Analysis on the Characteristics of the Casualties Caused by Earthquake Disasters in China in Recent Years

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Abstract. This paper intends to re-study the characteristics of earthquake disasters according to the 184 earthquake disaster events that occurred in mainland China from 2001 to 2016 on the basis of previous studies. Taking 184 earthquake cases as samples, a quantitative analysis of the main coupling factors of casualties caused by earthquakes is carried out to lay the foundation for establishing a more accurate casualty assessment model for earthquake disasters.

Keywords: Earthquake Disasters, Casualty, Coupling Factors, Disaster Assessment

1. Introduction
An earthquake is a natural phenomenon with extremely destructive power. Its unique burstiness and instantaneous destructive power often cause a large number of casualties and huge economic losses. With the rapid economic development, rapid population growth and accelerated urbanization in recent years, there are more and more earthquake disasters in China, which pose more and more threats to people's life and property safety. Therefore, it is necessary to explore the causes of casualties caused by earthquakes and analyze the factors that affect the number of casualties, so as to lay a good foundation for establishing a more accurate pre-evaluation model for casualties in earthquake disasters, so as to enhance the effectiveness and pertinence of post-earthquake emergency rescue.

2. Data Analysis of Main Earthquake Disasters in Mainland China since the 21st Century
On the basis of previous studies [1-7], this paper re-studies the 184 earthquake disaster events that occurred in mainland China from 2001 to 2016. Based on these data, the characteristics of earthquake disasters in China in recent years are analyzed, which lays a foundation for analyzing the coupling factors of casualties caused by earthquakes.

From 2001 to 2016, there were 184 earthquake disasters in mainland China, resulting in 73,433 deaths, 421,970 injuries, damage to 302,236,800 square meters of buildings, and direct economic losses of 1.069013 trillion yuan. In addition to Beijing, Shanghai, Tianjin, Ningxia and Hainan, all 25 provinces (municipalities directly under the Central Government) in mainland China have experienced earthquake disaster events. See Figure 1 and Table 1 for specific data. Table 2 lists the statistics of main earthquake disasters in mainland China from 1980 to 2016, and compares the earthquake disaster loss data of 1980-1989, 1990-1999, 2000-2005, 2006-2010, and 2011-2016. It can be seen that the casualties and economic losses caused by earthquake disasters in China are gradually increasing. In
particular, the direct economic losses caused by earthquakes accounted for a significant increase in the proportion of GDP in the same year. With the improvement of economic development, the loss caused by earthquake disasters is increasing.

Table 1. Statistical Data of Major Earthquake Disasters in Mainland China from 2001 to 2016 \cite{1-7}

| Year | Death toll | Number of injured | Destroyed area of buildings (10,000 m²) | Severe damaged area of buildings (10,000 m²) | Medium damaged area of buildings (10,000 m²) | Direct economic loss (Hundred Million Yuan) |
|------|------------|-------------------|--------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|
| 2001 | 7          | 1407              | -                                    | -                                        | -                                        | 16.33                                    |
| 2002 | 2          | 360               | 0.4                                  | 3.01                                     | 36.57                                    | 1.48                                     |
| 2003 | 319        | 7147              | 328.28                               | 477.72                                   | 998.54                                   | 46.2                                     |
| 2004 | 8          | 688               | 15.35                                | 81.72                                    | 205.45                                   | 9.5                                      |
| 2005 | 15         | 867               | 345.72                               | 54.35                                    | 991.63                                   | 26.28                                    |
| 2006 | 25         | 204               | 54.68                                | 9.4                                      | 337.66                                   | 8                                        |
| 2007 | 3          | 419               | 137.06                               | 30.19                                    | 580.95                                   | 20.19                                    |
| 2008 | 69283      | 377010            | 16862.66                             | 6108.63                                  | 53558.82                                 | 8594.96                                  |
| 2009 | 3          | 404               | 99.33                                | 21.82                                    | 683.54                                   | 27.38                                    |
| 2010 | 2705       | 11088             | 356.22                               | 106.94                                   | 335.05                                   | 235.67                                   |
| 2011 | 25         | 370               | 120.38                               | 123.26                                   | 767.06                                   | 46.77                                    |
| 2012 | 86         | 1331              | 227.59                               | 65.15                                    | 1263.96                                  | 82.88                                    |
| 2013 | 294        | 15669             | 588.16                               | 11.39                                    | 2922.79                                  | 994.05                                   |
| 2014 | 623        | 3666              | 644.15                               | 52.85                                    | 2393.36                                  | 331.87                                   |
| 2015 | 33         | 1237              | 281.21                               | 132.44                                   | 522.1                                    | 181.75                                   |
| 2016 | 2          | 103               | 46.37                                | 79.41                                    | 511.93                                   | 66.82                                    |
| 总计 | 73433      | 421970            | 20107.56                             | 7358.28                                  | 66109.41                                 | 10690.13                                 |

Figure 1. The Annual Frequency of Earthquake Disaster Events from 2001 to 2016
Table 2. Statistical Data of Major Earthquake Disasters in Mainland China from 1980 to 2016

| Year    | Death toll Unit: person | Number of injured Unit: person | Direct economic loss Unit: hundred million yuan | Loss as a percentage of GDP in the same year Unit:% |
|---------|--------------------------|--------------------------------|-----------------------------------------------|-----------------------------------------------|
| 1980-1989 | 1112                    | 12402                          | 49.81                                         | 0.0092                                        |
| 1990-1999 | 681                     | 51878                          | 112.24                                        | 0.021                                         |
| 2000-2005 | 351                     | 10469                          | 99.79                                         | 0.012                                         |
| 2006-2010 | 72019                   | 389125                         | 8886.2                                        | 0.5776                                        |
| 2011-2016 | 1063                    | 22376                          | 1704.14                                       | 0.0469                                        |

Note: The GDP data from 1980 to 2016 comes from data released publicly by the Data Center of the National Bureau of Statistics.

Table 3. List of Earthquake Disaster Losses of Provinces in Mainland China from 2001 to 2016

| Serial number | Province     | Frequency of earthquake disaster events | Death Toll | Number of injured | Economic loss (hundred million yuan) |
|---------------|--------------|------------------------------------------|------------|-------------------|-------------------------------------|
| 1             | Xinjiang     | 48                                       | 283        | 5267              | 167.25                              |
| 2             | Yunnan       | 45                                       | 795        | 9396              | 504.66                              |
| 3             | Sichuan      | 19                                       | 69475      | 390185            | 9288.73                             |
| 4             | Gansu        | 12                                       | 111        | 3005              | 252.87                              |
| 5             | Tibet        | 11                                       | 39         | 1096              | 149.99                              |
| 6             | Qinghai      | 9                                        | 2699       | 11013             | 249.33                              |
| 7             | Inner Mongolia | 6                                  | 5          | 1082              | 20.34                               |
| 8             | Chongqing    | 5                                        | 2          | 39                | 1.13                                |
| 9             | Shanxi       | 4                                        | 0          | 22                | 0.36                                |
| 10            | Hubei        | 3                                        | 0          | 5                 | 0.81                                |
| 11            | Guizhou      | 2                                        | 6          | 9                 | 5.17                                |
| 12            | Anhui        | 2                                        | 2          | 13                | 3.08                                |
| 13            | Guangxi      | 2                                        | 1          | 3                 | 1.27                                |
| 14            | Jilin        | 2                                        | 0          | 27                | 21.34                               |
| 15            | Zhejiang     | 2                                        | 0          | 0                 | 2.26                                |
| 16            | Jiangxi      | 1                                        | 13         | 775               | 20.38                               |
| 17            | Heilongjiang | 1                                        | 1          | 11                | 0.27                                |
| 18            | Jiangsu      | 1                                        | 1          | 3                 | 0.15                                |
| 19            | Henan        | 1                                        | 0          | 12                | 0.14                                |
| 20            | Shandong     | 1                                        | 0          | 6                 | 0                                   |
| 21            | Shaanxi      | 1                                        | 0          | 1                 | 0.13                                |
| 22            | Hebei        | 1                                        | 0          | 0                 | 0.1                                 |
| 23            | Fujian       | 1                                        | 0          | 0                 | 0.1                                 |
| 24            | Guangdong    | 1                                        | 0          | 0                 | 0.23                                |
| 25            | Liaoning     | 1                                        | 0          | 0                 | —                                   |

Table 3 gives a list of earthquake disaster losses in various provinces in mainland China from 2001 to 2016. From this table, it can be seen that earthquake disasters are mainly concentrated in the central and western provinces. Xinjiang has the most disaster events, which is caused by the high frequency of
earthquakes in the region. However, even if there are a lot of earthquake disasters, they are not too serious. The most severely affected province is Sichuan, which accounts for almost 95% of the country’s casualties and economic losses. The losses caused by the 2008 Wenchuan M8.0 earthquake and the 2013 Lushan M7.0 earthquake accounted for more than 99% of the province's total disaster losses. Earthquake disaster events are scattered in the eastern region, and the magnitudes are mostly below 5. They are disasters with small earthquakes.

3. Analysis of Coupling Factors of Casualties Caused by Earthquakes

Previous studies of earthquake cases have shown that there are many factors that affect the casualties caused by earthquakes. The casualties caused by earthquakes are the result of the coupling of multiple factors. They are not determined by a single factor. Chinese scholars have done a lot of research on the factors affecting the casualties of earthquake disasters \[9-11\]. Based on previous studies, this paper divides the main factors affecting casualties in earthquakes into five categories: intensity of the meizoseismal area, origin time of earthquake, population density, damage to buildings, and the impact of secondary disasters. Taking the aforementioned 184 earthquake disaster events that occurred in mainland China from 2001 to 2016 as the research object, this paper quantitatively explores the correlation between casualties and the five major factors. The casualty number here are all defined as the number of dead plus the number of seriously injured.

3.1 Impact of the Origin Time of Earthquake on Casualties

In order to explore the relationship between the number of casualties caused by the earthquake and the origin time of the earthquake, the 184 earthquake disaster events collected above are statistically analyzed between the origin time of earthquake and the number of casualties under different magnitude conditions. Figures 5 to 7 respectively show the statistical histograms of the number of casualties and the origin time of earthquake under different magnitude conditions in mainland China from 2001 to 2016. As can be seen from the figure below, there is no significant relationship between the origin time of earthquake and casualties, and the impact of the earthquake occurred at night or during the day on casualties is not obvious \[12\].

![Figure 2](image-url)  
Figure 2. The Statistical Histogram of the Corresponding Relationship Between the Number of Casualties of Earthquakes Above M7 and the Origin Time of Earthquake
Figure 3. The Statistical Histogram of the Corresponding Relationship Between the Number of Casualties of Earthquakes (6≤M < 7) and the Origin Time of Earthquake

Figure 4. The Statistical Histogram of the Corresponding Relationship Between the Number of Casualties of Earthquakes (5≤M < 6) and the Origin Time of Earthquake

3.2 Impact of Population Density in the Earthquake Area on Casualties

In order to quantitatively explore the correlation between the population density in the earthquake area and the casualties caused by the earthquake, the following analysis is carried out on the 184 earthquake disaster events collected above. In the analysis process, the regional population kilometer grid data of mainland China was used, so the population density data source of the area near the epicenter is relatively reliable and close to reality. According to Baidu Encyclopedia, the current average population density in China is 143 people per square kilometer. The eastern coastal area is densely populated with more than 400 people per square kilometer; The central area has more than 200 people per square kilometer; and the western plateau area is sparsely populated, with less than 10 people per square kilometer. In order to facilitate statistical analysis, the population density is simplified into 6 stages, which are 0-49; 50-149; 150-299; 300-499; 500-999 and more than 1000. The above units are all per person/km². Through analysis, it is found that for the above 184 disasters, the
The frequency of occurrence in different population density areas is shown in Figure 12. The largest number of earthquakes occurred in areas with a population density of less than 50 people/km², which is 103 events. Only one earthquake disaster event occurred in an area with the population density of more than 1,000 people/km², that is, the M4.8 earthquake in Rongchang County, Chongqing City on December 27, 2016. The intensity of the meizoseismal area was VI, and 2 people were injured. The direct economic loss is 33 million yuan, and the local population density is about 1,776 people/km².

![The Number Of Earthquake Disaster Events](image)

**Figure 5.** Frequency of disaster earthquake events in different population density areas

In order to better analyze the coupling relationship between population density and the earthquake disaster events, the corresponding relationship between the number of casualties and population density under the conditions of V~IX earthquake intensity in the disaster area is further analyzed. From the analysis results you can see some of these characteristics: First, earthquakes mostly occur in sparsely populated areas. Therefore, of the 184 earthquake disasters, 103 occurred in areas with a population density of less than 50 people/km². In the concrete analysis, the presupposition of the frequency difference of disaster events in different population density areas should be considered first. Second, after removing the influence of occurrence frequency, under the same earthquake intensity, the casualties in densely populated areas increase significantly. Especially for low-intensity earthquake events, densely populated areas are more likely to suffer casualties.

### 3.3 Impact of the Damage to Buildings on Casualties

In order to explore the correlation between the number of casualties caused by earthquakes and the damage to buildings, and to quantify the quantitative coupling relationship between casualties and building damage, SPSS statistical software is used in particular to analyze the above-mentioned 184 earthquake disaster events during 2001-2016. The medium damage area of the buildings in the earthquake disaster events is added to the severe damage area and the destroyed area. The defined variable is the medium or above damage area of the buildings. The number of casualties is defined as another variable. The calculation method is bivariate correlation analysis (Pearson algorithm). The calculation results show that the correlation coefficient between these two variables reaches 0.999, which means they are significantly correlated. At the same time, it further proves that the damage degree of buildings in the earthquake is very important to the number of casualties, and is an important factor affecting the casualties caused by the earthquake.

### 3.4 Impact of the Secondary Disaster on Casualties

The secondary disasters of earthquakes are a series of disasters caused by the destructive consequences of the shakes or the occurrence of earthquakes after strong ground shaking. Among the 184 earthquake disaster events mentioned above, there are 53 secondary disasters, accounting for about 29%. Among them, earthquake geological disasters are the most important secondary earthquake disasters, accounting for more than 95% of the total number of secondary disaster events. The occurrence of earthquake geological disasters not only damages houses, roads, bridges and other engineering
facilities, but also increases the number of casualties in the disaster areas, and often increases the difficulty of emergency rescue after earthquakes. In addition to geological disasters, there are also 3 coupling weather disasters and secondary fire incidents, which also increase the difficulty of casualties and emergency rescue.

4. Conclusion
This paper mainly analyzes the data of earthquake disaster events in mainland China from 2001 to 2006. Based on these data, the main factors causing casualties in earthquakes are analyzed qualitatively and quantitatively from the aspects of the intensity of the meizoseismal area, the origin time of earthquake, the population density, the damage to buildings, and the impact of secondary disasters. From the above analysis, it can be seen that the damage ratio of buildings, population density, and secondary disasters caused by earthquakes are the most critical coupling factors that affect the casualty data in the earthquake. The intensity of the meizoseismal area and the origin time of earthquake have less impact on the number of casualties, which differs from conventional understanding and is difficult to derive the correlation from the analysis of the above samples. It may be necessary to further refine the research objects and methods. The above research will provide a good basis for the establishment of a rapid earthquake casualty assessment model in the future.

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References
[1] Monitoring and Forecasting Department of China Earthquake Administration. Compilation of Earthquake Disaster Loss Assessment in Mainland China (2001-2005) [M], Beijing: Seismological Press, 2010.
[2] Monitoring and Forecasting Department of China Earthquake Administration. Compilation of Earthquake Disaster Loss Assessment in Mainland China (2006-2010) [M], Beijing: Seismological Press, 2015.
[3] Tongyan Zheng, Yi Zheng. Review of the 2011 Earthquake Disaster Loss in Mainland China [J]. Journal of Natural Disasters, vol.21, no.04, pp.88-97, 2012.
[4] Tongyan Zheng, Yi Zheng. Review of the 2012 Earthquake Disaster Loss in Mainland China [J]. Journal of Natural Disasters, vol.23, no.03, pp.166-169, 2013.
[5] Tongyan Zheng, Yi Zheng. Review of the 2014 Earthquake Disaster Loss in Mainland China [J]. World Earthquake Engineering, vol.24, no.01, pp.239-245, 2015.
[6] Tongyan Zheng, Wei Feng, Yi Zheng. Review of the 2015 Earthquake Disaster Loss in Mainland China [J]. Journal of Catastrophology, vol.31, no.02, pp.133-137, 2015.
[7] Xintao Wen, Tongyan Zheng. Review of the 2016 Earthquake Disaster Loss in Mainland China [J]. Journal of Catastrophology, vol.33, no.03, pp.141-144, 2018.
[8] Guangxian Xiao. Quick Assessment of Damage after the Earthquake [J]. Journal of Catastrophology, vol.06, no.04, pp.2002-2007, 1991.
[9] Zhiqian Yin. Earthquake Disaster Loss Prediction Research [A], Research Progress of Earthquake Engineering in China [C], Beijing: Seismological Press, 1992.
[10] Yuhong Ma, Lili Xie. Research on the Estimation Method of Earthquake Casualties [J]. Earthquake Engineering and Engineering Vibration, 2000.
[11] Zhengxiang Fu, Geping Li. Earthquake Life Loss Research [M], Beijing: Seismological Press, 1993.
[12] [online]Available:] http://www.stats.gov.cn/tjsj/zxfb/201405/t20140527_558611.html