Study on the Vulnerability Evaluation of Urban Seismic Disasters Based on AHP Method

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Abstract

At present, the population and wealth converge rapidly to cities on account of national “Urbanization” strategy. Big cities are the focus of earthquake prevention and mitigation and may benefit greatly from disaster reduction measures. The vulnerability evaluation of urban engineering structure, population and economic system are indispensable for earthquake disaster mitigation. A set of quantitative methods which is based on evaluating urban seismic disaster vulnerability of engineering structures, population, economic system and earthquake emergency relief and rescue ability are put forward by using Analytic Hierarchy Process(AHP). The multi-level urban vulnerability evaluation index system and its quantitative scoring criteria and influence weights are established, and the quantitative evaluation model for urban seismic hazard vulnerability is given from the view of natural science and social science research. As examples, the seismic disaster vulnerabilities of 10 cities are evaluated in China.

Keywords: earthquake disaster, vulnerability of urban, vulnerability of population , vulnerability of economic system , AHP

1. Introduction

The earthquake disaster vulnerability is one important research topic of natural disasters. In the 1950s and 1960s, a series of natural disasters such as earthquakes occurred in the United States. The sociology of natural disaster got the attention of government. Then, the study on social vulnerability of natural disasters began [Chen Yingfan et al., 2006]. At the end of 1970s, the study of disasters vulnerabilitywas focused on social structurevulnerability and analysis of historical, cultural, social and economic processes that affect people's ability to deal with disasters[Burton, Blaikie et al.,1994]. In 1981, Pelandadefined disasters are the result of one or more disaster factors hitting vulnerable populations, buildings, economic assets or sensitive environments [Shi Peijun,1991].

In the study of earthquake disaster vulnerability, the IDNDR (International Decade for Natural Disaster Reduction) Commission implemented a disaster reduction program----RADIS(Risk Assessment Tools for Diagnosis of Urban Areas Against Seismie Disasters) at the end of the 20th century. Its core content is to evaluate the risk of earthquake disasters in cities. It is aimed to measure the level of the risk. In 1997, Earthquake Disaster Risk Index (EDRI) was firstly established to evaluate the relative severity of potential earthquake disasters for various cities in Stanford University [Rachel Dvaidson, Haerhs C. Shah, 1997] .

In China, the study on disasters vulnerability was initiated in the 1990s with the implementation of IDNDR project. In the research of earthquake disaster vulnerability, National Natural Science Foundation of China supported the research on knowledge engineering in earthquake damage prediction during the "7th Five-Year Plan" period. The basic research on urban and engineering disaster prevention was conducted during the "8th Five-Year Plan" period [Hu Yuxian et al.,1998]. A large number of earthquake damage prediction and loss evaluation methods were prsented during the "9th Five-Year Plan" period. The theoretical methods were applied to the earthquake damage prediction in many areas (such as in Zigong, Quanzhou et al.,). These studies and applications had laid a certain theoretical foundation for the establishment of urban earthquake prevention and disaster reduction capability indicator systems[Zhao Zhendong et al., 2000]. Firstly, the the criteria for measuring earthquake prevention and disaster reduction capabilities was put forward by considering casualties, economic losses, and post-earthquake recovery time as parameters[Zhangfenghua, Xielili et al., 2002]. According to the three criteria, Six factors(including earthquake risk evaluation capability, earthquake monitoring and prediction capability, earthquake resistance capability, socio-economic disaster prevention capability, non-engineering disaster reduction capability, and emergency & recovery capability) were extracted to establish a city earthquake prevention and mitigation capability index system. Since then, some scholars have done further work based on the methods [Wang Wei et al., 2009-2009]. These efforts had deepened people's understanding of the problem.

In general, the study onvulnerability of earthquake disasters were extended to environmental and social aspects in the early 1970s abroad. The social vulnerability of earthquake disasters has become an indispensable part of the vulnerability. The study is mainly based on the analysis of the natural factors of resulting in disaster at present in domestic. There is no correct understanding and in-depth discussion of the social background of disaster formation. The existing research on the vulnerability of earthquake disasters lacks a relatively complete system, especially an effective evaluation index system. Extracting the influencing factors in the evaluation index system is based on the principle of detail and completeness. Thus, it affects the operability of evaluation.

In the paper, the vulnerability of urban earthquake disaster includes the vulnerability of engineering structures and the population & socio-economic system vulnerability caused by non-engineering structure damage during earthquake. And the impact of earthquake emergency relief and rescue capacity are also considered. Consequently, the comprehensive evaluation of vulnerability is carried out, and a quantitative evaluation model is established. Analytic Hierarchy Process(AHP) is used to establish the multi-level urban vulnerability evaluation index system for realizing the comprehensive evaluation of urban earthquake vulnerability. This study provides reference and service for urban earthquake prevention and disaster reduction work and lays foundation for future research on urban earthquake disaster risk.

2. Index system for evaluating the vulnerability of urban earthquake disaster

In the paper, the index system of earthquake disaster vulnerability evaluation is established by using AHP which was proposed by TLe Saati in the 1970s. The AHP is a qualitative and quantitative combination, systematic and hierarchical analysis method.

Following the principles of science, comparability, stratification, and operability, a comprehensive evaluation system is established by considering the vulnerability of urban engineering structure, population, economic system and the disaster relief capacity of urban by using AHP. The vulnerability of urban engineering structure mainly considers the influence of buildings and lifeline engineerings. The vulnerability of urban population takes into account the influence of urban population density, population physiology factors, population economy factors and population society factors. The vulnerability of urban economic system considers the influence of urban economic density and economic industrial structure. Urban disaster relief capacity considers the impact of urban self-help resources, transportation capacity and emergency shelter. Among them, self-help resources also include fire fighting ability and medical ability. The transportation ability considers urban road density and communicate capacity with the surrounding areas.

In summary, the index system is shown in Figure 1.

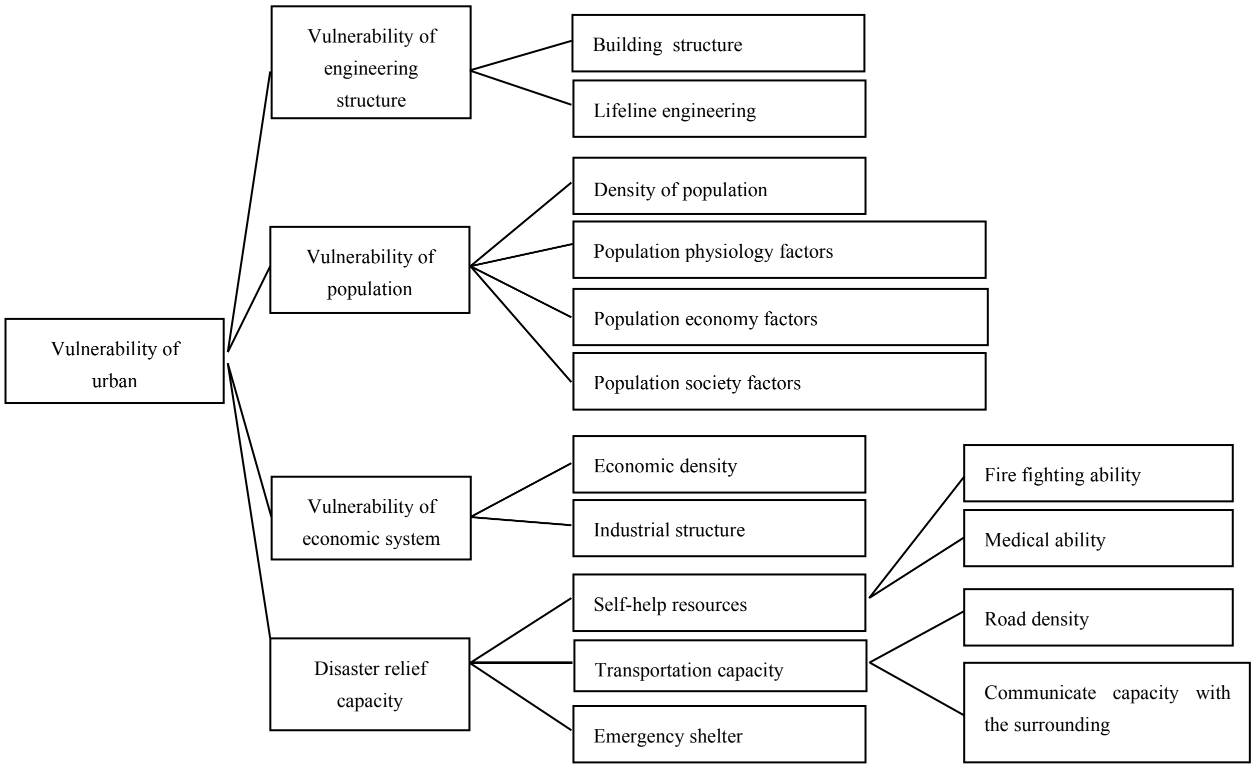

Fig. 1 Comprehensive evaluation index system of urban seismic disaster vulnerability

3. Index weight calculation and consistency test

Among four indicators of the second layer, the greatest impact on the urban vulnerability is undoubtedly engineering structures. The destruction of them is the main reason for causing casualties and economic losses. Therefore, the factor is significant more important than the other three factors. In addition, the better relief capacity is also an important means to mitigating disasters after earthquake. It is also more important than the other two factors. Relatively speaking, the vulnerability of the economic system is the least important among the four factors. Therefore, we have established the judgment matrix which is shown in Table 1.

According to the AHP method, the consistency check of the judgment matrix is performed. The matrix satisfies the consistency test. The calculated weights of the items are shown in Table 2.

Table 1- Judgment matrix of the second level indexes

	Engineering structure	**Population**	**Population**	**Disaster relief capacity**
Engineering structure	1	6	7	4
Population	1/6	1	3/2	1/3
Economic	1/7	2/3	1	1/2
Disaster relief capacity	1/4	3	2	1

Table2 - Weights and consistency test of the second indexes

Subentry	**Engineering structure**	**Population**	**Population**	**Disaster relief capacity**
Weight	0.624	0.097	0.082	0.197
$\lambda_{max} = 4.079$, CI=0.02618, CR=0.029093, Satisfy consistency				

Similarly, judgment matrices are established for third-level and fourth-level indicators. Then the calculated weights and consistency tests are performed. Due to the length of the article, it is no specifically given here. The calculated weights of the indicators are listed in Table 6.

4. Comprehensive Evaluation Model and Judgment Criteria

4.1 Vulnerability of buildings

In the 6th census of China, buildings of urban and rural were classified according to the "load-bearing type" of structures. They are 4 classes(Steel and reinforced concrete structures, Mixed structures, Brick and wood structures, Other structures). In this paper, the classification of buildings is divided according to these four categories. The vulnerability matrix of the four classes of buildings are given combining with previous studies. In addition, how to reflect the proportions of the four types building in different regions requires different area building allocation models on the basis of the buildings overall situationof various administrative units and the specific classification method of buildings. That is different urban building allocation models.

By analyzing the dozens of urban buildings data with carring out earthquake damage prediction and earthquake damage investigation, 11 models of cities are classified considering the scale, history, development status and geographical differences in this article. The proportion of the above 4 buildings classes are shown in Table 3 and Table 4 by residential and non-residential buildings.

The models are specifically determined as follows.

Model 1: Metropolis(1), a mega-city with long history, similar to Beijing. Model 2: Metropolis(2), most provincial capital cities, similar to Shenyang. Model 3: Metropolis(3), Metropolitan City, the slow transformation of the city, similar to the old city of Tianjin. Model 4: Middle cities in economically developed areas. Model 5: Medium cities in economically underdeveloped areas. Model 6: economically developed counties, similar to counties in the area of Jiangsu and Zhejiang. Model 7: Counties near the metropolis, similar to counties in the suburbs of Beijing and Tianjin. Model 8: Counties of metropolitan suburban, similar to counties in the outskirts of Beijing and Tianjin. Model 9: counties in economically underdeveloped regions, similar to counties in underdeveloped western regions. Model 10: Emerging development cities, similar to Tangshan and Shenzhen. Model 11: Cities of Hong Kong and Macau.

Table 3 - The proportion of residential buildings in various cities according to the structure type

Model No.	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Steel and reinforced concrete structures	43.2%	41.3%	33.3%	38.3%	32.4%	29.5%	14.8%	12.5%	11.2%	53.1%
Mixed structures	40.6%	49.1%	57.1%	44.2%	43.2%	33.8%	39.2%	37.1%	17.9%	43.1%
Brick and wood structures	15.7%	9.1%	9.1%	12.3%	17.3%	19.6%	24.5%	26.2%	43.4%	3.3%
Other structures	0.5%	0.5%	0.5%	5.2%	7.1%	17.1%	21.5%	24.2%	27.5%	0.5%

Table 4 - The proportion of non-residential buildings in various cities according to the structure type

Model No.	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Steel and reinforced concrete structures	61.5%	50.3%	43.3%	40.3%	35.4%	32.5%	24.6%	20.7%	16.1%	55.5%
Mixed structures	35.6%	43.8%	49.1%	41.2%	42.2%	37.6%	31.7%	35.7%	19.3%	40.7%
Brick and wood structures	2.4%	5.4%	7.1%	12.8%	15.3%	16.6%	22.5%	22.8%	41.3%	3.3%
Other structures	0.5%	0.5%	0.5%	5.7%	7.1%	13.3%	21.2%	20.8%	23.3%	0.5%

The average earthquake damage index(AEDI) is used to distinguish the vulnerability degree of buildings in this paper. The earthquake damage index is proposed by Mr. Hu Yuxian when investigating the Tonghai Earthquake[Hu YUxian,1988] , and widely used in future earthquake investigations. The earthquake damage index "1.0" means that all collapsed, and "0" means intact. The middle value corresponds to slight damage, moderate damage, and serious damage. The range of earthquake damage indices corresponding to various damage levels is shown in Table 5.

Table 5 - Seismic damage indexea table

Earthquake damage index	Intact	Slight damage	Moderate damage	Serious damage	Destroyed
Range	$D \le 0.1$	$0.1 < D \le 0.3$	$0.3 < D \le 0.55$	$0.55 < D \le 0.85$	$0.85 < D$
Representative value	0	0.2	0.4	0.7	1.0

For a city, the number of people, the per capita residential area, the ratio of residential to non-residential buildings can be obtained from open statistics datum. Then, the total area of buildings can be gotten. According to the 11 models of cities and the experience earthquake damage matrixes of four classes buildings, the average earthquake damage index of building structure under the intensities can be calculated.

In the paper, the average earthquake damage index of VIII degree is selected to distinguish the vulnerability degree of urban buildings. The calculated average damage index value of the urban buildings at VIII degrees is divided into five levels. They are shown in Table 6.

4.2 Vulnerability of Lifeline engineering

Historical earthquake damage shows that it is a gradual process to recover the lifeline function from the initial failure to the pre-earthquake level.

The initial failure function evaluation of lifeline systems requires detailed data and a lot of work. For the semi-quantitative evaluation of urban vulnerability, a brief evaluation method of is given in this article. Combining the 11 modelse of cities, the initial function failure of lifeline systems is roughly divided into five categories from small to large in terms of the construction time and economic degree of cities .

For different cities, different geographical locations determine the difficulty of recovery of lifeline systems. Recovery in remote and mountainous areas is much more difficult than in plain areas. In order to deal with the problem simply, the difficulty of recovery is determined by the altitude of the geographical location. It is divided into three categories. It is extremely difficult to recovery the corresponding elevation of 2000 meters or more, and it is difficult to recovery the corresponding elevation of 1000 to 2000 meters, and it is easy to recovery the corresponding elevation of 1000 meters or less.

4.3 Density of population

Density of population reflects the exposure of the population under seismic disasters. For a given spatial area, the larger the population is, the more casualties occur in the same intensity earthquake. Actually, the average population density of 286 municipal districts was 615 persons per square kilometer at the end of 2013 in China. The lower ones are only a few dozens persons per square kilometer and the lowest is 14.5 persons per square kilometer in Heihe City. The higher density ones are almost 2,000 persons per square kilometer. The largest one is 8,248 people per square kilometer in Shijiazhuang City. This paper divides the density of population into five levels(Table 6).

4.4 Population physiological factors

The population physiological factors will affect their degree of injure under the earthquake. Children, the elderly, the sick and the disabled are more vulnerable to injury because of immature, aged or defective bodily functions. It is also to say that the vulnerable groups are highly vulnerable. The analysis of the historically earthquake casualties composition shown tha the higher the proportion of the elderly and children is, the higher the vulnerability of population is. According to the results of the 6th census, the population aged 0-14 accounts for 12.23%, aged 15-59 accounts for 76.30 %, aged 60 and over accounts for 11.47% among the 286 cities. Considering the operability of the selection of indicators, the physiological factors of the population are divided five levels by the ratio of the young and old as the standard in this paper (Table 6).

4.5 Population economic factors

Population economic factors are mainly divided by the per capita GDP. The per capita GDP statistics of 286 cities was about 87,700 yuan (RMB) at the end of 2013. The lowest one was 10,265 yuan (RMB) in Bazhong, and the highest one was 467749 yuan(RMB) in Shenzhen. This paper divides the population economic factors into five levels according to per capita GDP (Table 6).

4.6 Population social factors

The population social factors are divided according to the educational level of the population(illiteracy rate). According to the results of the sixth census, the urban illiteracy rate was 1.90 % in China. the lowest one was 1 % in Hunan, the highest was 13.42 % in Tibet, and the second one was 3.88 % in Anhui. The population social factors n are divided into five levels according to the illiteracy rate(Table 6).

4.7 Economic density

According to economic density statistics of 286 municipal districts at the end of 2013, the average is 54 million per square kilometer. The largest one is 726.1 million per square kilometer in Shenzhen, and the lowest one is 190,000 in Heihe city. Then, the economic density is also divided into five levels (Table 6).

4.8 Industrial structure

The damage of the secondary industry caused by earthquake is the most difficult to recover from historical earthquake disaster. The more the proportion of the secondary industry is, the greater the impact of earthquake is. According to city statistics at the end of 2013, the average ratios of the primary industry, secondary industry and the tertiary industry respectively are 2.83 %, 47.62% and 49.54% in 286 cities. Thus, the economic industrial structure is divided into five types according to the proportion of the secondary industry(Table 6).

4.9 Fire fighting ability

The number of fire fighters per 10,000 people is selected as the evaluation parameter of the city's fire fighting ability in the paper. According to statistics on the firefighting capabilities of some cities at home and abroad, they generally have about 10 firefighters per 10,000 peoples in some big cities abroad (such as London and Paris). It has even reached 18.68 per 10,000 people in New York. But, the value is lower in China. it is 3.34 in Shanghai. The lowest one is 0.25 in Kaifeng. The fire fighting ability is divided into five levels by the number of fire fighting people per 10,000 people according to the actual situation(Table 6).

4.10 Medical ability

The number of doctors per 1000 people who can represent medical ability and can be operated is choosed as the evaluation index of medical ability in the paper. The average of doctors per 1,000 peoples was 3.53 at the end of 2013 in 286 cities. The largest one was 9.93 in Kaifeng and the least one 0.65 in Suihua City. The medical capacity is divided into five levels by the number of doctors per 1,000 peoples according to the actual situation (Table 6).

4.11 Road density

The road density of generally reflects the accessibility in cities. The denser the roads within the unit area is, the more smooth the traffic is. The urban road area(10000 square meters) and the administrative area(square kilometer) are given in the city statistical Yearbook at the end of the year. Then, the road density can be calculated from two parameters. According to road density statistics of 286 cities, the average is about 10.7 per 10,000. the largest one was 575.66 per 10,000 in Shenzhen and the least one was 0.23 per 10,000 in Jiuquan City. The road density is divided into 5 levels by numerical size(Table 6).

4.12 Communicate capacity with the surrounding area

The communicate capacity with the surrounding area is simply divided into five levels according to whether there are airports, high-speed railways, railways, highways (Table 6).

4.13 Emergency shelter

According to the datum from China city statistical yearbook , the urban green average coverage rate of Built-up Area was about 40% at the end of 2013 among 286 cities.The several larger ones were 60.58% in Binzhou City and 64.45% in Zhuhai City. The largest one reached 77.78 % in Xuancheng city. The less ones number was about 20%, such as 21.35 % in Wuwei City, 21.44 % in Weinan City, and 21.70 % in Tongren City. There were a few extreme examples, such as 1.04 % in Qingyang City, and 1 % in Pingliang City and 0.39 % in Shizuishan City. In summary, urban emergency shelters are also classified into five levels(Table 6).

According to the analysis of the impact parameters in the evaluation index system, every influence parameter is divided into 5 different levels from A to E. The corresponding to a comprehensive score are from 1 to 5. The parameters classification criteria and the comprehensive scoring criteria, as well as the weights calculated from the APH method for the impact factors are also listed in table 6.

Finnally, the classification criteria of urban earthquake vulnerability zones are given based on the actual investigation results of earthquake disasters in China(Table 7).

Table 6 - Evaluation criteria and weights of various parameters of urban seismic vulnerability

Levels	A	B	C	D	E	Weight
Buildings（AEDI at Ⅷ)	D≤0.28	0.28< D≤0.30	0.30<D≤0.35	0.35<D≤0.38	0.38<D	0.4992
Lifeline system	Model10,model 11	Model1,Model 2,Model4	Model3,Model 6,Model7	Model8,Model 5	Model9	0.1248
Density of population (1000peoples/ km²)	<0.1	0.1~0.4	0.4~0.8	0.8~1.8	>2.0	0.0606
Population physiological factors（ratio of the young and old)	<21%	21%~23%	23%~25%	25%~27%	>27%	0.0189
Population economic factors (per capita GDP Yuan/people)	>120000	90000~120000	50000~90000	30000~50000	＜30000	0.0083
Population social factors (illiteracy rate)	<1.2%	1.2%~1.7%	1.7%~2.2%	2.2%~2.7%	>2.7%	0.0091
Economic density（10000 Yuan/ km²)	＞20000	10000~20000	2000~10000	500~2000	＜500	0.0683
Proportion of the secondary industry	＜30%	30%~40%	40%~50%	50%~60%	＞60%	0.0137
Fire fighters per 10,000 people	＞15	10~15	5~10	2~5	>2	0.0310
Doctors per 1000 people	＞6	4~6	3~4	2~3	<2	0.0155
Road density（1/10000)	>30	13~30	8~13	4~8	<4	0.1008
Communicate capacity with the surrounding	With airport and high-speed railway	With high-speed railway, without airport	With railway and highway	With highway, without railway	Without railway and highway	0.0336
Green coverage rate（%)	>50%	42%~50%	38%~42%	25%~38%	＜25%	0.0162
Score	1	2	3	4	5	

Table 7 - Classification criteria of urban seismic vulnerability partitioning

Hazard level	**Extremely difficult to damage**	**Difficult to damage**	**General to damage**	**Easy to damage**	**Extremely easy to damage**
Rating Value	0~1.6	1.6~2.2	2.2~2.8	2.8~3.6	3.6~5

5. Evaluation examples

Ten cities are selected as examples to calculate the vulnerability of urban earthquake disasters in the paper. The selected cities include large, medium and small cities, which are distributed throughout the country. Some cities have experienced earthquakes and others have not. The 10 cities are Shanghai, Tianjin, Tangshan, Harbin, Xiamen, Dongguan, Lijiang, Lu'an, Guangyuan and Karamay. Most of the basic data comes from the literature[18] and literature[19]. Some supplementary data derived from the statistical Yearbook of each province & city, and the basic data which had been collected by the Earthquake Disaster Prediction Project of cities(Table 8).

Table 8 - Urban basic datum sheet

Cities	Model No. of structure	Average altitude (m)	Per capita housing area(m^2)	Population (10000)	Area (km^2)	Population density(people/km^2)	Per capita GDP (Yuan)	Proportion of the secondary industry	Doctors (people)
Shanghai	Model 1	<500	27.25	1364.1	5155	2643	156446	37.19	45060
Tianjin	Model 3	< 500	25.51	821.7	7399	1110	159934	50.40	28766
Tangshan	Model10	<500	30.10	302	3874	781	82132	61.18	9072
Harbin	Model2	<500	23.72	473.6	7086	668.40	68277	37.28	16551
Xiamen	Model1	< 500	30.29	196.8	1573	1250.99	153206	47.54	8669
Dongguan	Model4	< 500	26.37	188.9	2460	768.01	290477	45.88	14864
Lijiang	Model8	> 2000	31.27	15.2	1255	121.12	55405	40.45	563
Lu'an	Model5	< 500	32.2	187.9	70	526	17251	46.79	3166
Guangyuan	Model5	1200	33.28	93.5	3583	526.46	26654	54.87	2680
Karamay	Model9	< 500	28.00	37.9	7735	49.02	224502	76.99	828

Table 8 - Urban basic datum sheet

Cities	Administrative area (km^2)	Urban Road area(10000m^2)	Illiteracy rate	Green coverage rate of Built-up Area (%)	Doctors per 1000 people	Fire fighters per 10,000 people	Ratio of 0-14 age	Ratio of more than 60 age	GDP(10000Yuan)
Shanghai	6340	9932	2.06	38.4	2.4	3.34	8.61	15.01	213391800
Tianjin	11917	12440	1.68	35.4	3.5	1.24	9.8	13.02	131465527
Tangshan	13742	3050	1.33	44.14	3.0		13.04	12.10	24885900
Harbin	53068	4757	1.42	36.06	3.49		9.63	13.96	32363205
Xiamen	1573	3570	1.85	41.78	4.40		13.29	8.74	30181565
Dongguan	2460	10273	1.16	50.96	7.87		12.38	7.34	54900207
Lijiang	21219	179	2.71	40.91	3.70		13.84	10.99	831077
Lu'an	18011	1207	3.88	37.4	1.68	2.03	13.28	11.87	3260444
Guangyuan	16311	512	2.14	37.18	2.87		11.88	13.46	2478856
Karamay	7735	955	1.92	42.89	2.18		14.97	10.92	8531091

The score of each evaluation indicator for each city are calculated by using the datum in Table 8. The middle partition value is taken for cities that lack the value of fire fighters. The weights of each indicator are used to calculate the final score. The results of the comprehensive evaluation of the vulnerability in each city and the classification of vulnerability are shown in Table 9.

Table 9 - The results of comprehensive evaluation and classification of the vulnerability in cities

Cities	**Shanghai**	**Tianjin**	**Tangshan**	**Harbin**	**Xiamen**
Comprehensive evaluation score	1.93	2.75	1.51	2.11	1.92
Classification of vulnerability	Difficult to damage	General to damage	Extremely difficult to damage	Difficult to damage	Difficult to damage
Cities	Dongguan	Lijiang	Lu'an	Guangyuan	Karamay
Comprehensive evaluation score	2.27	4.28	4.15	3.39	3.06
Classification of vulnerability	General to damage	Extremely easy to damage	Extremely easy to damage	Easy to damage	Easy to damage

6. Conclusions

In this paper, the data of past earthquake damage are collected and arranged. Based on reviewing the progress of research on disaster vulnerability, a vulnerability evaluation system for urban earthquake disasters by AHP method is established by comprehensively considering the vulnerability of urban engineering structures, population, economic system and disaster relief & rescue capabilities. For the specific evaluation indicators, the detailed classification criteria are given based on the analysis of current statistical data. Then, a specific evaluation model which has the advantages of strong operability and few parameters is established.

The issues and recommendations are given as follow.

1)The suitable evaluation index of the vulnerability of urban earthquake disaster is selected in the paper. It makes the evaluation feasible and simple. But some factors that have important influence on vulnerability of urban earthquake disaster may have been missed. Some r revision and adjustment need to be made in future research.

2) The classification criteria for influencing parameters and the comprehensive evaluation criteria contain certain subjectivity judgments of the author. The definitions of these grading standards need to be more scientifically defined and tested.

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8. Copyrights

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