Grey Relational Analysis of Geological Hazards and Urbanization Construction in China

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Abstract. Urbanization is an important symbol of Chinese economic development and important measure and means for Chinese future strategic adjustment. However, the geological hazards seriously impede the development of urbanization; especially restrict the construction of urbanization. According to statistics, the total number of geological hazards in China between 2005 and 2016 were 286,267 times, resulted about 162,869 million yuan in economic consumption. In this paper, the correlation between urbanization construction and geological hazards is analyzed by means of grey relational analysis. The conclusions are as follows: The influence of ground collapses, debris flows and landslides on urbanization construction is the most enormous; the influence of ground settlements, ground fissures and collapses on urbanization construction is relatively small. So in the process of urbanization construction, it is important to prevent and control the ground collapses, debris flows and landslides, and also cannot ignore the impact of ground settlements, ground fissures and collapses.

1. Introduction
Urbanization is an important symbol of Chinese economic development, and it is also important measure and means for Chinese future to carry out strategic adjustment, solve the problems of agriculture and rural areas and promote economic transformation. According to previous studies, in 2016 the urbanization rate of China was 57.35%, which indicated that our country was currently in the stage of rapid urbanization by Northam's Urbanization Development Curve. Since modern times, our country has mainly focused on economic development, while ignored the deterioration of the natural environment, and even sacrificed the natural environment to develop the economy. The current situation of the natural environment in our country is extremely terrible. Nowadays, geological hazards have become a huge obstacle, which seriously hinder the construction of Chinese urbanization. In recent years, a large number of scholars have carried out research on urbanization and geological hazards. In 2007, HeDongXiao and others analysed the development status, conditions and development trend of geological hazards and put forward the hazards prevention monitoring strategy [1]. In 2016, XueKaiXi and others analysed the spatial and temporal development of geological hazards in recent ten years [2]. In 2016, Wang WeiLin and others under the GIS support, according to the different ways of land use degree of impact on ecological environment, used analytic hierarchy process to determine the ecological risk weighting of different land use types and built a comprehensive ecological risk index [3]. In 2017, QuXueYan and others analyzed the general characteristics of geological hazards in China and predicted the conditions of geological hazards in the next five years [4].

From the above, present research on urbanization and geological hazards have achieved fruitful results. However, most of researches focus on the relationship between urbanization and economy and
region, as well as the spatial and temporal distribution of geological hazards in China, resulting in casualties and economic losses. However the correlation between urbanization construction and geological hazards is relatively few. So this paper adopts the grey relational analysis to analyse the correlation between urbanization construction and various geological hazards in China, and shows the influence degree of various geological hazards on the urbanization construction to improve the scientifcity of the decision-making of urbanization construction in China.

2. The situation of geological hazards
China has a vast territory in which the mountainous areas account for about 30% and the tectonic movements are strong, which have the foundation of geological hazards, dense population and complex topography [5-6]. According to the study, in addition to the active volcano China has almost all types of geological hazards, damages are very serious, mainly including landslide, collapse, debris flow, ground collapse, ground fissure and ground settlement and so on.

In this paper, we gather the number of landslide, collapse, debris flow, ground collapse, ground fissure and ground settlement (N) occurred in China from 2005 to 2016 (Y), as shown in Figure 1. The number of geological hazards in 2006, 2007, 2008 and 2010 was significantly higher than other years and the quantitative development rule of landslide, ground subsidence and total geological hazards is similar in general; The number of collapses were decreasing year by year; Debris flow occurred more frequently in 2007, 2009 and 2013, and less in other years; Ground fissures were developed in large numbers in 2008 and developed in small amounts in the remaining years; Ground settlements occurred most in 2007, and since 2007, the numbers of occurrence have been decreasing. The occurrence frequency of all kinds of geological hazards in our country from high to low is: landslide > collapse > debris flow > ground collapse > ground fissure > ground settlement. Among them, the number of landslide occurred is 73%, collapse is 18%, debris flows is 6%, ground subsidence is 3%, ground fissures and ground subsidence are the least, accounting for less than 1%. It can be seen that landslide, collapse and debris flow are the most developed geological hazards in China [7-8].

![Figure 1. Annual development of various geological hazards](image)

3. Correlation analysis
According to the analysis of geological hazards in China, it can be seen that the major of geological hazards in China are landslide, collapse and debris flow, followed by ground collapse, ground fissure and ground subsidence. But it is the influencing degree of geological hazards on the urbanization construction? In order to solve this problem, Grey Relational Analysis (GRA) is established to analyse the correlation between urbanization construction and geological hazards. The influences of geological hazards on urbanization construction are mainly economy and geologic environmental condition, because the occurrence and management of geological hazards will consume a large amount of economy and geologic environmental condition directly affects the construction area of urbanization.
Therefore, the data analysed in this paper are the number of geological hazards, consumption of economic caused by geological hazards, and the area of urbanization construction in 2005-2016.

3.1. The selection of the compare sequences and the reference sequences
By analysing the original data and determining the frequency of geological hazards as independent variables, consumption of economic and urban construction area are the dependent variables[9]. The sequences of occurrences of geological hazards (landslide, collapse, debris flow, ground collapse, ground fissure and ground settlement) are set as compare sequence: the landslide data sequence is set as compare sequence X1(t), the collapse data sequence is set as compare sequence X2(t), the debris flow data sequence is set as compare sequence X3(t), the ground collapse data sequence is set as compare sequence X4(t), the ground fissure data sequence is set as compare sequence X5(t) and the ground settlement data sequence is set as compare sequence X6(t); The consumption data sequence of economic caused by geological hazards is set as parent reference sequence Y1(t) and the data sequence of urbanization construction area is set as reference sequence Y2(t). As shown in Table 1.

| Types             | Landslide (time) X1(t) | Collapse (time) X2(t) | Debris Flow (time) X3(t) | Ground Collapse (time) X4(t) | Ground Fissure (time) X5(t) | Ground Settlement (time) X6(t) | Consumption (ten thousand yuan) Y1(t) | Construction Area (km²) Y2(t) |
|-------------------|------------------------|------------------------|--------------------------|-------------------------------|-------------------------------|---------------------------------|-----------------------------------|-------------------------------|
| Years             |                        |                        |                          |                               |                               |                                 |                                   |                                |
| 2005              | 9359                   | 7654                   | 556                      | 137                           | 20                            | 15                              | 524538                            | 32520.7                        |
| 2006              | 88523                  | 13160                  | 417                      | 398                           | 271                           | 35                              | 625160                            | 33659.8                        |
| 2007              | 15478                  | 7722                   | 1215                     | 578                           | 225                           | 146                             | 492413                            | 35469.7                        |
| 2008              | 13450                  | 8080                   | 443                      | 451                           | 2129                          | 65                              | 856875                            | 36295.3                        |
| 2009              | 6657                   | 2309                   | 1426                     | 316                           | 115                           | 17                              | 732477                            | 38107.3                        |
| 2010              | 22329                  | 5575                   | 1988                     | 499                           | 238                           | 41                              | 1798322                           | 40058                          |
| 2011              | 11490                  | 2319                   | 1380                     | 360                           | 86                            | 29                              | 1341236                           | 43603.2                        |
| 2012              | 10888                  | 2088                   | 922                      | 347                           | 55                            | 22                              | 1649436                           | 45565.8                        |
| 2013              | 9849                   | 3313                   | 1541                     | 371                           | 301                           | 28                              | 2278931                           | 47855.3                        |
| 2014              | 8128                   | 1872                   | 543                      | 302                           | 51                            | 11                              | 2201066                           | 49772.6                        |
| 2015              | 5616                   | 1801                   | 486                      | 278                           | 27                            | 16                              | 2013191                           | 52102.3                        |
| 2016              | 7403                   | 1484                   | 584                      | 221                           | 12                            | 6                               | 1714524                           | 54331.5                        |

3.2. The dimensionless of original data
Through the Formulas (1) and (2), the original data sequences are dimensionless by means of the mean method, and the new data sequences are X1(t),X2(t),X3(t),X4(t),X5(t),X6(t),Y1(t),Y2(t). As shown in Table 2.

\[
X_{i(t)}' = \frac{X_{i(t)}}{X_i} \tag{1}
\]

\[
Y_{k(t)}' = \frac{Y_{k(t)}}{Y_k} \tag{2}
\]
Table 2. Dimensionless data sequences

| Types          | Landslide $X_i(t)$ | Collapse $X_i(t)$ | Debris Flow $X_i(t)$ | Ground Collapse $X_i(t)$ | Ground Fissure $X_i(t)$ | Ground Settlement $X_i(t)$ | Consumption $Y_i(t)$ | Construction Area $Y_i(t)$ |
|---------------|-------------------|------------------|---------------------|--------------------------|------------------------|-----------------------------|---------------------|-----------------------------|
| Years         |                   |                  |                     |                          |                        |                             |                     |                             |
| 2005          | 0.5369            | 1.6008           | 0.5801              | 0.3861                   | 0.0680                 | 0.4176                      | 0.3879              | 0.7662                      |
| 2006          | 5.0785            | 2.7523           | 0.4351              | 1.1217                   | 0.9212                 | 0.9744                      | 0.4623              | 0.7930                      |
| 2007          | 0.8880            | 1.6150           | 1.2677              | 1.6289                   | 0.7649                 | 4.0646                      | 0.3641              | 0.8357                      |
| 2008          | 0.7716            | 1.6899           | 0.4622              | 1.2710                   | 7.2373                 | 1.8096                      | 0.6336              | 0.8551                      |
| 2009          | 0.3819            | 0.4829           | 1.4879              | 0.8906                   | 0.3909                 | 0.4733                      | 0.5416              | 0.8978                      |
| 2010          | 1.2810            | 1.1660           | 2.0742              | 1.4063                   | 0.8091                 | 1.1414                      | 1.3298              | 0.9438                      |
| 2011          | 0.6592            | 0.4850           | 1.4399              | 1.0146                   | 0.2923                 | 0.8073                      | 0.9918              | 1.0273                      |
| 2012          | 0.6246            | 0.4367           | 0.9620              | 0.9779                   | 0.1870                 | 0.6125                      | 1.2197              | 1.0735                      |
| 2013          | 0.5650            | 0.6929           | 1.6079              | 1.0456                   | 1.0232                 | 0.7795                      | 1.6852              | 1.1275                      |
| 2014          | 0.4663            | 0.3915           | 0.5666              | 0.8511                   | 0.1734                 | 0.3062                      | 1.6276              | 1.1726                      |
| 2015          | 0.3222            | 0.3767           | 0.5071              | 0.7835                   | 0.0918                 | 0.4454                      | 1.4887              | 1.2275                      |
| 2016          | 0.4247            | 0.3104           | 0.6093              | 0.6228                   | 0.0408                 | 0.1670                      | 1.2678              | 1.2800                      |

3.3. The calculation of the difference sequences

Through the Formula (3), the difference sequences of consumption and various kinds of geological hazards are $\Delta_{\text{min}1} = 0.001772$, $\Delta_{\text{max}1} = 6.603691$, the difference sequences of urbanized construction area and various geological hazards are $\Delta_{\text{min}2} = 0.007234$, $\Delta_{\text{max}2} = 6.382201$.

$$\Delta(t) = \left| Y_i(t) - X_i(t) \right|$$ (3)

3.4. The calculation of relation coefficients and relation degrees

Through the Formulas (4) and (5) to calculate the relation coefficients and the relation degrees, and the resolution coefficient is selected as $\rho=0.2$. By this way, the relation degrees between consumption and geological hazards are calculated as $r_{11}=0.693$, $r_{12}=0.614$, $r_{13}=0.741$, $r_{14}=0.755$, $r_{15}=0.622$, $r_{16}=0.674$; The relation degrees between urbanization construction area and geological hazards are $r_{21}=0.714$, $r_{22}=0.648$, $r_{23}=0.734$, $r_{24}=0.815$, $r_{25}=0.673$, $r_{26}=0.692$. After the sorting: $r_{26}>r_{25}>r_{21}>r_{26}>r_{25}>r_{22}$.

$$\zeta_i(t) = \frac{\min_k \min_i \left| Y_i(t) - X_i(t) \right| + \rho \max_k \max_i \left| Y_i(t) - X_i(t) \right|}{\left| Y_i(t) - X_i(t) \right| + \rho \max_k \max_i \left| Y_i(t) - X_i(t) \right|}$$ (4)

$$r_i = \frac{1}{t} \sum_{\tau=1}^{t} \zeta_i(\tau) = \frac{1}{t} \left[ \zeta_i(1) + \zeta_i(2) + \cdots + \zeta_i(t) \right]$$ (5)

From high to low, the correlation degrees of various geological hazards and consumption are: ground collapse > debris flow > landslide > ground settlement > ground fissure > collapse; from high to low, the correlation degrees of various geological hazards and urbanization construction area are: ground collapse > debris flow > landslide > ground settlement > ground fissure > collapse.

4. Discussion

Through the gray correlation analysis of the economic consumption caused by geological hazards the urbanization construction area and geological hazards. It can be seen that:

Ground collapses have the greatest impact on Chinese urbanization construction. The ground collapses can be divided into: mining collapse, loss collapse and karst collapse. Ground collapses are widespread in China. Most of the ground collapses were caused by human engineering activities. They usually occur in mining areas, densely infrastructures and densely populated areas. Meanwhile, due to the difficulty in predicting and preventing, ground collapses usually cause casualties and a great deal of economic consumption, and cause destructive damage to the urbanization infrastructure[9-
Therefore, the ground collapses have the most serious influence on the urbanization construction in China.

The occurrence of debris flows are usually caused by unstable geological conditions, heavy rainfall and human engineering activities. The debris flows have the greatest impact on China’s large-scale projects, such as the railway lines, water conservancy facilities and water transportation facilities, etc [11-13]. It is difficult to prevent and control, which can cause a lot of casualties and economic consumption. But due to debris flows often happened in mountain area and time of occurrence was regular (rainy), and in the early stage of the urbanization construction planning can avoid the influence of debris flow areas, therefore, they have a great influence on Chinese urbanization construction [14].

The occurrences of landslides are the first in all kinds of geological hazards in China, and they are distributed all over the country. With similar debris flows, the conditions of landslides are also by unstable geological conditions, a lot of rainfall and human engineering activities. Landslides which mainly occurred in mountainous areas and time were seasonal. Landslides mainly affect the railway lines, water conservancy facilities and urban infrastructure in mountainous areas, which can cause casualties and economic property losses. But most of the urbanization construction land in our country for smooth and broad areas, and most of the landslides range compared with the influence of debris flows were small, so the landslides relatively large influence on the urbanization construction.

The ground settlements were mainly caused by the over-exploitation of groundwater in the region. Therefore, they mainly affect the areas that have already completed the urbanization, which have the characteristics of gradual degeneration, great difficulty in preventing and controlling, and irreversible effects. Ground settlements could cause the foundation of urban infrastructure to sink continuously, which caused the buildings to tilt, crack or even collapse. They disrupted the traffic facilities, incline the underground pipelines and broke them, caused the urban transportation, communication, drainage, natural gas transportation and other systems to be paralyzed, affected the normal operation of urban facilities [15-17]; At the same time, the ground settlements could cause the ground level and the ground elevation loss, which could not be ignored in the planning and design in the early stage of urbanization construction. However, the occurrence of ground settlements basically could not cause casualties, and the economic consumption was relatively small, so their influence on urbanization construction is relatively small.

The ground fissures are mainly caused by the fracture and the uneven ground subsidence caused by excessive pumping of groundwater, usually in a linear distribution. Ground fissures could lead to cracks in buildings, deformation of roads, faults in underground transportation pipelines, and damaged to communication facilities. But the destruction of ground fissures to urban infrastructure were usually local, the scope of damage and the resulting economic consumption were small. Meanwhile the damaged urban infrastructures tended to maintain its integrity and and most of them can be used normally. Therefore, the ground fissures have little influence on the urbanization construction.

5. Conclusions

From high to low, the influence degrees of various geological hazards with consumption are: ground collapses > debris flows > landslides > ground settlements > ground fissures > collapses; from high to low, the influence degrees of various geological hazards with urbanization construction area are: ground collapses > debris flows > landslides > ground settlements > ground fissures > collapses. Through the above analysis, due to the widely distributed, large range of influence and harm was serious, and difficult to forecast and control, so the influence of ground collapses, debris flows and landslides to Chinese urbanization construction are the most enormous, these severely hampered the process of urbanization in China, and threaten the life property safety of the urban residents. However, the ground settlements, ground fissures and collapses, due to the small threat range, were easy to avoid and
manage, and the economic consumption was relatively small, so the influence on urbanization construction is relatively small.

Therefore, in the process of urbanization construction in China, it is important to prevent and control the ground collapses, debris flows and landslides, and also cannot ignore the impact of ground settlements, ground fissures and collapses. For impending urbanization construction project we should do a good job in these areas of exploration evaluation work, fully considering the influence of human engineering activities on the geological environment, designing well plan to avoid or eliminate the influence of the geological hazards; For urbanization constructions which have been completed, we should take engineering management measures and monitor for existing geological hazards, or develop and utilize resources reasonably. By this way can make urbanization construction development safe and efficient.

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