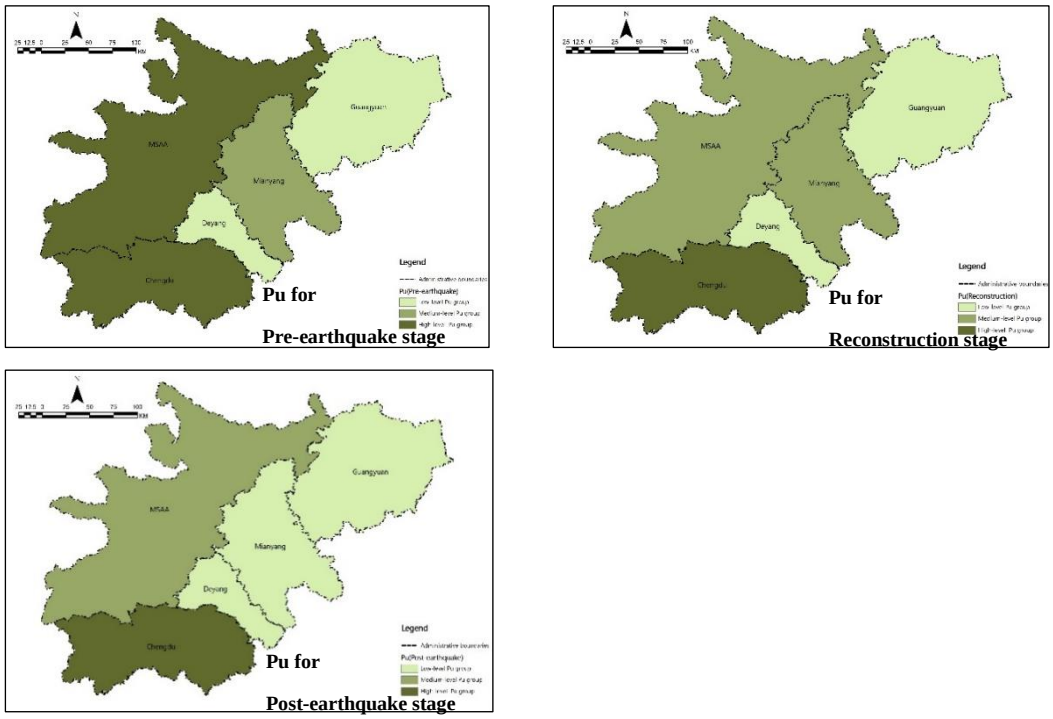
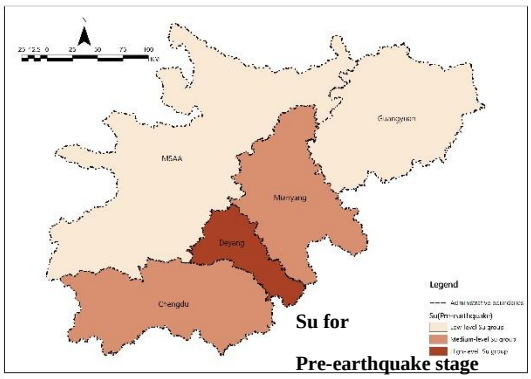
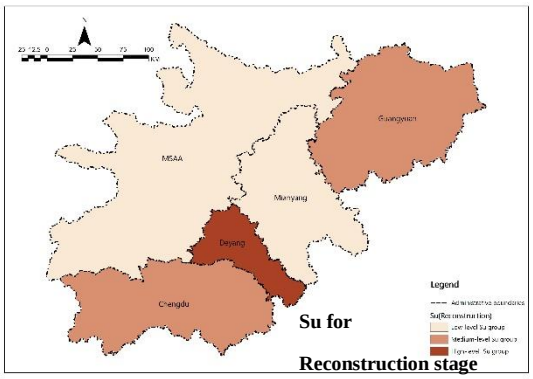


Fig 4- 23 Spatial distribution of Pu by stages for the MSAA





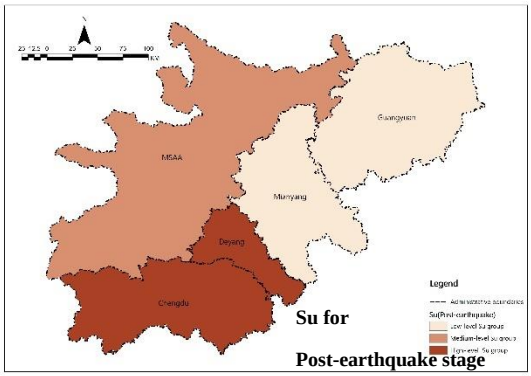
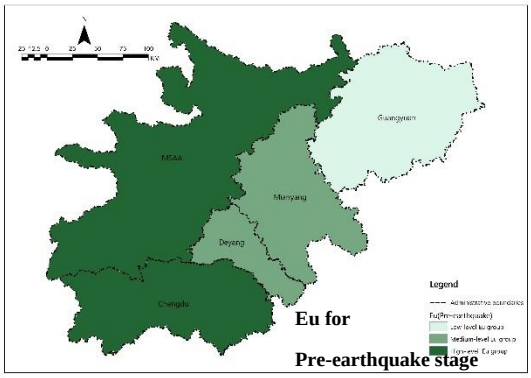
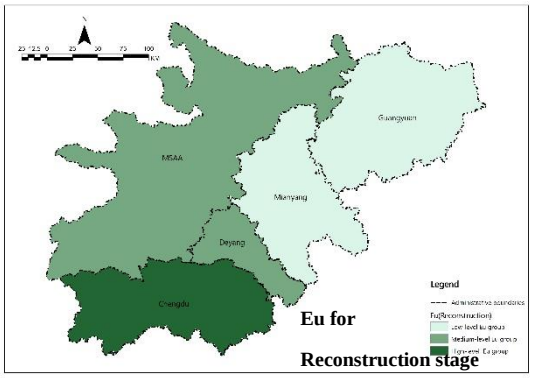


Fig 4- 24 Spatial distribution of Su by stages for the MSAA





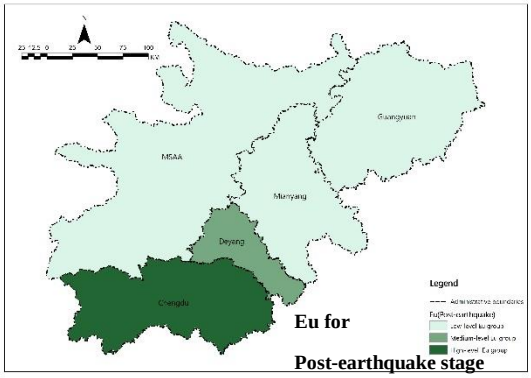


Fig 4- 25 Spatial distribution of Eu by stages for the MSAA

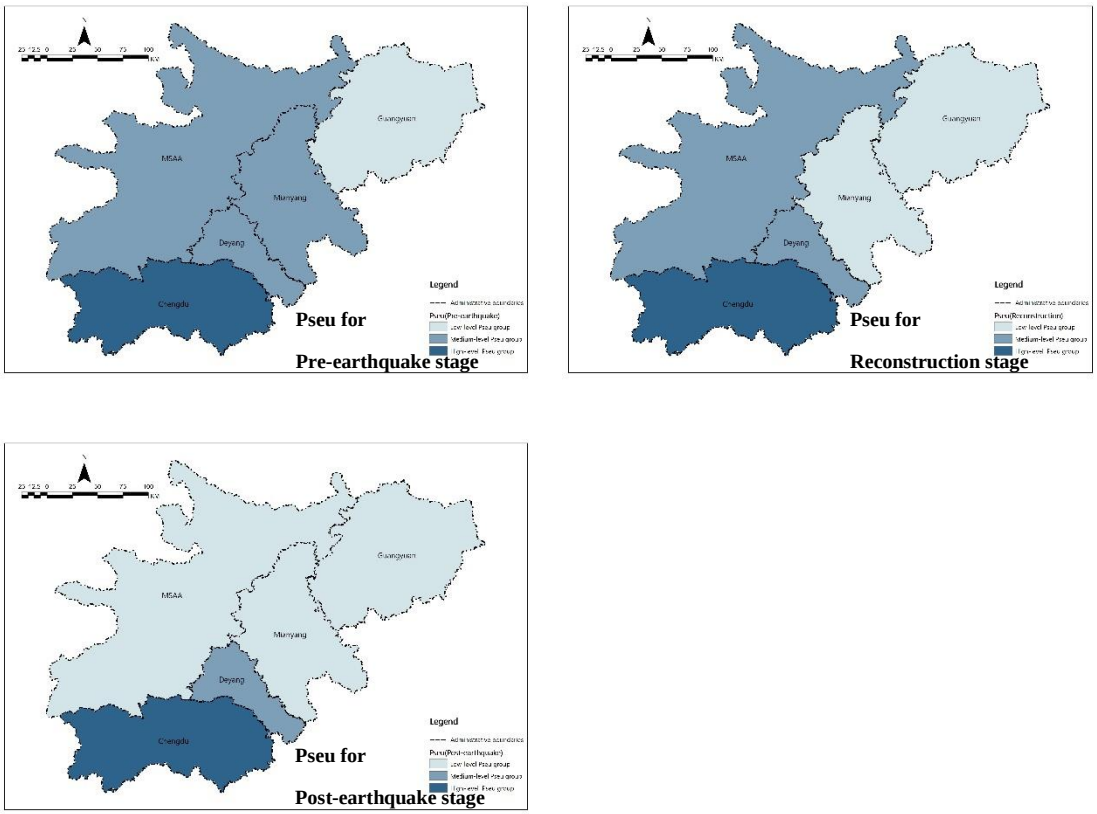


Fig 4- 26 Spatial distribution of Pseu by stages for the MSAA

4.3.2 Spatial distribution of urbanization for ten counties

After examine the temporal distribution of urbanization for ten counties, we also tested the spatial distribution at the county scale. To show the spatial distribution of the ten counties before and after the Wenchuan earthquake, we evaluated the variation of urbanization by Wenchuan, Dujiangyan, Pengzhou, Shifang, Mianzhu, Anxian, Maoxian, Beichuan, Pingwu and Qingchuan.

To show the spatial distribution of population urbanization (Pu), we divided these ten counties into low-level Pu group, medium-level Pu group, high-level Pu group by Nature Break. As shown in Figure 4-27, the mean values of Pu for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Wenchuan, Shifang and Mianzhu were evaluated as the high-level Pu group. While Dujiangyan, Pengzhou, Anxian, Maoxian, Beichuan were classified as medium-level Pu group. Pingwu and Qingchuan were grouped as low-level Pu group. At the reconstruction stage, the high-level Pu group was composed by Wenchuan, Dujiangyan, Shifang. There was no change in the low-level Pu group. The results showing that the Wenchuan earthquake weakened the Pu level of Mianzhu, but strengthened the Pu level of Dujiangyan. It was also shown that within the MSAA, the Wenchuan earthquake was not play the same effects at the county level. At the post-earthquake stage, Dujiangyan was the only one county classified in the high-level Pu group, indicating that Dujiangyan got the biggest reconstruction effects on Pu level. In a word, after the Wenchuan earthquake hit, there was spatial distribution variation the Pu level at the county level. Among them, Wenchuan, Shifang, and Mianzhu had declined from high-level Pu group into medium-level Pu group, while Dujiangyan upgraded from medium-level Pu group into high-level Pu group.

To show the spatial distribution of space urbanization (Su), we divided these ten counties into low-level Su group, medium-level Su group, high-level Su group by Nature Break. As shown in Figure 4-28, the mean values of Su for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Wenchuan, Shifang, Mianzhu, Beichuan and Pingwu were evaluated as the high-level Su group. While Dujiangyan, Pengzhou, Anxian, Maoxian, were classified as medium-level Su group. Only Qingchuan was grouped as low-level Su group. At the reconstruction stage, the high-level Su group was composed by Wenchuan, Dujiangyan and Pingwu. Shifang, Beichuan and Qingchuan degraded into medium-level Su group. In addition, Pengzhou, Maoxian, Mianzhu and Anxian degraded into low-level Su group. The results showing that the effects of Wenchuan earthquake were different with counties in the MSAA. Surprisingly, Dujiangyan and Qingchuan upgraded into high-level Su group and medium-level Su group, respectively. The reason for the increased level of Su in Dujiangyan is that other counties were affected by the Wenchuan earthquake and decreased a lot at the reconstruction stage. The reason for the increased in Qingchuan county was that the pre-earthquake Su level was very low and was not greatly affected by the earthquake. Furthermore, reconstruction measures should be designed for counties which was relative lower in Su level to fast recovery the Su level. At the post-earthquake stage, Dujiangyan, Pengzhou, Shifang, Mianzhu were evaluated as the high-level Su group, indicating that these counties got the biggest reconstruction effects on Su level. The results could be also reflected on the value of Su for these counties in 2017, that these four counties were the top 4 Su value counties. In a word, after the Wenchuan earthquake hit, there was spatial distribution variation the Su level at the county level. Among them, Wenchuan and Beichuan had declined from high-level Su group into medium-level Su group. At the same time, Pingwu degraded from high-level Su group into low-level Su group, and Maoxian also declined from medium-level Su group into low-level Su group. Conversely, Dujiangyan and Pengzhou upgraded from medium-level Su group into high-level Su group.

To show the spatial distribution of economy urbanization (Eu), we divided these ten counties into low-level Eu group, medium-level Eu group, high-level Eu group by Nature Break. As shown in Figure 4-29, the mean values of Eu for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Wenchuan, Shifang and Mianzhu were evaluated as the high-level Eu group. While Dujiangyan, Pengzhou and Maoxian were classified as medium-level Eu group. The rest of four counties were grouped as low-level Eu group. At the reconstruction stage, the high-level Eu group was only left Wenchuan. Shifang and Mianzhu were degraded into medium-level Eu group. The results showing that the effects of Wenchuan earthquake were different with counties in the MSAA. The Wenchuan earthquake only played negative effects to Shifang and Mianzhu, showing that industrial-dominated counties are more vulnerable to earthquakes. Under that context, reconstruction measures should be designed for industrial-dominated counties to fast recovery their Eu level. At the post-earthquake stage, Wenchuan, Dujiangyan and Shifang were evaluated as the high-level Eu group. While the rest of counties did not change their Eu level. In a word, after the Wenchuan earthquake hit, there was spatial distribution variation the Eu level at the county level. Among them, Dujiangyan upgraded from medium-level Eu group into high-level Eu group. While Mianzhu degraded from high-level Eu group into medium-level Eu group.

To present the spatial distribution of economy urbanization (Pseu), we divided these ten counties into low-level Pseu group, medium-level Pseu group, high-level Pseu group by Nature Break. As

shown in Figure 4-30, the mean values of Pseu for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Wenchuan, Shifang and Mianzhu were evaluated as the high-level Pseu group. While Dujiangyan, Pengzhou, Maoxian, Anxian, Beichuan and Pingwu were classified as medium-level Pseu group. Only Qingchuan was grouped as low-level Pseu group. At the reconstruction stage, the high-level Pseu group was shown as Wenchuan, Dujiangyan, and Shifang. Anxian and Mianzhu were degraded into low-level Pseu group and medium-level Pseu group, respectively. While Dujiangyan upgraded into high-level Pseu group. The results showing that the effects of Wenchuan earthquake were different with counties in the MSAA. The Wenchuan earthquake only played negative effects to Anxian and Mianzhu, showing that the comprehensive urbanization level of these two counties is more vulnerable to earthquakes. At the post-earthquake stage, only Dujiangyan was evaluated as the high-level Pseu group. While Wenchuan and Shifang degraded into medium-level Pseu group. Maoxian, Beichuan, Pingwu declined into low-level Pseu group. In a word, after the Wenchuan earthquake hit, there was spatial distribution variation the Pseu level at the county level. Among them, Dujiangyan upgraded from medium-level Pseu group into high-level Pseu group. While Wenchuan, Shifang, Mianzhu, Maoxian, Anxian, Beichuan, Pingwu degraded one level Pseu group.

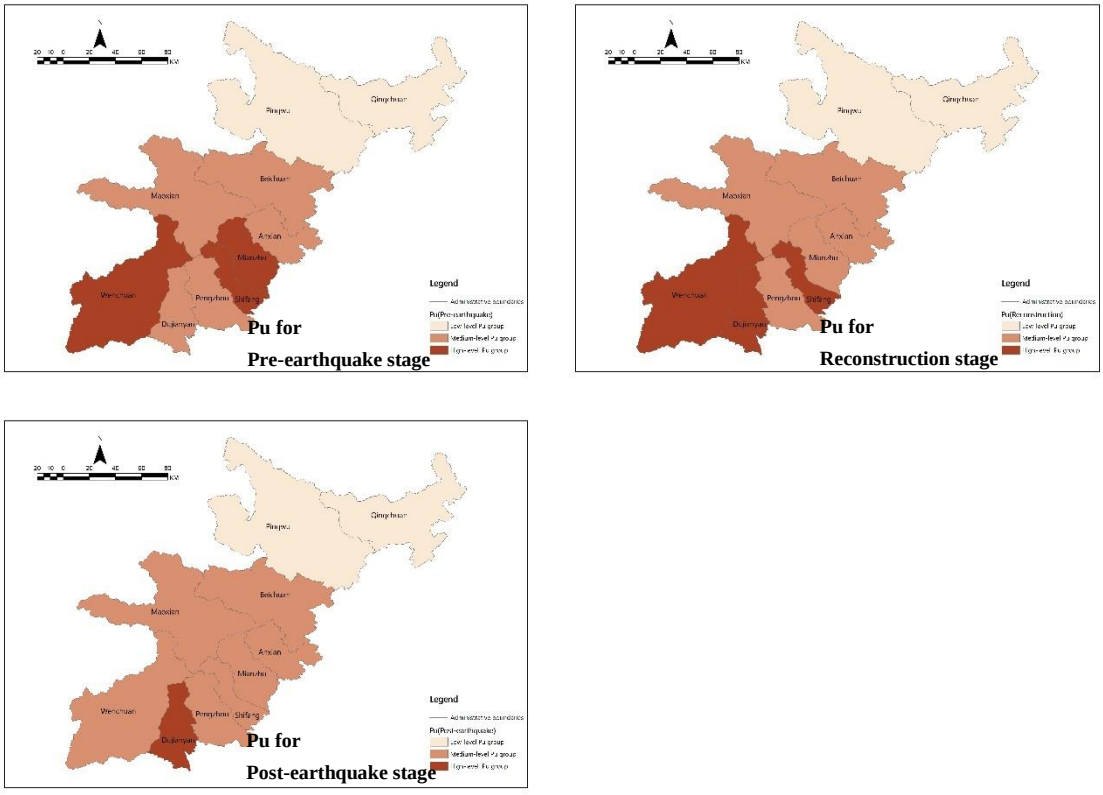
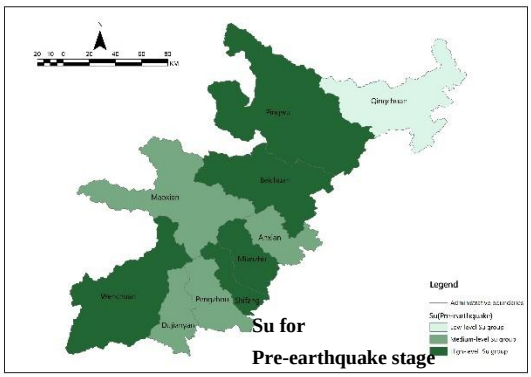
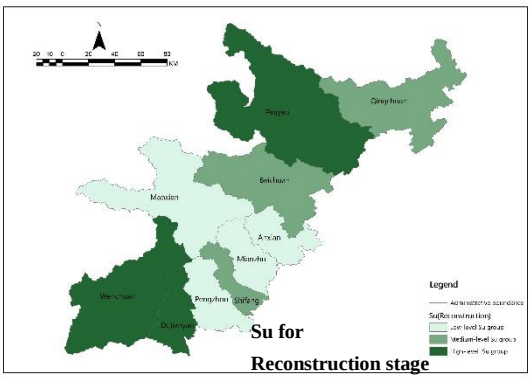


Fig 4- 27 Spatial distribution of Pu by stages for ten counties





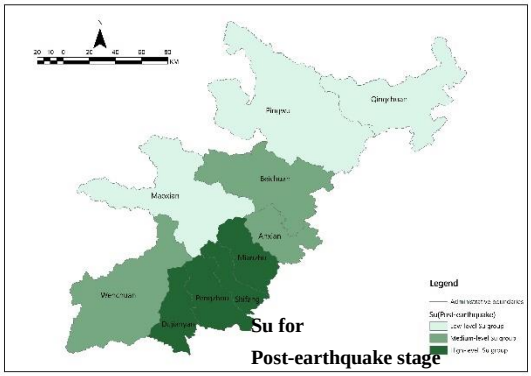
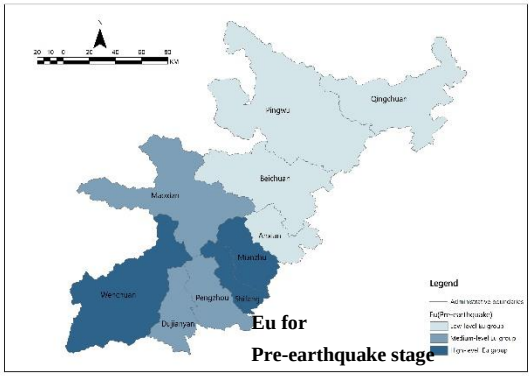
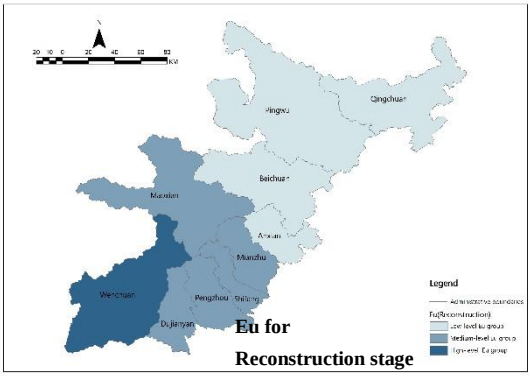


Fig 4- 28 Spatial distribution of Su by stages for ten counties





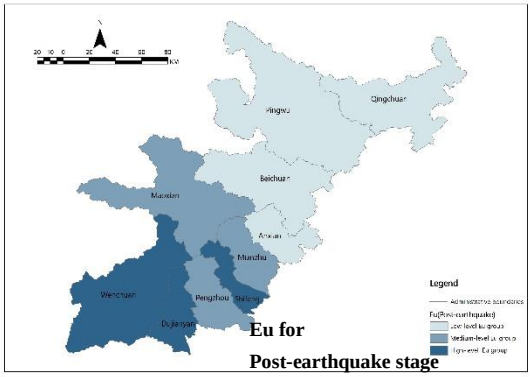


Fig 4- 29 Spatial distribution of Eu by stages for ten counties

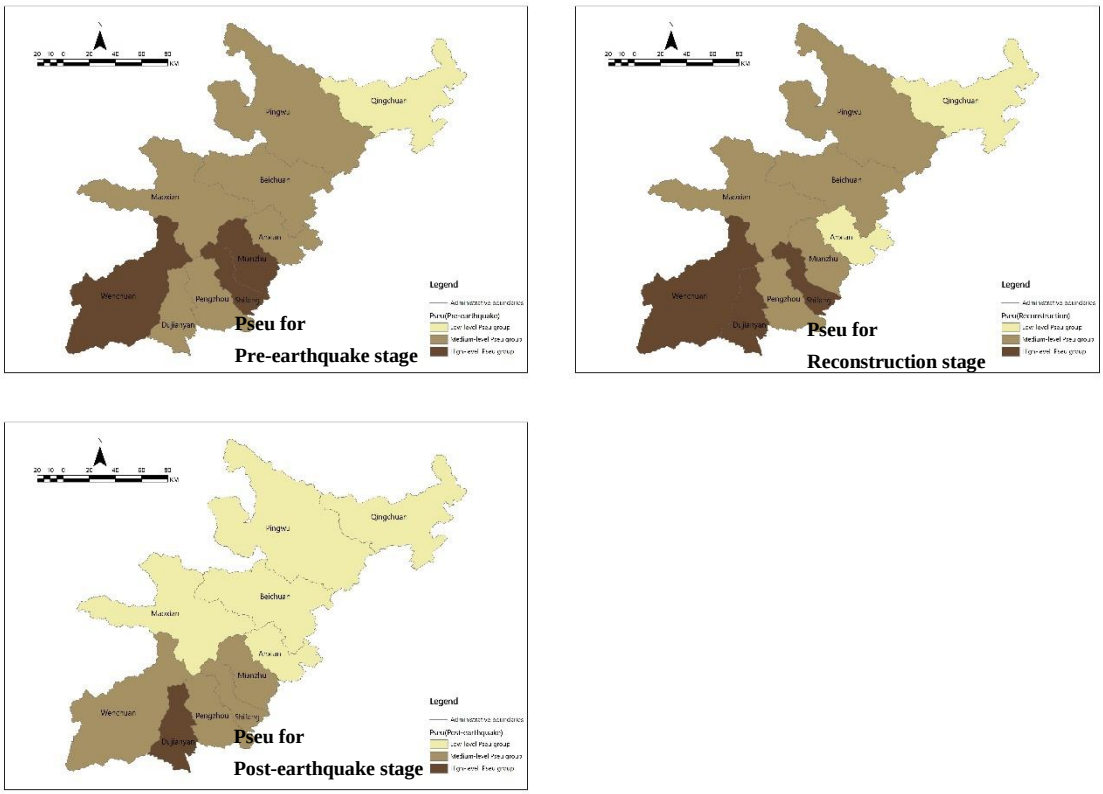


Fig 4- 30 Spatial distribution of Pseu by stages for ten counties

4.4 Summary

In this chapter, taking the MSAA and ten counties as research objects, we examined the temporal and spatial variation on Pu, Su, Eu and Pseu at the MSAA scale and county scale, respectively. The main conclusions of variation of urbanization and its characteristics under the Wenchuan earthquake context from 2001 to 2017 can be summarized as follows:

In terms of MSAA, (1) the value of Pu, Su, Eu and Pseu all increased from 2001 to 2017. Specifically, (2) the value of Pu, Eu, and Pseu all decreased in 2008, while due to the lag effect of Wenchuan earthquake, the value of Su conversely increased in the same year. Similarly, (3) different results were also shown in 2009 and 2011. In 2009, the Pseu and Su still declined to the lowest point (among 2001 to 2017) in 2009, while the value of Pu and Pseu raised to 0.333 (112.77% of 2008) and 0.312 (101.60% of 2008) in 2009. In 2011, due to the different impact of reconstruction measures, Su declined to 0.308 (82.66% of 2010) in 2011, while Pu, Eu and Pseu still increased in the same year. In addition, (4) the value distribution of Su was like a U-shape from 2008 to 2010. Furthermore, (5) Eu experienced the fastest annual growth rate (6.95%), while the lowest annual growth was index of Su with value 4.75%. Moreover, (6) the urbanization process at the scale of MSAA had obvious phase characteristics before and after the natural disasters. With respect to spatial distribution, (7) the variation of urbanization level for MSAA was shown different results on comprehensive urbanization level and subsystem urbanization level. After the Wenchuan earthquake hit, (8) the level of Su had become better, while Pu, Eu, and Pseu had become worse.

With respect to the ten severely affected counties, similar, (9) the value of Pu, Su, Eu and Pseu

for these counties all increased from 2001 to 2017. However, (10) there was lag effect on different types of urbanization for different counties. Specifically, the Wenchuan earthquake played lag effect on Su in the Wenchuan, Qingchuan, Pingwu, Pengzhou, Maoxian, Beichuan, and Anxian, while (11) the same result was also found on Eu in the Wenchuan, Pengzhou and Beichuan. In the meanwhile, (12) Pseu was shown the same result in the Wenchuan, Qingchuan, Pengzhou and Beichuan. Especially, (13) variation of these types of urbanization was different during the reconstruction years (2008 to 2010). Among them, (14) Pu showed the U-shape in the Wenchuan, Shifang, Pingwu, Mianzhu, Beichuan. In addition, (15) the distribution of Pu was shown like a Slash-shape in the Qingchuan, while that was shown like (17) a reverse Slash-shape in the Maoxian. Especially, (18) a Chair-shape was shown for the Pengzhou during the same period. In terms of Su, (19) Su showed the U-shape in the Wenchuan, Shifang, Pingwu, Mianzhu, Beichuan, Dujangyan, and Anxian, while (20) the Slash-shape of Su was shown in the Qingchuan, Maoxian from 2008 to 2010. Especially, (21) a Chair-shape was shown for the Pengzhou during the same period. With respect to Eu, (22) Eu showed the U-shape in the Wenchuan, Shifang, Mianzhu, while (23) the Slash-shape of Eu was shown in the Pingwu, Qingchuan, Maoxian, Beichuan, Dujiangyan, and Anxian from 2008 to 2010. In addition, (24) the distribution of Eu was shown like a Chair-shape in the Pengzhou during the same period. In terms of Pseu, (25) Pseu showed the U-shape in the Wenchuan, Shifang, Mianzhu, and Beichuan, while (26) the Slash-shape of Pseu was shown in the Qingchuan, Pingwu, Maoxian, Anxian from 2008 to 2010. Especially, (27) a Chair-shape was shown for the Pengzhou during the same period. In terms of spatial distribution, (28) the ten counties which are distributed in the MSAA, showed different variation of urbanization after the Wenchuan earthquake.

With respect to the effects of reconstruction measures, different results were shown on different types of urbanization in different counties. The result showed that (29) Pu of Pingwu lost the development power after the end of reconstruction measures, while (30) Eu of Qingchuan showed the same result, which was valuable to consider extend the implement time of reconstruction policies. In addition, (31) Su of Wenchuan, Qingchuan, Pingwu, Maoxian showed the same result in 2011. At last, (32) Pseu lost the development power for the Wenchuan, Qingchuan, Pingwu, which should be further explore in the future.

Specifically, the annual growth of urbanization varied in these ten counties. Among these ten counties, (33) there were two major modes on the urbanization annual growth rate. (34) One mode, such as Wenchuan, Pingwu, Pengzhou, Maoxian, Beichuan, Anxian, showed that the lowest annual growth rate was shown on Su, while the highest one was shown on Eu. (35) Another mode, such as Shifang, Qingchuan, Mianzhu, showed that the smallest annual growth rate was shown on Su, while the biggest one was shown on Eu.

Reference

[1] Parker R, Densmore A, Rosser N. Mass wasting triggered by the 2008 Wenchuan earthquake is greater than orogenic growth. Nature Geosci 2011;4:449–452. https://doi.org/10.1038/ngeo1154

[2] Jia D, Li YQ, Lin AM, Wang MM, Chen W, Wu XJ, Ren ZK, Zhao Y, Luo L.Structural model of 2008 Mw 7.9 Wenchuan earthquake in the rejuvenated Longmen Shan thrust belt, China. Tectonophysics 2012;491(1-4):174-184.

[3] Cui P, Dang C, Zhuang JQ. Landslide-dammed lake at Tangjiashan, Sichuan province, China (triggered by the Wenchuan Earthquake, May 12, 2008): risk assessment, mitigation strategy, and lessons learned. Environ Earth Sci 2012:65:1055–1065. https://doi.org/10.1007/s12665-010-0749-2.

[4] Ge Y, Chen X, Zhuang J, Zhu X. Characteristics, Impacts and Risks of Dammed Lakes Induced by Debris Flows at the Wenchuan Earthquake Areas. Journal of Water Resource and Protection 2014;6:1574-1588. https://doi: 10.4236/jwarp.2014.617144.

[5] Du Q. 5.12 Research on the sustainable development of the county economy in the severely hit Wenchuan earthquake. Science Press: Beijing, 2020.

[6] Http://www.shanghai.gov.cn/nw2/nw2314/nw9819/nw9820/u21aw547518.html (accessed on 20 March 2022).

[7] Dujiangyan Bureau of Statistics. Dujiangyan County National Economic and Social Development Statistics Bulletin; Dujiangyan Bureau of Statistics: Dujiangyan, China, 2019.

[8] https://www.amusingplanet.com/2014/06/beichuan-preserved-ruins-of-earthquake.html (accessed on 19 March 2022).

Chapter 5

Distribution of Coupling and coordination degree of urbanization before and after the Wenchuan earthquake

CHAPTER FIVE: DISTRIBUTION OF COUPLING AND COORDINATION DEGREE OF URBANIZATION BEFORE AND AFTER THE WENCHUAN EARTHQUAKE

Distribution of Coupling and coordination degree of urbanization before and after the Wenchuan earthquake

5.1 Introduction 5-1

5.2 Temporal distribution of coupling and coupling coordination degree before and after the Wenchuan earthquake 5-1

5.3.1 Temporal distribution of coupling and coupling coordination degree for the most severely affected area 5-1

5.3.2 Temporal distribution of coupling and coupling coordination degree for ten counties 5-3

5.3 Spatial distribution of coupling and coupling coordination degree before and after the Wenchuan earthquake 5-28

5.3.1 Spatial distribution of coupling and coupling coordination degree for the most severely affected area 5-28

5.3.2 Spatial distribution of coupling and coupling coordination degree for ten counties.. 5-30

5.4 Summary 5-33

Reference 5-35

5.1 Introduction

What is urbanization? According to previous studies, urbanization is the way that economy realizes a spatial transformation from rural to cities [1]. Specifically, this spatial transformation means the transformation into non-agricultural economy structure, which results in production factors flow and concentration from rural area to urban area [2]. The urbanization could be also believed that urbanization is high levels of concentration of urban population, especially for developing countries over the past half century [1]. Furthermore, urbanization is also the transformation of people's living which is associated with transportation and other infrastructure [3]. In addition, the urbanization is also considered as the process of agricultural land transformation into non-agricultural land [4], indicating that rural landscape converted into urban views [5]. In a word, urbanization could be majorly considered as the transformation on economy, population, land use and land cover change.

During the process of urbanization development, do the relationship between these three subsystems of urbanization become stronger or weaker? Moreover, are their relationship becoming more coordinate or not? According to previous studies, there are three major types of interrelationships on subsystems of urbanization around the world [6]. In the west Europe, the urbanization development is leading by the industrial development, which attracting people migrate from rural area to urban area, resulting in the expansion of urban built-up area. Their relationship become stronger and more coordinate. Another classic type of urbanization is represented by the Unite States, where the space expansion goes to first, the famous phenom is known as urban sprawl, then population settlement and economy development follows. Their relationship become stronger from weaker. The last mode is Latin American, where people move into the cities to find higher salary jobs. However, the opportunity of jobs which are created by the economy are not sufficient for them, and there is no large expansion of urban space in addition. As a result, their relationship fluctuated around some state. Outside of these urbanization developmental patterns, there is also special scenario that urbanization development is interrupted by natural disaster, such as hurricane, tsunami, earthquake and etc. al. Under the natural disaster context, what happened to urbanization? What is the relationship between population, space, economy urbanization? Are their interrelationship become stronger or weaker? In this charter, we examined these questions by the Wenchuan earthquake in the area scale and county scale to explore the answers.

5.2 Temporal distribution of coupling and coupling coordination degree before and after the Wenchuan earthquake

5.3.1 Temporal distribution of coupling and coupling coordination degree for the most severely affected area

As mentioned above, the Wenchuan earthquake affected 500,000 square kilometers [7]. Among the 237 impacted counties, ten counties, Anxian, Beichuan, Dujiangyan, Maoxian, Mianzhu, Pengzhou, Pingwu, Qingchuan, Shifang, Wenchuan, were evaluated as the most severely affected counties [8]. These 10 counties, with an area of 26,112.54 square kilometers, were classified as the most severely affected areas (MSAA), and were also the research area of this paper. where was marked as the most severely affected area (MSAA). First, we analyzed the dynamic coupling degree

(DCD) values to evaluate how the 2008 Wenchuan earthquake influenced the relationship between subsystems of urbanization in the MSAA. As shown in Figure 5-1, the DCD values of population-economy-space urbanization was fluctuated from 2001 to 2017. Specifically, the value of DCD increased dramatically from 2001 to 2002. The ratio between population urbanization, space urbanization, economy urbanization changed from 1.15:1:1.09 in 2001 to 1.20:1:0.97 in 2002. The results showed that the relative higher growth rate of population urbanization strengthened the interrelationship between the three subsystems urbanization from 2001 to 2002, which resulted in the increased of DCD values. In the next five years, the value of DCD did not change so much, showing like a straight line. Unsurprisingly, the value of DCD for MSAA dropped to 0.316 in 2008. Impacted by the Wenchuan earthquake, the MSAA lost 845.2 billion Yuan, collapsed 305.73 million houses with 69,277 people death, 374,644 injured and 17,995 missing, reducing the comprehensive degree interrelationship level for the three subsystems urbanization. It clearly indicated that serious natural disasters affected the development of urbanization of the whole MSAA area and gently decreased the coupling degree. Consequently, it's necessary to strengthen the early warning systems of natural hazards, migrate people in damage-suffering area, and reinforce the infrastructure capacity to resist the risks of natural hazards for the area scale. During the reconstruction years (2008–2010), the DCD values of population–economy–space urbanization increased slightly to 0.328. The result showed that natural disasters had a positive impact on the orderly of urbanization, while the aforementioned post-disaster reconstruction policies and measures effectively strengthened the interactions among population urbanization, economy urbanization, and space urbanization in the MSAA. During the post-earthquake years (2011–2017), the DCD values of population–economy–space urbanization kept around 0.325 in 2017, meaning that the interactions among population, economy and space urbanization did not change since the MSAA lost the external resources from 2011. The results showed that the reconstruction measures and policies should be extended to the year when the degree of correlation between the three subsystems urbanization did not decrease.

As for the stage analysis of the urbanization level, previous studies have demonstrated that the urbanization level at the scale of city (e.g., Beijing) had stage characteristics [9]. However, for different stages, no research has been carried out on the coupling and coordination among the dimensions of population, economy, and space urbanization at the MSAA scale. The results of this work further deepen our understanding in this aspect. Box and whisker plot could clearly demonstrate the variations in the DCD and DCCD values of the MSAA in different stages. As shown in Figure 5-2, there was stage characteristics for DCCD, while the DCD values showed the no stage characteristics. With respect to DCD, the DCD values after the earthquake was higher than the pre-earthquake stage, which was related to the post-disaster reconstruction policies and measures. The increased population size, rapid economy recovery and effective space optimization of the MSAA was mainly ascribed to the policy promotion of the revitalization, albeit the risks of geological disasters of the county could not be reduced soon due to the geographical location and developmental stage [10]. In terms of DCCD, the values of DCCD increased stages by stages, finally reached to antagonistic state in 2017. The results showed that there were strong internal driving forces to improve the coupling coordination state for three subsystems urbanization in the MSAA even hit by the destructive earthquake.

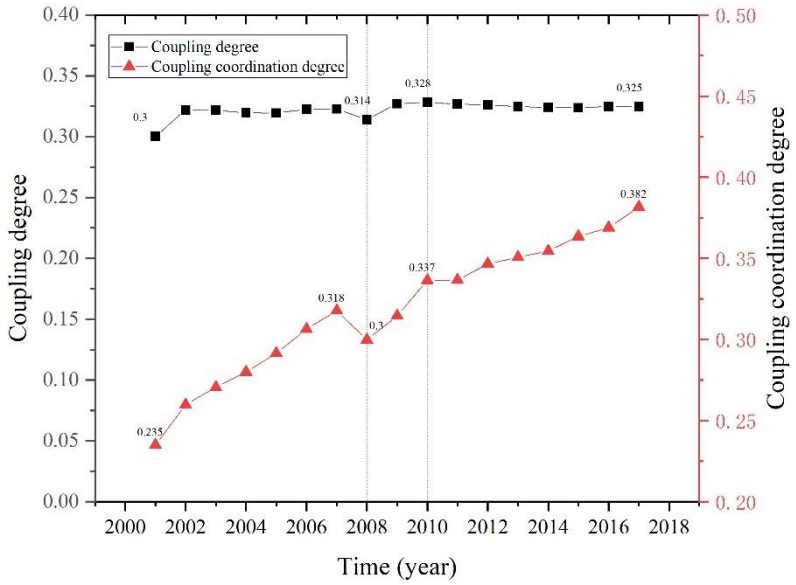


Fig 5- 1 Variation of dynamic coupling degree and dynamic coupling coordination degree of the most severely affected area (2001-2017)

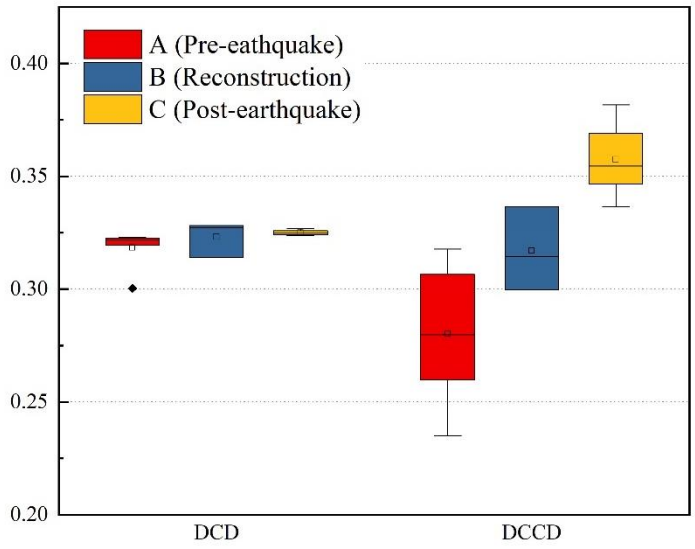


Fig 5- 2 Box and whisker plot for the DCD and DCCD values of the MSAA in different stages

5.3.2 Temporal distribution of coupling and coupling coordination degree for ten counties

As the epicenter, what happened on the urbanization of Wenchuan county before and after the earthquake should be paid more attentions. According to the reposts, Wenchuan county lost 64.2 billion Yuan and collapsed 608,198 houses with 15,941 people death, 34,583 injured and 7,295 missing. First, we evaluated what happened on the interrelationship between urbanization of population, economy and space before and after the Wenchuan earthquake by the dynamic coupling degree (DCD) values. As shown in Figure 5-3, the value of DCD decreased from 0.328 in 2001 to 0.316 in 2017, which was indicated that the interrelationship between urbanization of population,

economy and space had become weaker after the Wenchuan earthquake. Specifically, the DCD value was around 0.328 from 2001 to 2007, indicating that the degree of correlation between the three subsystems of urbanization was relative stable before the Wenchuan earthquake. In addition, the DCD values were shown as a reverse U-shape from 2008 to 2010. Among them, the DCD value was declined to 0.326 immediately in 2008 which was the year of Wenchuan earthquake hit. This declined DCD value showed that the relationship between urban people settlement, built up area expansion and non-agricultural industry development was interrupted suddenly by the destructive natural disaster. However, the DCD value increased to 0.330 in 2009 which was the maximum value from 2001 to 2017. This result could be explained that the strongest correlation between the subsystem of urbanization was shown in 2009, which could be also shown as the minimum ratio between population, space and economy urbanization was 1.21:1:0.97 in 2009. During the post-earthquake years, the DCD value decreased from 0.328 in 2011 to 0.316 in 2017, which was shown that degree of correlation between population urbanization, space urbanization and economy urbanization had become weaker and weaker from 2001 to 2017. In addition, the correlation between three subsystems of urbanization of Wenchuan county had become weaker after the earthquake struck, but the MSAA showed the opposite result, which would be helpful to propose distinguished reconstruction policies in county scale and MSAA scale.

Furthermore, we evaluated whether the correlation between population, space, economy urbanization was coordinate or not by DCCD. As shown in Figure 5-3, the DCCD value was around 0.328 from 2001 to 2007, indicating that the degree of correlation between the three subsystems of urbanization was relative stable before the Wenchuan earthquake. However, after the Wenchuan earthquake hit, there was a reverse U-shape of DCCD values from 2008 to 2010. Obviously, the Wenchuan earthquake which was the most destructive natural disaster in Chinese history since 1949 interrupted this trend of good development and caused the retreat of the coordinated state of the three subsystems of urbanization. Specifically, benefiting from the reconstruction policies and measures, the degree of coordination between population, space, economy urbanization recovered significantly just in two years, and even better before earthquake stuck. The result certified that external reconstruction policies and measures are very useful to urbanization of epicenter recovery and development, which would be helpful to make policies in other earthquake prone areas. Moreover, the value of DCCD fluctuated around 0.316 since 2011, showing that the degree of coordination between population urbanization, space urbanization, and economy urbanization developed into a relative higher level after the post-earthquake reconstruction. In addition, the level of DCCD in Wenchuan county in 2017 was lower than the level of most severely affected area, which showing that the degree of coordination between urbanization elements of population, space and economy in Wenchuan county was worse than the most severely area. It was also proved that different policies should be implemented in county scale and area scale to recover urbanization development after the natural disaster.

To evaluate whether there was differentiation in pre-earthquake, reconstruction, and post-earthquake stages, the Box Plot was used to measure the DCD and DCCD values. As shown in Figure 5-4, there was stage characteristics for DCD and DCCD in Wenchuan county. In terms of DCD, the average value of DCD for post-earthquake stage was 0.316 which was obviously lower than pre-earthquake stage (0.327) and reconstruction stage (0.328). However, there was no stage characteristics for the DCD in the MSAA, showing that there was no differentiation on correlation

degree of urbanization subsystems between pre-earthquake, reconstruction, post-earthquake stages in the MSAA, but Wenchuan county show the reverse result. According to the statistics data, benefiting from the tourism development, the average value of tertiary industry for Wenchuan county in post-earthquake stage was 2.31 times than the reconstruction stage. With respect to DCCD, the average value of DCCD was lower for the post-earthquake stage (0.316) than the other two stages, showing that the interrelationship between the population, space, economy urbanization had become less and less coordinate.

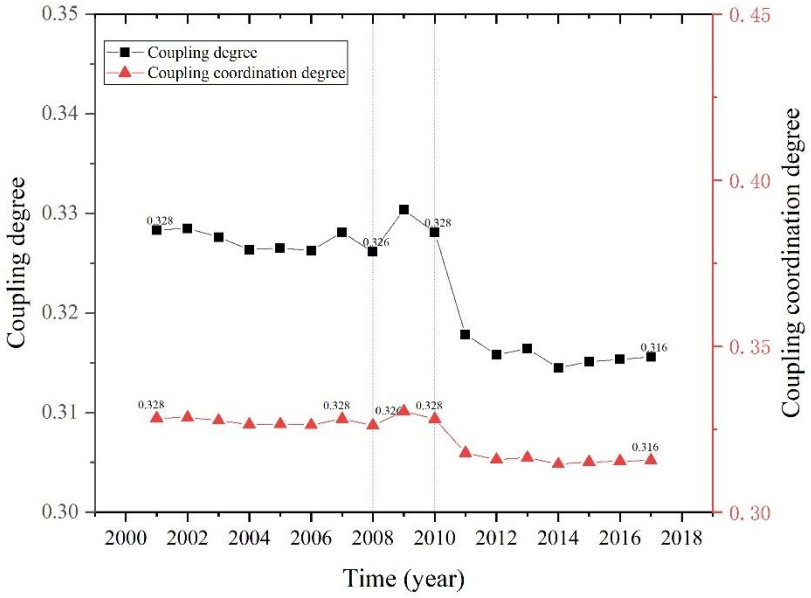


Fig 5- 3 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Wenchuan county (2001-2017)

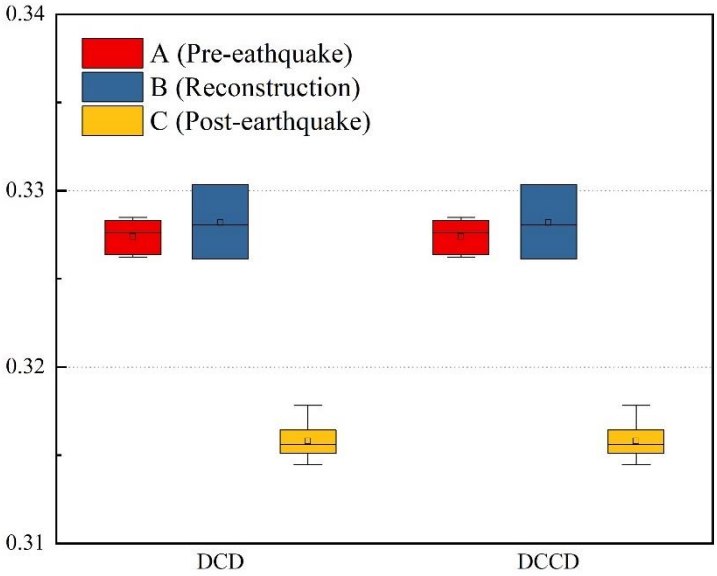


Fig 5- 4 Box and whisker plot for the population-economy-space urbanization of the Wenchuan county in different stages

Among these ten counties in the MSAA, Shifang was one of most impacted counties lost 88.9 billion Yuan with 5,942 people death, 33,075 injured and 98 missing. First, we measured what happened on the interrelationship between urbanization of population, economy and space before and after the Wenchuan earthquake by the dynamic coupling degree (DCD) values. As shown in Figure 5-5, the value of DCD decreased from 0.330 in 2001 to 0.321 in 2005, then increased to 0.327 in 2007, showing a U-shape before the Wenchuan earthquake struck. According to the ratio between population, space, economy urbanization in 2005 (1.95:1:1.51), the relative higher population urbanization score and economy urbanization score broke the strong correlation between the three subsystems of urbanization, which caused the decreased of DCD of Shifang. Specifically, there increasing trend of the DCD value was interrupted in 2008 which was the year of Wenchuan earthquake hit, and kept the same value in 2009. Although the value of DCD kept increased in 2008, the Wenchuan earthquake undermined the degree of correlation between population, space, economy urbanization in Shifang which led to the DCD value did not change in 2009. However, the DCD value raised to 0.333 in 2009 which was the maximum value from 2001 to 2017. Benefiting from the reconstruction measures, the strongest correlation between the subsystem of urbanization was shown in 2010, which could be also shown as the minimum ratio between population, space and economy urbanization was 1.12:1:1.12 in 2010. During the post-earthquake years, the DCD value declined from 0.328 in 2011 to 0.325 in 2017, which was shown that degree of correlation between population urbanization, space urbanization and economy urbanization had become weaker and weaker from 2011 to 2017. In addition, the correlation between three subsystems of urbanization for Shifang county and the MSAA showed the similar trend from 2001 to 2017, indicating that disaster reconstruction policies on urbanization for the MSAA would be also appropriate implemented for Shifang county.

Moreover, we evaluated whether the correlation between population, space, economy urbanization was coordinate or not by DCCD. As shown in Figure 5-5, the value of DCCD increased from 0.318 in 2001 to 0.433 in 2017, showing that the coordinating state for the three subsystems of urbanization improved gradually, and reached the low coordinate state in the final. Different to DCD, the values of DCCD obviously increased from 0.318 in 2001 to 0.383 in 2007, indicating that the degree of coordination between population migration from rural to the downtown, non-agricultural industry development, expansion of downtown area kept in a good state and continued to promote the development of urbanization. However, there was a U-shape of DCCD values from 2008 to 2010. Obviously, the Wenchuan earthquake degenerated the trend of good development of the coordinated state of the three subsystems of urbanization. Specifically, benefiting from the disaster reconstruction policies and measures, the degree of coordination between population, space, economy urbanization recovered to 0.374 in 2010. Apparently, external resources, such as paired-reconstruction policies, financial assistance, special land policies, were very useful to urbanization recovery and development for the industry-oriented county. Moreover, the value of DCCD increased to 0.433 in 2017, showing that the degree of coordination between population urbanization, space urbanization, and economy urbanization developed into a relative higher level after the post-earthquake reconstruction. In addition, the level of DCCD for Shifang county in 2017 was higher than the level of MSAA, showing that the degree of coordination between urbanization elements of population, space and economy in Shifang county was better than the MSAA. It was also indicated that the policies for the MSAA would achieve the better results for the county which was dominated by non-agricultural industry on the development of urbanization.

To assess whether there was differentiation in pre-earthquake, reconstruction, and post-earthquake stages, the Box Plot was used to measure the DCD and DCCD values. According to Figure 5-6, there was no stage characteristics for DCD in Shifang county, but the DCCD showed the reverse result. In terms of DCD, the average value of DCD was 0.326, 0.331, 0.326 for pre-earthquake stage, reconstruction stage, post-earthquake stage, respectively. Similarly, there was no stage characteristics for the DCD in the MSAA, showing that there was no differentiation on correlation degree of urbanization subsystems between pre-earthquake, reconstruction, post-earthquake stages in both Shifang county and the MSAA. As the county where industrial urbanization drove the development of population urbanization and space expansion, the ratio between subsystems of urbanization in Shifang county did not show significantly change between these stages. With respect to DCCD, the average value of DCCD was higher for the post-earthquake stage (0.412) than the other two stages, showing that the interrelationship between the population, space, economy urbanization had become more and more coordinate. Furthermore, similar stage characteristics with increasing coordination degree by stage was also found in the MSAA, showing that the same reconstruction policies were both beneficial to Shifang county and the most severely affected area.

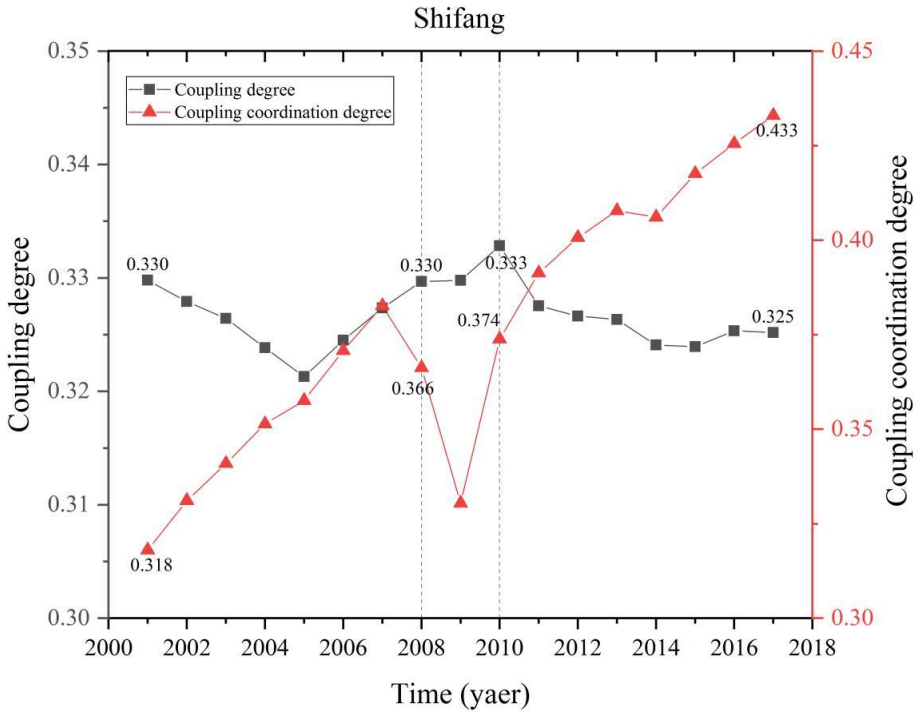


Fig 5- 5 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Shifang county (2001-2017)

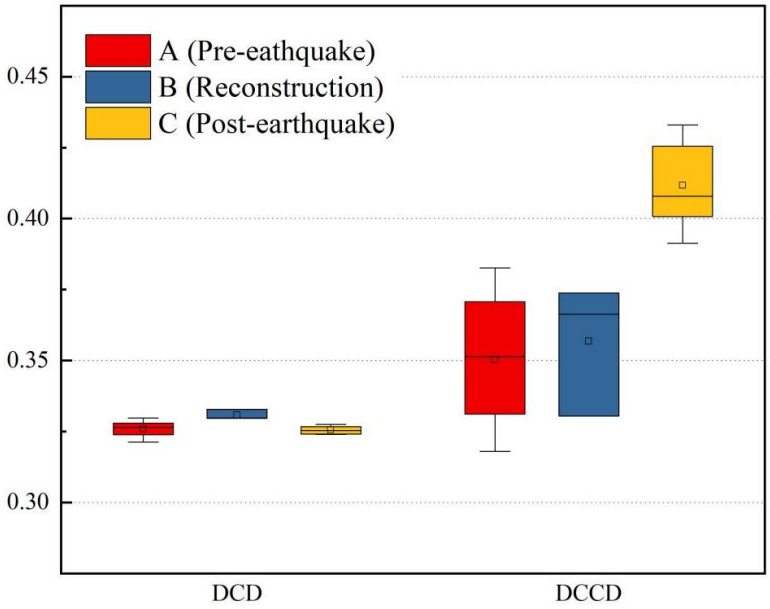


Fig 5- 6 Box and whisker plot for the population-economy-space urbanization of the Shifang county in different stages

Among these ten counties in the most severely affected area, most of Qingchuan area were distributed along the Longmen Mountain, which lead to was one of most impacted counties lost 50.4 billion Yuan with 4,695 people death, 15,456 injured and 124 missing. First, we assessed what happened on the interrelationship between urbanization of population, economy and space before and after the Wenchuan earthquake by the dynamic coupling degree (DCD) values. As shown in Figure 5-7, the value of DCD decreased from 0.322 in 2001 to 0.287 in 2004, then increased to 0.309 in 2007, showing a U-shape before the Wenchuan earthquake struck. Where the agricultural industry accounted for more than 45% of GDP before 2004, the level of economy urbanization of Qingchuan county inevitably lower than the level of population and space urbanization, which caused the DCD value declined before 2004. The decreased of DCD value could be also showed by the ratio between population, space, economy urbanization in 2004 (1.45:1:0.36). After that, the value of DCD increased to 0.309 in 2007 with the development of non-agricultural industry. Specifically, after the Wenchuan earthquake in 2008, the value of DCD turned downward, reached to 0.302 in 2008. Benefiting from the post-disaster reconstruction, it rose to 0.321 in 2010. As we could see, the Wenchuan earthquake undermined the degree of correlation between population, space, economy urbanization in Qingchuan which led to the DCD value declined in 2008. However, the DCD value raised to 0.333 in 2009 which was the maximum value from 2001 to 2017. Advantaging from the reconstruction measures, the degree of correlation between three subsystems of urbanization had been improved during 2009 to 2010, which could be also shown as the shirked ratio between population, space and economy urbanization was 0.521:1:0.637 in 2010. During the post-earthquake years, the DCD value increased from 0.329 in 2011 to 0.331 in 2017. The degree of correlation between population urbanization, space urbanization and economy urbanization had become stronger, but it was still in antagonistic state. In addition, the correlation between three subsystems of urbanization for Qingchuan county and the MSAA showed the similar trend from 2001 to 2017, indicating that disaster reconstruction policies on urbanization for the MSAA would be also appropriate implemented for Qingchuan county.

Moreover, we evaluated whether the correlation between population, space, economy urbanization was coordinate or not by DCCD. As shown in Figure 5-7, the value of DCCD increased from 0.165 in 2001 to 0.305 in 2017, showing that the coordinating state for the three subsystems of urbanization improved gradually. Different to DCD, the values of DCCD sharply increased from 0.165 in 2001 to 0.223 in 2007, showing that the degree of coordination between population migration from rural to the downtown, non-agricultural industry development, expansion of downtown area kept in a good state and continued to promote the development of urbanization. Furthermore, this trend did not affect by the Wenchuan earthquake for the value of DCCD kept increased from 2008 to 2010. Obviously, where the primary industry as the leading industry, when the coordination degree below 0.3, the values of DCCD would not be affected by the Wenchuan earthquake. However, the DCCD value declined from 0.314 in 2010 to 0.219 in 2011, then gradually increased to 0.305 in 2017. Without external resources, fixed asset investment per land, average fiscal expenditure per land both declined to 69.67% and 35.14%, respectively. Significant reduction of land investment broke the coordinate state of urbanization subsystems in Shifang, which lead to the sharply decreased of DCCD values. With the redevelopment of economy and the recovered the investment on land, the degree coordination between population, space, economy urbanization increased again to 0.305 in 2017. Moreover, the value of DCCD increased from 0.165 to 0.305 from 2001 to 2017, showing that the degree of coordination state had been improved to antagonistic state. In addition, the level of DCCD in Qingchuan county in 2017 was lower than the level of MSAA, showing that the degree of coordination between urbanization elements of population, space and economy in Qingchuan county was poorer than the MSAA, but still in the same level. The reconstruction policies for the most severely affected area would be also applicable for Qingchuan county.

To assess whether there was differentiation in pre-earthquake, reconstruction, and post-earthquake stages, the Box Plot was used to test the DCD and DCCD values. According to Figure 5-8, there was stage characteristics for DCD and DCCD in Qingchuan county. In terms of DCD, the average value of DCD for post-earthquake stage was 0.331 which was obviously higher than pre-earthquake stage (0.302) and reconstruction stage (0.315). However, there was no stage characteristics for the DCD in the MSAA, showing that there was no differentiation on correlation degree of urbanization subsystems between pre-earthquake, reconstruction, post-earthquake stages in the MSAA, but Qingchuan county show the reverse result. Benefiting from the opening of industrial park which was assist by Beijing city, the added value of secondary industry increased from 392 million Yuan to 1.498 billion Yuan, which had realized 2.82 times increasing from 2007 to 2017. The average value of tertiary industry for Qingchuan county in post-earthquake stage was 2.31 times than the reconstruction stage. With respect to DCCD, the average value of DCCD was higher for the post-earthquake stage (0.286) than the other two stages, showing that the interrelationship between the population, space, economy urbanization had become more and more coordinate. Moreover, similar stage characteristics with increasing coordination degree by stage was also found in the MSAA. It was interesting to found that the degree of coordination between the MSAA and the Qingchuan county was similar, which provided basis to design reconstruction policies in county scale and area scale.

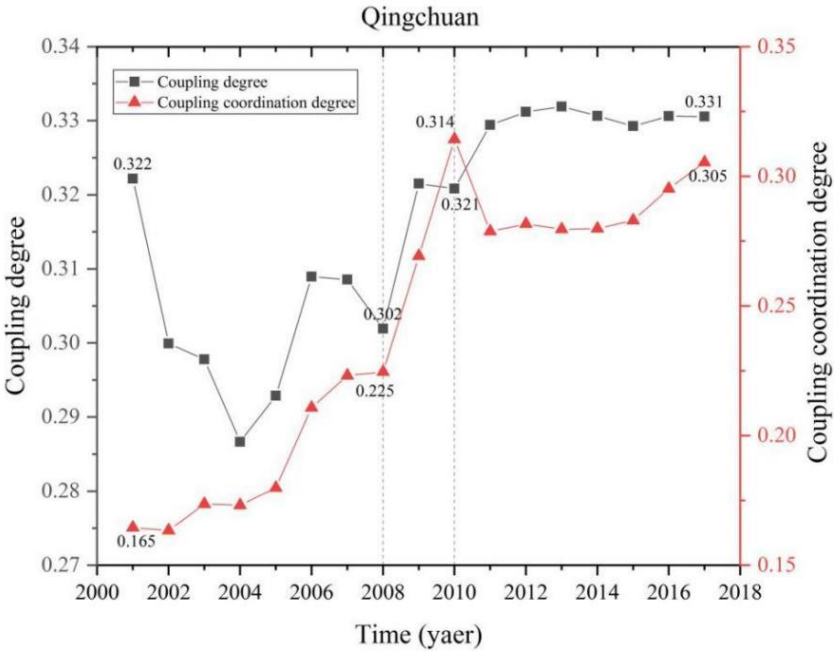


Fig 5- 7 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Qingchuan county (2001-2017)

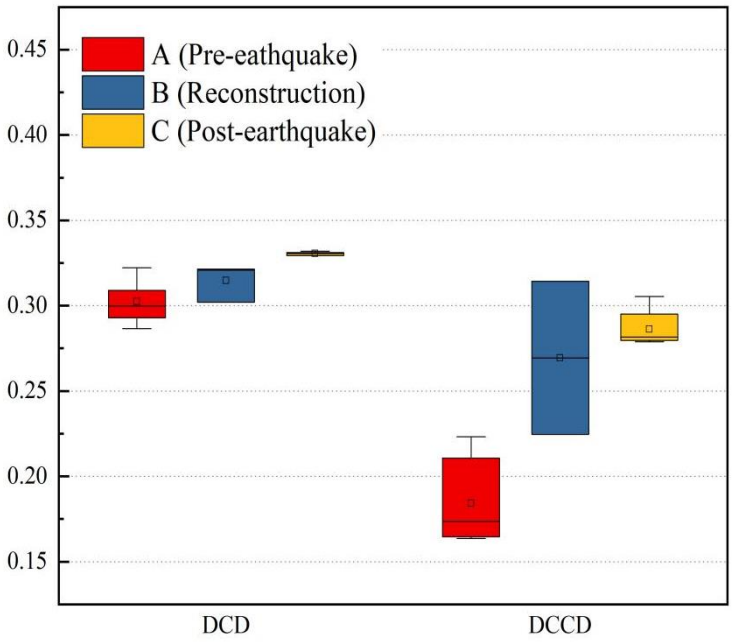


Fig 5- 8 Box and whisker plot for the population-economy-space urbanization of the Qingchuan county in different stages

Like Qingchuan county, most of Pingwu area were distributed within the Longmen Mountain, which lead to Pingwu county had become one of most impacted counties lost 34.85 billion Yuan with 3,014 people death, 32,193 injured and 2,647 missing. First, we assessed what happened on the interrelationship between urbanization of population, economy and space before and after the Wenchuan earthquake by the dynamic coupling degree (DCD) values. As shown in Figure 5-7, the value of DCD fluctuated around 0.315 from 2001 to 2007, showing that the degree correlation

between population urbanization, space urbanization, economy urbanization did not change so much before the Wenchuan earthquake. The fluctuated DCD value could be also reflected by the ratio between population, space, economy urbanization 0.87:1:0.45 in 2001 and 0.59:1:0.52 in 2007. During the reconstruction years (2008-2010), the value of DCD was shown as a reverse U-shape. Specifically, after the Wenchuan earthquake hit in 2008, the value of DCD turned downward, reached to 0.312 in 2008. Affecting by the post-disaster reconstruction, the degree correlation between urbanization subsystems had become stronger, which the value of DCD rose to 0.324 in 2009. However, it declined to 0.313 in 2010. In the same year, the level of space urbanization was 1.34 times than 2009, while population and economy urbanization still kept in the old level. It is should be shed a light that except for space expansion, urban population and economy development should keep in the same increasing rate. During the post-earthquake years, the DCD value fluctuated from 0.321 in 2011 to 0.323 in 2017, which was shown as a U-shape. The reason why the DCD declined during 2011 to 2014 was that proportion of employees in secondary and tertiary industries had decreased from 36.98% to 26.27%. Affecting by the internet, extraordinarily development of feature agricultural attracted people come back to rural area, which result in the differentiation between population, space, economy urbanization. The degree of correlation between population urbanization, space urbanization and economy urbanization had become stronger, but it was still in antagonistic state. In addition, the correlation between three subsystems of urbanization for Pingwu county and the MSAA showed the similar trend from 2001 to 2017, indicating that disaster reconstruction policies on urbanization for the MSAA would be also appropriate implemented for Pingwu county.

Moreover, we evaluated whether the correlation between population, space, economy urbanization was coordinate or not by DCCD. As shown in Figure 5-9, the value of DCCD increased from 0.197 in 2001 to 0.311 in 2017, showing that the coordinating state for the three subsystems of urbanization improved gradually. Different to DCD, the values of DCCD obviously increased from 0.197 in 2001 to 0.310 in 2007, indicating that the degree of coordination between population migration from rural to the downtown, non-agricultural industry development, expansion of downtown area kept in a good state and continued to promote the development of urbanization. However, the values of DCCD still increased from 2008 to 2010. Obviously, the Wenchuan earthquake degenerated the trend of good development of the coordinated state of the three subsystems of urbanization. Specifically, benefiting from the disaster reconstruction policies and measures, the degree of coordination between population, space, economy urbanization recovered to 0.332 in 2010. Apparently, external resources, such as paired-reconstruction policies, financial assistance, special land policies, were very useful to urbanization recovery and development for the industry-oriented county. Moreover, the value of DCCD gradually increased to 0.311 in 2017, showing that the degree of coordination between population urbanization, space urbanization, and economy urbanization developed into a relative higher level after the post-earthquake reconstruction. In addition, the level of DCCD in Pingwu county in 2017 was lower than the level of MSAA, which showing that the degree of coordination between urbanization elements of population, space and economy in Pingwu county was poorer than the MSAA. It indicated that the policies for the MSAA would be also appropriate for the Pingwu county.

To evaluate whether there was differentiation in pre-earthquake, reconstruction, and post-earthquake stages, the Box Plot was used to measure the DCD and DCCD values. According to the

Figure 5-10, there was stage characteristics for DCCD in Pingwu county, but the values of DCD showed the reverse results. In terms of DCD, the average value of DCD for pre-earthquake stage was 0.321 which was obviously higher than post-earthquake stage (0.316) and reconstruction stage (0.316), showing that there was no differentiation on correlation degree of urbanization subsystems between pre-earthquake, reconstruction, post-earthquake stages in the Pingwu county. With respect to DCCD, the average value of DCCD was higher for the reconstruction stage (0.314) than the other two stages. Furthermore, among the other two stages, the value of DCCD for post-earthquake stage (0.292) was higher than the pre-earthquake stage (0.253). The results indicated that the degree of interrelationship between the population, space, economy urbanization had been improved by the Wenchuan earthquake reconstruction measures, but deteriorated since the end of these measures. According to the results, the implementation of the post-disaster reconstruction policies should be extended for Pingwu on extra time to assistant the coordinated development of the three systems of urbanization. Moreover, stage characteristics were both found for the Pingwu county and the MSAA, but stage trends for them were different. Specific to counties like Pingwu, extra time should be reconsideration for the natural disaster policies.

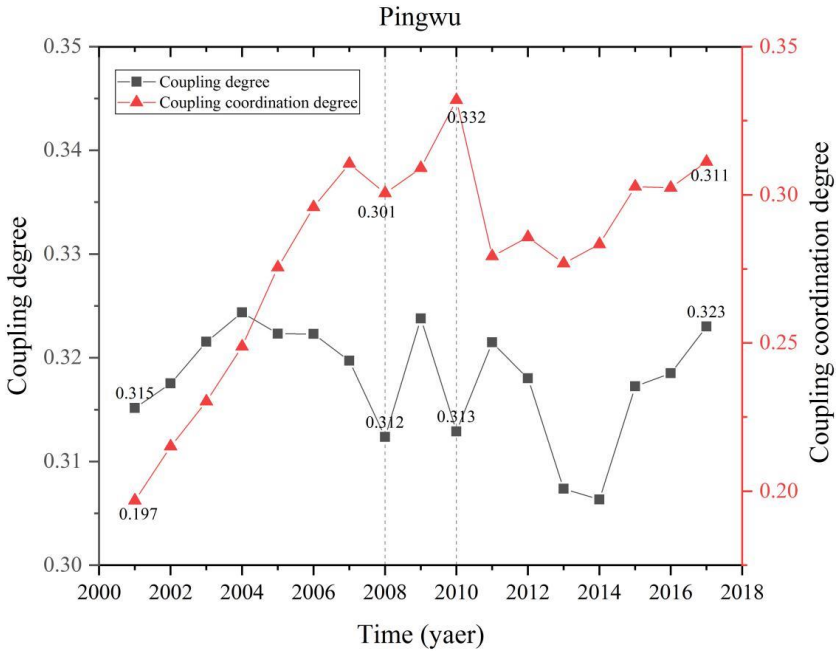


Fig 5- 9 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Pingwu county (2001-2017)

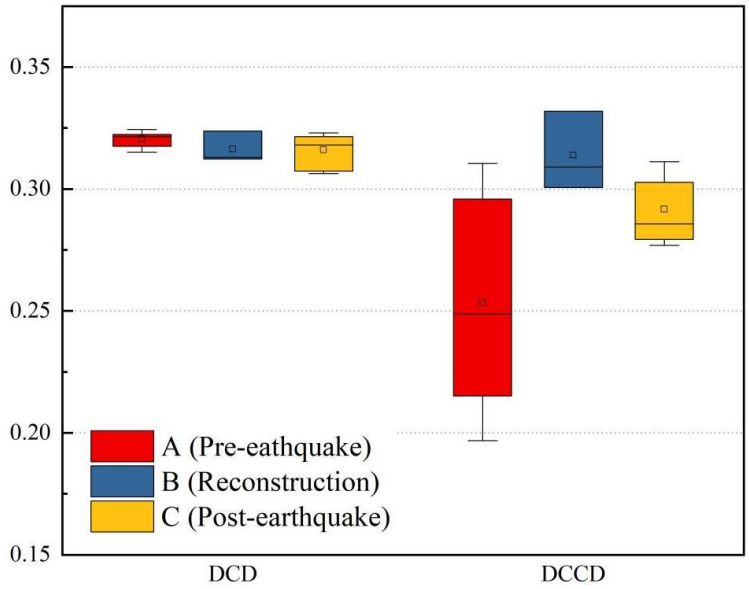


Fig 5- 10 Box and whisker plot for the population-economy-space urbanization of the Pingwu county in different stages

As one the ten counties which was distributed in the most severely affected area, Pengzhou lost 27.3 billion Yuan, collapsed 0.622 million houses, got 956 people death, 5,775 injured and 35 missing. First, we measured what happened on the interrelationship between urbanization of population, economy and space before and after the Wenchuan earthquake by the dynamic coupling degree (DCD) values. As shown in Figure 5-11, the value of DCD fluctuated around 0.332 from 2001 to 2010, then slightly declined to 0.327 in 2017, showing almost like a straight line. Specifically, the ratio between population, space, economy urbanization dropped from 1.21:1:0.97 in 2001 to 1.44:1:1 in 2003, then recovered to 1.36:1:1.10 in 2007, showing that the degree correlation between subsystems of urbanization for Pengzhou was remained in the same level before the Wenchuan earthquake hit. The values of DCD for Pengzhou were remained in the same value as 0.332 from 2008 to 2010, indicating that the degree correlation between population, space, economy urbanization had not been affected by the Wenchuan earthquake. Compared to 0.77 million population in Pengzhou, the number of missing and death population were accounted for 0.13%, which would little affect the proportion of urbanization population, resulting in the degree of interrelationship between subsystems of urbanization would not significantly change. Since the end of natural disaster reconstruction measures, the values of DCD had declined from 0.332 in 2011 to 0.327 in 2017, showing that the level for each three subsystems of urbanization was imbalance. In other words, the level of one of the subsystems of urbanization had been beyond or behind other two subsystems of urbanization after shut down the reconstruction assistant measures. In addition, the correlation between three subsystems of urbanization for Pengzhou county and the MSAA showed the similar trend from 2001 to 2017, indicating that disaster reconstruction policies on urbanization for the MSAA would be also appropriate implemented for Pengzhou county.

Moreover, we evaluated whether the correlation between population, space, economy urbanization was coordinate or not by DCCD. As shown in Figure 5-11, the value of DCCD increased from 0.267 in 2001 to 0.429 in 2017, indicating that the coordinating state for the three subsystems of urbanization improved gradually. Different to DCD, the values of DCCD obviously

increased from 0.267 in 2001 to 0.346 in 2007, showing that the degree of coordination between population migration from rural to the downtown, non-agricultural industry development, expansion of downtown area kept in a good state and continued to promote the development of urbanization. Unexpectedly, the value of DCCD still increased after the Wenchuan earthquake hit. According to the Figure 5-11, the value of DCCD increased from 0.312 in 2008 to 0.346 in 2010. Actually, the rapid recovery of spatial urbanization and economy urbanization had brought the ratios of the three to a close approach, jointly promoting the coordinated development of urbanization, which could be reflected from indicators that fixed asset investment per land, average economy output of secondary and tertiary industries, GDP per capital, secondary industry added value per person in 2010 were 1.50 times, 1.33 times, 1.43 times, and 2.19 times than 2008, respectively. Apparently, the Pengzhou county which did not loss large proportion urbanization population from earthquake, but received advantages from disaster reconstruction measures on space urbanization and economy urbanization. Moreover, the value of DCCD increased to 0.429 in 2017, showing that the degree of coordination between population urbanization, space urbanization, and economy urbanization developed into the low-level coordination state, after the post-earthquake reconstruction. In addition, the level of DCCD in Pengzhou county in 2017 was higher than the level of MSAA, showing that the degree of coordination between urbanization elements of population, space and economy in Pengzhou county was better than the MSAA. It was also indicated that the policies for the MSAA would achieve the better results for the county which was dominated by non-agricultural industry on the development of urbanization.

To assess whether there was differentiation in pre-earthquake, reconstruction, and post-earthquake stages, the Box Plot was used to measure the DCD and DCCD values. According to Figure 5-10, there was no stage characteristics for DCD for Pengzhou county, but the DCCD showed the reverse result. In terms of DCD, the average value of DCD was 0.330, 0.332, 0.330 for pre-earthquake stage, reconstruction stage, post-earthquake stage, respectively. Similarly, there was no stage characteristics for the DCD in the MSAA, showing that there was no differentiation on correlation degree of urbanization subsystems between pre-earthquake, reconstruction, post-earthquake stages in both Pengzhou county and the MSAA. With respect to DCCD, the average value of DCCD was higher for the post-earthquake stage (0.389) than the other two stages, showing that the interrelationship between the population, space, economy urbanization had become more and more coordinate. As for Pengzhou, the expansion of built-up area, running of 0.8 million tons of ethylene project and aerodynamics project comprehensive improved the degree coordination between subsystems urbanization. Furthermore, similar stage characteristics with increasing coordination degree by stage was also found in the MSAA, showing that the same reconstruction policies were both beneficial to Pengzhou county and the MSAA.

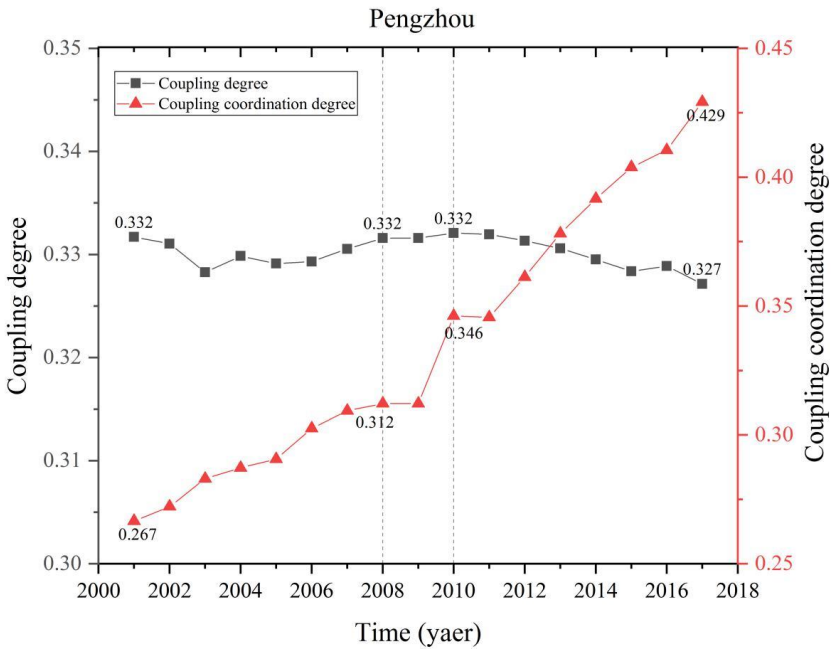


Fig 5- 11 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Pengzhou county (2001-2017)

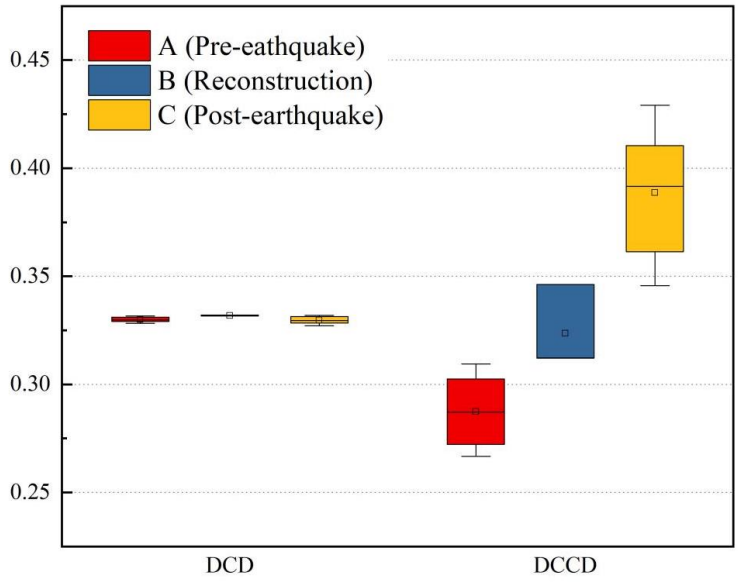


Fig 5- 12 Box and whisker plot for the population-economy-space urbanization of the Pengzhou county in different stages

As one the ten counties which was distributed in the most severely affected area, Mianzhu lost 142.3 billion Yuan, collapsed 1.39 million houses, got 11,117 people death, 37,208 injured and 258 missing. First, we measured what happened on the interrelationship between urbanization of population, economy and space before and after the Wenchuan earthquake by the dynamic coupling degree (DCD) values. As shown in Figure 5-13, the value of DCD fluctuated around 0.328 from 2001 to 2007, then almost shown like a straight line from 2008 to 2010, finally slightly declined to 0.329 in 2017. Specifically, the ratio between population, space, economy urbanization dropped from 1.43:1:1.53 in 2001 to 1.80:1:1.58 in 2004, then recovered to 1.30:1:1.54 in 2007, showing that the degree correlation between subsystems of urbanization for Mianzhu county was remained

in the same level before the Wenchuan earthquake hit. Unexpectedly, the value of DCD for Mianzhu county still increased to 0.330 in 2008. In the case of Mianzhu, there were over ten thousand urbanization population death and amount 142.3 billion yuan lost after the Wenchuan earthquake hit, resulted in the level of population urbanization and economy urbanization declined to realize the degree of correlation between subsystems of urbanization reached in the new value. After the Wenchuan earthquake struck, savings deposit balances of urban and rural residents, proportion of built-up area to regional area, the proportion of the economy output of the primary industries in GDP were both recovered and developed in the same rate, resulted in the DCD almost keep in the same value from 2008 to 2010. The values of DCD had fluctuated around 0.330 from 2011 to 2017, showing that the level for degree correlation of subsystems of urbanization still kept adjust after lost the external assistant during these years. In addition, the correlation between three subsystems of urbanization for Mianzhu county and the MSAA showed the similar trend from 2001 to 2017, indicating that disaster reconstruction policies on urbanization for the MSAA would be also appropriate implemented for Mianzhu county.

Moreover, we evaluated whether the correlation between population, space, economy urbanization was coordinate or not by DCCD. As shown in Figure 5-13, the value of DCCD increased from 0.304 in 2001 to 0.441 in 2017, indicating that the coordinating state for the three subsystems of urbanization had improved into another level. Different to DCD, the values of DCCD obviously increased from 0.304 in 2001 to 0.365 in 2007, showing that the degree of coordination between population migration from rural to the downtown, non-agricultural industry development, expansion of downtown area kept in a good state and continued to promote the development of urbanization. However, there was a U-shape of DCCD values from 2008 to 2010. Obviously, the Wenchuan earthquake degenerated the trend of good development of the coordinated state of the three subsystems of urbanization. According to the statistics data, number of students in ordinary high schools had declined to 91.25% in 2008 than 2007, which was shown as the level of population dropped sharply, resulted in the degree of coordination between subsystems of urbanization declined. Specifically, benefiting from the disaster reconstruction policies and measures, the degree of coordination between population, space, economy urbanization recovered to 0.345 in 2010. Apparently, external resources, such as paired-reconstruction policies, financial assistance, special land policies, were very useful to urbanization recovery and development for the industry-oriented county. Moreover, the value of DCCD increased to 0.441 in 2017, showing that the degree of coordination between population urbanization, space urbanization, and economy urbanization developed into a relative higher level after the post-earthquake reconstruction. In addition, the level of DCCD in Mianzhu county in 2017 was higher than the level of the MSAA, showing that the degree of coordination between urbanization elements of population, space and economy in Shifang county was better than the most severely area. It was also indicated that the policies for the MSAA would achieve the better results for the county which was dominated by non-agricultural industry on the development of urbanization.

To assess whether there was differentiation in pre-earthquake, reconstruction, and post-earthquake stages, the Box Plot was used to measure the DCD and DCCD values. According to Figure 5-14, there was no stage characteristics for DCD in Mianzhu county, but the DCCD showed the reverse result. In terms of DCD, the average value of DCD was 0.326, 0.330, 0.327 for pre-earthquake stage, reconstruction stage, post-earthquake stage, respectively. Similarly, there was no

stage characteristics for the DCD in the MSAA, showing that there was no differentiation on correlation degree of urbanization subsystems between pre-earthquake, reconstruction, post-earthquake stages in both Tianzhu county and the most severely affected area. With respect to DCCD, the average value of DCCD was higher for the post-earthquake stage (0.393) than the other two stages, showing that the interrelationship between the population, space, economy urbanization had become more and more coordinate. Furthermore, similar stage characteristics with increasing coordination degree by stage was also found in the MSAA, showing that the same reconstruction policies were both beneficial to Shifang county and the MSAA.

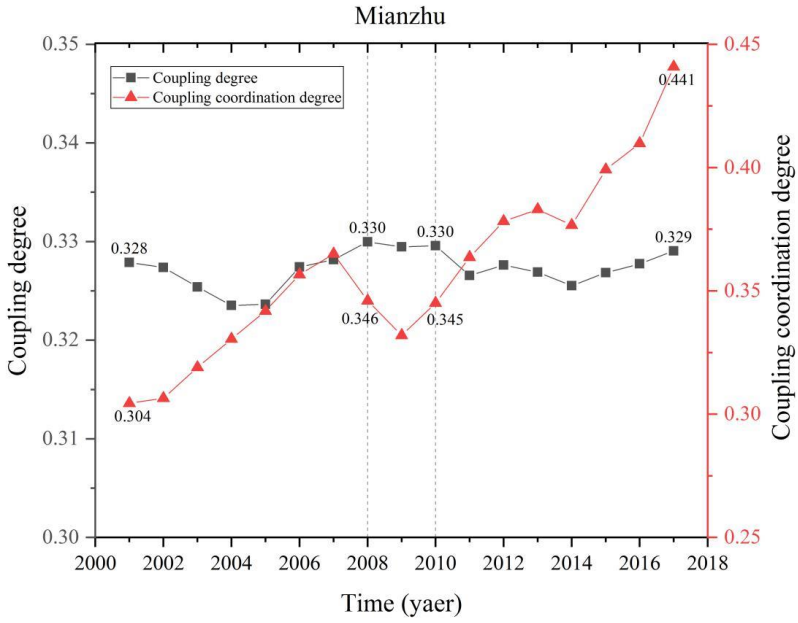


Fig 5- 13 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Mianzhu county (2001-2017)

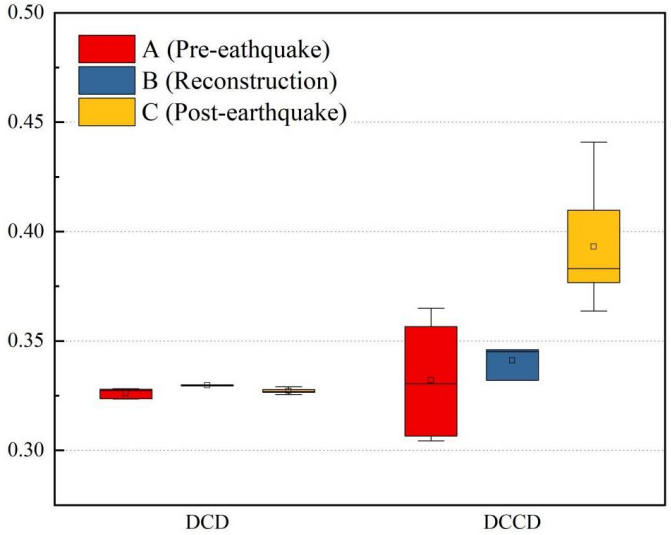


Fig 5- 14 Box and whisker plot for the population-economy-space urbanization of the Mianzhu county in different stages

Among these ten counties in the MSAA, whole of Maoxian area were distributed along the

Longmen Mountain, lost 26.0 billion Yuan and collapsed 0.3 million houses with 4,016 people death, 8,183 injured and 72 missing after the Wenchuan earthquake. First, we evaluated what happened on the interrelationship between urbanization of population, economy and space before and after the Wenchuan earthquake by the dynamic coupling degree (DCD) values. As shown in Figure 5-15, the value of DCD decreased from 0.331 in 2001 to 0.318 in 2007, then increased to 0.328 in 2010, finally decreased to 0.313 in 2017, showing a U-shape before the Wenchuan earthquake struck. Specifically, the values of DCD did not change so much from 2001 to 2005, showing that degree correlation between three subsystems of urbanization still kept in round the same level. However, proportion of employees in secondary and tertiary industries, number of students in ordinary high schools were both increased 110.92% and 114.08% from 2005 to 2007, respectively. During the same years, fixed asset investment per land for Maoxian decreased 61.38% from 2005 to 2007. Population urbanization significant development with deterioration of space urbanization induced the correlation between three subsystems urbanization had been weakened. Due to the fixed asset investment per land was 1.99 times in 2010 than 2008, which was benefited from the paired-reconstruction assistant measures, the values of DCD increased from 0.322 to 0.328 in 2010. During the post-earthquake years, the DCD value decreased from 0.328 in 2010 to 0.331 in 2017. The degree of correlation between population urbanization, space urbanization and economy urbanization had become weaker, but it was still in antagonistic state. In addition, the correlation between three subsystems of urbanization for Maoxian county and the MSAA showed the similar trend from 2001 to 2017, indicating that disaster reconstruction policies on urbanization for the MSAA would be also appropriate implemented for Maoxian county.

Moreover, we evaluated whether the correlation between population, space, economy urbanization was coordinate or not by DCCD. As shown in Figure 5-15, the value of DCCD increased from 0.233 in 2001 to 0.350 in 2017, showing that the coordinating state for the three subsystems of urbanization improved gradually, but still in the same antagonistic state. Different to DCD, the values of DCCD sharply increased from 0.233 in 2001 to 0.286 in 2007, showing that the degree of coordination between population migration from rural to the downtown, non-agricultural industry development, expansion of downtown area kept in a good state and continued to promote the development of urbanization. Apparently, the Wenchuan earthquake stopped and reversed the increasing trend of DCCD, the values of DCCD decreased from 0.294 in 2007 to 0.286 in 2008. After that, the values DCCD had been increased to 0.350 during the disaster reconstruction and post-earthquake years. Rightfully, the economy urbanization and space urbanization recovered extraordinary during the reconstruction years for the proportion of general fiscal budget revenue in GDP, secondary industry added value per person, and fixed asset investment per land were 2.52, 3.01, and 4.50 times than 2008. It was interesting to found out that the values of DCCD were still increased without external resources for natural disaster reconstruction, indicating that the internal development of secondary and third industry, such as industrial park and Qiang minority tourism, replaced the extra resources and played very well to coordinate the interrelationship between subsystems of urbanization. In addition, the level of DCCD in Maoxian county in 2017 was lower than the level of the MSAA, showing that the degree of coordination between urbanization elements of population, space and economy in Maoxian county was poorer than the MSAA, but still in the same level. The reconstruction policies for the MSAA would be also applicable for Maoxian county.

To evaluate whether there was differentiation in pre-earthquake, reconstruction, and post-

earthquake stages, the Box Plot was used to measure the DCD and DCCD values. According to the Figure 5-16, there was stage characteristics for DCD and DCCD in Maoxian county. In terms of DCD, the average value of DCD for pre-earthquake stage was 0.328 which was obviously higher than post-earthquake stage (0.325) and reconstruction stage (0.315), showing that there was differentiation on correlation degree of urbanization subsystems between pre-earthquake, reconstruction, post-earthquake stages in the Maoxian county. With respect to DCCD, the average value of DCCD was higher stages by stages, especially for the post-earthquake stage. Furthermore, among the other two stages, the value of DCCD for post-earthquake stage (0.325) was higher than the reconstruction stage (0.315). The results indicated that the degree of interrelationship between the population, space, economy urbanization did not deteriorate, but still improved after end of the Wenchuan earthquake reconstruction measures. According to the results, for the Maoxian county that were still dominated by industry after the earthquake, the end of the post-disaster reconstruction policy would not affect the mutual integration and promotion of their urbanization subsystems. The results also mean that appropriate post-disaster reconstruction policies could realize the recovery and development of urbanization for the counties which was industry dominated, which was beneficial to saving funds for other county's post-disaster reconstruction. It was interesting to found that the degree of coordination between the MSAA and the Maoxian county was similar, which provided basis to design reconstruction policies in county scale and area scale.

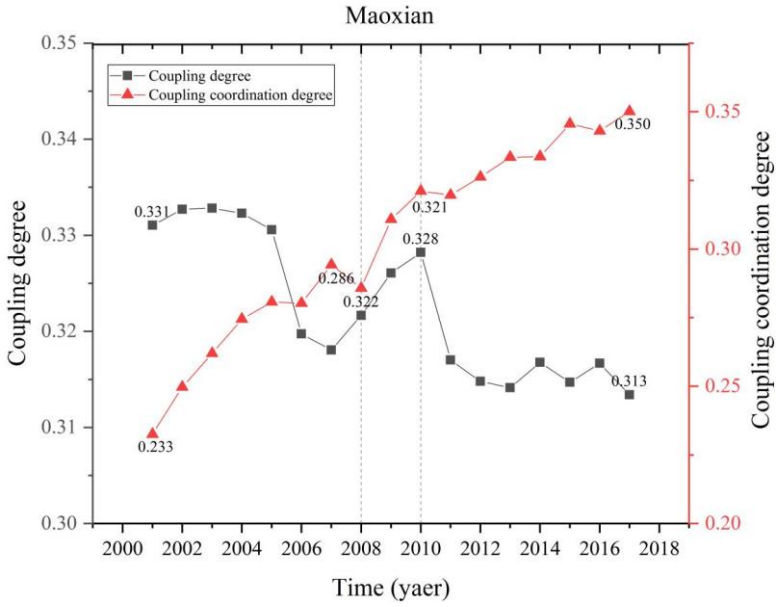


Fig 5- 15 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Maoxian county (2001-2017)

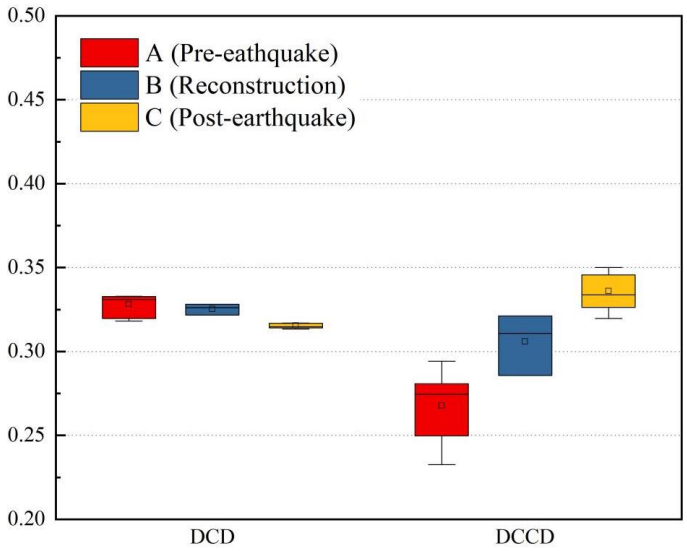


Fig 5- 16 Box and whisker plot for the population-economy-space urbanization of the Maoxian county in different stages

Next, we analyzed the DCD values to evaluate how the 2008 Wenchuan earthquake influenced the urbanization of the Dujiangyan county. As shown in Figure 6, the DCD values of population-economy-space urbanization increased rapidly from 2001 to 2002. During the pre-earthquake period (2001 – 2007), the DCD values of population – economy – space urbanization rose rapidly from 0.09 in 2001 to 0.32 in 2002, indicating that the interactions between the three subsystems of population, economy, and space urbanization were greatly enhanced at this stage. It was mainly due to the substantial increase in the population urbanization index from 2001 to 2002, resulting in an intensified interaction of population – economy – space urbanization. Then the DCD values was in a quite good status in most of the years (2002-2007), meaning that the entire urbanization tended to an orderly structure. When Dujiangyan county faced the Wenchuan earthquake, the DCD values at the year of 2008 dropped dramatically to a level lower than 2002. It clearly indicated that serious natural disasters greatly affected the development of urbanization of a county and substantially decreased the coupling degree, even with a relatively high level of urbanization. Consequently, it's necessary to strengthen the early warning systems of natural hazards, migrate people in damage-suffering area, and reinforce the infrastructure capacity to resist the risks of natural hazards for the county-level units [11]. In the reconstruction stage (2008 – 2010), the DCD values of population – economy – space urbanization first dropped dramatically to 0.26, which was even lower than 2002. Then it was rapidly increased to 0.33 in 2010. The result showed that natural disasters had a negative impact on the orderly of urbanization, while the aforementioned post-disaster reconstruction policies and measures effectively strengthened the interactions among population urbanization, economy urbanization, and space urbanization in the Dujiangyan county. In the post-earthquake stage (2011 – 2017), the DCD values of population – economy – space urbanization was relatively stable and fluctuated at around 0.33, meaning that the interactions among population, economy and space urbanization didn't changed significantly at this stage.

To better analyze the mutual relationships of population – economy – space urbanization in Dujiangyan county, the dynamic coupling coordination degree (DCCD) value of the population – economy – space urbanization were further determined. As shown in Figure 5-17, the DCCD value rose gradually from 0.07 in 2001 to 0.52 in 2017. Specifically, at the pre-earthquake stage (2001 –

2007), the DCCD value was below 0.38, belonging to a low-level coordination coupling type at this urbanization stage. At the reconstruction stage (2008-2010), the DCCD value increased from 0.25 in 2008 to 0.39 in 2010. At the post-earthquake stage (2011 – 2017), the coupling coordination degree of population – economy – space urbanization increased rapidly, where its DCCD values rose rapidly from 0.45 to 0.52. In this period, the overall coupling stage changed from an antagonistic stage to a running-in stage. It indicated that although the urbanization of Dujiangyan county was attacked by a severe earthquake, the suitable post-disaster policies and measures could effectively strengthen the coordination degree between the urbanization subsystems. Therefore, the county scale with smaller population size compared to city scale is expected to recover faster from the earthquake if the county could obtain enough financial resources required for reconstruction locally.

As for the stage analysis of the level of urbanization, previous studies have demonstrated that the urbanization level at the scale of city (e.g., Beijing) had stage characteristics. However, for different stages, no research has been carried out on the coupling and coordination among the dimensions of population, economy, and space urbanization at the scale of county. The results of this work further deepen our understanding in this aspect. Box and whisker plot could clearly demonstrate the variations in the DCD and DCCD values of the Dujiangyan county in different stages. As shown in Figure 5-18, the DCD values showed apparent differences in the post-earthquake stage. Similarly, the DCCD showed the same results. It clearly indicated that for the three stages (pre-earthquake, reconstruction, and post-earthquake), there were stage differences in the degree of coupling of the urbanization of population, economy, and space, and the coupling coordination degree for the Dujiangyan county. The DCD values after the earthquake was higher than the pre-earthquake stage, which was related to the post-disaster reconstruction policies and measures. The increased population size, rapid economy recovery and effective space optimization of the Dujiangyan county was mainly ascribed to the policy promotion of the revitalization, albeit the risks of geological disasters of the county could not be reduced soon due to the geographical location and developmental stage.

For counties with different urbanization levels and coupling degrees, different strategies should be applied to realize sustainable urbanization. For the counties prone to geological disaster losses, different strategies should be explored before and after the earthquake to achieve sustainable urbanization. For the counties with a low urbanization level and coupling among economy-population-space dimensions, they need to strength infrastructure construction (e.g., road density, drainage pipes, water supply, etc.) and increase the allocation of regional medical resources (e.g., number of doctors per ten thousand people) to enhance the resistance for natural disaster. For the counties with a relatively high urbanization levels, they need to increase the disaster prevention capacity. For example, increasing the funds for disaster early-warning systems, including the monitoring, investigation and resolution of geological disaster sites. After the earthquake, the urbanization and coupling degrees for economy-population-space urbanization is relatively inhibited. Therefore, in the post-disaster reconstruction stage, the policy support and sufficient relief funds from central and local government both have pivotal importance to mitigate the impact of earthquake on urbanization for the county scale.

As mentioned above, the Wenchuan earthquake affected 500,000 square kilometers [7]. Among the 237 impacted counties, ten counties, Anxian, Beichuan, Dujiangyan, Maoxian, Mianzhu, Pengzhou, Pingwu, Qingchuan, Shifang, Wenchuan, were evaluated as the most severely affected

counties [8]. These 10 counties, with an area of 26,112.54 square kilometers, were classified as the most severely affected areas (MSAA), and were also the research area of this paper. where was marked as the most severely affected area (MSAA). First, we analyzed the dynamic coupling degree (DCD) values to evaluate how the 2008 Wenchuan earthquake influenced the relationship between subsystems of urbanization in the MSAA. As shown in Figure 5-1, the DCD values of population-economy-space urbanization was fluctuated from 2001 to 2017. Specifically, the value of DCD increased dramatically from 2001 to 2002. The ratio between population urbanization, space urbanization, economy urbanization changed from 1.15:1:1.09 in 2001 to 1.20:1:0.97 in 2002. The results showed that the relative higher growth rate of population urbanization strengthened the interrelationship between the three subsystems urbanization from 2001 to 2002, which resulted in the increased of DCD values. In the next five years, the value of DCD did not change so much, showing like a straight line. Unsurprisingly, the value of DCD for MSAA dropped to 0.314 in 2008. Impacted by the Wenchuan earthquake, the MSAA lost 845.2 billion Yuan, collapsed 305.73 million houses with 69,277 people death, 374,644 injured and 17,995 missing, reducing the comprehensive degree interrelationship level for the three subsystems urbanization. It clearly indicated that serious natural disasters affected the development of urbanization of the whole MSAA area and gently decreased the coupling degree. Consequently, it's necessary to strengthen the early warning systems of natural hazards, migrate people in damage-suffering area, and reinforce the infrastructure capacity to resist the risks of natural hazards for the area scale. During the reconstruction years (2008–2010), the DCD values of population–economy–space urbanization increased slightly to 0.328. The result showed that natural disasters had a positive impact on the orderly of urbanization, while the aforementioned post-disaster reconstruction policies and measures effectively strengthened the interactions among population urbanization, economy urbanization, and space urbanization in the MSAA. During the post-earthquake years (2011–2017), the DCD values of population–economy–space urbanization kept around 0.325 in 2017, meaning that the interactions among population, economy and space urbanization did not change since the MSAA lost the external resources from 2011. The results showed that the reconstruction measures and policies should be extended to the year when the degree of correlation between the three subsystems urbanization did not decrease.

As for the stage analysis of the urbanization level, previous studies have demonstrated that the urbanization level at the scale of city (e.g., Beijing) had stage characteristics [9]. However, for different stages, no research has been carried out on the coupling and coordination among the dimensions of population, economy, and space urbanization at the MSAA scale. The results of this work further deepen our understanding in this aspect. Box and whisker plot could clearly demonstrate the variations in the DCD and DCCD values of the MSAA in different stages. As shown in Figure 5-2, there was stage characteristics for DCCD, while the DCD values showed the no stage characteristics. With respect to DCD, the DCD values after the earthquake was higher than the pre-earthquake stage, which was related to the post-disaster reconstruction policies and measures. The increased population size, rapid economy recovery and effective space optimization of the MSAA was mainly ascribed to the policy promotion of the revitalization, albeit the risks of geological disasters of the county could not be reduced soon due to the geographical location and developmental stage [10]. In terms of DCCD, the values of DCCD increased stages by stages, finally reached to antagonistic state in 2017. The results showed that there were strong internal driving forces to improve the coupling coordination state for three subsystems urbanization in the MSAA

even hit by the destructive earthquake.

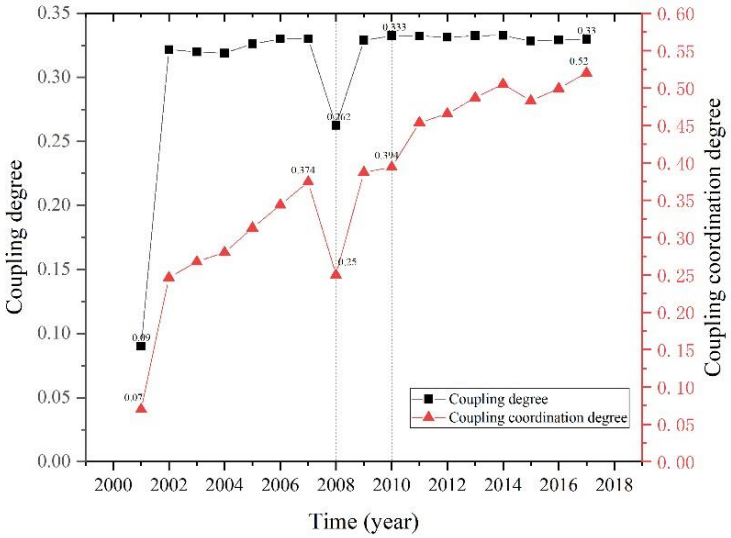


Fig 5- 17 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Dujiangyan county (2001-2017)

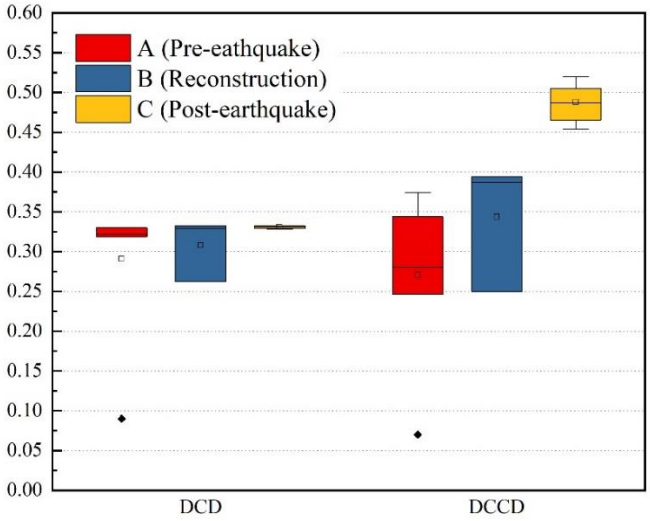


Fig 5- 18 Box and whisker plot for the population-economy-space urbanization of the Dujiangyan county in different stages

As one of these ten counties which is located in the MSAA, most of Beichuan area were distributed along the Longmen Mountain, which lead to Beichuan collapsed 0.35 million houses and lost 58.6 billion Yuan with 15,645 people death, 26,915 injured and 4412 missing. First, we assessed what happened on the interrelationship between urbanization of population, economy and space before and after the Wenchuan earthquake by the dynamic coupling degree (DCD) values. As shown in Figure 5-19, the value of DCD increased from 0.309 in 2001 to 0.319 in 2006, then decreased to 0.315 in 2007, showing a reverse U-shape before the Wenchuan earthquake struck. According to the Figure 5-19, the score for economy population, population urbanization, space urbanization in 2006 were 0.97, 1.05, 1.08 times than 2005. It was interesting to found out that the relative lower growth rate of economy urbanization reduced the coupling degree of the three

subsystems of urbanization from 2005 to 2006. Unsurprisingly, the values of DCD kept decreased to 0.304 in 2008, which was the year the Wenchuan earthquake hit. As we could see, the Wenchuan earthquake undermined the degree of correlation between population, space, economy urbanization in Beichuan which led to the DCD value declined in 2008. In the end of natural disaster reconstruction year, DCD rose to 0.333 in 2010. Advantaging from the reconstruction measures, the degree of correlation between three subsystems of urbanization had been improved from 2008 to 2010, which could be also shown as the shirked ratio between population, space and economy urbanization was 0.993:1:1.066 in 2010. During the post-earthquake years, the DCD value fluctuated around 0.328 from 2011 to 2017. The degree of correlation between population urbanization, space urbanization and economy urbanization had become slightly weaker, but it was still in antagonistic state. Due to the downtown of Beichuan was rebuilt in another place, three subsystems urbanization was still in low coupling state. Extending the validity time of natural disaster reconstruction measures would be very helpful to improve the coupling state on urbanization for Beichuan county. In addition, the correlation between three subsystems of urbanization for Beichuan county and the MSAA showed the similar trend from 2001 to 2017, indicating that disaster reconstruction policies on urbanization for the MSAA would be also appropriate implemented for Beichuan county.

Moreover, we evaluated whether the correlation between population, space, economy urbanization was coordinate or not by DCCD. As shown in Figure 5-19, the value of DCCD increased from 0.309 in 2001 to 0.360 in 2017, showing that the coordinating state for the three subsystems of urbanization improved gradually, but still in low coordinate state. Different to DCD, the values of DCCD sharply increased from 0.309 in 2001 to 0.317 in 2007, showing that the degree of coordination between population migration from rural to the downtown, non-agricultural industry development, expansion of downtown area kept in a good state and continued to promote the development of urbanization. However, after the Wenchuan earthquake hit, there was a U-shape of DCCD values from 2008 to 2010. Obviously, the Wenchuan earthquake which was the most destructive natural disaster in Chinese history since 1949 interrupted this trend of good development and caused the retreat of the coordinated state of the three subsystems of urbanization. The DCCD value for Beichuan dropped to the lowest level in 2009 which was mainly due to the reconstruction in different places. Specifically, benefiting from the reconstruction policies and measures, the degree of coordination between population, space, economy urbanization recovered significantly just in one year. The result certified that external reconstruction policies and measures are very useful to the county that was rebuilt in another place, which would be helpful to make policies in other earthquake prone areas. It was interesting to found out that the values of DCCD were still increased during the post-earthquake years (2011-2017). According to the Figure 5-19, the values of DCCD were still increased from 0333 in 2010 to 0.360 in 2017. The reason why the coupling coordination improved from 2010 to 2017 could be conclude as: (1) the low-level space urbanization formed by off-site reconstruction; (2) the lower level of economy urbanization caused by the transformation of the secondary industry; (3) the low-level population urbanization caused by the second loss of people after the Wenchuan earthquake. The low-level coupling coordination of the three subsystems urbanization leads to the continuous rise of the DCCD value. In addition, the level of DCCD in Beichuan county in 2017 was lower than the level of the MSAA, showing that the degree of coordination between urbanization elements of population, space and economy in Beichuan county was poorer than the MSAA, but still in the same level. The reconstruction policies for the MSAA

would be also applicable for Beichuan county.

To assess whether there was differentiation in pre-earthquake, reconstruction, and post-earthquake stages, the Box Plot was used to test the DCD and DCCD values. According to Figure 5-20, there were stage characteristics for DCD and DCCD in Beichuan county. In terms of DCD, the average value of DCD for post-earthquake stage was 0.329 which was obviously higher than pre-earthquake stage (0.313) and reconstruction stage (0.323). However, there was no stage characteristics for the DCD in the MSAA, showing that there was no differentiation on correlation degree of urbanization subsystems between pre-earthquake, reconstruction, post-earthquake stages in the MSAA, but Beichuan county show the reverse result. With respect to DCCD, the average value of DCCD was higher for the post-earthquake stage (0.332) than the other two stages, showing that the interrelationship between the population, space, economy urbanization had become more and more coordinate. Moreover, similar stage characteristics with increasing coordination degree by stage was also found in the MSAA. It was interesting to found that the degree of coordination between the MSAA and the Beichuan county was similar, which provided basis to design reconstruction policies in county scale and area scale.

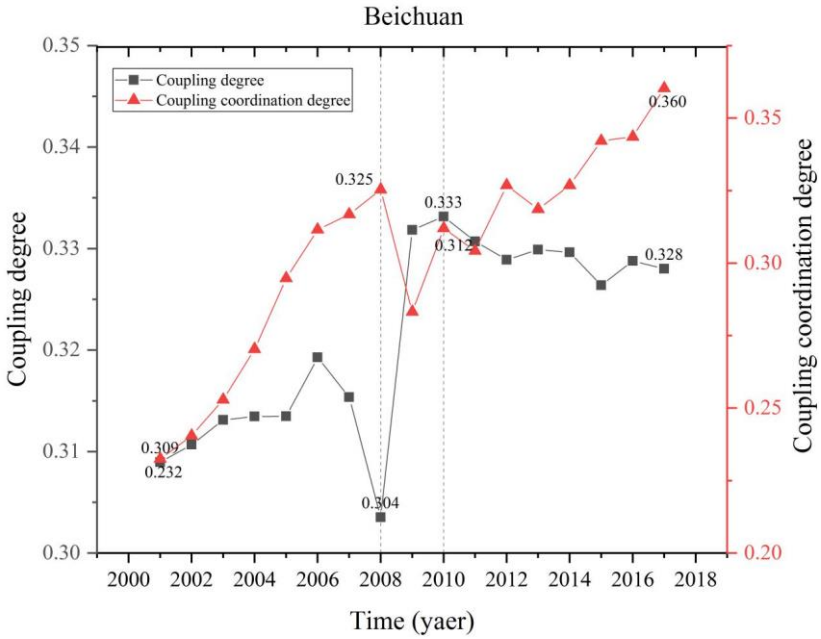


Fig 5- 19 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Beichuan county (2001-2017)

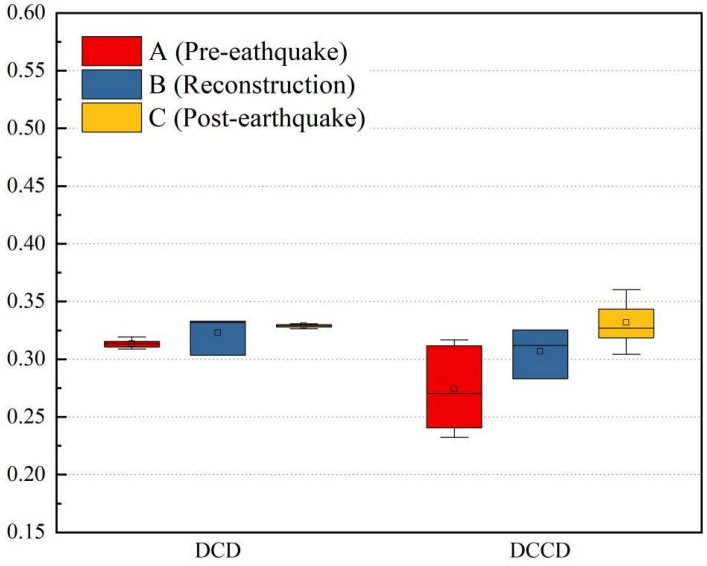


Fig 5- 20 Box and whisker plot for the population-economy-space urbanization of the Beichuan county in different stages

Among these ten counties in the MSAA, Anxian was one of most impacted counties collapsed 0.77 houses and lost 43.0 billion Yuan with 2,640 people death, 88,623 injured and 655 missing. First, we measured what happened on the interrelationship between urbanization of population, economy and space before and after the Wenchuan earthquake by the dynamic coupling degree (DCD) values. As shown in Figure 5-21, the value of DCD increased from 0.318 in 2001 to 0.325 in 2003, then decreased to 0.309 in 2005, finally increased to 0.322 in 2007, fluctuating before the Wenchuan earthquake struck. According to the score of economy urbanization, the annual growth rate was 97.41% and 88.79% in 2004 and 2005, respectively. The growth rate of industrial urbanization is lower than that of population urbanization and spatial urbanization, resulting in the values of DCD decreased from 2003 to 2005. During 2008 to 2010, there was a U-shape for DCD values. Specifically, the increasing trend of the DCD value was interrupted in 2008, which was the year of Wenchuan earthquake hit, and did not recover in 2009. According to the score of population urbanization, the annual growth rate was 147.15% in 2009, which was relative higher than that of space urbanization and economy urbanization, resulting in the correlation degree between three subsystems urbanization decreased from 2008 to 2009. However, the DCD value raised to 0.331 in 2010, which was benefited from the disaster reconstruction measures. During the post-earthquake years, the DCD value declined from 0.331 in 2011 to 0.324 in 2017, which was shown that degree of correlation between population urbanization, space urbanization and economy urbanization had become weaker and weaker from 2011 to 2017. In addition, the correlation between three subsystems of urbanization for Anxian county and the MSAA were both in the same level, indicating that the strength of disaster reconstruction policies on urbanization for the MSAA would be also appropriate implemented for Anxian county.

Moreover, we evaluated whether the correlation between population, space, economy urbanization was coordinate or not by DCCD. As shown in Figure 5-21, the value of DCCD increased from 0.236 in 2001 to 0.351 in 2017, showing that the coordinating state for the three subsystems of urbanization improved gradually. Different to DCD, the values of DCCD obviously

increased from 0.236 in 2001 to 0.274 in 2007, indicating that the degree of coordination between population migration from rural to the downtown, non-agricultural industry development, expansion of downtown area kept in a good state and continued to promote the development of urbanization. Unsurprisingly, the value of DCCD decreased immediately since the Wenchuan earthquake hit. However, the values of DCCD still increased from 2008 to 2010. Obviously, the Wenchuan earthquake degenerated the trend of good development of the coordinated state of the three subsystems of urbanization. Specifically, benefiting from the disaster reconstruction policies and measures, the degree of coordination between population, space, economy urbanization recovered to 0.298 in 2010. Apparently, external resources, such as paired-reconstruction policies, financial assistance, special land policies, were very useful to urbanization recovery and development for the industry-oriented county. It was interesting to found out that the values of DCCD were still increased without external resources for natural disaster reconstruction, indicating that the industrialization-led the development on spatial urbanization and population urbanization was excellent for coupling coordination urbanization. In addition, the level of DCCD in Anxian county in 2017 was lower than the level of MSAA, which showing that the degree of coordination between urbanization elements of population, space and economy in Anxian county was poorer than the MSAA, but still in the same level. The reconstruction policies for the MSAA would be also applicable for Anxian county.

To assess whether there was differentiation in pre-earthquake, reconstruction, and post-earthquake stages, the Box Plot was used to test the DCD and DCCD values. According to Figure 5-22, there were stage characteristics for DCD and DCCD in Anxian county. In terms of DCD, the average value of DCD for post-earthquake stage was 0.330 which was obviously higher than pre-earthquake stage (0.319) and reconstruction stage (0.323). However, there was no stage characteristics for the DCD in the MSAA, showing that there was no differentiation on correlation degree of urbanization subsystems between pre-earthquake, reconstruction, post-earthquake stages in the MSAA, but Anxian county show the reverse result. With respect to DCCD, the average value of DCCD was higher for the post-earthquake stage (0.337) than the other two stages, showing that the interrelationship between the population, space, economy urbanization had become more and more coordinate. Moreover, similar stage characteristics with increasing coordination degree by stage was also found in the most severely affected area. It was interesting to found that the degree of coordination between the MSAA and the Anxian county was similar, which provided basis to design reconstruction policies in county scale and area scale.

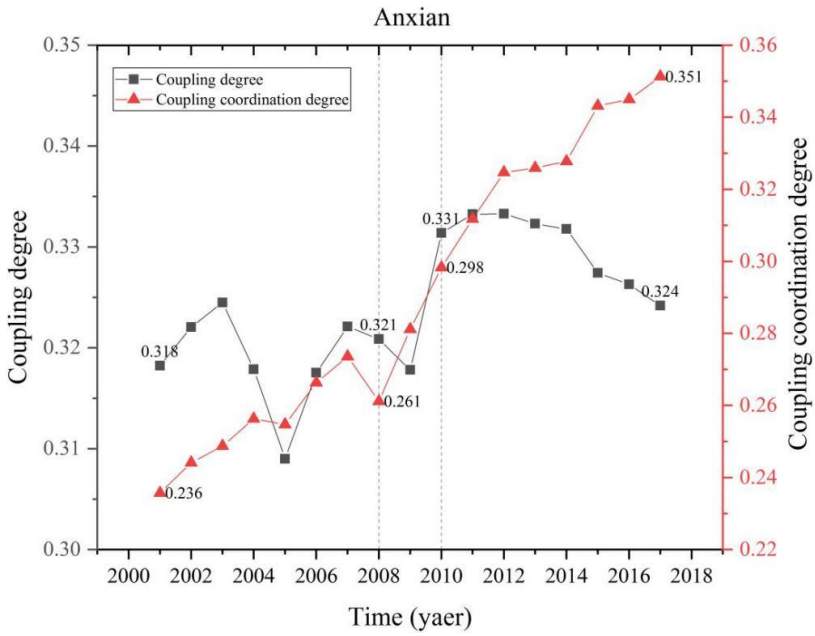


Fig 5- 21 Variation of dynamic coupling degree and dynamic coupling coordination degree of the Anxian county (2001-2017)

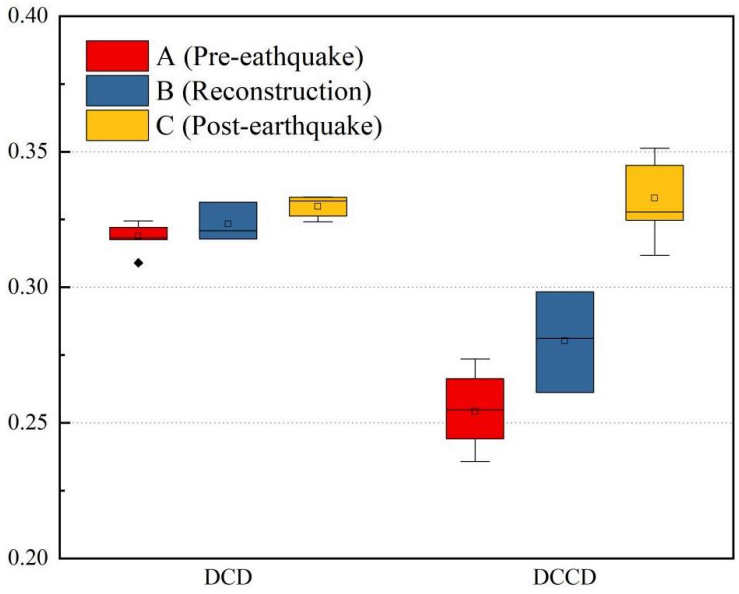


Fig 5- 22 Box and whisker plot for the population-economy-space urbanization of the Anxian county in different stages

5.3 Spatial distribution of coupling and coupling coordination degree before and after the Wenchuan earthquake

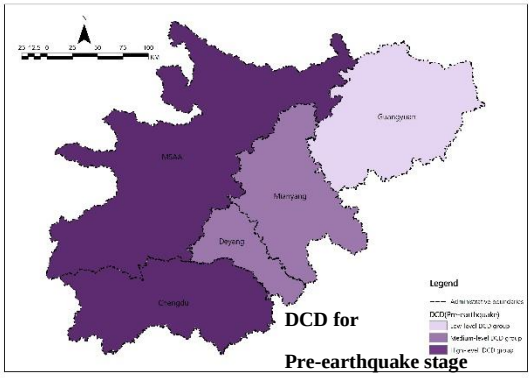
5.3.1 Spatial distribution of coupling and coupling coordination degree for the most severely affected area

After examine the temporal distribution of coupling and coupling coordination degree for MSAA, we also tested the spatial distribution at the regional scale. To show the spatial distribution of MSAA before and after the Wenchuan earthquake, we evaluated the variation of coupling and coupling

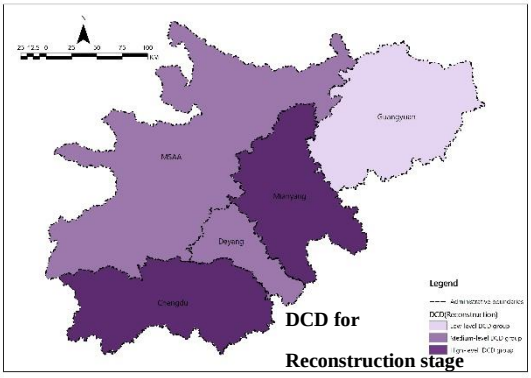
coordination degree by Chengdu, Deyang, Mianyang, Guangyuan and MSAA. In our cases, different counties were deducted from their respective prefecture-level cities.

To show the spatial distribution of dynamic coupling degree (DCD), we divided these prefecture-level cities, Chengdu, Deyang, Mianyang, Guangyuan, MSAA, into low-level DCD group, medium-level DCD group, high-level DCD group by Nature Break. As shown in Figure 5-23, the mean values of DCD for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Chengdu and MSAA were evaluated as the high-level DCD group. While Deyang and Mianyang was classified as medium-level DCD group. Only Guangyuan was grouped as low-level DCD group. The results indicated that the level of DCD for the MSAA and Chengdu were higher than Deyang, Mianyang and Guangyuan before the Wenchuan earthquake. At the reconstruction stage, the high-level DCD group were Chengdu and Mianyang. MSAA and Deyang were classified as medium-level group, while Guangyuan did not change their DCD level. The results showing that the Wenchuan earthquake weakened the DCD level of MSAA, but strengthened the DCD level of Mianyang. At the post-earthquake stage, MSAA upgraded its DCD level, indicating that reconstruction measures played positive effects on its DCD level. But Deyang declined into low-level DCD group. In a word, after the Wenchuan earthquake hit, MSAA did not change its DCD level among these prefecture cities.

Similarly, we also tested dynamic coupling coordination degree (DCCD) among these prefecture-level cities by Natural Break. As shown in Figure 5-24, the mean values of DCCD for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Chengdu was the only prefecture-level city that evaluated as the high-level DCCD group. While MSAA, Deyang and Mianyang were assessed as medium-level DCCD group. Only Guangyuan was classified in the low-level DCCD group. At the reconstruction stage and the post-earthquake stage, relative place for these ten counties on DCCD was not change. The results showing that the Wenchuan earthquake did not change the DCCD level of these ten counties. In a word, dynamic coupling coordination degree of MSAA did not affect by the Wenchuan earthquake.



DCD for Pre-earthquake stage



DCD for Reconstruction stage

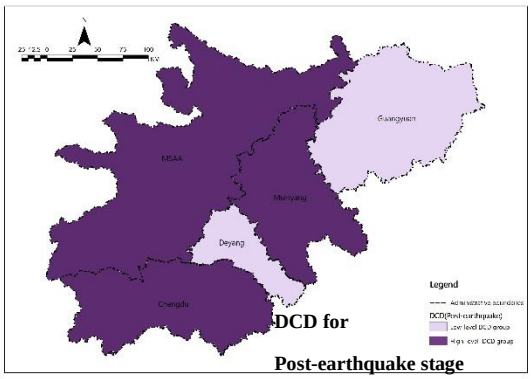
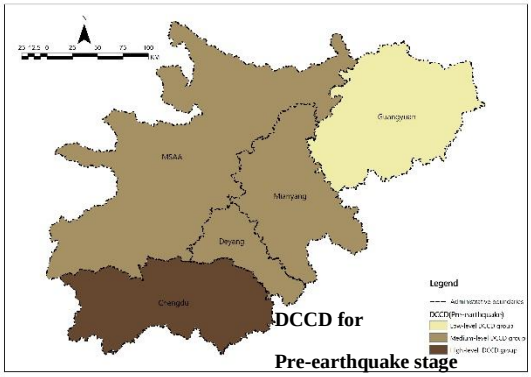
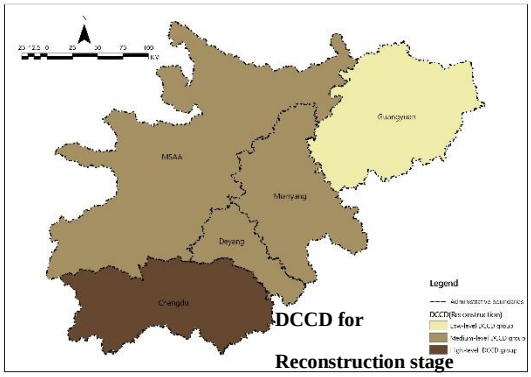


Fig 5- 23 Spatial distribution of DCD by stages for the MSAA





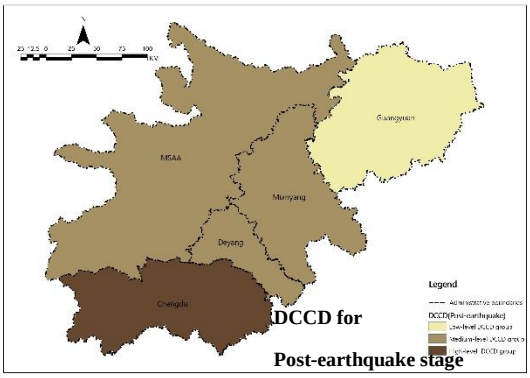


Fig 5- 24 Spatial distribution of DCCD by stages for the MSAA

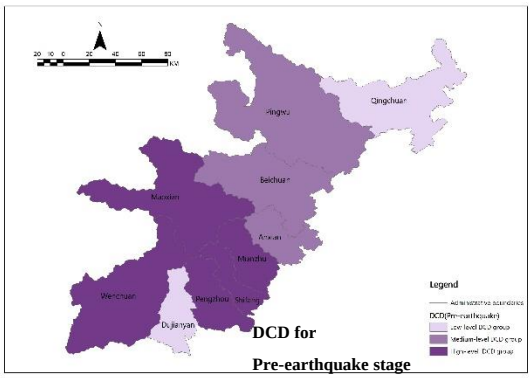
5.3.2 Spatial distribution of coupling and coupling coordination degree for ten counties

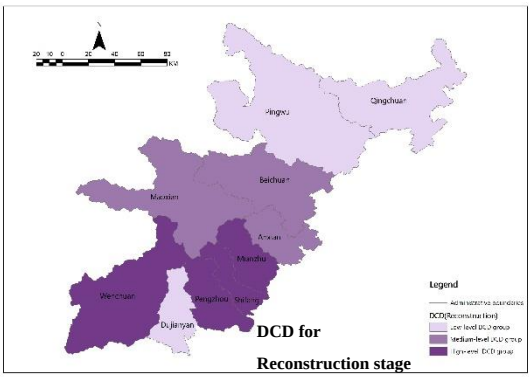
After examine the temporal distribution of urbanization for ten counties, we also tested the spatial distribution at the county scale. To show the spatial distribution of the ten counties before and after the Wenchuan earthquake, we evaluated the variation of urbanization by Wenchuan, Dujiangyan, Pengzhou, Shifang, Mianzhu, Anxian, Maoxian, Beichuan, Pingwu and Qingchuan.

To show the spatial distribution of dynamic coupling degree (DCD), we divided these ten counties into low-level DCD group, medium-level DCD group, high-level DCD group by Nature Break. As shown in Figure 5-25, the mean values of DCD for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Wenchuan, Shifang, Mianzhu,

Pengzhou and Maoxian were evaluated as the high-level DCD group. While Anxian, Beichuan, and Pingwu were classified as medium-level DCD group. Dujiangyan and Qingchuan were grouped as low-level DCD group. At the reconstruction stage, the high-level DCD group was composed by Wenchuan, Pengzhou, Mianzhu, Shifang. At the same stage, Pingwu declined into the low-level DCD group and Maoxian degraded into the medium-level DCD group, respectively. The results showing that the Wenchuan earthquake weakened the DCD level of Pingwu and Maoxian. It was also shown that within the MSAA, the Wenchuan earthquake was not play the same effects at the county level. At the post-earthquake stage, Dujiangyan, Pengzhou, Anxian, Beichuan and Qingchuan were classified as the high-level DCD group, indicating that these counties got the biggest reconstruction effects on DCD level. In a word, after the Wenchuan earthquake hit, there was spatial distribution variation the DCD level at the county level. Among them, Shifang and Mianzhu had declined from high-level DCD group into medium-level DCD group. Wenchuan and Maoxian degraded from high-level DCD group into low-level DCD group, while Pingwu declined from medium-level DCD group to low-level DCD group. Conversely, Dujiangyan and Qingchuan upgraded from low-level DCD group into high-level DCD group. Anxian and Beichuan changed their level from medium-level DCD group into high-level DCD group.

To show the spatial distribution of dynamic coupling coordination degree (DCCD), we divided these ten counties into low-level DCCD group, medium-level DCCD group, high-level DCCD group by Nature Break. As shown in Figure 5-26, the mean values of DCCD for pre-earthquake stage, reconstruction stage, post-earthquake stage were presented. At the pre-earthquake stage, Wenchuan, Shifang, Mianzhu were evaluated as the high-level DCCD group. While Dujiangyan, Pengzhou, Anxian, Maoxian, Beichuan and Pingwu were classified as medium-level DCCD group. Only Qingchuan was grouped as low-level DCCD group. At the reconstruction stage, Dujiangyan, upgraded into high-level DCCD group. In addition, Anxian and Wenchuan degraded into low-level DCCD group and medium-level DCCD group, respectively. The results showing that the effects of Wenchuan earthquake were different with counties in the MSAA. Surprisingly, DCCD level of Dujiangyan improved at the reconstruction stage. The reason for the increased level of DCCD in Dujiangyan is that other counties were affected by the Wenchuan earthquake and decreased a lot at the reconstruction stage. The reason for the increased in Qingchuan county was that the pre-earthquake DCCD level was very low and was not greatly affected by the earthquake. At the post-earthquake stage, Dujiangyan, Pengzhou, Shifang, Mianzhu were evaluated as the high-level DCCD group, indicating that these counties got the biggest reconstruction effects on DCCD level. The results could be also reflected on the value of DCCD for these counties in 2017, that these four counties were the top 4 DCCD value counties. At the same stage, Anxian upgraded into medium-level DCCD group, while Pingwu degraded into low-level DCCD group. In a word, after the Wenchuan earthquake hit, there was spatial distribution variation the DCCD level at the county level. Among them, Wenchuan and Pingwu had declined into medium-level DCCD group and low-level DCCD group, respectively. During the same period, Dujiangyan and Pengzhou upgraded from medium-level DCCD group into high-level DCCD group.





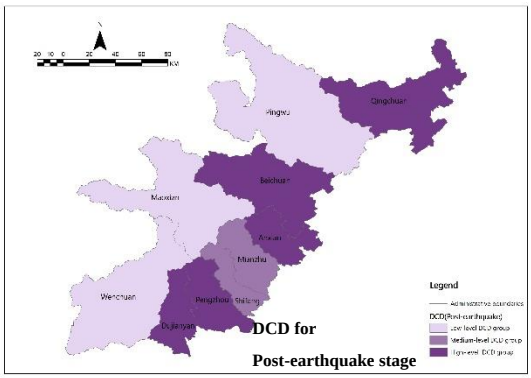
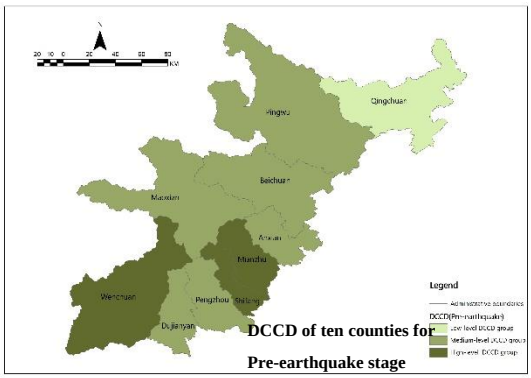
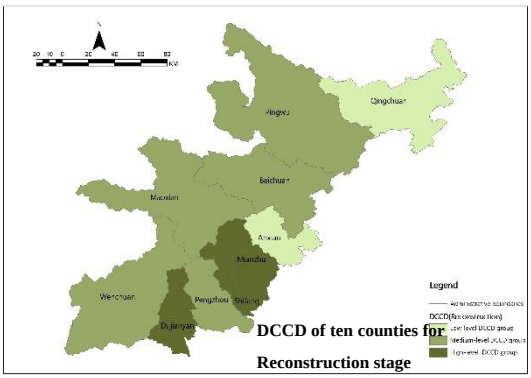


Fig 5- 25 Spatial distribution of DCD by stages for ten counties





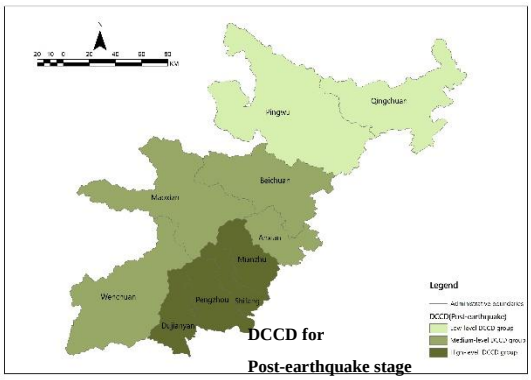


Fig 5- 26 Spatial distribution of DCCD by stages for ten counties

5.4 Summary

In this chapter, taking the Wenchuan earthquake as example, we measured correlation between population urbanization, space urbanization, economy urbanization, and evaluated their coordination state by dynamic coupling degree and dynamic coupling coordination degree, respectively. The main conclusions of variation of coupling coordination characteristics of three subsystems of urbanization under the Wenchuan earthquake context from 2001 to 2017 can be summarized as follows:

In the most severely affected area (MSAA), (1) the degree of correlation between population urbanization, space urbanization, economy urbanization had been stronger from 2008 to 2010, indicating that post-disaster reconstruction policies and measures effectively strengthened the interactions among these three subsystems urbanization. However, the degree of correlation for MSAA did not change sharply in both pre-earthquake (2001 to 2007) and post-earthquake years (2011 to 2017). With respect to interrelationship state of urbanization, the values of DCCD had increased from 0.337 in 2011 to 0.382 in 2017, indicating that (2) the degree of interrelationship on subsystems urbanization in the MSAA improved during these years. Specifically, there are a Slash-shape for the DCCD values during the reconstruction years, showing that the suitable post-disaster policies and measures could effectively strengthen the coordination degree between the urbanization subsystems. In addition, we found that (3) there are stage characteristics for DCCD, while the DCD shows the reverse results. The results indicated that deconstruction earthquake would not affect the degree correlation between population urbanization, space urbanization, economy urbanization in area scale, but improve their interrelationship state by appropriate reconstruction measures and policies. In terms of spatial distribution, (4) the DCD and DCCD level of MSAA did not affect by the Wenchuan earthquake.

With respect to counties, the results break our expectation. Among these ten counties, (5) DCD values for Anxian, Mianzhu, Beichuan, Pingwu, Qingchuan increased during the whole period from 2001 to 2017, which break the assumption that the Wenchuan earthquake would reduce the inter-correlation of the three subsystems of urbanization. While (6) Pengzhou, Shifang, Maoxian, Wenchuan confirms the hypothesis. Furthermore, the values of DCCD increased from 2001 to 2017 for ten counties, indicating that (7) the coupling and coordination state of three subsystems urbanization for all ten counties in the MSAA improved in the same period. With respect to spatial distribution, the ten counties which are distributed in the MSAA, showed different variation of DCCD after the Wenchuan earthquake.

When we evaluate whether there is stage characteristics on DCD and DCCD for these ten counties in the MSAA, interesting results were found. (8) Anxian, Beichuan, Qingchuan, Maoxian, Wenchuan show the stage characteristics on DCD, indicating that there are variation between pre-earthquake stage (2001 to 2007), reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017). The results show that counties dominated by the primary industry, the inter-correlation of their urbanization subsystems will be affected by the Wenchuan earthquake. (9) The other counties show the reverse results. Varying to DCD, the DCCD show different results. For pre-earthquake stage (2001 to 2007), reconstruction stage (2008 to 2010) and post-earthquake stage (2011 to 2017), (10) all ten counties show the stage features on DCCD.

Special results are found during the reconstruction stage (2008 to 2010). In the reconstruction

stage (2008 to 2010), (11) there is a U-shape on DCD value for Anxian county, while (12) Pingwu and Wenchuan represent a reverse U-shape on DCD in the reconstruction stage (2008 to 2010). In terms of Anxian, the reconstruction measures and policies strengthen the degree of correlation between population urbanization, space urbanization, economy urbanization. While Pingwu and Wenchuan show the reverse results. In the same period, (13) only Beichuan, Mianzhu, Shifang and Wenchuan show a U-shape on DCCD, indicating that the coupling and coordination state for these four counties are all benefit from the reconstruction measures and policies.

Reference

[1] Henderson, J. Vernon.Handbook of Economic Growth. Chapter 24 - Urbanization and Growth. Elsevier: 2005:1543-1591.

[2] Chen LQ. Industrial Development and Urbanization. China Development 2005;(03):38-44.

[3] Henderson, Vernon. Urbanization in Developing Countries. The World Bank Research Observer. 2002,17(1):89-112.

[4] Yao SM, Li YJ. On the Urban Spatial Evolution in the Process of Urbanization in China. Geography and Territorial Research 200;16(2):12-16.

[5] Antrop M, Bao ZT, Zou JY, Landscape change and the urbanization process in Europe. Antrop, Marc. Landscape and Urban Planning.2004,67(1):9-26.

[6] Qiu BX. Foreign models and the choice of China's urbanization path. People's Tribune 2005;(6):42-44.

[7] http://www.scio.gov.cn/ztk/dtzt/24/4/Document/630438/630438.htm (accessed on 20 March 2022).

[8] http://www.gov.cn/zwgk/2008-07/22/content_1052835.htm (accessed on 20 March 2022).

[9] Gu, S. The developmental characteristics and strategic ideas of urbanization in China. Chinese Geographical Science 1993;3:97-111. https://doi.org/10.1007/BF02664551

[10] Huang X, Jin H, Bai H. Vulnerability assessment of China's coastal cities based on DEA cross-efficiency model. Int J Disaster Risk Re. 2019;36:101091.

[11] Jiao M, Wang Y, Hu M, Xia B. Spatial deconstruction and differentiation analysis of early warning for ecological security in the Pearl River Delta, China. Sustain. Cities Soc. 2021; 64:102557.

Chapter 6

Comparison and Classification of comprehensive urbanization before and after the Wenchuan earthquake

CHAPTER SIX: COMPARION STUDY OF COMPREHENSIVE URBANIZATION BEFORE AND AFTER THE WENCHUAN EARTHQUAKE

Comparison and Classification of comprehensive urbanization before and after the Wenchuan earthquake

6.1 Introduction 6-1

6.2 Differentiation on urbanization before and after Wenchuan earthquake 6-1

6.2.1 Urbanization difference of MSAA at different stages 6-1

6.2.2 Urbanization difference of Wenchuan county at different stages 6-3

6.2.3 Urbanization difference of Shifang county at different stages 6-5

6.2.4 Urbanization difference of Qingchuan county at different stages 6-7

6.2.5 Urbanization difference of Pingwu county at different stages 6-9

6.2.6 Urbanization difference of Pengzhou county at different stages 6-11

6.2.7 Urbanization difference of Mianzhu county at different stages 6-13

6.2.8 Urbanization difference of Maoxian county at different stages 6-15

6.2.9 Urbanization difference of Dujiangyan county at different stages 6-17

6.2.10 Urbanization difference of Beichuan county at different stages 6-19

6.2.11 Urbanization difference of Anxian county at different stages 6-21

6.3 Differentiation on Coupling coordination characteristics of urbanization before and after Wenchuan earthquake 6-23

6.3.1 Coupling Coordination difference of MSAA at different stages 6-23

6.3.2 Coupling Coordination difference of Wenchuan county at different stages 6-24

6.3.3 Coupling Coordination difference of Shifang county at different stages 6-26

6.3.4 Coupling Coordination difference of Qingchuan county at different stages 6-28

6.3.5 Coupling Coordination difference of Pingwu county at different stages 6-29

6.3.6 Coupling Coordination difference of Pengzhou county at different stages 6-31

6.3.7 Coupling Coordination difference of Mianzhu county at different stages 6-32

6.3.8 Coupling Coordination difference of Maoxian county at different stages 6-34

6.3.9 Coupling Coordination difference of Dujiangyan county at different stages 6-35

6.3.10 Coupling Coordination difference of Beichuan county at different stages 6-37

6.3.11 Coupling Coordination difference of Anxian county at different stages 6-39

6.4 Spatial differentiation by counties before and after Wenchuan earthquake 6-40
6.4.1 Spatial differentiation on population urbanization by counties..... 6-40
6.4.2 Spatial differentiation on space urbanization by counties..... 6-41
6.4.3 Spatial differentiation on economy urbanization by counties 6-42
6.4.4 Spatial differentiation on population-space-economy urbanization by counties..... 6-42
6.4.5 Spatial differentiation on coupling degree by counties 6-43
6.4.6 Spatial differentiation on coupling coordination degree by counties..... 6-44
6.5 Comparative examination on variation of urbanization modes before and after Wenchuan earthquake..... 6-45
6.5.1 Transformation of urbanization modes for the MSAA 6-45
6.5.2 Transformation of urbanization modes for the Wenchuan county..... 6-46
6.5.3 Transformation of urbanization modes for the Shifang county..... 6-47
6.5.4 Transformation of urbanization modes for the Qingchuan county..... 6-48
6.5.5 Transformation of urbanization modes for the Pingwu county..... 6-49
6.5.6 Transformation of urbanization modes for the Pengzhou county 6-50
6.5.7 Transformation of urbanization modes for the Mianzhu county..... 6-51
6.5.8 Transformation of urbanization modes for the Maoxian county..... 6-52
6.5.9 Transformation of urbanization modes for the Dujiangyan county..... 6-53
6.5.10 Transformation of urbanization modes for the Beichuan county 6-54
6.5.11 Transformation of urbanization modes for the Anxian county..... 6-55
6.6 Classification of urbanization before and after Wenchuan earthquake 6-56
6.6.1 Classification of population urbanization before and after Wenchuan earthquake 6-56
6.6.2 Classification of space urbanization before and after Wenchuan earthquake 6-57
6.6.3 Classification of economy urbanization before and after Wenchuan earthquake..... 6-58
6.6.4 Classification of population-space-economy urbanization before and after Wenchuan earthquake..... 6-59
6.6.5 Classification of urbanization quality before and after Wenchuan earthquake 6-60
6.7 Summary..... 6-62
Reference 6-65

6.1 Introduction

In Chapter 4, temporal distribution on Pu, Su, Eu, and Pseu in the MSAA and ten counties were examined. The results showed that Pu, Su, Eu, and Pseu all increased from 2001 to 2017, but lag effect [1-2] which was caused by the Wenchuan earthquake and external effect [3-5] which was produced by the reconstruction policies and measures were both shown on these types of urbanization. In addition, stage distribution on Pu, Su, Eu, and Pseu in the MSAA and the same ten counties were also tested to show that there are stage characteristics. However, lag effect and external effect whether means variation of urbanization level still need to be tested. Furthermore, stage characteristics whether indicate that there are stage differences should be also examined.

In Chapter 5, temporal distribution on DCD and DCCD in the MSAA and ten counties were examined. The results showed that the interrelationship between subsystem of these types urbanization varied in the MSAA and these ten counties. Moreover, the coupling coordination state all improved from 2001 to 2017 in the MSAA and these ten counties. In addition, stage distribution on DCD and DCCD in the MSAA and the same ten counties were also tested to show that there are stage characteristics. However, whether the interrelationship between these types of urbanization was affected by the Wenchuan earthquake and reconstruction measure is worth to test. If the interrelationship between these types of urbanization did affect by the Wenchuan earthquake and reconstruction measures, whether the coupling coordination state significant changed is also valuable to examine. Furthermore, stage characteristics whether indicate that there are stage differences should be also examined.

In this Chapter, the MSAA and these ten most severely affected counties were analyzed on urbanization difference, coupling degree difference, coupling coordination degree difference, urbanization mode difference. The T-test was employed to examine the statistics significant difference between the mean value of the whole period (2001 to 2017) and the mean value of pre-earthquake stage (2001 to 2007), reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017). Paired sample T-test was applied to studied whether there is statistic significant difference between each paired stage. These two methods were both used to test urbanization difference, coupling degree difference, and coupling coordination degree difference. At last, the triangle model was used to examine the urbanization mode difference between these three stages.

6.2 Differentiation on urbanization before and after Wenchuan earthquake

6.2.1 Urbanization difference of MSAA at different stages

As shown in Chapter 4, urbanization of MSAA showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-1, there were statistically significant difference between the mean value of population urbanization for the MSAA during the whole stage (0.357) and that of reconstruction stage (0.332) and post-earthquake stage (0.411). However, different results were shown on space urbanization, economy urbanization and comprehensive urbanization. Furthermore, the mean value of post-earthquake was higher than that of the whole period on population urbanization, space urbanization, economy urbanization, and comprehensive urbanization. While the mean value of pre-earthquake was lower than that of the

whole period on the comprehensive urbanization and two subsystems of urbanization, except for the Population urbanization. Affected by the Wenchuan earthquake, the statistic significant difference was only shown on Population urbanization for the reconstruction stage.

Table 6- 1 Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.320	0.240	0.248	0.288
	Std. deviation	0.057	0.014	0.043	0.044
	T test *P* value	0.144	**0.021***	**0.000****	**0.013***
Reconstruction Stage	Cases	3	3	3	3
	Mean value	0.332	0.326	0.332	0.330
	Std. deviation	0.009	0.022	0.045	0.029
	T test *P* value	**0.033***	0.197	0.285	0.441
Post-earthquake Stage	Cases	7	7	7	7
	Mean value	0.411	0.311	0.510	0.411
	Std. deviation	0.420	0.008	0.049	0.037
	T test *P* value	**0.018***	**0.017***	**0.000****	**0.004****
The whole period (2001 to 2017)	Cases	17	17	17	17
	Mean value	0.357	0.285	0.371	0.346

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be examined to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization and design the policy for the urbanization development under special context, such as earthquake attacking. As shown in Table 6-2, significant difference was found between mean value of pre-earthquake stage and that of post-earthquake stage on Population urbanization, space urbanization, economy urbanization, and comprehensive urbanization. In terms of pre-earthquake stage and reconstruction stage, the significant difference was shown on Population urbanization,

space urbanization, and economy urbanization. While reconstruction stage and post-earthquake stage was shown difference on population urbanization and economy urbanization.

Table 6- 2 Urbanization level differences between stages for the MSAA

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Mean Difference	-0.067	-0.091	-0.046
	Std. deviation	0.024	0.027	0.008
	Degree of Freedom	2	6	2
	P value	**0.040***	**0.000****	**0.010****
Space urbanization score	Mean Difference	-0.119	-0.071	0.033
	Std. deviation	0.034	0.017	0.036
	Degree of Freedom	2	6	2
	P value	**0.025***	**0.000****	0.253
Economy urbanization score	Mean Difference	-0.121	-0.262	-0.132
	Std. deviation	0.034	0.013	0.032
	Degree of Freedom	2	6	2
	P value	**0.026***	**0.000****	**0.019***
Comprehensive urbanization score	Mean Difference	-0.058	-0.123	-0.049
	Std. deviation	0.072	0.047	0.024
	Degree of Freedom	2	6	2
	P value	0.298	**0.000****	0.075

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

6.2.2 Urbanization difference of Wenchuan county at different stages

As shown in Chapter 4, urbanization of Wenchuan county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-3, there were statistically significant difference between the mean value of the whole period and pre-earthquake stage on space urbanization (the P value was 0.028), economy urbanization (the P value was 0.001), and comprehensive urbanization (the P value was 0.024). They were all smaller than that of the whole period. The same result was also found for the reconstruction stage as the MSAA. The mean value of reconstruction stage on population urbanization was significant smaller than that of the whole period. The result suggested that the population subsystem was the only one which was affected by the Wenchuan earthquake among the three urbanization subsystems at the reconstruction stage. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on population urbanization (the P value was 0.011), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.000). The results suggested that except for the space urbanization, all other urbanization subsystem were developed well at the post-earthquake stage.

Table 6- 3 Wenchuan Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.421	0.279	0.419	0.373
	Std. deviation	0.092	0.048	0.073	0.070
	T test *P* value	0.568	**0.028***	**0.001****	**0.024***
Reconstruction Stage	Cases	3	3	3	3
	Mean value	0.391	0.443	0.579	0.471
	Std. deviation	0.012	0.088	0.091	0.060
	T test *P* value	**0.017***	0.159	0.935	0.645
Post-earthquake Stage	Cases	7	7	7	7
	Mean value	0.484	0.337	0.751	0.524
	Std. deviation	0.031	0.012	0.039	0.023
	T test *P* value	**0.011***	0.314	**0.000****	**0.000****
2001 to 2017	Cases	17	17	17	17
	Mean value	0.442	0.332	0.371	0.453

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be examined to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Wenchuan county. As shown in Table 6-4, significant difference was found between mean value of pre-earthquake stage and that of reconstruction stage on space urbanization and comprehensive urbanization. In terms of pre-earthquake stage and post-earthquake stage, the significant difference was shown on comprehensive urbanization and all of three subsystems urbanization. The results indicated that the Wenchuan earthquake indeed changed the level of urbanization and all three subsystems for the Wenchuan county. While reconstruction stage and post-earthquake stage was shown difference on population urbanization.

Table 6- 4 Urbanization level differences between stages for the Wenchuan county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Mean Difference	-0.054	-0.064	-0.069
	Std. deviation	0.069	0.066	0.018

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Space urbanization score	Degree of Freedom	2	6	2
	P value	0.307	**0.043***	**0.022***
	Mean Difference	-0.205	-0.058	0.110
	Std. deviation	0.076	0.047	0.085
	Degree of Freedom	2	6	2
	P value	**0.043***	**0.017***	0.146
Economy urbanization score	Mean Difference	-0.228	-0.332	-0.138
	Std. deviation	0.054	0.059	0.063
	Degree of Freedom	2	6	2
	P value	0.051	**0.000***	0.158
Comprehensive urbanization score	Mean Difference	-0.162	-0.151	-0.031
	Std. deviation	0.062	0.052	0.064
	Degree of Freedom	2	6	2
	P value	**0.045***	**0.000***	0.486

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

6.2.3 Urbanization difference of Shifang county at different stages

As shown in Chapter 4, urbanization of Shifang county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be tested. As shown by the independent samples T test results in Table 6-5, there were statistically significant difference between the mean value of the whole period and pre-earthquake stage on space urbanization (the P value was 0.001), economy urbanization (the P value was 0.001), and comprehensive urbanization (the P value was 0.018). They were all smaller than that of the whole period. The result was the same as the MSAA at the reconstruction stage. Different to Wenchuan county, there were no statistic difference between the Shifang county and the MSAA on population urbanization, space urbanization, economy urbanization and comprehensive urbanization at the reconstruction stage. The result indicated that the mean level of urbanization at the reconstruction stage was not significant different to the whole period. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on population urbanization, space urbanization, economy urbanization, and comprehensive urbanization, but only the last three were statistic significant. The results suggested that except for the population urbanization, all other urbanization subsystem were developed well at the post-earthquake stage.

Table 6- 5 Shifang Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.458	0.277	0.400	0.378

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Reconstruction Stage	Std. deviation	0.076	0.030	0.054	0.050
	T test *P* value	0.927	**0.001****	**0.001****	**0.018***
	Cases	3	3	3	3
	Mean value	0.431	0.336	0.392	0.386
Post-earthquake Stage	Std. deviation	0.028	0.049	0.080	0.048
	T test *P* value	0.265	0.753	0.115	0.197
	Cases	7	7	7	7
	Mean value	0.463	0.419	0.686	0.522
2001 to 2017	Std. deviation	0.036	0.023	0.059	0.038
	T test *P* value	0.595	**0.000****	**0.000****	**0.001****
	Cases	17	17	17	17
	Mean value	0.456	0.346	0.516	0.439

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be examined to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Shifang county. As shown in Table 6-6, the mean value of pre-earthquake stage and that of reconstruction stage were different on population urbanization, space urbanization, economy urbanization and comprehensive urbanization, but they were all not statistics significant. In terms of pre-earthquake stage and post-earthquake stage, the significant differences were shown on space urbanization, economy urbanization and comprehensive urbanization suggesting that the Wenchuan earthquake indeed changed the level of these urbanization for the Shifang county. While reconstruction stage and post-earthquake stage was shown difference on space urbanization.

Table 6- 6 Urbanization level differences between stages for the Shifang county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Mean Difference	-0.046	-0.005	-0.008
	Std. deviation	0.069	0.057	0.036
	Degree of Freedom	2	6	2
	P value	0.363	0.825	0.744

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Space urbanization score	Mean Difference	-0.034	-0.285	-0.239
	Std. deviation	0.085	0.026	0.092
	Degree of Freedom	2	6	2
	P value	0.562	**0.000****	**0.046***
Economy urbanization score	Mean Difference	-0.228	-0.332	-0.138
	Std. deviation	0.054	0.059	0.063
	Degree of Freedom	2	6	2
	P value	0.051	**0.000****	0.158
Comprehensive urbanization score	Mean Difference	-0.053	-0.144	-0.104
	Std. deviation	0.053	0.014	0.052
	Degree of Freedom	2	6	2
	P value	0.221	**0.000****	0.073

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

6.2.4 Urbanization difference of Qingchuan county at different stages

As shown in Chapter 4, urbanization of Qingchuan county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-7, there were statistically significant difference between the mean value of the whole period and pre-earthquake stage on space urbanization (the P value was 0.001), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.000). They were all smaller than that of the whole period. The same results were also found for the reconstruction stage as the MSAA and the Wenchuan county. Similar as Shifang county, there were no statistic difference between the Qingchuan county and the MSAA on population urbanization, space urbanization, economy urbanization and comprehensive urbanization at the reconstruction stage. The result indicated that the mean level of urbanization at the reconstruction stage was not significant different to the whole period. It also suggested that earthquake reconstruction policies and measures played positive role for the Qingchuan county on the urbanization development. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on population urbanization (the P value was 0.011), space urbanization (the P value was 0.044), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.000). The results indicated that all urbanization subsystem were developed well at the post-earthquake stage.

Table 6- 7 Qingchuan Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.165	0.118	0.057	0.113
	Std. deviation	0.039	0.033	0.018	0.029
	T test *P* value	0.058	**0.001****	**0.000****	**0.000****
Reconstruction Stage	Cases	3	3	3	3
	Mean value	0.199	0.326	0.174	0.233
	Std. deviation	0.021	0.095	0.097	0.071
	T test *P* value	0.983	0.148	0.969	0.403
Post-earthquake Stage	Cases	7	7	7	7
	Mean value	0.234	0.227	0.285	0.248
	Std. deviation	0.025	0.028	0.030	0.018
	T test *P* value	**0.011***	**0.044***	**0.000****	**0.000 ****
2001 to 2017	Cases	17	17	17	17
	Mean value	0.200	0.199	0.171	0.190

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be tested to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Qingchuan county. As shown in Table 6-8, significant difference was found between mean value of pre-earthquake stage and that of reconstruction stage on population urbanization and space urbanization. In terms of pre-earthquake stage and post-earthquake stage, the significant difference was shown on comprehensive urbanization and all of three subsystems urbanization. The results indicated that the Wenchuan earthquake indeed changed the level of urbanization and all three subsystems for the Qingchuan county. While reconstruction stage and post-earthquake stage was shown difference on comprehensive urbanization and other three subsystems, but they were no statistic significant difference.

Table 6- 8 Urbanization level differences between stages for the Qingchuan county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Mean Difference	-0.066	-0.069	-0.050
	Std. deviation	0.006	0.053	0.048
	Degree of Freedom	2	6	2
	P value	**0.003***	**0.014****	0.212
Space urbanization score	Mean Difference	-0.235	-0.109	0.122
	Std. deviation	0.085	0.009	0.080
	Degree of Freedom	2	6	2
	P value	**0.041***	**0.000****	0.117
Economy urbanization score	Mean Difference	-0.124	-0.228	-0.084
	Std. deviation	0.059	0.008	0.050
	Degree of Freedom	2	6	2
	P value	0.171	**0.000****	0.232
Comprehensive urbanization score	Mean Difference	-0.142	-0.135	-0.004
	Std. deviation	0.062	0.013	0.071
	Degree of Freedom	2	6	2
	P value	0.059	**0.000****	0.930

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

6.2.5 Urbanization difference of Pingwu county at different stages

As shown in Chapter 4, urbanization of Pingwu county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be tested. As shown by the independent samples T test results in Table 6-9, there was statistically significant difference between the mean value of the whole period and pre-earthquake stage on economy urbanization (the P value was 0.002). The result indicated that population urbanization was the only subsystem of urbanization which lagged than others at the pre-earthquake stage. The result was also different to the MSAA, the Wenchuan county, Shifang county, Qingchuan county. The mean value of reconstruction stage on population urbanization and space urbanization were significantly higher than that of the whole period. The result suggested that the population subsystem and space subsystem was majorly benefited from the reconstruction measures. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on economy urbanization (the P value was 0.000), but smaller on space urbanization (the P value was 0.000). The results suggested that economy urbanization subsystem was developed well at the post-earthquake stage. While the space urbanization showed the reverse result.

Table 6- 9 Pingwu Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.198	0.271	0.144	0.204
	Std. deviation	0.037	0.105	0.060	0.067
	T test *P* value	0.563	0.857	**0.002****	0.117
Reconstruction Stage	Cases	3	3	3	3
	Mean value	0.225	0.454	0.256	0.312
	Std. deviation	0.004	0.067	0.055	0.035
	T test *P* value	**0.012***	**0.046***	0.777	0.093
Post-earthquake Stage	Cases	7	7	7	7
	Mean value	0.207	0.210	0.393	0.270
	Std. deviation	0.047	0.016	0.029	0.022
	T test *P* value	0.975	**0.000****	**0.000****	0.055
2001 to 2017	Cases	17	17	17	17
	Mean value	0.207	0.278	0.267	0.250

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be tested to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Pingwu county. As shown in Table 6-10, significant difference was found between mean value of pre-earthquake stage and that of reconstruction stage on space urbanization, economy urbanization and comprehensive urbanization. In terms of pre-earthquake stage and post-earthquake stage, the significant difference was shown on economy urbanization and comprehensive urbanization. The results suggested that the Wenchuan earthquake indeed changed the level of economy urbanization and comprehensive urbanization for the Pingwu county. While reconstruction stage and post-earthquake stage was shown difference on space urbanization and economy urbanization.

Table 6- 10 Urbanization level differences between stages for the Pingwu county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Mean Difference	-0.058	0.009	0.039
	Std. deviation	0.029	0.040	0.034

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Space urbanization score	Degree of Freedom	2	6	2
	P value	0.071	0.570	0.179
	Mean Difference	-0.276	0.060	0.256
	Std. deviation	0.054	0.097	0.055
	Degree of Freedom	2	6	2
	P value	**0.013***	0.152	**0.015***
Economy urbanization score	Mean Difference	-0.168	-0.249	-0.111
	Std. deviation	0.038	0.041	0.030
	Degree of Freedom	2	6	2
	P value	**0.017***	**0.000****	**0.023***
Comprehensive urbanization score	Mean Difference	-0.167	-0.066	0.061
	Std. deviation	0.019	0.046	0.035
	Degree of Freedom	2	6	2
	P value	**0.004****	**0.009****	0.094

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

6.2.6 Urbanization difference of Pengzhou county at different stages

As shown in Chapter 4, urbanization of Pengzhou county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-11, there were statistically significant difference between the mean value of the whole period and pre-earthquake stage on population urbanization (the P value was 0.002), space urbanization (the P value was 0.000), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.000). They were all smaller than that of the whole period. Compared to the MSAA and Wenchuan county, Shifang county, Qingchuan county, Pingwu county, this result was the most comprehensive difference, indicating that the level of urbanization for the Pengzhou county was overall lower than the whole of period. However, there was not significant difference on comprehensive urbanization and three subsystems at the reconstruction stage. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on population urbanization (the P value was 0.013), economy urbanization (the P value was 0.002), space urbanization (the P value was 0.006), and comprehensive urbanization (the P value was 0.006). The results suggested that all urbanization subsystem were developed well at the post-earthquake stage.

Table 6- 11 Pengzhou Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.302	0.222	0.229	0.251

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Reconstruction Stage	Std. deviation	0.037	0.018	0.029	0.027
	T test *P* value	**0.002****	**0.000****	**0.000****	**0.000****
	Cases	3	3	3	3
	Mean value	0.343	0.280	0.327	0.316
	Std. deviation	0.019	0.036	0.061	0.039
	T test *P* value	0.087	0.527	0.313	0.282
Post-earthquake Stage	Cases	7	7	7	7
	Mean value	0.468	0.376	0.540	0.461
	Std. deviation	0.069	0.040	0.105	0.071
	T test *P* value	**0.013****	**0.002****	**0.006****	**0.006****
2001 to 2017	Cases	17	17	17	17
	Mean value	0.378	0.296	0.374	0.349

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be examined to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Pengzhou county. As shown in Table 6-12, significant difference was found between mean value of pre-earthquake stage and that of reconstruction stage on population urbanization and comprehensive urbanization. In terms of pre-earthquake stage and post-earthquake stage, the significant difference was shown on comprehensive urbanization and all of three subsystems urbanization. The results indicated that the Wenchuan earthquake indeed changed the level of urbanization and all three subsystems for the Pengzhou county. The result was the same as the Wenchuan county. While reconstruction stage and post-earthquake stage was shown difference on space urbanization, economy urbanization and comprehensive urbanization.

Table 6- 12 Urbanization level differences between stages for the Pengzhou county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Mean Difference	-0.072	-0.166	-0.068
	Std. deviation	0.014	0.035	0.031
	Degree of Freedom	2	6	2

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Space urbanization score	*P* value	**0.012***	**0.000****	0.063
	Mean Difference	-0.072	-0.153	-0.058
	Std. deviation	0.032	0.024	0.021
	Degree of Freedom	2	6	2
Economy urbanization score	*P* value	0.060	**0.000****	**0.042***
	Mean Difference	-0.123	-0.311	-0.112
	Std. deviation	0.054	0.078	0.038
	Degree of Freedom	2	6	2
Comprehensive urbanization score	*P* value	0.058	**0.000****	**0.037***
	Mean Difference	-0.089	-0.210	-0.080
	Std. deviation	0.025	0.044	0.018
	Degree of Freedom	2	6	2
	P value	**0.025***	**0.000****	**0.017***

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

6.2.7 Urbanization difference of Mianzhu county at different stages

As shown in Chapter 4, urbanization of Mianzhu county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-13, there were statistically significant difference between the mean value of the whole period and pre-earthquake stage on space urbanization (the P value was 0.005), economy urbanization (the P value was 0.007), and comprehensive urbanization (the P value was 0.019). They were all smaller than that of the whole period. The same result was also found for the reconstruction stage as the MSAA, the Wenchuan county, Shifang county, and Qingchuan county. The mean value of reconstruction stage were all lower than that of the whole period, while only economy urbanization and comprehensive urbanization was significant smaller. The result suggested that the economy subsystem and the comprehensive urbanization were affected by the Wenchuan earthquake among the three urbanization subsystems at the reconstruction stage. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on space urbanization (the P value was 0.015), economy urbanization (the P value was 0.003), and comprehensive urbanization (the P value was 0.017). The results suggested that except for the population urbanization, all other urbanization subsystem were developed well at the post-earthquake stage.

Table 6- 13 Mianzhu Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.389	0.249	0.382	0.340

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Reconstruction Stage	Std. deviation	0.051	0.040	0.065	0.048
	T test *P* value	0.660	**0.005****	**0.007****	**0.019***
	Cases	3	3	3	3
	Mean value	0.346	0.293	0.421	0.353
Post-earthquake Stage	Std. deviation	0.025	0.011	0.013	0.016
	T test *P* value	0.067	0.081	**0.016****	**0.040***
	Cases	7	7	7	7
	Mean value	0.429	0.391	0.604	0.475
2001 to 2017	Std. deviation	0.060	0.060	0.069	0.063
	T test *P* value	0.223	**0.015***	**0.003****	**0.017***
	Cases	17	17	17	17
	Mean value	0.398	0.315	0.480	0.398

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be examined to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Pengzhou county. As shown in Table 6-14, significant difference was found between mean value of pre-earthquake stage and that of reconstruction stage on space urbanization, economy urbanization and comprehensive urbanization. In terms of pre-earthquake stage and post-earthquake stage, the significant difference was shown like the results as pre-earthquake stage and reconstruction stage. The results indicated that the Wenchuan earthquake indeed changed the level of urbanization, space subsystem, and economy subsystem for the Wenchuan county. While reconstruction stage and post-earthquake stage was shown difference on economy urbanization and comprehensive urbanization. In a word, the economy urbanization and the comprehensive urbanization showed the significant difference at each paired stage for the Pengzhou county.

Table 6- 14 Urbanization level differences between stages for the Mianzhu county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Mean Difference	-0.007	-0.040	-0.047
	Std. deviation	0.036	0.054	0.045

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Space urbanization score	Degree of Freedom	2	6	2
	P value	0.779	0.098	0.210
	Mean Difference	-0.076	-0.142	-0.057
	Std. deviation	0.012	0.023	0.027
	Degree of Freedom	2	6	2
	P value	**0.009****	**0.000****	0.066
Economy urbanization score	Mean Difference	-0.095	-0.223	-0.130
	Std. deviation	0.009	0.017	0.031
	Degree of Freedom	2	6	2
	P value	**0.003****	**0.000****	**0.019***
Comprehensive urbanization score	Mean Difference	-0.059	-0.135	-0.078
	Std. deviation	0.018	0.027	0.031
	Degree of Freedom	2	6	2
	P value	**0.031***	**0.000****	**0.050***

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

6.2.8 Urbanization difference of Maoxian county at different stages

As shown in Chapter 4, urbanization of Maoxian county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-15, there were statistically significant difference between the mean value of the whole period and pre-earthquake stage on space urbanization (the P value was 0.037), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.003). They were all smaller than that of the whole period. The same result was also found for the reconstruction stage as the MSAA, the Wenchuan county, Shifang county, Qingchuan county, and Mianzhu county. Similar as the Shifang county, the Qingchuan county, and Pengzhou county, there were differences between the mean value of reconstruction stage and that of the whole period, but they were not statistic significant. The result suggested that the mean level of urbanization at the reconstruction stage was not significant different to the whole period. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on population urbanization (the P value was 0.007), space urbanization (the P value was 0.005), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.000). The results suggested that all urbanization subsystem were developed well at the post-earthquake stage.

Table 6- 15 Maoxian Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.246	0.180	0.235	0.220
	Std. deviation	0.072	0.021	0.040	0.037
	T test *P* value	0.059	**0.037***	**0.000****	**0.003****
Reconstruction Stage	Cases	3	3	3	3
	Mean value	0.310	0.214	0.342	0.289
	Std. deviation	0.011	0.043	0.062	0.031
	T test *P* value	0.907	0.654	0.681	0.960
Post-earthquake Stage	Cases	7	7	7	7
	Mean value	0.372	0.216	0.490	0.359
	Std. deviation	0.042	0.010	0.033	0.024
	T test *P* value	**0.007****	**0.005****	**0.000****	**0.000****
2001 to 2017	Cases	17	17	17	17
	Mean value	0.309	0.201	0.359	0.290

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be tested to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Maoxian county. As shown in Table 6-16, significant difference was found between mean value of pre-earthquake stage and that of reconstruction stage on population urbanization, economy urbanization and comprehensive urbanization. In terms of pre-earthquake stage and post-earthquake stage, the significant difference was shown on comprehensive urbanization and all of three subsystems urbanization. The results indicated that the Wenchuan earthquake indeed changed the level of urbanization and all three subsystems for the Maoxian county. While reconstruction stage and post-earthquake stage was shown difference on economy urbanization and comprehensive urbanization. In a word, similar as Pengzhou county, the economy urbanization and the comprehensive urbanization showed the significant difference at each paired stage for the Maoxian county.

Table 6- 16 Urbanization level differences between stages for the Maoxian county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Mean Difference	-0.131	-0.127	-0.024
	Std. deviation	0.048	0.045	0.025
	Degree of Freedom	2	6	2
	P value	**0.042***	**0.000****	0.232
Space urbanization score	Mean Difference	-0.037	-0.036	0.006
	Std. deviation	0.026	0.023	0.038
	Degree of Freedom	2	6	2
	P value	0.135	**0.006****	0.812
Economy urbanization score	Mean Difference	-0.140	-0.255	-0.134
	Std. deviation	0.051	0.026	0.035
	Degree of Freedom	2	6	2
	P value	**0.042***	**0.000****	**0.022***
Comprehensive urbanization score	Mean Difference	-0.103	-0.139	-0.051
	Std. deviation	0.011	0.015	0.016
	Degree of Freedom	2	6	2
	P value	**0.004****	**0.000****	**0.032***

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

6.2.9 Urbanization difference of Dujiangyan county at different stages

As shown in Chapter 4, urbanization of Dujiangyan county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be tested. As shown by the independent samples T test results in Table 6-17, there were statistically significant difference between the mean value of the whole period and pre-earthquake stage on population urbanization (the P value was 0.036), space urbanization (the P value was 0.000), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.003). Different to counties analyzed above, the mean value of Dujiangyan county at the pre-earthquake stage was totally lower than that of the whole of period on all subsystem of urbanization and comprehensive urbanization, indicating that the urbanization development was dramatic fast after the Wenchuan earthquake hit. This result could be also seen from the significant increasing on urban population, expansion built-up space, growth economy after the Wenchuan earthquake attack. Similar as the Shifang county, the Qingchuan county, Pengzhou county, and Maoxian county, there were differences between the mean value of reconstruction stage and that of the whole period, but they were not statistic significant. The result suggested that the mean level of urbanization at the reconstruction stage was not significant different to the whole period. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on population urbanization (the P value was 0.000), space urbanization (the P value was 0.007), economy urbanization (the P value was 0.004), and comprehensive urbanization (the P value was 0.002). The results suggested that all other urbanization subsystem were developed well at the post-earthquake stage.

Table 6- 17 Dujiangyan Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.496	0.269	0.338	0.368
	Std. deviation	0.092	0.018	0.042	0.049
	T test *P* value	**0.036***	**0.000****	**0.000****	**0.003****
Reconstruction Stage	Cases	3	3	3	3
	Mean value	0.504	0.306	0.405	0.405
	Std. deviation	0.039	0.028	0.076	0.047
	T test *P* value	0.064	0.363	0.325	0.186
Post-earthquake Stage	Cases	7	7	7	7
	Mean value	0.718	0.390	0.611	0.573
	Std. deviation	0.047	0.043	0.086	0.056
	T test *P* value	**0.000****	**0.007****	**0.004****	**0.002****
2001 to 2017	Cases	17	17	17	17
	Mean value	0.589	0.326	0.462	0.459

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be examined to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Dujiangyan county. As shown in Table 6-18, significant difference was found between mean value of pre-earthquake stage and that of reconstruction stage on population urbanization, space urbanization and comprehensive urbanization. In terms of pre-earthquake stage and post-earthquake stage, the significant difference was shown on comprehensive urbanization and all of three subsystems urbanization. The results indicated that the Wenchuan earthquake indeed changed the level of urbanization and all three subsystems for the Dujiangyan county. While reconstruction stage and post-earthquake stage was shown difference on population urbanization and comprehensive urbanization. In a word, different to Pengzhou county, the population urbanization and the comprehensive urbanization showed the significant difference at each paired stage for the Dujiangyan county.

Table 6- 18 Urbanization level differences between stages for the Dujiangyan county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Mean Difference	-0.092	-0.223	-0.175
	Std. deviation	0.018	0.056	0.013
	Degree of Freedom	2	6	2
	P value	**0.012***	**0.000****	**0.002****
Space urbanization score	Mean Difference	-0.053	-0.121	-0.051
	Std. deviation	0.020	0.026	0.022
	Degree of Freedom	2	6	2
	P value	**0.043***	**0.000****	0.059
Economy urbanization score	Mean Difference	-0.010	-0.273	-0.139
	Std. deviation	0.060	0.047	0.070
	Degree of Freedom	2	6	2
	P value	0.100	**0.000****	0.075
Comprehensive urbanization score	Mean Difference	-0.082	-0.206	-0.122
	Std. deviation	0.022	0.018	0.029
	Degree of Freedom	2	6	2
	P value	**0.023***	**0.000****	**0.018***

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

6.2.10 Urbanization difference of Beichuan county at different stages

As shown in Chapter 4, urbanization of Beichuan county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-19, there were statistically significant difference between the mean value of the whole period and pre-earthquake stage on population urbanization (the P value was 0.048), and economy urbanization (the P value was 0.000). They were all smaller than that of the whole period. The same result was also found for the reconstruction stage as the MSAA. The mean value of reconstruction stage on population urbanization was significant smaller than that of the whole period. The result suggested that the population subsystem was the only one which was affected by the Wenchuan earthquake among the three urbanization subsystems at the reconstruction stage. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on population urbanization (the P value was 0.011), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.000). The results suggested that except for the space urbanization, all other urbanization subsystem were developed well at the post-earthquake stage.

Table 6- 19 Beichuan Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
	Cases	7	7	7	7

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Mean value	0.251	0.333	0.142	0.242
	Std. deviation	0.056	0.077	0.042	0.058
	T test *P* value	**0.048***	0.430	**0.000****	0.070
	Cases	3	3	3	3
Reconstruction Stage	Mean value	0.278	0.354	0.250	0.294
	Std. deviation	0.007	0.183	0.052	0.053
	T test *P* value	**0.028***	0.707	0.802	0.905
	Cases	7	7	7	7
Post-earthquake Stage	Mean value	0.366	0.264	0.378	0.336
	Std. deviation	0.063	0.022	0.035	0.038
	T test *P* value	**0.039***	**0.002****	**0.000****	**0.019***
2001 to 2017	Cases	17	17	17	17
	Mean value	0.303	0.308	0.258	0.290

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be examined to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Beichuan county. As shown in Table 6-20, significant difference was found between mean value of pre-earthquake stage and that of reconstruction stage on population urbanization and economy urbanization. In terms of pre-earthquake stage and post-earthquake stage, the significant difference was shown on comprehensive urbanization and all of three subsystems urbanization. The results indicated that the Wenchuan earthquake indeed changed the level of urbanization and all three subsystems for the Beichuan county. While reconstruction stage and post-earthquake stage was not shown significant difference. In a word, significant difference was found out on the paired pre-earthquake stage and reconstruction stage, and pre-earthquake and post-earthquake stage for Beichuan county.

Table 6- 20 Urbanization level differences between stages for the Beichuan county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
	Mean Difference	-0.083	-0.116	-0.036

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Std. deviation	0.010	0.021	0.019
	Degree of Freedom	2	6	2
	P value	**0.005****	**0.000****	0.085
Space urbanization score	Mean Difference	-0.090	0.068	0.106
	Std. deviation	0.198	0.058	0.197
	Degree of Freedom	2	6	2
	P value	0.511	**0.020***	0.449
Economy urbanization score	Mean Difference	-0.145	-0.235	-0.102
	Std. deviation	0.039	0.028	0.053
	Degree of Freedom	2	6	2
	P value	**0.023***	**0.000****	0.080
Comprehensive urbanization score	Mean Difference	-0.106	-0.094	-0.011
	Std. deviation	0.060	0.026	0.076
	Degree of Freedom	2	6	2
	P value	0.093	**0.000****	0.832

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

6.2.11 Urbanization difference of Anxian county at different stages

As shown in Chapter 4, urbanization of Anxian county showed stage characteristics. Whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-21, there were statistically significant difference between the mean value of the whole period and pre-earthquake stage on population urbanization (the P value was 0.021), space urbanization (the P value was 0.001), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.000). Similar as Dujiangyan county, the mean value of Anxian county at the pre-earthquake stage was totally lower than that of the whole of period on all subsystem of urbanization and comprehensive urbanization, indicating that the urbanization development was dramatic fast after the Wenchuan earthquake hit. Similar as the Shifang county, the Qingchuan county, Pengzhou county, Maoxian county, and Dujiangyan county, there were differences between the mean value of reconstruction stage and that of the whole period, but they were not statistic significant. The result suggested that the mean level of urbanization at the reconstruction stage was not significant different to the whole period. With respect to the post-earthquake stage, the mean value was higher than that of the whole period on space urbanization (the P value was 0.002), economy urbanization (the P value was 0.000), and comprehensive urbanization (the P value was 0.001). The results suggested that except for the population urbanization, all other urbanization subsystem were developed well at the post-earthquake stage.

Table 6- 21 Anxian Urbanization level differences between each stage and the whole period in specific types of urbanization

Period	T-test	Population urbanization score	Space urbanization score	Economy urbanization score	Comprehensive urbanization score
Pre-earthquake Stage	Cases	7	7	7	7
	Mean value	0.274	0.203	0.132	0.203
	Std. deviation	0.036	0.017	0.017	0.021
	T test *P* value	**0.021***	**0.001****	**0.000****	**0.000****
Reconstruction Stage	Cases	3	3	3	3
	Mean value	0.295	0.257	0.177	0.243
	Std. deviation	0.056	0.019	0.049	0.029
	T test *P* value	0.572	0.398	0.183	0.310
Post-earthquake Stage	Cases	7	7	7	7
	Mean value	0.368	0.283	0.360	0.337
	Std. deviation	0.065	0.019	0.048	0.032
	T test *P* value	0.081	**0.002****	**0.000****	**0.001****
2001 to 2017	Cases	17	17	17	17
	Mean value	0.317	0.245	0.234	0.265

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems should be examined to show how the urbanization and its three subsystems development before, under, after the earthquake hit. The results would be helpful to deepen the understanding of urbanization under the destructive earthquake context and design special policy for the Anxian county. As shown in Table 6-22, significant difference was found between mean value of pre-earthquake stage and that of reconstruction stage on space urbanization and comprehensive urbanization. In terms of pre-earthquake stage and post-earthquake stage, the significant difference was shown on comprehensive urbanization and all of three subsystems urbanization. The results indicated that the Wenchuan earthquake indeed changed the level of urbanization and all three subsystems for the Anxian county. While reconstruction stage and post-earthquake stage was shown difference on economy urbanization and comprehensive urbanization. In a word, the economy urbanization and the comprehensive urbanization showed the significant difference at each paired stage for the Anxian county.

Table 6- 22 Urbanization level differences between stages for the Anxian county

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
	Mean Difference	-0.058	-0.094	-0.020

Types of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake Stage
Population urbanization score	Std. deviation	0.051	0.038	0.052
	Degree of Freedom	2	6	2
	P value	0.187	**0.001****	0.582
Space urbanization score	Mean Difference	-0.068	-0.080	-0.042
	Std. deviation	0.018	0.033	0.036
	Degree of Freedom	2	6	2
	P value	**0.024***	**0.001****	0.190
Economy urbanization score	Mean Difference	-0.054	-0.228	-0.138
	Std. deviation	0.037	0.039	0.027
	Degree of Freedom	2	6	2
	P value	0.129	**0.000****	**0.012***
Comprehensive urbanization score	Mean Difference	-0.060	-0.134	-0.066
	Std. deviation	0.020	0.014	0.014
	Degree of Freedom	2	6	2
	P value	**0.036***	**0.000****	**0.015***

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

6.3 Differentiation on Coupling coordination characteristics of urbanization before and after Wenchuan earthquake

6.3.1 Coupling Coordination difference of MSAA at different stages

As shown in Chapter 5, relationship of urbanization subsystems of MSAA showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-23, there were statistically significant difference between the mean value of coupling degree for the MSAA during the whole stage (0.323) and that of pre-earthquake stage (0.321). However, coupling coordination degree of pre-earthquake was smaller than the of the whole period, while post-earthquake stage had a higher mean value than the whole period.

Table 6- 23 Coupling and Coupling Coordination Degree differences of the MSAA

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.321	0.289
	Std. deviation	0.002	0.024
	T test *P* value	**0.027***	**0.008** **
Reconstruction Stage	Cases	3	3
	Mean value	0.325	0.325
	Std. deviation	0.004	0.015
	T test *P* value	0.549	0.981

Period	T-test	Coupling Degree	Coupling Coordination Degree
Post-earthquake Stage	Cases	7	7
	Mean value	0.324	0.361
	Std. deviation	0.001	0.016
	T test *P* value	0.058	**0.001** **
2001 to 2017	Cases	17	17
	Mean value	0.323	0.325

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-24, significant difference of coupling degree was found between pre-earthquake stage and post-earthquake stage, suggesting that the Wenchuan earthquake only impacted the interrelationship of reconstruction stage between population urbanization, space urbanization, economy urbanization. In terms of coupling and coordination degree, the significant difference was shown between pre-earthquake and reconstruction stage, post-earthquake stage, showing that the Wenchuan earthquake indeed changed the coupling coordination state between three subsystems of urbanization after the earthquake hit.

Table 6- 24 Coupling and Coupling Coordination Degree differences between stages for the MSAA

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	-0.002	-0.003	0.000
	Std. deviation	0.006	0.001	0.005
	Degree of Freedom	2	6	2
	P value	0.539	**0.000****	1.000
Coupling Coordination Degree	Mean Difference	-0.119	-0.071	0.033
	Std. deviation	0.034	0.017	0.036
	Degree of Freedom	2	6	2
	P value	**0.025***	**0.000****	0.253

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

6.3.2 Coupling Coordination difference of Wenchuan county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Wenchuan showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that

of the whole period should be tested. As shown by the independent samples T test results in Table 6-25, there were statistically significant difference between the mean value of coupling degree for the Wenchuan during the whole stage (0.323) and that of pre-earthquake stage (0.327). The same results were also shown at reconstruction stage (0.328), post-earthquake stage (0.316). The results indicated that the interrelationship between subsystem of urbanization changed dramatically at different stages. However, coupling coordination degree of pre-earthquake was smaller (the P value was 0.043) than the of the whole period, while post-earthquake stage had a higher mean value (the P value was 0.000) than the whole period, suggesting that the coupling coordination degree of urbanization had become stronger after the Wenchuan earthquake.

Table 6- 25 Coupling and Coupling Coordination Degree differences of the Wenchuan county

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.327	0.348
	Std. deviation	0.001	0.033
	T test *P* value	**0.000****	**0.043***
Reconstruction Stage	Cases	3	3
	Mean value	0.328	0.392
	Std. deviation	0.002	0.024
	T test *P* value	**0.046***	0.473
Post-earthquake Stage	Cases	7	7
	Mean value	0.316	0.406
	Std. deviation	0.001	0.008
	T test *P* value	**0.000****	**0.000****
2001 to 2017	Cases	17	17
	Mean value	0.323	0.380

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-26, there were mean value significant difference (the P value was 0.040) on coupling coordination degree between pre-earthquake stage and reconstruction stage, while coupling degree did not show the same result. The result indicated that the Wenchuan earthquake did not significant change correlation within the three subsystems of urbanization, but undermine the degree of order between them. According to Table 6-26, the reverse result was shown between reconstruction stage and post-earthquake stage. The result suggested that interrelationship between subsystems of urbanization was significant weaken between reconstruction stage and post-earthquake stage, but coordinating state did not dramatic change. With respect to pre-earthquake stage and post-earthquake stage, significant differences were both found out on coupling degree and coupling coordination degree. Furthermore, the mean value difference of coupling degree was positive (0.012), while coupling coordination degree was negative (-0.058), indicating that the quality of urbanization for the Wenchuan county had become better, while the interrelationship between three subsystems had undermined.

Table 6- 26 Coupling and Coupling Coordination Degree differences between stages for the Wenchuan county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	0.000	0.012	0.011
	Std. deviation	0.002	0.001	0.003
	Degree of Freedom	2	6	2
	P value	1.000	**0.000****	**0.023***
Coupling Coordination Degree	Mean Difference	-0.074	-0.058	-0.006
	Std. deviation	0.026	0.026	0.025
	Degree of Freedom	2	6	2
	P value	**0.040***	**0.001****	0.722

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

6.3.3 Coupling Coordination difference of Shifang county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Shifang showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be tested. As shown by the independent samples T test results in Table 6-27, there were statistically significant difference between the mean value of coupling coordination degree for the Shifang county during the whole stage (0.377) and that of pre-earthquake stage (0.021). The same results were also shown at post-earthquake stage (0.001). The results indicated that the coordination state between subsystem of urbanization changed dramatically before and after the Wenchuan earthquake. However, coupling degree of reconstruction stage was significant higher (the P value was 0.048) than the of the whole period, while pre-earthquake stage and post-earthquake stage had a smaller mean value than the whole period, indicating that the coupling degree of urbanization was the stronger at the reconstruction stage.

Table 6- 27 Coupling and Coupling Coordination Degree differences of the Shifang county

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.326	0.350
	Std. deviation	0.003	0.023
	T test *P* value	0.525	**0.021***
Reconstruction Stage	Cases	3	3
	Mean value	0.331	0.357

Period	T-test	Coupling Degree	Coupling Coordination Degree
Post-earthquake Stage	Std. deviation	0.002	0.023
	T test *P* value	**0.048***	0.275
	Cases	7	7
	Mean value	0.326	0.412
2001 to 2017	Std. deviation	0.002	0.015
	T test *P* value	0.122	**0.001****
	Cases	17	17
	Mean value	0.327	0.377

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-28, there were mean value significant difference (the P value was 0.000) on coupling coordination degree between pre-earthquake stage and post-earthquake stage, which was the only statistic significant value between stages. Moreover, the mean value difference of coupling coordination degree was negative (-0.061), indicating that, compared with pre-earthquake stage, the urbanization harmony degree of Shifang County has been greatly improved at the post-earthquake stage. While coupling degree did not show the same result. There was gentle difference on mean value of coupling degree between three paired stages, but none of them were statistic significant. The result indicated that the Wenchuan earthquake did not significant change correlation within the three subsystems of urbanization between each paired stage.

Table 6- 28 Coupling and Coupling Coordination Degree differences between stages for the Shifang county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	-0.003	0.000	0.004
	Std. deviation	0.004	0.002	0.003
	Degree of Freedom	2	6	2
	P value	0.286	0.673	0.120
Coupling Coordination Degree	Mean Difference	-0.027	-0.061	-0.043
	Std. deviation	0.025	0.009	0.024
	Degree of Freedom	2	6	2
	P value	0.207	**0.000****	0.091

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the 0.01 level

6.3.4 Coupling Coordination difference of Qingchuan county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Qingchuan showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be tested. As shown by the independent samples T test results in Table 6-29, there were statistically significant difference between the mean value of coupling degree for the Qingchuan county during the whole stage (0.316) and that of pre-earthquake stage (0.303). The same results were also shown at post-earthquake stage (0.331). The results indicated that the interrelationship between subsystem of urbanization was dramatic lower before the Wenchuan earthquake, while that of urbanization was greatly higher after the Wenchuan earthquake. Similarly, the coupling coordination degree showed the same results as coupling degree on these three stages. The mean value of coupling coordination degree was extreme smaller than that of the whole period at the pre-earthquake stage, while it was great higher at the post-earthquake stage. The results showed that the coupling coordinate state had become better after the Wenchuan earthquake.

Table 6- 29 Coupling and Coupling Coordination Degree differences of the Qingchuan county

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.303	0.184
	Std. deviation	0.117	0.023
	T test *P* value	**0.022***	**0.001****
Reconstruction Stage	Cases	3	3
	Mean value	0.315	0.269
	Std. deviation	0.011	0.045
	T test *P* value	0.871	0.388
Post-earthquake Stage	Cases	7	7
	Mean value	0.331	0.286
	Std. deviation	0.001	0.046
	T test *P* value	**0.000****	**0.000****
2001 to 2017	Cases	17	17
	Mean value	0.316	0.241

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-30, there were mean value significant difference (the P value was 0.000) on coupling coordination degree between pre-earthquake stage and post-earthquake stage. The same result was shown between pre-earthquake stage and reconstruction stage (the P value was 0.048). Moreover, the mean value difference of coupling coordination degree was negative (-0.102), indicating that, compared with pre-earthquake stage, the urbanization harmony degree of Qingchuan County has been greatly improved at the reconstruction stage and post-earthquake stage. While coupling degree did not show the same result. There was gentle difference on mean value of coupling degree between three paired stages, but only

that between pre-earthquake stage and post-earthquake stage was statistic significant. The result indicated that the Wenchuan earthquake undermine the interrelationship after the Wenchuan earthquake hit.

Table 6- 30 Coupling and Coupling Coordination Degree differences between stages for the Qingchuan county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	-0.008	-0.028	-0.016
	Std. deviation	0.025	0.012	0.010
	Degree of Freedom	2	6	2
	P value	0.616	**0.001****	0.111
Coupling Coordination Degree	Mean Difference	-0.102	-0.102	-0.011
	Std. deviation	0.040	0.014	0.044
	Degree of Freedom	2	6	2
	P value	**0.048***	**0.000****	0.707

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

6.3.5 Coupling Coordination difference of Pingwu county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Pingwu showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be tested. As shown by the independent samples T test results in Table 6-31, there were not statistically significant difference between the mean value of coupling coordination degree for the Pingwu county during the whole stage and that of pre-earthquake stage. The same results were also shown at post-earthquake stage and reconstruction stage. The results suggested that the coordination state between subsystem of urbanization did not change greatly before and after the Wenchuan earthquake. Similarly, there were not significant differences of coupling degree on pre-earthquake stage, reconstruction stage, and post-earthquake stage, indicating that the interrelationship between three subsystems of urbanization were not greatly change between these stages and the whole period.

Table 6- 31 Coupling and Coupling Coordination Degree differences of the Pingwu county

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.320	0.253
	Std. deviation	0.003	0.042

Period	T-test	Coupling Degree	Coupling Coordination Degree
Reconstruction Stage	*T* test *P* value	0.071	0.149
	Cases	3	3
	Mean value	0.316	0.314
	Std. deviation	0.007	0.016
Post-earthquake Stage	*T* test *P* value	0.723	0.067
	Cases	7	7
	Mean value	0.316	0.292
	Std. deviation	0.007	0.013
2001 to 2017	*T* test *P* value	0.450	0.060
	Cases	17	17
	Mean value	0.318	0.280

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-32, there were mean value significant difference (the P value was 0.001) on coupling coordination degree between pre-earthquake stage and reconstruction stage (the P value was 0.016). Moreover, the mean value difference of coupling coordination degree was both negative (-0.100 and -0.038, respectively), indicating that, compared with pre-earthquake stage, the urbanization harmony degree of Pingwu county has been greatly improved at the reconstruction stage and post-earthquake stage. While coupling degree did not show the same result. There was gentle difference on mean value of coupling degree between three paired stages, but none of them were statistic significant. The result indicated that the Wenchuan earthquake did not significant change correlation within the three subsystems of urbanization between each paired stage.

Table 6- 32 Coupling and Coupling Coordination Degree differences between stages for the Pingwu county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	0.002	0.005	0.001
	Std. deviation	0.008	0.009	0.009
	Degree of Freedom	2	6	2
	P value	0.691	0.226	0.860
Coupling Coordination Degree	Mean Difference	-0.100	-0.038	0.033
	Std. deviation	0.005	0.031	0.019

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
	Degree of Freedom	2	6	2
	P value	**0.001****	**0.016***	0.091

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

6.3.6 Coupling Coordination difference of Pengzhou county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Pengzhou showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-33, the mean value of coupling degree for pre-earthquake stage, reconstruction stage, post-earthquake stage was not significant difference to that of the whole period. The results indicated that the interrelationship between subsystem of urbanization did not change dramatically at different stages. However, coupling coordination degree of pre-earthquake was smaller (the P value was 0.000) than the of the whole period, while post-earthquake stage had a higher mean value (the P value was 0.003) than the whole period, suggesting that the coupling coordination degree of urbanization had become stronger after the Wenchuan earthquake.

Table 6- 33 Coupling and Coupling Coordination Degree differences of the Pengzhou county

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.330	0.287
	Std. deviation	0.001	0.0152
	T test *P* value	0.721	**0.000****
Reconstruction Stage	Cases	3	3
	Mean value	0.332	0.323
	Std. deviation	0.000	0.020
	T test *P* value	/	0.395
Post-earthquake Stage	Cases	7	7
	Mean value	0.330	0.389
	Std. deviation	0.002	0.029
	T test *P* value	0.502	**0.003****
2001 to 2017	Cases	17	17
	Mean value	0.330	0.336

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-34, there were mean value significant difference on coupling coordination degree between pre-earthquake stage and reconstruction stage (the P value was 0.019), pre-earthquake stage and post-earthquake stage (the P

value was 0.000), reconstruction stage and post-earthquake stage (the P value was 0.019). The result indicated that the coordination state changed dramatically between each paired stage. Furthermore, the mean value difference of coupling coordination degree was negative (-0.049, -0.101, -0.038, respectively), indicating that the quality of urbanization for the Wenchuan county had become better and better. According to Table 6-26, the reverse result was shown for the coupling degree at all paired stages. The result suggested that interrelationship between subsystems of urbanization was not significant change at all paired stages.

Table 6- 34 Coupling and Coupling Coordination Degree differences between stages for the Pengzhou county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	-0.002	0.000	0.001
	Std. deviation	0.002	0.002	0.001
	Degree of Freedom	2	6	2
	P value	0.300	0.726	0.184
Coupling Coordination Degree	Mean Difference	-0.049	-0.101	-0.038
	Std. deviation	0.012	0.014	0.005
	Degree of Freedom	2	6	2
	P value	**0.019***	**0.000****	**0.019****

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

6.3.7 Coupling Coordination difference of Mianzhu county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Mianzhu showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-35, there were statistically significant difference between the mean value of coupling coordination degree for the Mianzhu county during the whole stage (0.359) and that of pre-earthquake stage (0.332). The same results were also shown at post-earthquake stage (0.393). The results indicated that the coordination state between subsystem of urbanization changed dramatically before and after the Wenchuan earthquake. However, coupling degree of reconstruction stage was significant higher (the P value was 0.018) than the of the whole period, while pre-earthquake stage had a smaller mean value than the whole period, indicating that the coupling degree of urbanization was the stronger at the reconstruction stage.

Table 6- 35 Coupling and Coupling Coordination Degree differences of the Mianzhu count

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.326	0.332
	Std. deviation	0.002	0.024
	T test *P* value	0.166	**0.025***
Reconstruction Stage	Cases	3	3
	Mean value	0.330	0.341
	Std. deviation	0.001	0.008
	T test *P* value	**0.018***	0.059
Post-earthquake Stage	Cases	7	7
	Mean value	0.327	0.393
	Std. deviation	0.001	0.026
	T test *P* value	0.558	**0.013***
2001 to 2017	Cases	17	17
	Mean value	0.327	0.359

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-36, there were mean value significant difference (the P value was 0.000) on coupling coordination degree between pre-earthquake stage and post-earthquake stage. The same result was shown between pre-earthquake stage and reconstruction stage (the P value was 0.030). Moreover, the mean value difference of coupling coordination degree was negative (-0.061 and -0.031, respectively), indicating that, compared with pre-earthquake stage, the urbanization harmony degree of Mianzhu County has been greatly improved at the reconstruction stage and post-earthquake stage. While coupling degree did not show the same result. There was gentle difference on mean value of coupling degree between three paired stages, but only that between pre-earthquake stage and post-earthquake stage was statistic significant (the P value was 0.035). The result indicated that the Wenchuan earthquake undermine the interrelationship after the Wenchuan earthquake hit.

Table 6- 36 Coupling and Coupling Coordination Degree differences between stages for the Mianzhu county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	-0.003	-0.001	0.002
	Std. deviation	0.002	0.001	0.001
	Degree of Freedom	2	6	2
	P value	0.095	**0.035***	0.073

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Coordination Degree	Mean Difference	-0.031	-0.061	-0.034
	Std. deviation	0.010	0.010	0.014
	Degree of Freedom	2	6	2
	P value	**0.030***	**0.000****	0.055

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

6.3.8 Coupling Coordination difference of Maoxian county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Maoxian showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be tested. As shown by the independent samples T test results in Table 6-37, there were statistically significant difference between the mean value of coupling degree for the Maoxian county during the whole stage (0.322) and that of post-earthquake stage (0.315). The results indicated that the interrelationship between subsystem of urbanization was dramatic lower after the Wenchuan earthquake. Relatively, the coupling coordination degree showed the different results on these three stages. The mean value of coupling coordination degree was extreme smaller than that of the whole period at the pre-earthquake stage, while it was great higher at the post-earthquake stage. The results showed that the coupling coordinate state had become better after the Wenchuan earthquake.

Table 6- 37 Coupling and Coupling Coordination Degree differences of the Maoxian county

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.328	0.268
	Std. deviation	0.006	0.021
	T test *P* value	0.052	**0.004****
Reconstruction Stage	Cases	3	3
	Mean value	0.325	0.306
	Std. deviation	0.003	0.018
	T test *P* value	0.238	0.775
Post-earthquake Stage	Cases	7	7
	Mean value	0.315	0.336
	Std. deviation	0.002	0.011
	T test *P* value	**0.000****	**0.000****
2001 to 2017	Cases	17	17
	Mean value	0.322	0.303

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-38, there were mean value significant difference (the P value was 0.000) on coupling coordination degree between pre-earthquake stage and post-earthquake stage. The same result was shown between pre-earthquake stage and reconstruction stage (the P value was 0.002). Moreover, the mean value difference of coupling coordination degree was negative (-0.068 and -0.058, respectively), indicating that, compared with pre-earthquake stage, the urbanization harmony degree of Maoxian County has been greatly improved at the reconstruction stage and post-earthquake stage. Similarly, coupling degree showed the same result. The mean value of coupling degree was significant different between pre-earthquake stage and reconstruction stage (the P value was 0.026). The same result was also found between pre-earthquake stage and post-earthquake stage (the P value was 0.002). Furthermore, the mean difference was 0.007 and 0.013, respectively. The result indicated that the Wenchuan earthquake undermine the interrelationship between three subsystems of urbanization after the Wenchuan earthquake hit to 2017.

Table 6- 38 Coupling and Coupling Coordination Degree differences between stages for the Maoxian county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	0.007	0.013	0.010
	Std. deviation	0.002	0.006	0.005
	Degree of Freedom	2	6	2
	P value	**0.026***	**0.002****	0.063
Coupling Coordination Degree	Mean Difference	-0.058	-0.068	-0.020
	Std. deviation	0.004	0.106	0.119
	Degree of Freedom	2	6	2
	P value	**0.002****	**0.000****	0.098

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

6.3.9 Coupling Coordination difference of Dujiangyan county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Dujiangyan showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be examined. As shown by the independent samples T test results in Table 6-39, there were statistically significant difference between the mean value of coupling coordination degree for the Dujiangyan county during the whole stage (0.382) and that of pre-

earthquake stage (0.344). The same results were also shown at post-earthquake stage (0.429). The results indicated that the coordination state between subsystem of urbanization changed dramatically before and after the Wenchuan earthquake. However, coupling degree of reconstruction stage was significant higher (the P value was 0.012) than the of the whole period, indicating that the coupling degree of urbanization was the stronger at the reconstruction stage.

Table 6- 39 Coupling and Coupling Coordination Degree differences of the Dujiangyan county

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.323	0.344
	Std. deviation	0.004	0.021
	T test *P* value	0.798	**0.003****
Reconstruction Stage	Cases	3	3
	Mean value	0.326	0.363
	Std. deviation	0.006	0.021
	T test *P* value	**0.012****	0.263
Post-earthquake Stage	Cases	7	7
	Mean value	0.323	0.429
	Std. deviation	0.001	0.022
	T test *P* value	0.304	**0.001****
2001 to 2017	Cases	17	17
	Mean value	0.323	0.382

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-40, there were mean value significant difference on coupling coordination degree between pre-earthquake stage and reconstruction stage (the P value was 0.022), pre-earthquake stage and post-earthquake stage (the P value was 0.000), reconstruction stage and post-earthquake stage (the P value was 0.032). The result indicated that the coordination state changed dramatically between each paired stage. Furthermore, the mean value difference of coupling coordination degree was negative (-0.038, -0.086, -0.048, respectively), indicating that the quality of urbanization for the Dujiangyan county had become better and better. According to Table 6-40, the reverse result was shown for the coupling degree at all paired stages. There was not significant difference for the mean value of coupling degree at each paired stage. The result suggested that interrelationship between subsystems of urbanization was not significant change at all paired stages.

Table 6- 40 Coupling and Coupling Coordination Degree differences between stages for the Dujiangyan county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	0.000	0.000	0.004
	Std. deviation	0.003	0.005	0.002
	Degree of Freedom	2	6	2
	P value	0.840	0.941	0.074
Coupling Coordination Degree	Mean Difference	-0.038	-0.086	-0.048
	Std. deviation	0.010	0.006	0.015
	Degree of Freedom	2	6	2
	P value	**0.022***	**0.000****	**0.032***

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

6.3.10 Coupling Coordination difference of Beichuan county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Beichuan showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be tested. As shown by the independent samples T test results in Table 6-41, there were statistically significant difference between the mean value of coupling degree for the Beichuan county during the whole stage (0.322) and that of pre-earthquake stage (0.313). The same results were also shown at post-earthquake stage (0.329). The results indicated that the interrelationship between subsystem of urbanization was dramatic lower before the Wenchuan earthquake, while that of urbanization was greatly higher after the Wenchuan earthquake. Relatively, the coupling coordination degree showed different results on coupling coordination degree at these three stages. The mean value of coupling coordination degree was extreme higher at the post-earthquake stage. The results showed that the coupling coordinate state of Beichuan county had become better after the Wenchuan earthquake.

Table 6- 41 Coupling and Coupling Coordination Degree differences of the Beichuan county

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.313	0.274
	Std. deviation	0.003	0.034
	T test *P* value	**0.000****	0.064
Reconstruction Stage	Cases	3	3
	Mean value	0.323	0.307
	Std. deviation	0.016	0.022
	T test *P* value	0.889	0.833

Period	T-test	Coupling Degree	Coupling Coordination Degree
Post-earthquake Stage	Cases	7	7
	Mean value	0.329	0.332
	Std. deviation	0.002	0.018
	T test *P* value	**0.000****	**0.007****
2001 to 2017	Cases	17	17
	Mean value	0.322	0.304

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-42, there were mean value significant difference (the P value was 0.050) on coupling coordination degree between pre-earthquake stage and reconstruction stage. The same result was shown between pre-earthquake stage and post-earthquake stage (the P value was 0.000). Moreover, the mean value difference of coupling coordination degree was negative (-0.065 and -0.058, respectively), indicating that, compared with pre-earthquake stage, the urbanization harmony degree of Beichuan County has been greatly improved at the reconstruction stage and post-earthquake stage. While coupling degree did not show the same result. There was gentle difference on mean value of coupling degree between three paired stages, but only that between pre-earthquake stage and post-earthquake stage was statistic significant (the P value was 0.000). The result indicated that the Wenchuan earthquake undermine the interrelationship after the Wenchuan earthquake hit.

Table 6- 42 Coupling and Coupling Coordination Degree differences between stages for the Dujiangyan county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	-0.012	-0.016	-0.007
	Std. deviation	0.015	0.004	0.017
	Degree of Freedom	2	6	2
	P value	0.294	**0.000****	0.556
Coupling Coordination Degree	Mean Difference	-0.065	-0.058	-0.010
	Std. deviation	0.026	0.019	0.033
	Degree of Freedom	2	6	2
	P value	**0.050***	**0.000****	0.648

* Statistically Significant at the 0.05 level

** Statistically Significant at the 0.01 level

6.3.11 Coupling Coordination difference of Anxian county at different stages

As shown in Chapter 5, relationship of urbanization subsystems of Anxian showed stage characteristics. Moreover, whether the mean value of stages were significant differences than that of the whole period should be tested. As shown by the independent samples T test results in Table 6-43, there were statistically significant difference between the mean value of coupling degree for the Anxian county during the whole stage (0.324) and that of pre-earthquake stage (0.319). The same results were also shown at post-earthquake stage (0.330). The results indicated that the interrelationship between subsystem of urbanization was dramatic smaller before the Wenchuan earthquake, while that of urbanization was greatly higher after the Wenchuan earthquake. Similarly, the coupling coordination degree showed the same results as coupling degree at these three stages. The mean value of coupling coordination degree was extreme smaller than that of the whole period at the pre-earthquake stage, while it was great higher at the post-earthquake stage. The results showed that the coupling coordinate state had become better after the Wenchuan earthquake.

Table 6- 43 Coupling and Coupling Coordination Degree differences of the Anxian county

Period	T-test	Coupling Degree	Coupling Coordination Degree
Pre-earthquake Stage	Cases	7	7
	Mean value	0.319	0.254
	Std. deviation	0.005	0.013
	T test *P* value	**0.035***	**0.000****
Reconstruction Stage	Cases	3	3
	Mean value	0.323	0.280
	Std. deviation	0.007	0.019
	T test *P* value	0.863	0.405
Post-earthquake Stage	Cases	7	7
	Mean value	0.330	0.333
	Std. deviation	0.004	0.014
	T test *P* value	**0.009****	**0.000****
2001 to 2017	Cases	17	17
	Mean value	0.324	0.291

* Statistically Significant at the $_{0.05}$ level

** Statistically Significant at the $_{0.01}$ level

Furthermore, whether there are significant statistic stage differences on urbanization and its three subsystems also examined to show how the coupling and coupling and coordination degree development before, under, after the earthquake hit. As shown in Table 6-44, there were mean value significant difference on coupling coordination degree between pre-earthquake stage and reconstruction stage (the P value was 0.033), pre-earthquake stage and post-earthquake stage (the P value was 0.000) , reconstruction stage and post-earthquake stage (the P value was 0.026). The result indicated that the coordination state changed dramatically between each paired stage. Furthermore, the mean value difference of coupling coordination degree was negative (-0.037, -0.786, -0.041, respectively), indicating that the quality of urbanization for the Anxian county had become better and better. According to Table 6-44, different result was shown for the coupling degree at all paired stages. There were slight difference at each paired stages, but only pre-earthquake stage and post-

earthquake stage was significant difference on the mean value of coupling degree. The result suggested that interrelationship between subsystems of urbanization was significant change since the end of earthquake reconstruction.

Table 6- 44 Coupling and Coupling Coordination Degree differences between stages for the Anxian county

Relationship of Urbanization	Paired T-test	Pre-earthquake Stage/Reconstruction Stage	Pre-earthquake Stage/Post-earthquake Stage	Reconstruction Stage/ Post-earthquake
Coupling Degree	Mean Difference	-0.002	-0.011	-0.009
	Std. deviation	0.005	0.005	0.007
	Degree of Freedom	2	6	2
	P value	0.630	**0.002****	0.160
Coupling Coordination Degree	Mean Difference	-0.037	-0.786	-0.041
	Std. deviation	0.012	0.005	0.118
	Degree of Freedom	2	6	2
	P value	**0.033***	**0.000****	**0.026***

* Statistically Significant at the 0·05 level

** Statistically Significant at the 0·01 level

6.4 Spatial differentiation by counties before and after Wenchuan earthquake

6.4.1 Spatial differentiation on population urbanization by counties

To show the spatial differences on population urbanization, we used local Moran's I to evaluate Pu spatial differences at pre-earthquake stage, reconstruction stage, post-earthquake stage. At the pre-earthquake stage, there was a cold point, Maoxian, showing that Pu level of Maoxian was significantly lower than other adjacent counties. At the reconstruction stage, there were a hot point, Pengzhou, and a cold point, Pingwu, showing that Pengzhou had become the highest point on Pu to affect other close counties and Pingwu was the lowest point around adjacent counties. At the post-earthquake stage, the hot points had increased to Wenchuan, Dujiangyan, and Pengzhou counties, showing that Pu level was gathered in this area. While the low level of Pu still agglomerated around Pingwu. The results indicated that the higher Pu level agglomerated at Wenchuan, Dujiangyan, and Pengzhou, and the lower Pu level agglomerated around the Pingwu county after the Wenchuan earthquake.

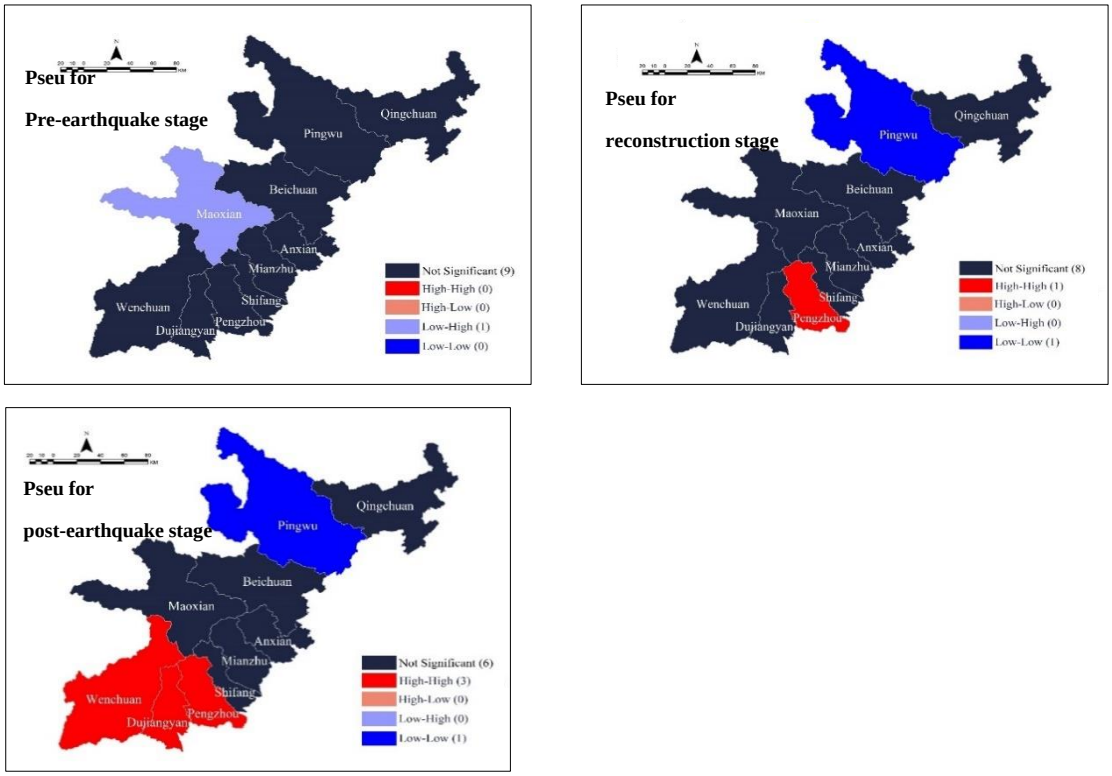
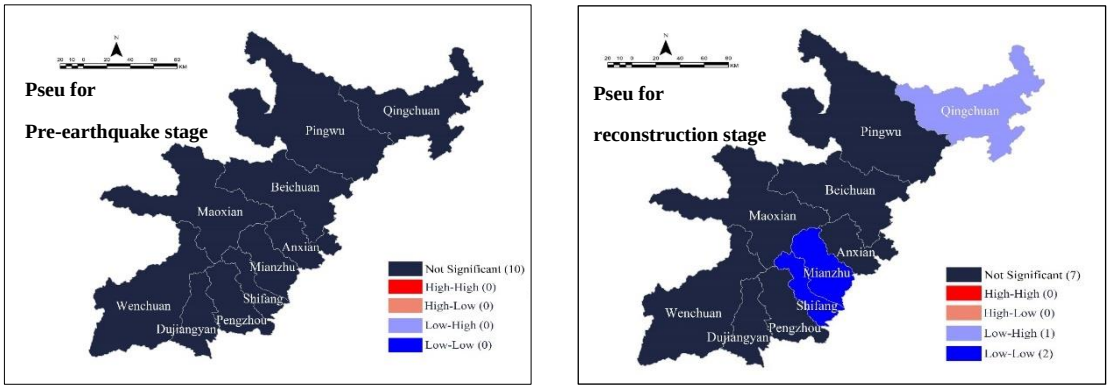


Fig 6- 1 Local Moran's I of Pu by stages for ten counties

6.4.2 Spatial differentiation on space urbanization by counties

To show the spatial differences on space urbanization, we used local Moran's I to evaluate Su spatial differences at pre-earthquake stage, reconstruction stage, post-earthquake stage. At the pre-earthquake stage, there was random distribution on Su among these ten counties. At the reconstruction stage, Qingchuan was significantly lower than counties which around it. During the same time, Shifang and Mianzhu was lower than counties which around it. The results showed that there was agglomeration phenomena at the reconstruction stage. At the post-earthquake stage, there was a hot point of Su in Pengzhou, and a cold point of Su in Beichuan. The results indicated that the higher Su level agglomerated at Pengzhou, and the lower Su level agglomerated around the Beichuan county after the Wenchuan earthquake.



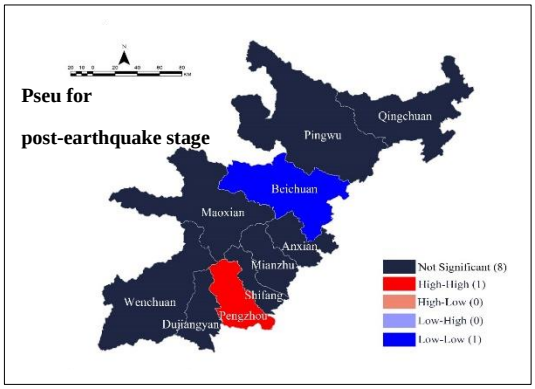
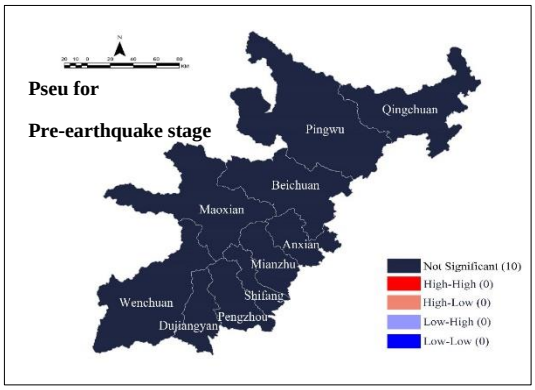
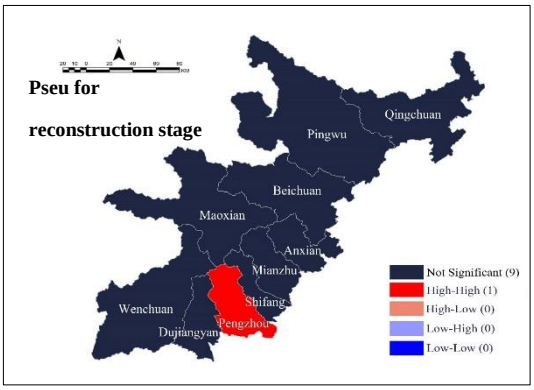


Fig 6- 2 Local Moran's I of Su by stages for ten counties

6.4.3 Spatial differentiation on economy urbanization by counties

To show the spatial differences on economy urbanization, we used local Moran's I to evaluate Eu spatial differences at pre-earthquake stage, reconstruction stage, post-earthquake stage. At the pre-earthquake stage, there was random distribution on Eu among these ten counties. At the reconstruction stage, there was a hot point, Pengzhou, which agglomerated higher level of Eu around it. At the post-earthquake stage, same result was shown. The results indicated that the higher Eu level agglomerated at Pengzhou after the Wenchuan earthquake.





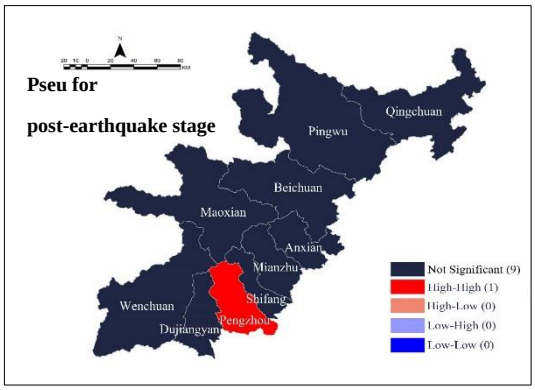


Fig 6- 3 Local *Moran's I* of Eu by stages for ten counties

6.4.4 Spatial differentiation on population-space-economy urbanization by counties

To show the spatial differences on population-space-economy urbanization, we used local Moran's I to evaluate Pseu spatial differences at pre-earthquake stage, reconstruction stage, post-

earthquake stage. At the pre-earthquake stage, there was random distribution on Pseu among these ten counties. At the reconstruction stage, the Pseu level of Pengzhou was relative lower than counties which around it. The results indicated that there were agglomeration phenomena at the reconstruction stage. At the post-earthquake stage, two hot points, Wenchuan and Pengzhou were shown, indicating that higher level of Pseu agglomerated. During the same stage, Beichuan and Pingwu were shown as cold points. The results indicated that the higher Pseu level agglomerated at Wenchuan and Pengzhou, while lower level of Pseu agglomerated around Beichuan and Pingwu after the Wenchuan earthquake.

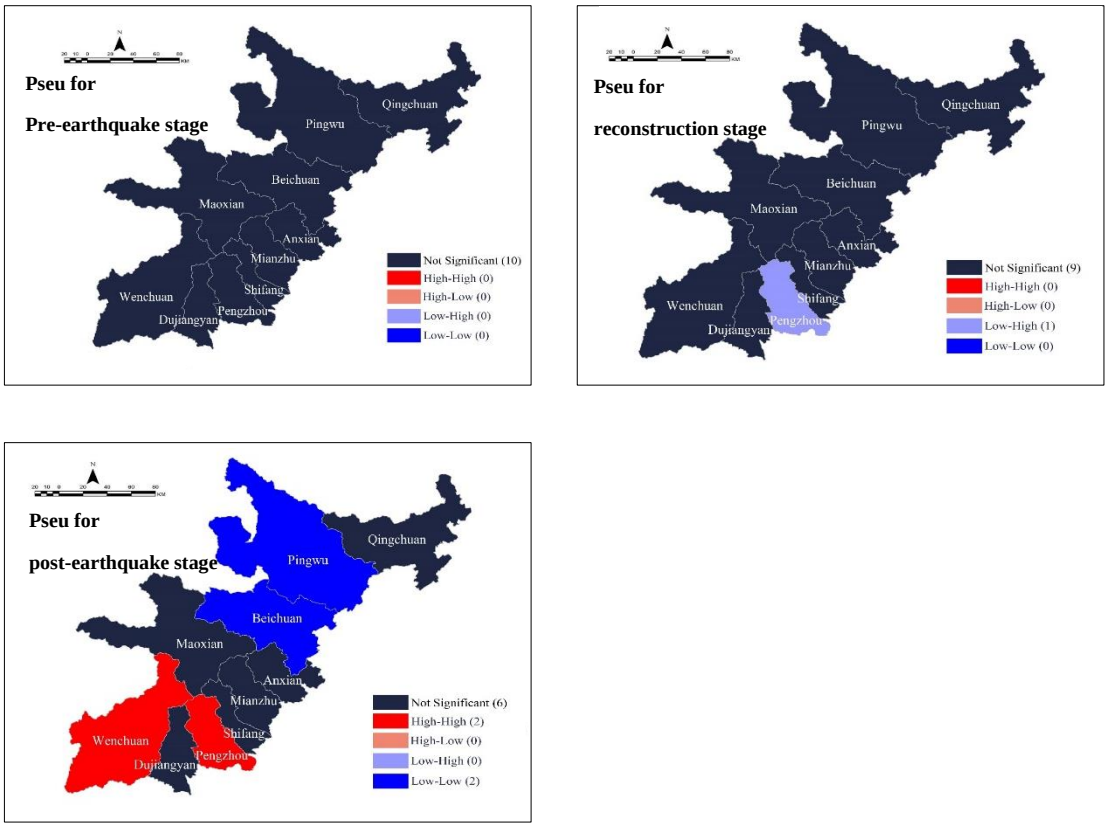


Fig 6- 4 Local *Moran's I* of Pseu by stages for ten counties

6.4.5 Spatial differentiation on coupling degree by counties

To show the spatial differences on dynamic coupling degree, we used local Moran's I to evaluate DCD spatial differences at pre-earthquake stage, reconstruction stage, post-earthquake stage. At the pre-earthquake stage, there was a hot point, Shifang, showing that DCD level of Shifang was significantly higher than other adjacent counties. During the same stage, DCD level of Dujiangyan was lower than counties which around it. At the reconstruction stage, there were two hot points, Maoxian and Shifang, showing that Maoxian and Shifang had become the highest point on DCD to adjacent other close counties. At the post-earthquake stage, there was no agglomeration phenomena. The results indicated that there was not agglomeration phenomena on DCD after the Wenchuan earthquake.

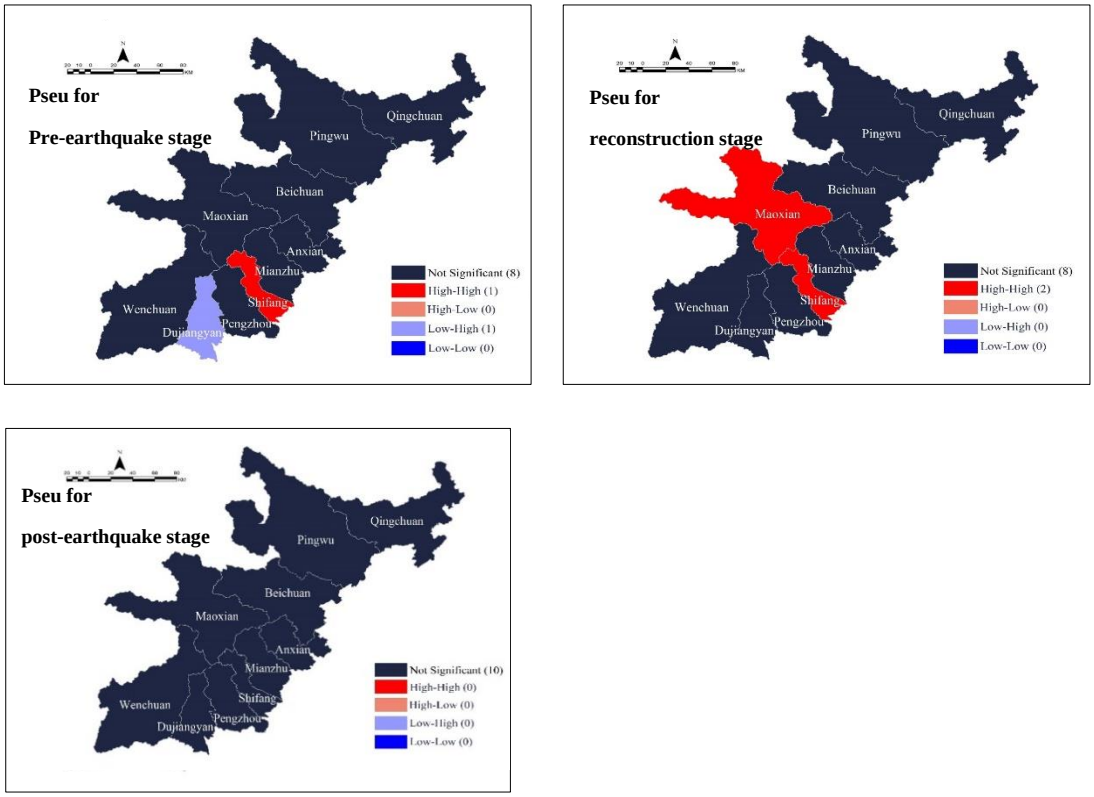
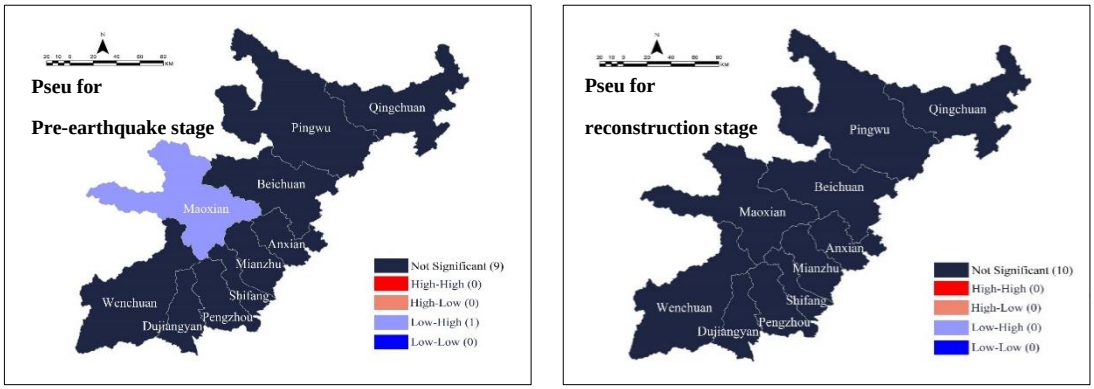


Fig 6- 5 Local *Moran's I* of DCD by stages for ten counties

6.4.6 Spatial differentiation on coupling coordination degree by counties

To show the spatial differences on dynamic coupling coordination degree, we used local Moran's I to evaluate DCCD spatial differences at pre-earthquake stage, reconstruction stage, post-earthquake stage. At the pre-earthquake stage, Maoxian was relative lower than counties which around it. At the reconstruction stage, there was no agglomeration phenomena. At the post-earthquake stage, there was a hot point, Pengzhou, showing that Pengzhou had become the highest point on DCCD to adjacent other close counties. The results indicated that there was an agglomeration phenomenon on DCCD after the Wenchuan earthquake.



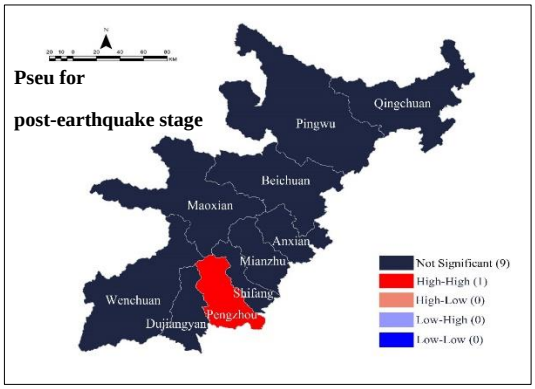


Fig 6- 6 Local *Moran's I* of DCCD by stages for ten counties

6.5 Comparative examination on variation of urbanization modes before and after Wenchuan earthquake

6.5.1 Transformation of urbanization modes for the MSAA

Due to the level for one the of three subsystem urbanization is different, there are different the modes of urbanization for the same area during different periods. Impacted by the Wenchuan earthquake, which is the most destructive earthquake since 1949, whether there is change on the mode of urbanization for the MSAA was assessed by the novel triangle model in quantitative way. As shown in Figure 6-1, all the points of population-space-economy urbanization level distributed in the triangle model. At the pre-earthquake stage (2001 to 2007), majority of the points allocated in the II quadrant, corresponding to the mode that population quality is higher than those of economy quality and space quality. It indicated that the urbanization pattern of MSAA was mostly driven by the population urbanization before the Wenchuan earthquake. At earthquake reconstruction stage (2008 to 2010), the mode of urbanization changed dramatically. In the 2008, the balance point of the three subsystems assigned in the IV quadrant, showing that the huge loss of population from the Wenchuan earthquake leads to the transformation of the urban model from population urbanization to economy urbanization. In the next 2009 and 2010, the points distributed in the IV quadrant. The result showed that benefiting from the reconstruction measures and projects, the economy urbanization become the primary driven subsystem of urbanization. At the post-earthquake stage (2011 to 2017), all the population-space-economy points allocated in the III quadrant, suggesting that the economy equality had replaced the population equality in the post-earthquake period. The results showed that the mode of urbanization for the MSAA had transferred from the population urbanization pattern into economy urbanization pattern.

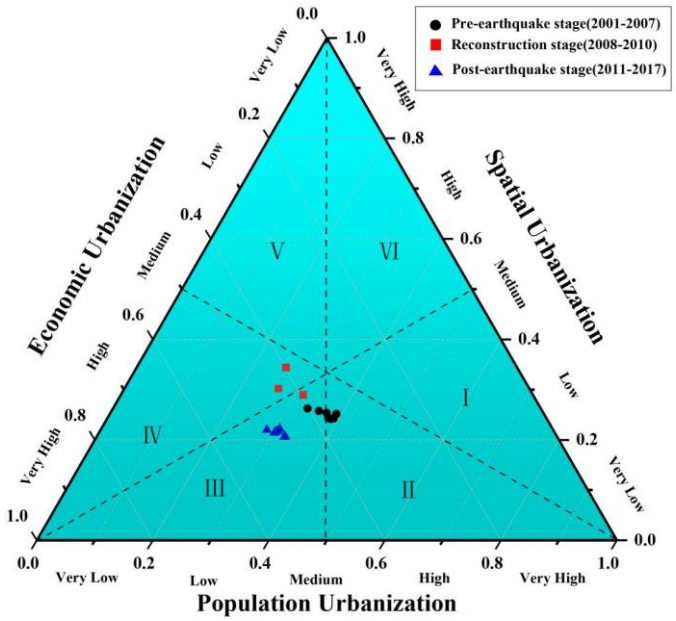


Fig 6- 7 Conceptual model diagram for the urbanization of population, economy, and space in the MSAA

6.5.2 Transformation of urbanization modes for the Wenchuan county

According to the results in Chapter 5, the level of population urbanization, space urbanization, economy urbanization was different, indicating that the leading subsystem of urbanization was different during the period. Furthermore, whether the leading pattern of urbanization was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was evaluated by the novel triangle model. The triangle model was designed to measure the interrelationship between population, space and economy. As shown in Figure 6-2, all the equilibrium points scattered in I, II, III, IV, V quadrants, suggesting that there were at least three major types of the urbanization modes before and after the Wenchuan earthquake (2001 to 2017). At the pre-earthquake stage (2001 to 2007), all the points allocated in the I and II quadrants, showing that the urbanization mode was dominated by population urbanization in the Wenchuan county during this period. At earthquake reconstruction stage (2008 to 2010), the population-economy-space points were shown in II, IV, V quadrants, suggesting that the urbanization mode was shifted from the economy urbanization mode to space urbanization mode in this period. Furthermore, due to the large loss on population and migrate from the earthquake reconstruction projects, the second subsystem shifted between population urbanization and space urbanization. At earthquake reconstruction stage (2008 to 2010), all the points located in III quadrant, showing that economy-led urbanization dominated as the only one urbanization pattern in this period. The result suggested that urbanization mode of Wenchuan county reached to the stage of rapid development led by the economy. The urbanization mode of Wenchuan county primarily transferred from population-led urbanization to the economy-led urbanization during the whole period (2001 to 2017).

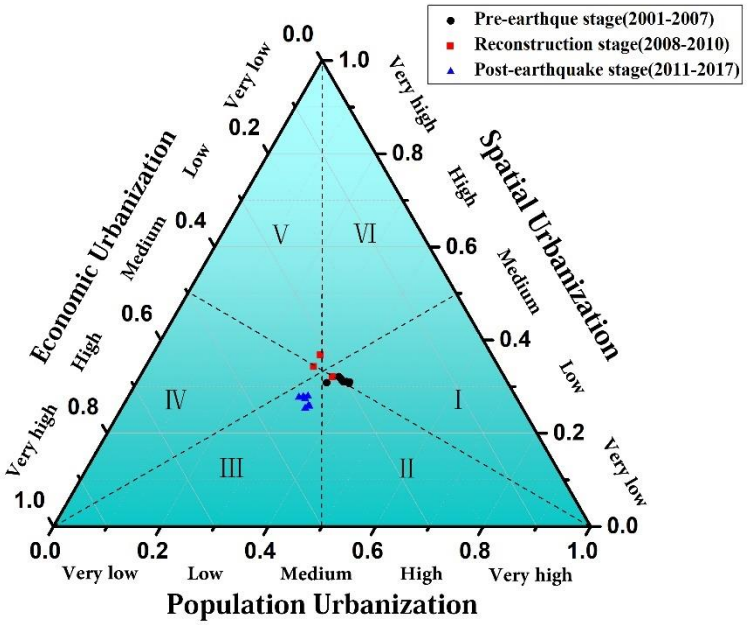


Fig 6- 8 Conceptual model diagram for the urbanization of population, economy, and space in the Wenchuan county

6.5.3 Transformation of urbanization modes for the Shifang county

As one of the counties distributed in the MSAA, whether the leading pattern of urbanization was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was assessed by the novel triangle model. As shown in Figure 6-3, expect for one point, all the other equilibrium points scattered in II and III quadrants, suggesting that the economy driven urbanization and population driven urbanization were two major types of the urbanization modes before and after the Wenchuan earthquake (2001 to 2017). At the pre-earthquake stage (2001 to 2007), all the points scattered in the II and III quadrants, showing that Shifang county completed a transition from economic urbanization mode to population urbanization mode before the Wenchuan earthquake. At the earthquake reconstruction stage (2008 to 2010), the population-economy-space points were also shown in the II quadrant, suggesting that the urbanization mode was also driven by the population-led urbanization in this period. At the post-earthquake stage (2011 to 2017), all the points located in III quadrant, showing that economy-led urbanization dominated as the only one urbanization pattern in this period. The result suggested that urbanization mode of Wenchuan county reached to the stage of rapid development led by the economy. In a word, there was only one major mode and two sub-modes change for the urbanization mode at the pre-earthquake stage, reconstruction stage, and post-earthquake stage. The urbanization mode of Shifang county transferred from population-led urbanization to the economy-led urbanization during the whole period (2001 to 2017).

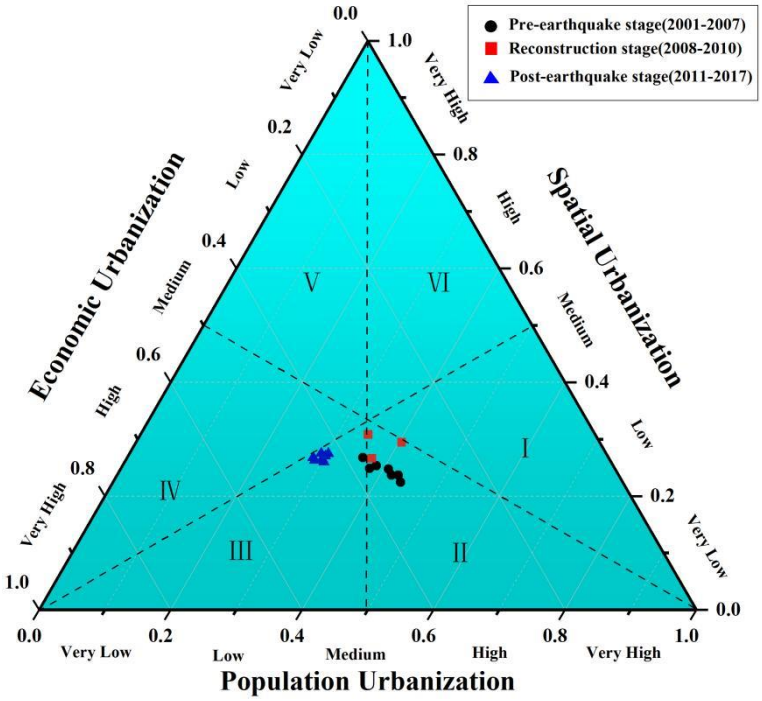


Fig 6- 9 Conceptual model diagram for the urbanization of population, economy, and space in the Shifang county

6.5.4 Transformation of urbanization modes for the Qingchuan county

Similar to the Wenchuan county, the Qingchuan was also one of the severely affected counties by the Wenchuan earthquake. According to the results in Chapter 5, the level of population urbanization, space urbanization, economy urbanization was different. Moreover, whether the driven mode of urbanization was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was measured by the novel triangle model. As shown in Figure 6-4, all the population-space-economy points scattered in all the I, II, III, IV, V, VI quadrants, suggesting that the urbanization mode changed dramatically before and after the Wenchuan earthquake (2001 to 2017). At the pre-earthquake stage (2001 to 2007), all the points located in the I quadrant, showing that the population-led urbanization pattern was the only urbanization type during this period. At earthquake reconstruction stage (2008 to 2010), the population-economy-space points were shown in V and VI quadrants, indicating that the urbanization mode had transferred from population driven pattern in to the space driven urbanization pattern. Furthermore, two equilibrium points for 2008 and 2009 were shown in the VI quadrant, and one balanced point for 2010 was presented in the V quadrant. It suggested that the dominant urbanization model of Qingchuan county has not changed, but economy urbanization has replaced population urbanization as the second urbanization model during the post-disaster reconstruction period. Without assistant from the earthquake reconstruction, the urbanization model shifted to population-led urbanization in 2011. At the rest of post-earthquake stage (2012 to 2017), all population-space-economy points located in III and IV quadrants, corresponding to economy driven urbanization mode for the Qingchuan county. In a word, the urbanization pattern had been transferred from population-led urbanization mode at the pre-earthquake stage to space-led urbanization mode at the earthquake reconstruction stage, and finally transferred to the economy-led urbanization mode at the post-earthquake stage.

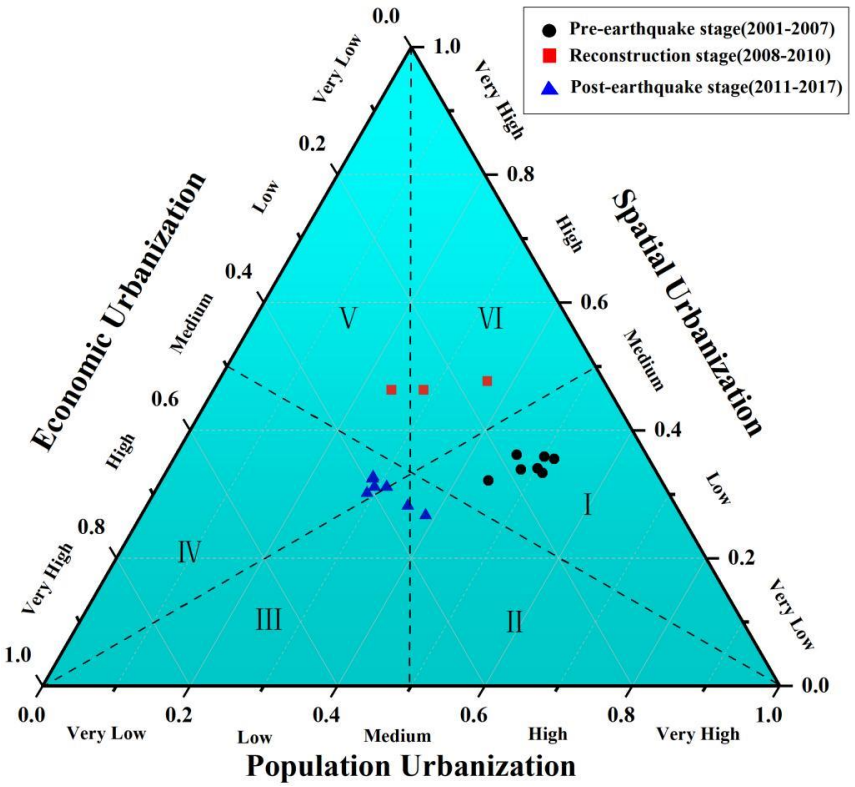


Fig 6- 10 Conceptual model diagram for the urbanization of population, economy, and space in the Qingchuan county

6.5.5 Transformation of urbanization modes for the Pingwu county

Similar to the Wenchuan county, the Pingwu county was also one of the severely affected counties by the Wenchuan earthquake. According to the results in Chapter 5, the level of population urbanization, space urbanization, economy urbanization was different. Moreover, whether the driven mode of urbanization was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was measured by the novel triangle model. As shown in Figure 6-5, all the population-space-economy points distributed in all the III, IV, V, VI quadrants, suggesting that there were two major transformations on the urbanization mode before and after the Wenchuan earthquake (2001 to 2017). At the pre-earthquake stage (2001 to 2007), all the points located in the VI quadrant, showing that the space-led urbanization pattern was the only urbanization type during this period. At earthquake reconstruction stage (2008 to 2010), the population-economy-space points were shown in V and VI quadrants, indicating that the urbanization mode did not change, but the economic development replaced the population settlement and had become the second driven factor for the Pingwu's urbanization development. During the post-earthquake years (2011 to 2017), all equilibrium points located in III and IV quadrants, corresponding to economy driven urbanization mode for the Pingwu county. It suggested that the urbanization mode shifted from the space-led urbanization pattern to the economy-led urbanization pattern after the end of the Wenchuan earthquake reconstruction. In a word, the urbanization pattern of Pingwu county had been transferred from space driven urbanization mode to economy driven urbanization mode from 2001 to 2017.

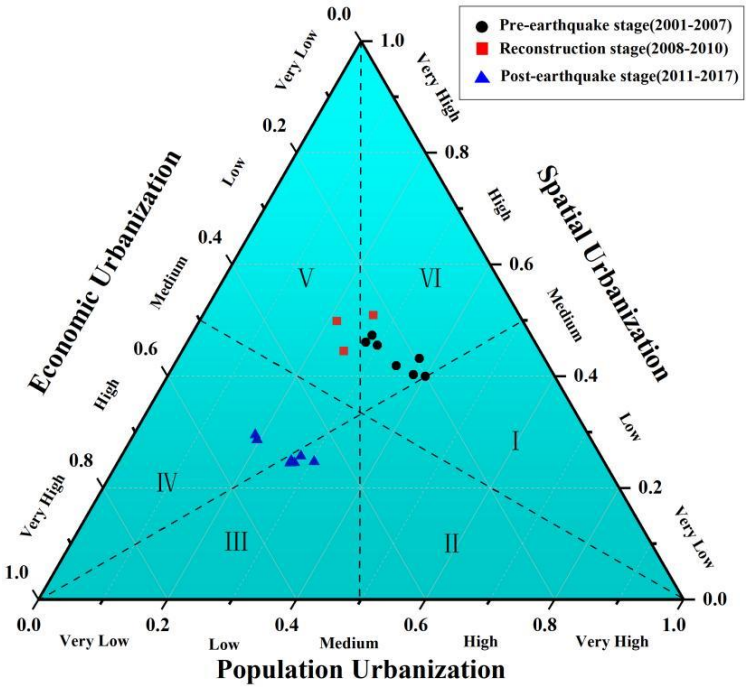


Fig 6- 11 Conceptual model diagram for the urbanization of population, economy, and space in the Pingwu county

6.5.6 Transformation of urbanization modes for the Pengzhou county

As one of the counties distributed in the MSAA, whether the leading pattern of urbanization for Pengzhou county was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was assessed by the novel triangle model. As shown in Figure 6-6, all the equilibrium points distributed in I, II, III quadrants, suggesting that the economy driven urbanization and population driven urbanization were two major types of the urbanization modes before and after the Wenchuan earthquake (2001 to 2017). At the pre-earthquake stage (2001 to 2007), all the points scattered in the I and II quadrants, showing that population-led urbanization mode was the only type of urbanization in Pengzhou county before the Wenchuan earthquake. Moreover, the economy urbanization exceeded the space urbanization for the 0.8 million tons ethylene petrochemical under running. At the earthquake reconstruction stage (2008 to 2010), points scattered in II and III quadrants, indicating that the type of urbanization had been shifted from population-led to economy-led mode. It verified that reconstruction measures help the Pengzhou county realize the transformation on urbanization pattern. During the post-earthquake years (2011 to 2017), all equilibrium points located in the III quadrants, suggesting that there was only one type of urbanization during the period. It indicated that the economy-led urbanization had become the primary driven subsystem of urbanization after completed the transformation in 2011. In a word, there was only two major mode and three sub-modes change for the urbanization mode at the pre-earthquake stage, reconstruction stage, and post-earthquake stage. The urbanization mode of Pengzhou county transferred from population-led urbanization to the economy-led urbanization since 2011.

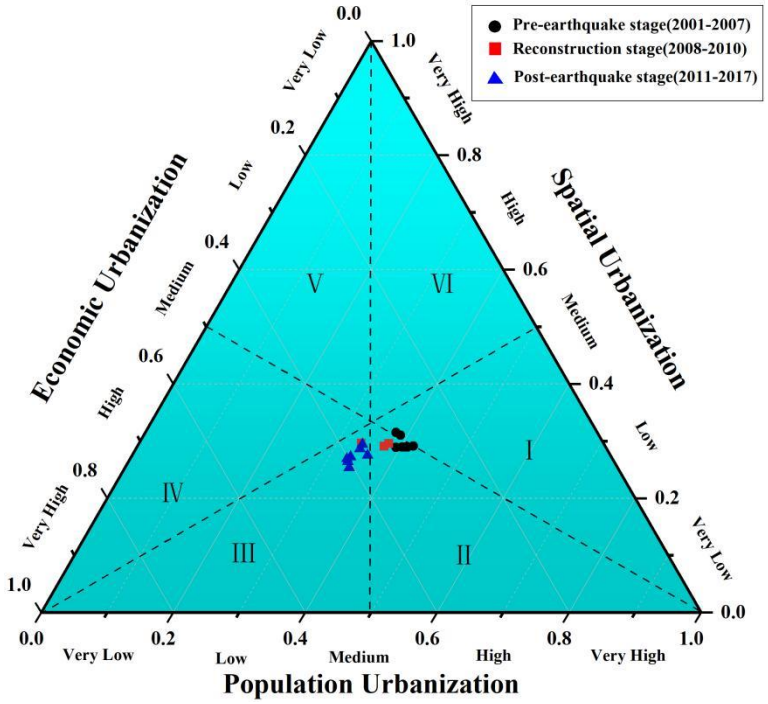


Fig 6- 12 Conceptual model diagram for the urbanization of population, economy, and space in the Pengzhou county

6.5.7 Transformation of urbanization modes for the Mianzhu county

As one of the counties distributed in the MSAA, whether the leading pattern of urbanization for Mianzhu county was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was assessed by the novel triangle model. As shown in Figure 6-7, all the equilibrium points distributed in II and III quadrants, suggesting that the economy driven urbanization and population driven urbanization were the two major types of the urbanization modes before and after the Wenchuan earthquake (2001 to 2017). At the pre-earthquake stage (2001 to 2007), all the points scattered in the II and III quadrants, showing that there was transformation on the urbanization mode before the Wenchuan earthquake. As shown in the Figure 6-6, the urbanization mode was shifted from population-led to economy-led mode. As the county which was leading by the non-agricultural industry, the result was the same as expectation. At the earthquake reconstruction stage (2008 to 2010), points scattered in III quadrant, indicating that there was only one type of urbanization. It proved that the Wenchuan earthquake did not affect the urbanization mode of Mianzhu county. During the post-earthquake years (2011 to 2017), all equilibrium points still located in the III quadrant, suggesting that the only one type of urbanization did not change during the period. It indicated that the economy-led urbanization had become the primary driven subsystem of urbanization during the period. In a word, there was only two major mode and two sub-modes change for the urbanization mode at the pre-earthquake stage, reconstruction stage, and post-earthquake stage. The urbanization mode of Mianzhu county transferred from population-led urbanization to the economy-led urbanization since 2007.

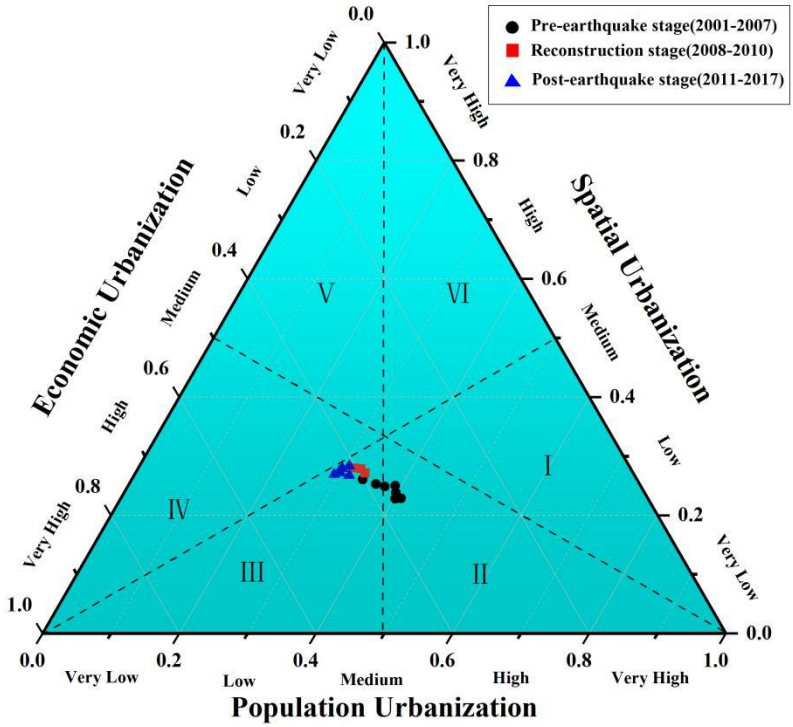


Fig 6- 13 Conceptual model diagram for the urbanization of population, economy, and space in the Mianzhu county

6.5.8 Transformation of urbanization modes for the Maoxian county

As one of the counties distributed in the MSAA, whether the leading pattern of urbanization for Maoxian county was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was assessed by the novel triangle model. As shown in Figure 6-8, all the population-space-economy points scattered in all the II, III, IV quadrants, indicating that there were two major types of urbanization mode changed before and after the Wenchuan earthquake (2001 to 2017). At the pre-earthquake stage (2001 to 2007), the population-space-economy points scattered in the II and IV quadrant, showing that the economy-led urbanization pattern transferred to population-led urbanization pattern during this period. This urbanization mode did not change even under the attack of the Wenchuan earthquake in 2008. This result may be related to the relative lower loss of human life for the Maoxian county, which accounted for only 5.99% in the MSAA. In the next two years (2009 to 2010), the population-economy-space points were shown in III quadrant, indicating that the urbanization mode had transferred from population driven pattern in to the economy driven urbanization pattern. It suggested that the dominant urbanization model of Maoxian county has changed into economy urbanization mode for the large assistant from the earthquake reconstruction. At the post-earthquake stage (2011 to 2017), all population-space-economy points still located in III quadrant, corresponding to economy driven urbanization mode for the Maoxian county. In a word, the urbanization pattern had been transferred from population-led urbanization mode at the pre-earthquake stage to economy-led urbanization mode at the earthquake reconstruction stage.

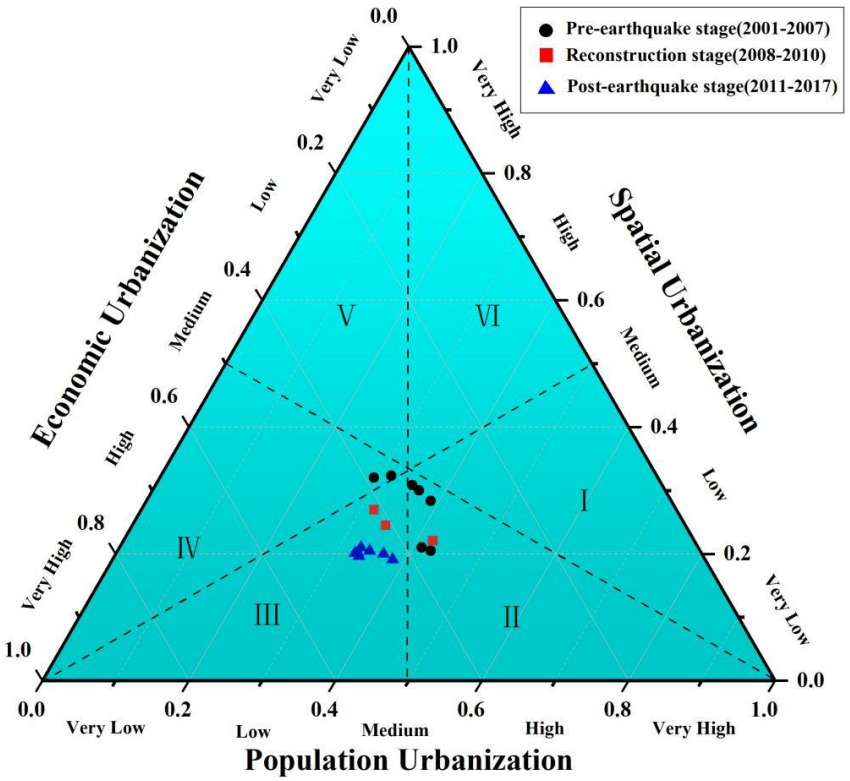


Fig 6- 14 Conceptual model diagram for the urbanization of population, economy, and space in the Maoxian county

6.5.9 Transformation of urbanization modes for the Dujiangyan county

As one of the counties distributed in the MSAA, whether the leading pattern of urbanization for Dujiangyan county was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was assessed by the novel triangle model. At the pre-earthquake stage (2001 to 2007), the population-space-economy points scattered in the VI quadrant, showing that the space-led urbanization pattern was the dominate urbanization mode during this period. It indicated that the urbanization development of the Dujiangyan county was mostly driven by the space urbanization before the earthquake. At the earthquake reconstruction stage (2008 to 2010), all the points scattered in the I and II quadrants, showing that population-led urbanization mode was become the primary type of urbanization in Dujiangyan county. Similar to Maoxian county, it was still shown that population-led urbanization mode of Dujiangyan county did not affect by the Wenchuan earthquake. It would be related to large people got jobs from reconstruction projects during this period, which was shown the average value of proportion of employees in secondary and tertiary industries increased to 73.72% from 2008 to 2010. During the post-earthquake years (2011 to 2017), all equilibrium points still located in the I and II quadrants, suggesting that the urbanization mode of Dujiangyan county was still the population driven pattern. The average value of proportion of employees in secondary and tertiary industries increased to 82.45% in this period, indicating that the urbanization mode which was driven by the population was strengthened after the Wenchuan earthquake. In a word, the urbanization mode of the Dujiangyan county was basically a shift from space-dominated to population-dominated before and after the earthquakes. It indicated that the natural disasters, such as destructive earthquake, will exert great impact on the urbanization patterns at the county scale.

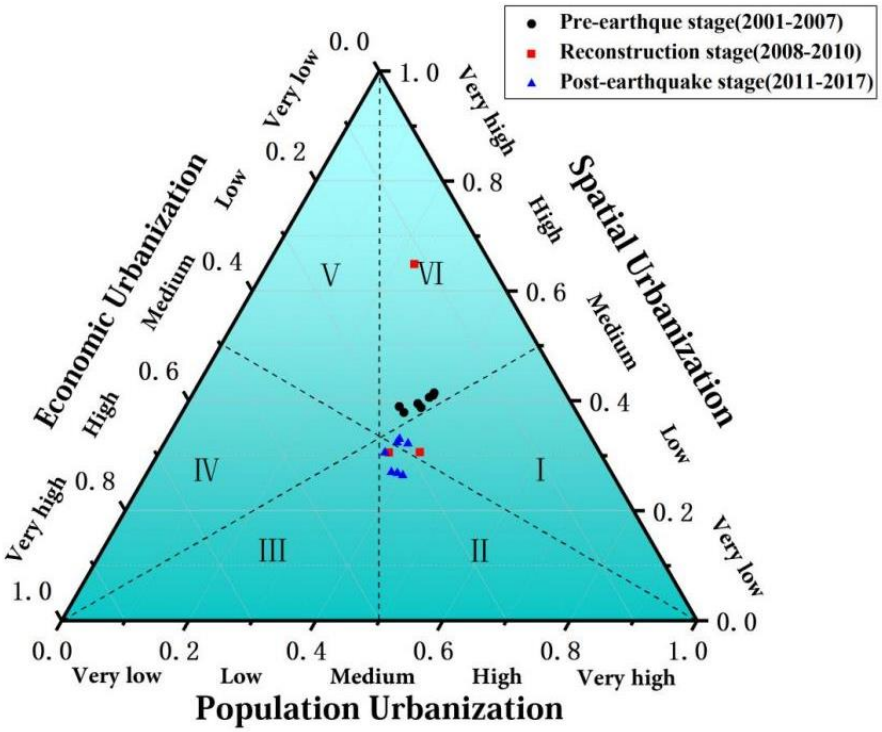


Fig 6- 15 Conceptual model diagram for the urbanization of population, economy, and space in the Dujiangyan county

6.5.10 Transformation of urbanization modes for the Beichuan county

As one of the counties distributed in the MSAA, whether the leading pattern of urbanization for Beichuan county was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was evaluated by the novel triangle model. As shown in Figure 6-10, all the equilibrium points distributed in II, III, IV, VI quadrants, suggesting that the economy driven urbanization and population driven urbanization were the three major types of the urbanization modes before and after the Wenchuan earthquake (2001 to 2017). As shown in Figure 6-10, all the population-space-economy points distributed in all the VI quadrant, suggesting that the urbanization mode of Beichuan county was majorly driven by space expansion before the earthquake hit. It is interesting to found out that urbanization mode of Beichuan county changed dramatically. According to the Figure 6-10, the equilibrium points were shown in II, IV, VI quadrants, indicating that the urbanization mode of Beichuan county was driven by population settlement, space expansion, non-agricultural industrial development each year, respectively. Specifically, the urbanization mode of Beichuan county was still drove by the space expansion in 2008. It indicated that space-led urbanization mode did not affect by the Wenchuan earthquake, even when human losses accounted for 23.34% of the MSAA. However, the point relocated in II quadrant in 2009, showing that urbanization pattern of Beichuan county had converted to population-led urbanization mode. It objectively confirmed the policy implementation of Beichuan County's off-site reconstruction. Furthermore, the population-space-economy point relocated again in IV quadrant, indicating that economy drove urbanization was the last and dominate urbanization mode for the Beichuan county in 2010. During the post-earthquake years (2011 to 2017), all equilibrium points located in II and III quadrants, corresponding to economy driven and population driven

urbanization mode for the Beichuan county. The results showed that the urbanization development model of Beichuan county was not stable after the earthquake, and was alternately dominated by two modes of population urbanization and economic urbanization. In conclusion, the urbanization pattern of Beichuan county was dominate by the space-led urbanization before the Wenchuan earthquake. During the earthquake reconstruction period, the urbanization pattern of Beichuan county had been dominated by space-led urbanization, population-led urbanization, economy-led urbanization each year. The urbanization mode was alternately dominated by economy-led urbanization and population-led urbanization after from 2011 to 2017.

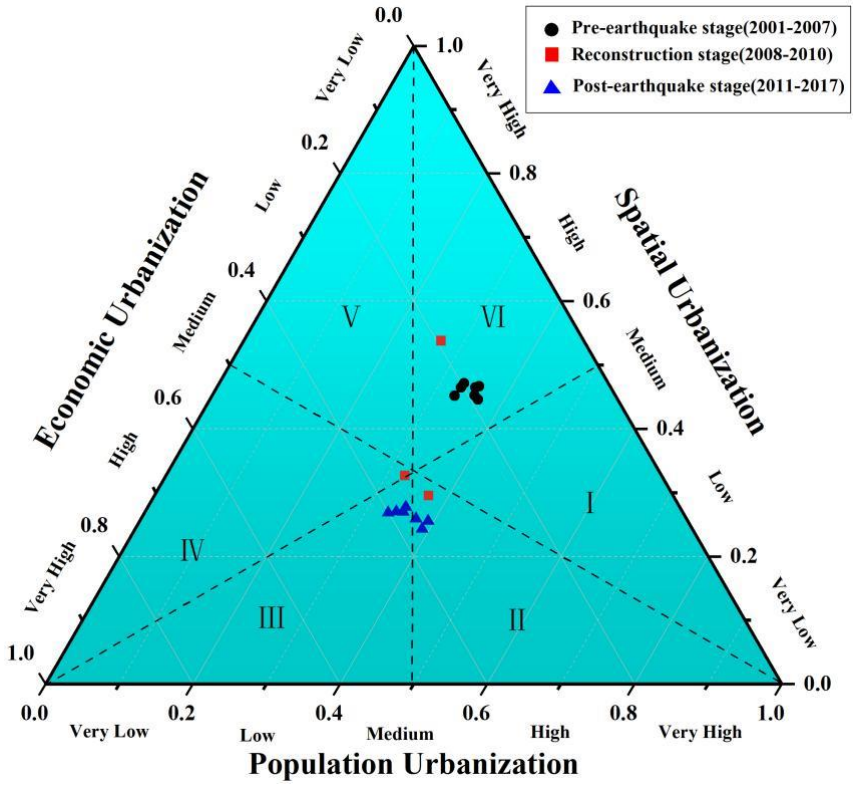


Fig 6- 16 Conceptual model diagram for the urbanization of population, economy, and space in the Beichuan county

6.5.11 Transformation of urbanization modes for the Anxian county

As one of the counties distributed in the MSAA, whether the leading pattern of urbanization for Anxian county was changed at the pre-earthquake stage (2001 to 2007), earthquake reconstruction stage (2008 to 2010), post-earthquake stage (2011 to 2017) was assessed by the novel triangle model. As shown in Figure 6-11, all the population-space-economy points scattered in all the I, II, III, IV, VI quadrants, indicating that there were three major types of urbanization mode changed before and after the Wenchuan earthquake (2001 to 2017). At the pre-earthquake stage (2001 to 2007), the equilibrium points scattered in the I quadrant, showing that the population urbanization pattern lead the development of urbanization of Anxian county during this period. Similar as Qingchuan county, the urbanization mode changed dramatically during the earthquake reconstruction period. In the 2008, the urbanization mode was transferred from population-led urbanization to space-led urbanization. Then the mode of urbanization converted back to population-led urbanization in 2009 and 2010. It indicated that the huge lost on proportion of employees in secondary and tertiary industries, number of beds per thousand people in health institutions, number of students in ordinary

high schools by the Wenchuan earthquake changed the urbanization mode into space-led urbanization. Since the implement of earthquake reconstruction projects, lots of jobs for non-agricultural were created and municipal service facilities, such as hospitals and schools were rebuilt for the rest of people to push the population-led urbanization re-become the dominated urbanization mode of Beichuan county in 2009 and 2010. At the post-earthquake stage (2011 to 2017), the points scattered in I, II, III, IV quadrants, indicating that the major transformation of urbanization mode was happened only between population-led urbanization and economy-led urbanization. Affected by China's issuance of one trillion local special bonds in 2015, Anxian's economic development was fluctuated during 2011 to 2017, resulting in the alternation of population urbanization and economic urbanization to become the dominant mode of urbanization in Anxian. In a word, the population driven the urbanization mode before the Wenchuan earthquake. The urbanization mode was transferred between the population-led urbanization and space-led urbanization during the earthquake reconstruction period. With respect to post-earthquake years, the transformation was between population-led urbanization and economy-led urbanization.

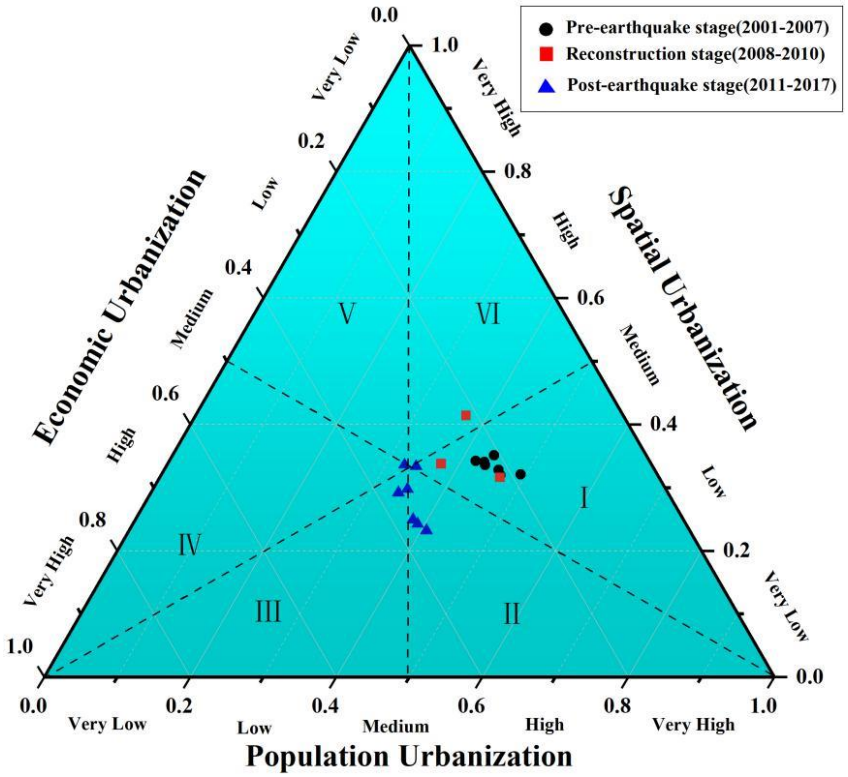


Fig 6- 17 Conceptual model diagram for the urbanization of population, economy, and space in the Anxian county

6.6 Classification of urbanization before and after Wenchuan earthquake

6.6.1 Classification of population urbanization before and after Wenchuan earthquake

Results in section 6.2 had been shown that there are temporal and stage differences on population urbanization in county level. Therefore, it is necessary to classified these counties to design specific policies to improve the quality of population urbanization. In this section, Nature Break was employed to category these ten counties into three group, high level Pu group, medium level Pu group, and low-level Pu group. As shown in Table 6-45, the Pu could be divided into three groups

at each stage. With respect to pre-earthquake stage, four counties were categorized into high level Pu group (Dujianyan, Shifang, Wenchuan, Mianzhu), while four counties distributed in medium level Pu group (Pengzhou, Anxian, Beichuan, Maoxian). Pingwu and Qingchuan were classified into low Pu group. In terms of reconstruction stage, the number of counties had been changed as two counties in high level of Pu group, six counties in medium level of Pu group, and two counties in low level Pu group. With regards to post-earthquake stage, the composition of the three groups had been becomes to 1:7:2.

Table 6- 45 Classification of population urbanization at different stage

Stage	Classification			
Pre-earthquake stage	Group	High level Pu group	Medium level Pu group	Low level Pu group
	Counties	Dujianyan; Shifang; Wenchuan; Mianzhu	Pengzhou; Anxian; Beichuan; Maoxian	Pingwu; Qingchuan
	Pu Value	0.389-0.496	0.251-0.302	0.165-0.198
	Number	4	4	2
Reconstruction stage	Group	High level Pu group	Medium level Pu group	Low level Pu group
	Counties	Dujianyan; Shifang	Pengzhou; Anxian; Beichuan; Maoxian; Wenchuan; Mianzhu	Pingwu; Qingchuan
	Pu Value	0.431-0.504	0.278-0.346	0.199-0.225
	Number	2	6	2
Post-earthquake stage	Group	High level Pu group	Medium level Pu group	Low level Pu group
	Counties	Dujianyan	Shifang; Pengzhou; Anxian; Beichuan; Maoxian; Wenchuan; Mianzhu	Pingwu; Qingchuan
	Pu Value	0.718	0.366-0.468	0.207-0.234
	Number	1	7	2

6.6.2 Classification of space urbanization before and after Wenchuan earthquake

Results in section 6.2 had been shown that there are temporal and stage differences on space urbanization in county level. Therefore, it is necessary to classified these counties to design specific policies to improve the quality of space urbanization. In this section, Nature Break was employed to category these ten counties into three group, high level Su group, medium level Su group, and low-level Su group. As shown in Table 6-46, the Su could be divided into three groups at each stage. With respect to pre-earthquake stage, six counties were categorized into high level Su group (Beichuan, Dujiangyan, Shifang, Pingwu, Wenchuan, Mianzhu), while three counties distributed in medium level Su group (Pengzhou, Anxian, Maoxian). Qingchuan was classified into low Su group. In terms of reconstruction stage, the number of counties had been changed as two counties in high level of Su group, five counties in medium level of Su group, and three counties in low level Su

group. With regards to post-earthquake stage, the composition of the three groups had been becomes to 5:2:3.

Table 6- 46 Classification of space urbanization at different stage

Stage	Classification			
Pre-earthquake stage	Group	High level Su group	Medium level Su group	Low level Su group
	Counties	Beichuan; Wenchuan; Shifang; Pingwu; Mianzhu; Dujianyan	Pengzhou; Anxian; Maoxian	Qingchuan
	Su Value	0.2489-0.333	0.180-0.222	0.117
	Number	6	3	1
Reconstruction stage	Group	High level Su group	Medium level Su group	Low level Su group
	Counties	Pingwu; Wenchuan	Beichuan; Shifang; Qingchuan; Dujiangyan; Mianzhu	Pengzhou; Anxian; Maoxian
	Su Value	0.443-0.453	0.293-0.354	0.214-0.280
	Number	2	5	3
Post-earthquake stage	Group	High level Su group	Medium level Su group	Low level Su group
	Counties	Shifang; Mianzhu; Dujiangyan; Pengzhou; Wenchuan	Anxian; Beichuan	Qingchuan; Maoxian; Pingwu
	Su Value	0.337-0.418	0.264-0.283	0.210-0.226
	Number	5	2	3

6.6.3 Classification of economy urbanization before and after Wenchuan earthquake

Results in section 6.2 had been shown that there are temporal and stage differences on economy urbanization in county level. Therefore, it is necessary to classified these counties to design specific policies to improve the quality of space urbanization. In this section, Nature Break was employed to category these ten counties into three group, high level Eu group, medium level Eu group, and low-level Eu group. As shown in Table 6-47, the Eu could be divided into three groups at each stage. With respect to pre-earthquake stage, six counties were categorized into high level Eu group (Beichuan, Dujianyan, Mianzhu, Pingwu, Shifang, Wenchuan), while three counties distributed in medium level Eu group (Pengzhou, Anxian, Maoxian). Qingchuan was classified into low Eu group. In terms of reconstruction stage, the number of counties had been changed as two counties in high level of Eu group, five counties in medium level of Eu group, and three counties in low level Eu group. With regards to post-earthquake stage, the composition of the three groups had been becomes to 5:2:3.

Table 6- 47 Classification of economy urbanization at different stage

Stage	Classification			
Pre-earthquake stage	Group	High level Su group	Medium level Su group	Low level Su group
	Counties	Beichuan; Wenchuan; Shifang; Pingwu; Mianzhu; Dujianyan	Pengzhou; Anxian; Maoxian	Qingchuan
	Su Value	0.2489-0.333	0.180-0.222	0.117
	Number	6	3	1
Reconstruction stage	Group	High level Su group	Medium level Su group	Low level Su group
	Counties	Pingwu; Wenchuan	Beichuan; Shifang; Qingchuan; Dujiangyan; Mianzhu	Pengzhou; Anxian; Maoxian
	Su Value	0.443-0.453	0.293-0.354	0.214-0.280
	Number	2	5	3
Post-earthquake stage	Group	High level Su group	Medium level Su group	Low level Su group
	Counties	Shifang; Mianzhu; Dujiangyan; Pengzhou; Wenchuan	Anxian; Beichuan	Qingchuan; Maoxian; Pingwu
	Su Value	0.337-0.418	0.264-0.283	0.210-0.226
	Number	5	2	3

6.6.4 Classification of population-space-economy urbanization before and after Wenchuan earthquake

Results in section 6.2 had been shown that there are temporal and stage differences on population-space-economy urbanization in county level. Therefore, it is necessary to classified these counties to design specific policies to improve the quality of population urbanization. In this section, Nature Break was employed to category these ten counties into three group, high level Pseu group, medium level Pseu group, and low-level Pseu group. As shown in Table 6-48, the Pseu could be divided into three groups at each stage. With respect to pre-earthquake stage, four counties were categorized into high level Pseu group (Dujianyan, Shifang, Wenchuan, Mianzhu), while five counties distributed in medium level Pseu group (Pengzhou, Anxian, Beichuan, Maoxian, Pingwu). Only Qingchuan was classified into low Pseu group. In terms of reconstruction stage, the number of counties had been changed as three counties in high level of Pseu group, five counties in medium level of Pseu group, and two counties in low level Pseu group. With regards to post-earthquake stage, the composition of the three groups had been becomes to 5:3:2.

Table 6- 48 Classification of population-space-economy urbanization at different stage

Stage	Classification			
Pre-earthquake stage	Group	High level Pseu group	Medium level Pseu group	Low level Pseu group

Stage	Classification			
	Counties	Shifang; Wenchuan; Dujianyan; Mianzhu	Pengzhou; Beichuan; Maoxian; Anxian; Pingwu	Qingchuan
	Pseu Value	0.339-0.378	0.202-0.250	0.113
	Number	4	5	1
Reconstruction stage	Group	High level Pseu group	Medium level Pseu group	Low level Pseu group
	Counties	Wenchuan; Dujianyan; Shifang	Mianzhu; Pengzhou; Pingwu; Beichuan; Maoxian	Anxian; Qingchuan
	Pseu Value	0.386-0.471	0.288-0.353	0.233-0.243
	Number	3	5	2
Post-earthquake stage	Group	High level Pseu group	Medium level Pseu group	Low level Pseu group
	Counties	Dujianyan; Shifang; Wenchuan; Mianzhu; Pengzhou	Maoxian; Anxian; Beichuan	Qingchuan; Pingwu
	Pseu Value	0.461-0.573	0.336-0.359	0.248-0.270
	Number	5	3	2

6.6.5 Classification of urbanization quality before and after Wenchuan earthquake

Results in section 6.3 had been shown that there are temporal and stage differences on population-space-economy urbanization quality in county level. Therefore, it is necessary to classified these counties to design specific policies to improve the quality of population urbanization. In this section, we used two dimensions evaluation model to classified the Pseu and DCCD. As shown in Figure 6-18, at the pre-earthquake stage, Shifang, Wenchuan, and Mianzhu were assessed as high urbanization quality group. While Qingchuan was evaluated as low urbanization quality group. With respect to reconstruction stage, only Wenchuan, Shifang, Dujiangyan, and Mianzhu were assessed as high urbanization quality group. While Qingchuan and Anxian were assessed as low urbanization quality group. In terms of post-earthquake stage, Dujiangyan, Mianzhu, Shifang, and Pengzhou were assessed as high urbanization quality group. While Qingchuan and Pingwu were evaluated as low urbanization quality group.

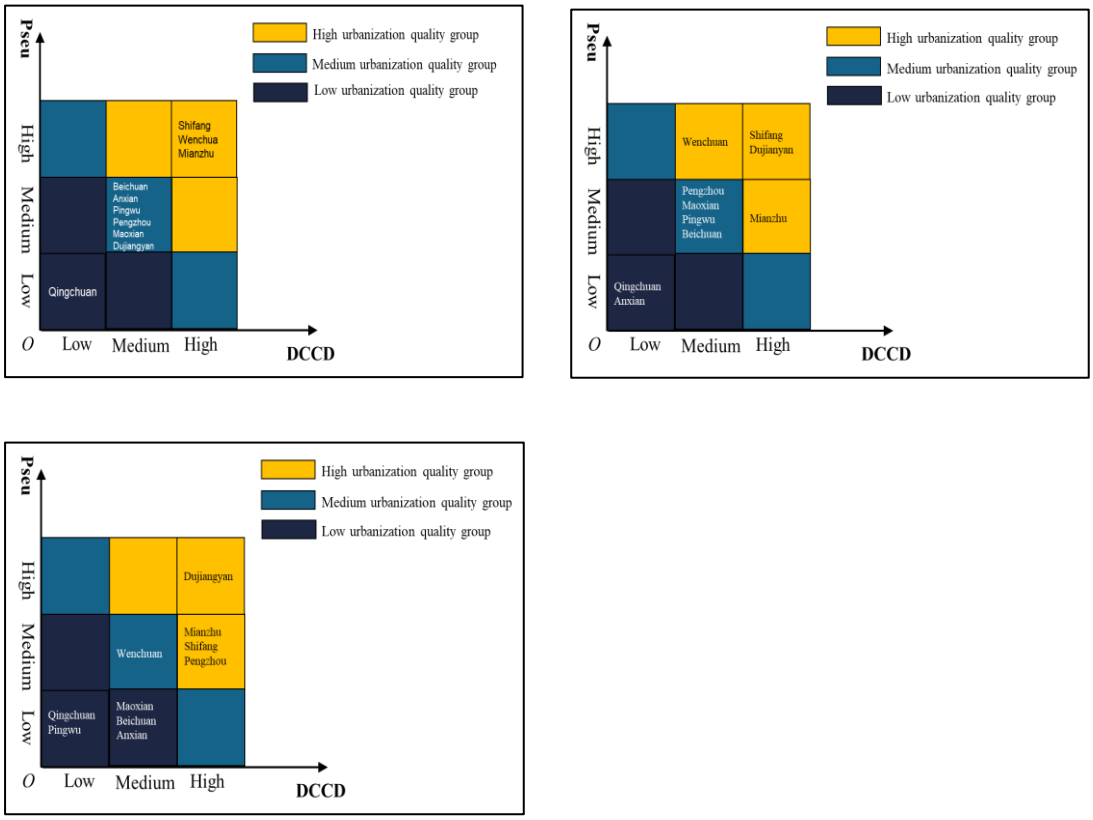


Fig 6- 18 Two dimensions evaluation model for classification of quality of urbanization by stages for ten counties

Furthermore, based on the classification results from two dimensions evaluation model, it is possible to summarized whether comprehensive urbanization level and urbanization quality level of these ten counties varied or not before and after the Wenchuan earthquake. The classification of become better means that the level of Pseu and DCCD had become better after the Wenchuan earthquake. Contrast, the classification of become worse indicates that the level of Pseu and DCCD had become worse after the Wenchuan earthquake. In addition, the classification of not change shows that the level of Pseu and DCCD did not change after the Wenchuan earthquake. According to Table 6-49, only Pengzhou and Dujiangyan could be divided into become better classification, indicating that the urbanization level and urbanization quality of Pengzhou and Dujiangyan become better after the Wenchuan earthquake. While, Wenchuan, Anxian, Beichuan, Maoxian and Pingwu belongs to the become worse classification. The rest of counties categorized as not change classification.

Table 6- 49 Classification of quality urbanization before and after Wenchuan earthquake

Classification	Before and after Wenchuan earthquake	Counties	Number
Become better	Medium level urbanization quality group -High level urbanization quality group	Pengzhou Dujiangyan	2
Not change	Low level urbanization quality group -Low level urbanization quality group	Qingchuan	3

Classification	Before and after Wenchuan earthquake	Counties	Number
Become worse	High level urbanization quality group -High level urbanization quality group	Mianzhu Shifang	5
	High level urbanization quality group- Medium level urbanization quality group	Wenchuan	
	Medium level urbanization quality group -Low level urbanization quality group	Anxian Beichuan Maoxian Pingwu	

6.7 Summary

In this chapter, taking the MSAA and these ten most severely affected counties as research objects, we examined urbanization difference, coupling degree difference, coupling coordination degree difference, urbanization mode difference at the MSAA scale and county scale, respectively. The main conclusions can be summarized as follows:

In the most severely affected area (MSAA), (1) significant difference was found on Su between the reconstruction stage and the whole period, and post-earthquake stage and the whole period. (2) While variation of Su, Eu, Pseu were found between pre-earthquake stage and the whole period, and the post-earthquake stage and the whole period. At last, (3) the coupling degree and coupling coordination degree were found significant difference between pre-earthquake stage and the whole period. In terms of stage difference, (4) significant difference was found on Su and Eu between all paired stage. While (5) Su was found significant difference between pre-earthquake stage and reconstruction stage, and pre-earthquake stage and post-earthquake stage. In addition, (6) Pseu was only shown significant difference between the pre-earthquake stage and reconstruction stage. Furthermore, (7) coupling degree was found significant difference between pre-earthquake stage and post-earthquake stage, while (8) coupling coordination degree was shown on pre-earthquake stage and reconstruction stage, and pre-earthquake stage and post-earthquake stage. At last, (9) the urbanization mode had been transferred from population-led urbanization mode into economy-led urbanization mode.

With respect to these ten severely affected counties, (1) mean value of Pu was found significant difference between the pre-earthquake stage and the whole period in Pengzhou, Dujiangyan, Beichuan, Anxian. While the same result was only shown in Wenchuan between the reconstruction stage and that of the whole period. The difference of mean value of Pu was also shown in Wenchuan, Qingchuan, Pengzhou, Maoxian, Dujiangyan, Beichuan between the post-earthquake stage and that of the whole period. With respect to stage difference, the statistic significant difference of Pu was shown between pre-earthquake stage and reconstruction stage in Qingchuan, Pengzhou, Maoxian, Dujiangyan, Beichuan. While the same results of Pu were shown between pre-earthquake stage and post-earthquake stage in Wenchuan, Qingchuan, Pengzhou, Maoxian, Dujiangyan, Beichuan, Anxian. Moreover, that of Pu was also shown between reconstruction stage and post-earthquake stage only in Wenchuan and Dujiangyan.

Similarly, (1) mean value of Su was found significant difference between the pre-earthquake stage and the whole period in all these ten counties except for Pingwu. While significant difference between the reconstruction stage and that of the whole period was not shown in all these ten counties. The difference of mean value of Su was also shown in Shifang, Qingchuan, Pengzhou, Mianzhu, Maoxian, Dujiangyan, Beichuan, Anxian between the post-earthquake stage and that of the whole period. With respect to stage difference, the statistic significant difference of Su was shown between pre-earthquake stage and reconstruction stage in Wenchuan, Qingchuan, Pingwu, Mianzhu, Dujiangyan, Anxian. While the same results of Su were shown in these ten counties except for Pingwu between pre-earthquake stage and post-earthquake stage. Moreover, that of Su was also shown between reconstruction stage and post-earthquake stage only in Shifang, Pingwu, Pengzhou.

Moreover, (1) mean value of Eu was found significant difference between the pre-earthquake stage and the whole period in all these ten counties. Moreover, the same result was also found between the post-earthquake and the whole period in all these ten counties. While the same result was only shown in Mianzhu between the reconstruction stage and that of the whole period. With respect to stage difference, the statistic significant difference of Eu was shown between pre-earthquake stage and reconstruction stage in Pingwu, Mianzhu, Maoxian, Dujiangyan, Beichuan. While the same results of Eu were shown between pre-earthquake stage and post-earthquake stage in Wenchuan, Shifang, Qingchuan, Pingwu, Mianzhu, Maoxian, Beichuan, Anxian. Moreover, stage difference of Eu was also shown between reconstruction stage and post-earthquake stage in Pingwu, Mianzhu, Maoxian, Dujiangyan, Anxian.

Furthermore, (1) mean value of Pseu was found significant difference between the pre-earthquake stage and the whole period in all these ten counties, except for Pingwu and Beichuan. While between the reconstruction stage and the whole period, the mean value difference of Pseu was only found in the Mianzhu county. Moreover, significant difference on the mean value of Pseu was found between the pre-earthquake stage and the whole period in all these ten counties except for Pingwu. With respect to stage difference, the statistic significant difference of Pseu was shown between pre-earthquake stage and reconstruction stage in Wenchuan, Pingwu, Pengzhou, Mianzhu, Maoxian, Dujiangyan, Beichuan, Anxian. While the same results of Pseu were shown between pre-earthquake stage and post-earthquake stage in all these ten counties expect for Beichuan. Moreover, stage difference of Pseu was also shown between reconstruction stage and post-earthquake stage in Pengzhou, Mianzhu, Maoxian, Dujiangyan, Beichuan, Anxian.

With respect to DCD in these ten counties, the mean value difference was found between pre-earthquake period and that of the whole period in Wenchuan, Qingchuan, Beichuan, Anxian. While difference of mean value was only found in Wenchuan, Shifang, Mianzhu, Dujiangyan, Beichuan between reconstruction period and the whole period. In addition, the results varied that only Wenchuan, Qingchuan, Maoxian, Beichuan, Anxian showed the difference. In terms of DCD stage difference, the significant difference was only found in Maoxian between pre-earthquake stage and reconstruction stage. While, Wenchuan, Qingchuan, Mianzhu, Maoxian, Beichuan, Anxian showed the difference of mean value between pre-earthquake and post-earthquake stage. In addition, the stage difference was only shown in Wenchuan between reconstruction stage and post-earthquake stage.

Compare to DCD, the DCCD showed the different results. The difference of mean value was

shown in all these ten counties except for Pingwu and Beichuan between the pre-earthquake period and the whole period. While, there was no mean value difference in the ten counties between the reconstruction period and the whole period. Furthermore, between the post-earthquake period and the whole period, only Pingwu was not show the mean value of difference on the DCCD. With respect to stage difference, expect for Shifang, difference of DCCD was shown in the ten counties between pre-earthquake and reconstruction stage. However, DCCD difference was shown in all ten counties between pre-earthquake stage and post-earthquake stage. In addition, between reconstruction stage and post-earthquake stage, DCCD difference was only shown in Pengzhou, Dujiangyan and Anxian county.

In terms of spatial differentiation, agglomeration was presented on Pu, Su, Eu, Pseu and DCCD after the Wenchuan earthquake. While DCD was not shown the same results. The hot point and cold point were different on these types of urbanization and urbanization quality. Specific policies should be designed for them.

With regard to urbanization mode, Pingwu and Beichuan had been transferred from space urbanization-led mode into economy urbanization-led mode from the pre-earthquake stage to post-earthquake stage. However, the urbanization mode of Dujiangyan was transferred from space urbanization-led mode into population urbanization-led mode. Furthermore, the rest of counties had achieved the results that population urbanization-led mode was replace by the economy urbanization-led mode.

As regard to classification, these ten counties showed different results after the Wenchuan earthquake. In terms of Pu, Shifang, Wenchuan, Mianzhu become worse after the Wenchuan earthquake. While Dujiangyan become better after the Wenchuan earthquake. With respect to Su, Beichuan, Pingwu, Maoxian, and Wenchuan become worse, while Pengzhou and Dujiangyan become better on Su after the Wenchuan earthquake. In terms of Eu, Mianzhu were assessed as they become worse classification, while Dujiangyan was evaluated as become better classification. When we comprehensively consider the level of urbanization and the quality of urbanization, Pengzhou and Dujiangyan were the two counties which become better classification, while Qingchuan, Mianzhu and Shifang was the county which not change classification after the Wenchuan earthquake.

Reference

[1] Norman VL, Eduardo O, Jamele R, Luc C. Natural Disasters and Growth: Going Beyond the Averages. World Development 2012;40(7):1317-1336.

[2] Anita A. Pena & Sammy Zahran & Anthony Underwood & Stephan Weiler, 2014. "Effect of Natural Disasters on Local Nonprofit Activity," Growth and Change, Wiley Blackwell, vol. 45(4), pages 590-610

[3] Panwar V, Sen S. Economic Impact of Natural Disasters: An Empirical Re-examination. Margin: The Journal of Applied Economic Research. 2019;13(1):109-139. doi:10.1177/0973801018800087

[4] Ryo M, Kozo N, Kimio T. Reconstruction of the Aceh Region following the 2004 Indian Ocean tsunami disaster: A transportation perspective, IATSS Research 2012;(36)1:11-19.

[5] Kamran S, Clive MJ, Warren. Empowerment and legitimization of effected communities in post-disaster reconstruction. Procedia Engineering 2018;212:1171-1178.

Chapter 7

Conclusion

7.1 Conclusion

As the most important settlement mode of human beings in nowadays, the cities accommodate over half of the planet's population and produce four-fifths of the global GDP. Naturally, as one of the most important indicators to evaluate the level of city's development, urbanization attracts extensive and deepen attention, and reports large number and profound results to help us understand urbanization's internal development rules and design effective policies to assistant its sustainable development. As one of special context, urbanization development under the attack of natural disaster is valuable to explore what happen of the urbanization and how the urbanization variation, especially for natural disaster-prone area. In this paper, we take the Wenchuan earthquake, where the epicenter is located in the Longmenshan fault zone which is the boundary between the Qinghai-Tibet Plateau and the Sichuan Basin, as the case to investigate results. The results would be helpful to deepen the acknowledgement of urbanization development under special conditions and benefit the design the disaster reconstruction policies.

With the above motivation, the major contributions of this study include: (1) a comprehensive indicators system (Population-space-economy urbanization, Pseu) has been proposed to evaluate the urbanization level from population urbanization (Su), space urbanization (Su) and economy urbanization (Eu) dimensions. Furthermore, (2) the temporal distribution characteristics and stages (pre-earthquake stage, reconstruction stage, post-earthquake stage) features of urbanization and their interrelationship and coordination state were found out in the region scale and in the county scale. Moreover, (3) variation of urbanization-led mode and classification of urbanization were summarized to help to design the specific reconstruction policies and measures to similar earthquake prone areas. However, more works could be done in the future, such as add one of dimension on social urbanization in the evaluation indicators system, compare urbanization level in county unit by topographies to show the impact of terrain, compare the urbanization level in these ten most severely affected counties and media affected counties and etc. The main conclusions in each chapter could be summarized as follows:

In Chapter 1, *BACKGROUND AND PURPOSE OF THE STUDY*, research background and significance of the variation of urbanization under the earthquake hit is shown. In addition, the previous study about urbanization and natural disaster is reviewed. Then the purpose of the study is proposed.

In Chapter 2, *METHODS AND DATA IN THE RESEARCH OF COMPREHENSIVE POPULATION-ECONOMY-SPACE URBANIZATION*, the urbanization assessment systems for the comprehensive urbanization level, degree of interrelationship, degree of coordination, urbanization mode, and urbanization classification were proposed, including: (1) introducing the data sources; (2) designing the indicator system to show the population urbanization level (Su), space urbanization level (Su), economy urbanization (Eu), and comprehensive urbanization level (Pseu); (3) determining the weight criteria and detailed calculation method; (4) presenting the detailed methods to examine interrelationship between subsystems of urbanization, coupling coordination degree, urbanization-led mode, and category of urbanization. (5) In addition, other methods to show the stage differences was also shown.

In Chapter 3, *OVERVIEW OF THE STUDY AREA AND WENCHUAN EARTHQUAKE LOSS*

AND RECONSTRUCTION POLICY, overview of the study area was reviewed. Selected these ten most severely affected counties as the research area, (1) overview social-economic development was reviewed on the urbanization level, economic level, fixed assets investment, the proportion of general fiscal budget revenue, the balance of savings deposits of urban and rural residents were all presented from 2001 to 2007. (2) Overview of disaster loss from economy, population, houses, land and secondary disaster were also shown in this Chapter. At last, (3) reconstruction policies and the paired-reconstruction mode which was proposed by the Central Chinese government was detailed introduced.

In Chapter 4, *DISTRIBUTION OF POPULATION-ECONOMY-SPACE URBANIZATION BEFORE AND AFTER THE WENCHUAN EARTHQUAKE*, the temporal-spatial on Pu, Su, Eu and Pseu at the MSAA scale and county scale were examined, respectively. In terms of MSAA, (1) the value of Pu, Su, Eu and Pseu all increased from 2001 to 2017. Specifically, (2) the lag effect of Wenchuan earthquake was only shown on the value of Su for it conversely increased in 2008. In addition, (3) the value distribution of Su and Pseu was like a U-shape from 2008 to 2010. Furthermore, (4) Eu experienced the fastest annual growth rate (6.42%), while the lowest annual growth was index of Su with value 3.45%. Moreover, (5) the urbanization process at the scale of MSAA had obvious phase characteristics before and after the natural disasters. With respect to the ten severely affected counties, (6) the value of Pu, Su, Eu and Pseu for these counties all increased from 2001 to 2017. However, (7) there was lag effect on different types of urbanization for different counties. Especially, (8) variation of these types of urbanization was different during the reconstruction years (2008 to 2010). With respect to the effects of reconstruction measures, (9) different results were shown on different types of urbanization in different counties, which was valuable to consider extend the implement time of reconstruction policies. Specifically, (10) there were two major modes on the urbanization annual growth rate. One mode was shown with the lowest annual growth rate on Su with highest Eu. Another mode was shown the smallest annual growth rate on Su, while the biggest one was Eu. In addition, (12) stage characteristics were also found on Su, Su, Eu, Pseu in these ten counties. With respect to spatial distribution, (13) the variation of urbanization level for MSAA was shown different results on comprehensive urbanization level and subsystem urbanization level. After the Wenchuan earthquake hit, (14) the level of Su had become better, while Pu, Eu, and Pseu had become worse. At the county level, (15) the ten counties which are distributed in the MSAA, showed different variation of urbanization after the Wenchuan earthquake.

In Chapter 5, *DISTRIBUTION OF COUPLING AND COORDINATION DEGREE OF URBANIZATION BEFORE AND AFTER THE WENCHUAN EARTHQUAKE*, we measured correlation between Su, Su, Eu, and their coordination state by dynamic coupling degree and dynamic coupling coordination degree, respectively. In terms of the most severely affected area (MSAA), (1) dynamic coupling degree (DCD) fluctuated from 2001 to 2017, while the dynamic coupling coordination degree (DCCD) increased in the same period. Specifically, (2) there are a Slash-shape for the DCD and a U-shape for the DCCD values from 2008 to 2010, showing that the suitable post-disaster policies and measures could effectively strengthen the coordination degree between the urbanization subsystems. In addition, we found that (3) there are stage characteristics for DCCD, while the DCD shows the reverse results. With respect to counties, the results break our expectation. Among these ten counties, (4) DCD values for Anxian, Mianzhu, Beichuan, Pingwu,

Qingchuan increased during the whole period from 2001 to 2017, which break the assumption that the Wenchuan earthquake would reduce the inter-correlation of the three subsystems of urbanization. While Dujiangyan, Pengzhou, Shifang, Maoxian, Wenchuan confirms the hypothesis. Furthermore, (5) the values of DCCD increased from 2001 to 2017 for ten counties, indicating that the coupling and coordination state of three subsystems urbanization for all ten counties in the MSAA improved in the same period. When we evaluate whether there is stage characteristics on DCD and DCCD for these ten counties in the MSAA, interesting results were found. (6) Anxian, Beichuan, Qingchuan, Maoxian, Wenchuan show the stage characteristics on DCD, indicating that counties dominated by the primary industry, the inter-correlation of their urbanization subsystems will be affected by the Wenchuan earthquake. (7) The other counties show the reverse results on DCD. Varying to DCD, (8) All ten counties show the stage features on DCCD. Special results are found during the reconstruction stage (2008 to 2010). In the reconstruction stage (2008 to 2010), (8) there is a U-shape on DCD value for Anxian and Mianzhu, while Pingwu and Wenchuan represent a reverse U-shape. Furthermore, Pengzhou shows like a Horizontal line-shape, while the rest of counties show like Slash-shape. In the same period, (9) only Beichuan, Mianzhu, Shifang and Wenchuan show a U-shape on DCCD. Qingchuan, Pingwu, Maoxian, Dujiangyan, Anxian represent like a Slash-shape on DCCD. Only distribution of DCCD value of Pengzhou shows like a Chair-shape. In terms of spatial distribution, (10) the DCD and DCCD level of MSAA did not affect by the Wenchuan earthquake. At the county level, (11) the ten counties which are distributed in the MSAA, showed different variation of DCCD after the Wenchuan earthquake.

In Chapter 6, *COMPARION STUDY OF COMPREHENSIVE URBANIZATION BEFORE AND AFTER THE WENCHUAN EARTHQUAKE*, urbanization difference, coupling degree difference, coupling coordination degree difference, urbanization mode difference was tested at the MSAA scale and county scale, respectively. In terms of MSAA, (1) significant difference was found on Su, Su, Eu, Pseu between the mean value of different stage and the whole period. While, (2) DCD and DCCD were found significant difference between pre-earthquake stage and the whole period. In terms of stage difference, (3) significant difference was found on Su, Su, Eu, Pseu in different compared stages. Furthermore, (4) DCD was found significant difference between pre-earthquake stage and post-earthquake stage, while DCCD was shown on pre-earthquake stage and reconstruction stage, and pre-earthquake stage and post-earthquake stage. In addition, (5) the urbanization mode had been transferred from population-led urbanization mode into economy-led urbanization mode in the MSAA. With respect to these ten severely affected counties, (6) significant difference was found on Su, Su, Eu, Pseu between the mean value of different stage and the whole period in different counties. While, DCD and DCCD were found significant difference between pre-earthquake stage and the whole period. In terms of stage difference, (7) significant difference was found on Su, Su, Eu, Pseu, DCD, DCCD between different compared stages in different counties. With regard to urbanization mode, (8) Pingwu and Beichuan had been transferred from space urbanization-led mode into economy urbanization-led mode from the pre-earthquake stage to post-earthquake stage. However, (9) the urbanization mode of Dujiangyan was led by the population urbanization mode at the post-earthquake stage. Furthermore, (10) the population urbanization-led mode had been replaced by the economy urbanization-led mode in the rest of counties. In terms of spatial differentiation, (11) agglomeration was presented on Pu, Su, Eu, Pseu and DCCD after the Wenchuan earthquake. While DCD was not shown the same results. As regard to classification, (12) these ten counties showed different results after the Wenchuan earthquake. When we

comprehensively consider the level of urbanization and the quality of urbanization, (13) Pengzhou was the only one county which become better classification, while Pingwu was the county which become worse classification after the Wenchuan earthquake.

In Chapter 7, *CONCLUSION*, we presented the whole summary of each chapter.