# Study on the city planning for geological disasters defence based on the model of safe city planning

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**Abstract**

It is difficult to take geological disasters defence into city planning, which can greatly prevent lands for construction from geological disasters and ensure the rationality, safety and high-efficiency of land-use. Based on the model of safe city planning and discussing from the angle of safe land arrangement, this paper proposes the system of the city planning for geological disasters defence. It focuses on the defence of mutant geological disasters and takes the geological hazards assessment as the foundation. It makes the detailed regulations of the "specific control and management", which guarantees both the defence and the control of disasters from technology aspect. Besides, it puts forward methods with highly couple of different measures to defend different disasters in city planning system which can enhance the operability to answer the reality.

*Keywords:* city planning for geological disasters defence, safe city planning, mutant geological disasters, specific control and management, city planning system

## 1 Introduction

### 1.1 THE CONCEPTION OF SAFE CITY

The conception and research emphasis of "safe city" are different in countries all around the world. In Occident, because of the social issue, "safe city" is usually connected with prevention of crime. While "safe city" in Japan attracts more emphasis on defending natural disasters like earthquake, flood, storm etc [1]. In China, most related researches of "safe city" focus on disasters prevention and mitigation in cities. As a future development pattern of cities, like the eco city and the healthy city, the safe city attaches importance to urban emergency, share of security resources and disasters prevention. Meanwhile, it also emphasizes the urban ability of sustaining the daily safety condition [2-4].

### 1.2 THE CONCEPTION AND MODEL OF SAFE CITY PLANNING

The conception of safety in city planning should be based on the foundation of urban public safety3. Therefore, the safe city planning needs the construction with an aggregative model which integrates safe decision-making, safe land arrangement, safe facilities planning and safe policies and regulations on technology level (Figure 1).

The safe decision-making means aims and strategic deployment about prevention and mitigation of disasters. It also needs to construct a wholesome and effective urban safe system to guarantee the safety of cites by the all-around and multilevel mean [5].

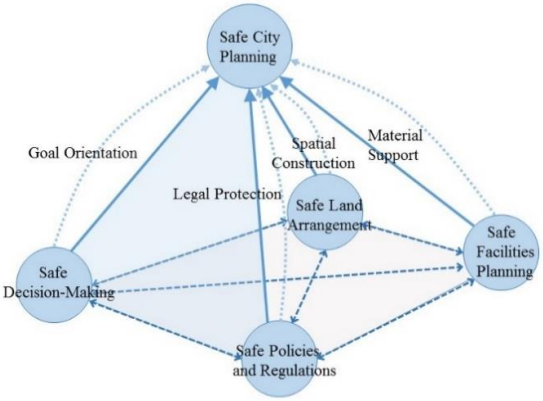


FIGURE 1 The model of the safe city planning

The safe land arrangement means making the safe decision-making practicable in urban space by using technological means of city planning. It includes the safety of urban lands, evacuation ability of roads and the planning of emergency refuge space [6].

The safe facility planning covers planning of facility for disasters defence, salvation and rebuilding [7]. It is an important infrastructure which guarantees cities' regular operation in the periods of preventing, avoiding and replying disasters.

The safe policies and regulations which have rigid restrain in city planning system [8] guarantee the implement of the planning achievement to be legal provisions.

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## 2 Progress of study on the geological disasters defence in city planning

On one hand, the geological disaster owns features of strong destructive power, concatenate diffusivity, hard reconstruction and long recovery [9]. Thus city planning usually takes defence as the principle to avoid the hazardous area to the greatest extent when choose lands for construction. On the other hand, in China, due to the large population and limited land, the lands threatened by geological disasters can be used after the hazard control if conditions permitted. In worldwide, there exist some advances in the research of prediction, investigation and emergency measures of geological disasters. Some are researches on individual cases and some universal methods and applications have been proposed. More and more researchers have realized the intimate relationship between geological disasters defence and land utilization in city planning and carried out some researches [10, 11]. However, researches on the connection of geological disasters defence and city planning is insufficient. In spite that some regulations like "Regulation on Geologic Disasters Defence" have already been promulgated in China, there still exist some deficiencies in the application of city, land and traffic planning [12].

## 3 The frame of city planning for geological disasters defence

City planning should pay sufficient attention to geological disasters defence. However, there exists blank in research on the combination between them. While as one kind of special public staff, city safety is lack of economic benefit and less intervened by the market organization4. The consideration coming from the system of city planning is especially important (Figure 2).

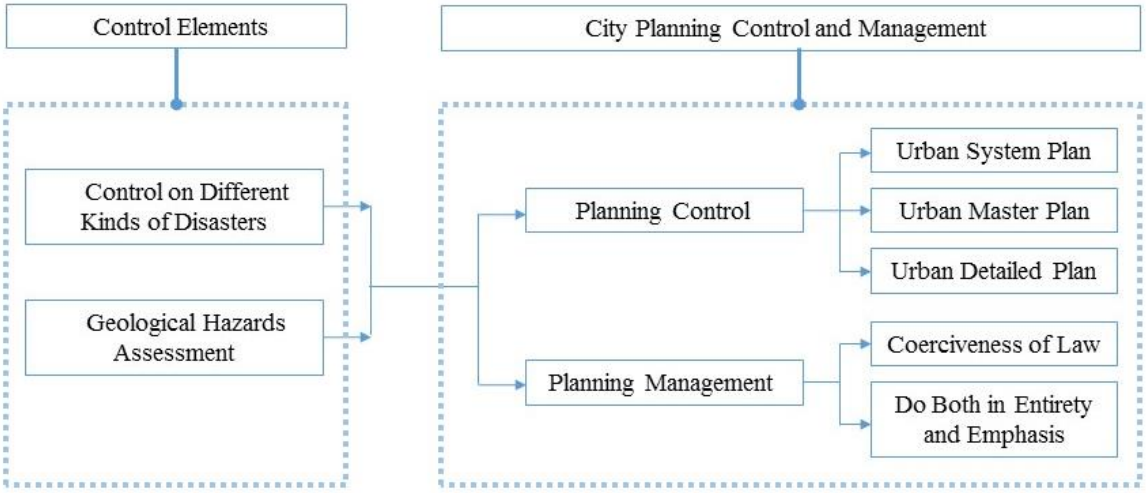


FIGURE 2 Frame of city planning for geological disasters defence

## 4 The mathematical model and content of city planning for geological disasters defence

### 4.1 CONGRUITY AND CLASSIFY OF DISASTERS

The geological disaster in this paper refers to the geological-related disasters caused by natural factors or human activities that endanger people's lives and property. It includes rock fall, landslide, debris flow, ground collapse, ground fissure and land subsidence [13]. They are divided into two categories: mutant and gradual geological disasters. As mutant geological disasters has kept a quite high proportion in quantity statistics of geological disasters from 2006 to 2013, China (usually up to 97%) (Figure 3), they are emphasized in this paper (Table 1).

TABLE 1 Category of mutant and gradual geological disasters

| Category of Disasters | Definition | Disasters Including | Measures |
|---|---|---|---|
| **Mutant** | disasters that happen in sudden and finish in short time | rock fall<br>landslide<br>debris flow | emphasis; especially in data of avoiding |
| **Gradual** | disasters that happen and develop slowly, and develop over time | ground collapse<br>ground fissure<br>land subsidence | not emphasis; proposing related code and guide |

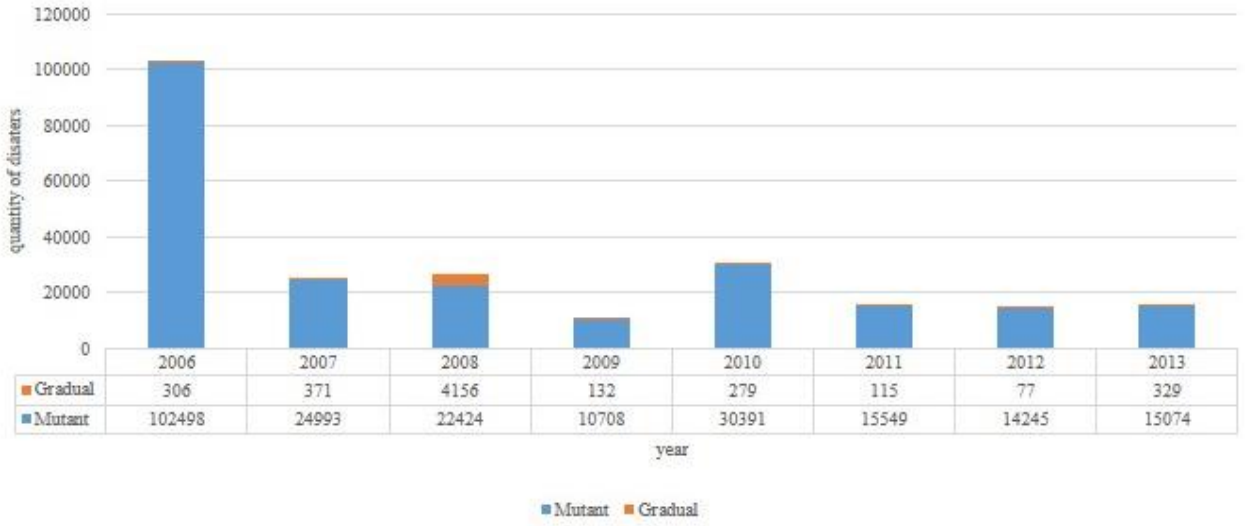


FIGURE 3 Classification chart of geological disasters in china from 2006 to 2013 [14]

Here are equations to calculate damage area of three mutant geological disasters [15].

$$L_{\max} = \frac{V_{\max}^2 \cos^2 \partial}{2g(\mathrm{f} - \sin\theta)} + d \,, \tag{1}$$

where

$$V_{\max} = \sqrt{2g(\mathrm{H} - \mathrm{f} \cdot \mathrm{L}) + V_0^2} \,. \tag{2}$$

The damage area of landslide can be ascertained by the maximum distance of movement ($L_{\max}$). It can be calculated by Equation (1), where $V_{\max}$ is the maximum slip velocity; $\partial$ is the angle between the maximum sliding direction and the bottom slip layer; g is the gravitational acceleration; f is the dynamic friction coefficient of the bottom slip layer; $\theta$ is the gradient of the bottom slip layer; d is the distance from centre of gravity to the front of the debris. $V_{\max}$ can be calculated by Equation (2), where $H$ is the level difference of bottom slip layer; $L$ is the horizontal distance of the bottom slip layer; $V_0$ is the initial velocity of the slip mass.

$$S = \frac{2}{3} L \cdot B - \frac{1}{12} B^2 ctg \frac{1}{2} R \,, \tag{3}$$

where

$$L = 0.7523 + 0.0060A + 0.1261H + 0.0607D - 0.0192G \,, \tag{4}$$

where

$$B = 0.2331 - 0.0091A + 0.1960H + 0.0983D + 0.0048G \tag{5}$$

and

$$R = 47.8296 + 8.8876H - 1.3085D \,. \tag{6}$$

The damage area of debris flow can be ascertained by the proportion, the maximum length and the maximum breadth of the deposition fan of debris (*S*, *L*, *B* and *R* respectively) by Equation (3). Besides, in Equations (4-6), *A* is the drainage area; *H* is the relative height of it; *D* is the length of the main gully; *G* is the average gradient of it.

$$L = \eta \frac{QS_0}{M} t \,. \tag{7}$$

The damage area of ground collapse of ground collapse can be ascertained by the radius of subsidence (L). It can be calculated by Equation (7), where $\eta$ is the coefficient related to the soil properties; $Q$ is the exploitation quantity of groundwater; $S_0$ is the effective drawdown under surface of basement rock; $M$ is the overburden thickness; $t$ is the duration of pumping.

## 4.2 PURPORT AND CONTENT

### *4.2.1 Different solutions to mutant and gradual geological disasters respectively*

1) The layout of lands in cities and towns must avoid areas influenced by mutant geological disasters. For areas influenced by gradual geological disasters, comprehensive controls should be taken when social economic and technological conditions permit.

2) Divide dangerousness of mutant geological disasters into 4 grades: low, middle, high and sky-high. This needs achievement of geological survey as important basis.

3) Due to the individual differences in geological disasters, related detail regulations should be established in the master planning and detailed planning respectively.

### *4.2.2 The geological hazards assessment*

The geological hazards assessment is an important basis

of city planning for geological disaster defence and it plays a significant part in each stages of city planning. See Figures 4 and 5.

The geological hazards assessment is influenced by the predictive probability index [16].

$$Y = 0.62D + 0.38R. \quad (8)$$

The predictive probability index of geological disasters ($Y$) can be calculated by Equation (8), where $D$ is complexity index of geological environment and $R$ is index of the precipitation.

## 4.3 DETAILED REGULATIONS OF MANAGEMENT AND CONTROL IN CITY PLANNING SYSTEM

### *4.3.1 Detailed regulations of control in urban system planning*

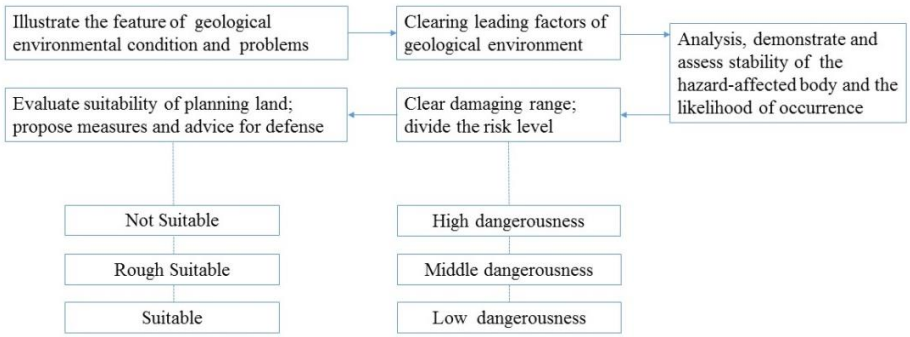


FIGURE 4 The process of geological hazards assessment

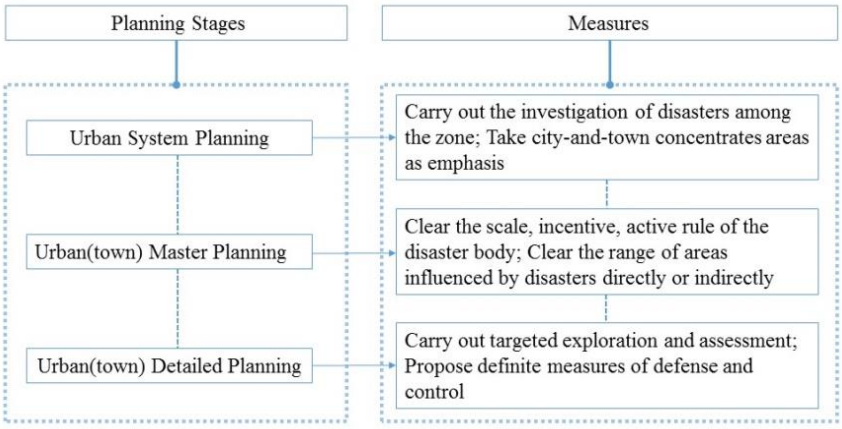


FIGURE 5 Key points of geological hazards assessment in different planning stage

### *4.3.2 Detailed regulations of control in city (town) master planning*

1) Based on the geological hazards assessment, we should evaluate the suitability of the urban (town) lands for construction, and propose planning measures for geological disasters defence on urban land choosing, layout of function, important infrastructure planning.

1) Put avoidance and defence as the main purpose. Predominating direction of city development, the layout of infrastructures and social facilities must avoid areas with high hazard, and choose areas for them with low or no geological disasters in prior.

2) The site selection of important projects should avoid areas with high dangerous ones, and avoid the possibility of geological disasters induced by the project construction.

3) In areas with high dangerous ones, the development scale of existing city or town must be controlled and it is not suitable for expanding the scale of land.

4) The existing city, town and housing estate in areas with sky-high dangerous mutant geological disasters should be removed when conditions permits.

2) Areas harmed by mutant geological disasters directly must be ranked as forbidding constructing areas.

3) The lifeline engineering should avoid high hazardous areas. Or effective control measures must be taken.

4) The detailed regulations of six kinds of geological disasters defence are shown in Table 2.

TABLE 2 Detailed regulations of geological disasters defence in master planning

| Type of Disasters | Areas with the Disaster | Body be Formalized | Detailed Regulations |
|---|---|---|---|
| **Mutant** | 1) Rock Fall | cities with high or middle possibility of disasters | compile the special planning |
| | | high hazardous areas | clear the disaster body and condition of threaten |
| | | areas harmed and influenced by disasters | construction forbidden |
| | | assessed as low disaster incident areas after governing | can be used as green space or square |
| | | lands on upward and downward side of rock bodies | reserve protective safe distance in advance |
| | 2) Landslide | areas influenced by disasters | manage and control in zonal |
| | | areas with incident disasters | restrict development intensity, be suitable for green space and forestland |
| | | urban lands for construction | safe avoiding distance (20~800m) |
| | | high hazardous areas | control the scale and density of cities and towns |
| | | existing cities(towns) in high hazardous areas | control the scale and form; remove housing estates and important architectures in direct hazardous areas |
| | 3) Debris Flow | route of regional infrastructure | avoid or decrease the possibility of inducing disaster |
| | | channel of disasters and their influencing scopes | clear the mode of avoiding, arrange lands for construction in safe areas |
| | | infrastructure construction | avoid channel of the mud, reserve space for drainage in advance |
| | 4) Ground collapse | the choose of urban constructive lands | advise its suitability degree based on the distance from the boundary of disasters |
| **Gradual** | 1) Ground fissure | lands choosing for new constructive areas | control the scale, avoid high hazardous areas, step back a distance for 100~200m |
| | 2) Land Subsidence | existing districts in high hazardous areas | restrict high-rise and high dense building groups |
| | | main traffic facilities | arrange in middle and low hazardous areas; need preventive measures when through high hazardous areas |
| | | high hazardous areas | suitable for arranging green space and forestland; consider self-restraint and recovery of underground water |

TABLE 3 Detailed regulations of geological disasters defence in detailed planning

| Type of Disasters | Areas with the Disaster | Body be Formalized | Detailed Regulations |
|---|---|---|---|
| **Mutant** | 1) Rock Fall | buildings (structures) | avoiding areas threatened with rocks; reserve 20~30m for defence in advance |
| | | dangerous rock body | no buildings(structures) on areas influenced by disasters; green space and forestland can be ranged under it |
| | | dangerous rock body that can be governed | carry out project and biological measures; then can be land for construction after passing the assessment |
| | 2) Landslide | planning areas with landslide body | Constructions and project lifelines avoid the scope and influencing area |
| | | areas must be used for construction | carry out reasonable governs to the safe standard |
| | 3)Debris Flow | constructions in city | stay away from the scope; clear the distance for avoiding according to the specific condition |
| | | measures of defence and governing | stay back from it for 5% to 20% of its width according to the type of disasters |
| | 4) Ground Collapse | existing buildings | housing estate and important buildings should be removed; strengthen the power of buildings resistance to disasters |
| | | constructions in city | stay back from the area at least 500m |
| | | the area with incident disasters | forbid planning land for construction except green areas |
| | | areas influenced by mined deformation collapse | control the development intensity |
| | | main traffic facilities and important projects | stay back from the incident areas above 500m |
| | | existing housing estate in high hazardous areas | remove and avoid |
| **Gradual** | 1) Ground Fissure | areas with karst collapse | avoid or govern it until reach the standard of assessment; mainly buildings stay back from it above 150m |
| | | constructive lands with disasters | stay away from the disaster for 6~40m according the Importance of lands or buildings |
| | | municipal engineering pipelines | avoid spanning the ground fissure; govern it and check it at regular interval if it can't be avoided. |
| | 2) Land Subsidence | high hazardous areas | need to have assessment; control its development capacity |
| | | important traffic facilities | stay back from high hazardous areas and areas influenced by it for 200~500m. |
| | | important projects and projects, which have 7m above excavation of foundation pit | must consider the influence to land subsidence; propose governing measures to uneven subsidence |
| | | projects with deep excavation by using drainage in high areas | clear the governing measures according to the risk assessment report |

### *4.3.3 Detailed regulations of control in city (town) detailed planning*

1) In the regulatory plan, measures of prevention and control should be taken in aspects of lands layout, constructive intensity, traffic, infrastructure planning etc. While in the site plan, measures should be taken in aspects of architectural layout, ground vertical, municipal project pipeline.

2) The planning lands that located in the area with dense constructions and assessed as high hazardous ones,

can be used reasonably after disasters control and reaching the level of middle or low.

3) In the regulatory plan, the site and predicted scope of hazards must be labelled in planning map clearly. And planning control guideline and advice for defence or governing should be definitely proposed.

4) The detailed regulations of six kinds of geological disasters defence are shown in Table 3.

*4.3.4 Detailed regulations of management in city planning system*

1) Consummate the system of laws and regulations to safeguard the requirement of coerciveness in city planning system.

2) According to the degree of geological disasters comprehensive hazards and different percentages of the mutant geological disaster in planning areas, clear the different requirements in specialized planning about the geological disaster defence in the planning achievement.

## 5 Conclusions

In this research, we propose the frame of city planning for geological disasters defence based on the model of safe city planning. The frame owns two important control elements. 1) Take control by different kinds of geological disasters and the mutant geological disasters are emphasized. 2) Take the geological hazards assessment as the important basis. In order to guarantee the effective implement of city planning for geological disasters defence in practice, further we makes the detailed regulations of the "specific control and management", which aims at different geological disasters in the city planning system respectively.

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