Preliminary study on disaster prevention planning system from the perspective of high-density urban environment

Ziang Xie¹*, Shenzhi Dai¹

¹College of Architecture and Urban Planning, Tongji University, Shanghai. 200092, China
*Corresponding author’s e-mail: xza9584@163.com

Abstract. High-density development mode is a realistic and rational choice of urban space in the process of high-speed urbanization in China. However, as the disaster-bearing body of urban disasters, the high-density characteristics of urban space also make it vulnerable and sensitive in dealing with disasters. Therefore, how to strengthen the protection of urban disaster prevention facilities and continuously improve the adaptability and flexibility of the city is an important factor to promote the sustainable development of high-density cities, which has great research value. Based on this, this paper aims to study and summarize the disaster characteristics of the high-density global metropolis, and preliminarily explore the content of disaster prevention planning system in high-density urban environment, so as to provide a pertinent research basis for the relevant issues of high-density urban disaster prevention.

1. Introduction

Urban safety and comprehensive disaster prevention are the premise and foundation for the healthy and prosperous development of cities. At present, the world is entering a new period of "vibration mode" and "climate change", with frequent disasters and serious damage. In the past 30 years, various disasters have caused great damage to Chinese economy and people's lives and property. Since 2000, China has paid more and more attention to disaster risk and safety. Especially after the Wenchuan earthquake, the whole society has focused on the research and practice in the field of urban safety and comprehensive disaster prevention. After the 19th National Congress, China's urban master plan has been generally revised. From the new round of urban master plan documents such as Shanghai Urban Master Plan (2017-2035), it can be seen that governments attach great importance to urban security issues for future development.

The difference between urban and rural environment lies in its close building coverage and high-density population pattern, which greatly increases the vulnerability of urban environment. At present, China is still in the rapid development stage of urbanization process, which makes many metropolises have the characteristics of high density and complexity. Once affected by disasters, it will cause tremendous losses and even the failure of the overall function of the city, which will easily lead to the further spread and expansion of the disaster situation, resulting in severe casualties, economic losses and adverse social effects. Therefore, this paper takes disaster prevention plan of cities in high-density environment as the research content, which has important practical significance and is also the key problem to be solved urgently in urban development.
2. Disaster characteristics in high-density urban environment

2.1. Hazard-formative environment in high-density urban environment

The meaning of high-density urban environment includes the high-density characteristics of various elements of a city, such as high-density population, buildings, facilities and information, etc [1] (Table 1). Therefore, the high-density environment can be understood as the number of elements contained in the unit space. Generally, it is defined by two kinds of indicators: population density and building density [2]. The spatial characteristics of high-density urban environment make its own system vulnerable. Its potential disasters are characterized by high concentration, multi-hazard types, difficult identification of risk sources and complex risk management.

Table 1. Analysis of hazard-formative environment in high density urban environment.

| Item             | High-density characteristics | Potential disaster risk                                        |
|------------------|------------------------------|---------------------------------------------------------------|
| Position         | Usually in the city's core area | Superposition of two complex factors "high density" and "core". |
| Urban Elements   |                              |                                                               |
| High-density population |                             | Less buffer space between elements (small scales for separating and mitigating disasters), and opportunities for mutual contact are increased, which is prone to disasters; High-density information is complex, which interferes with the judgment of the surrounding environment and affects the action of refuge. |
| High-density building |                             |                                                               |
| High-density information |                             |                                                               |
| High-density other elements |                             |                                                               |
| Flow             | Frequent flow of people, vehicles, logistics and information | Frequent flow of all kinds of factors leads to high probability of disasters. |
| Per capita share | Per capita occupancy of various facilities and spaces has a smaller scale and opportunity | When the total shelter space is fixed, the shelter space per capita is relatively small. |

Note: Combined with reference [1]

2.2. Main disaster issues in high-density cities

In order to further determine the types of main disaster and the trend of disaster prevention in today’s high-density cities, on the basis of the study by Professor Dai’s studio, the authors selected 9 global metropolises with similar development level, geographical location and population of more than 10 million to study the safety and comprehensive disaster prevention involved in their urban master plan (or strategic plan) documents. The basic situation and disaster prevention issues of each city are summarized as follows (Table 2).

Table 2. Summary of safety and disaster prevention in 9 global metropolises.

| City              | Location            | Density (pop./km²) | Planning situation                  | Planning name                  | Planning properties                                          | Disaster issues                                           | Causes of disasters                  |
|-------------------|---------------------|--------------------|-------------------------------------|-------------------------------|-------------------------------------------------------------|-----------------------------------------------------------|---------------------------------------|
| Shanghai          | Coastal City, China | 3,823 (2018)       | Shanghai Master Plan 2017-2035      | Excellent global city, attractive city of innovation, humanity and ecology | Climate change, water supply security, storm flood, earthquake, air attack, fire, terrorist attack, air pollution, water pollution, public health | Geographical conditions, urban characteristics, population intensity, social situation, facilities status, limitation of resources |
| Hong Kong         | Coastal City, China | 6,765 (2018)       | Develop Hong Kong into Asia's international metropolis | Hong Kong 2030 Planning Vision and Strategy | Public health, infectious diseases, air pollution, water pollution | Population density and urban spatial situation |
According to the definition of disaster emergencies in the *Emergency Response Law of the P. R. China* (2007), disaster emergencies are mainly divided into four categories: natural disasters, accident disasters, public health events and social security events [3]. According to this classification method, the urban safety and disaster prevention issues in the 9 urban planning documents mentioned above are summarized in Table 3. It can be seen that in the new era, the new disaster issues faced by cities have surpassed the traditional disaster issues and become more and more diversified, which also reflects the increasing attention paid to "people" in the master plan of global metropolises.

| Classification of safety and comprehensive disaster prevention | Disaster issues | Number |
|---------------------------------------------------------------|-----------------|--------|
| Traditional disaster issues | Natural disasters: Storm flood, fire, earthquake, windstorm, geological disaster, water pollution | 6 |
| | Accident disasters: Water supply safety | 2 |
| New Disaster issues | Public health events: Air pollution, public health, infectious diseases, food safety | 4 |
| | Social security events: Terrorist attack, air strike, crisis of social differentiation, energy crisis | 9 |
| | 2030 Seoul Master Plan: Citizen cities full of communication, care and happiness | 1 |
| | 2030 Seoul Master Plan: Public health, energy crisis, water supply safety, air pollution | 3 |

Table 3. Classification and summary of main disaster issues in 9 global metropolises.
2.3. Causes of main disaster issues in high-density cities

In order to express the causes of disasters more intuitively, the author summarizes the causes of disasters in Table 1 into 9 factors (Figure 1): geographic and geological conditions, population density, urban importance, infrastructure status, social situation, resource limitation, climate change, historical issues and urban spatial conditions. Based on the 9 factors, the main disaster issues affected by each factor are summarized. The number of issues affected by each factor is the frequency (Figure 2).

It can be seen from Figure 2, population density, geographical conditions, urban spatial conditions and climate change are the 4 main factors affecting urban safety and disaster prevention in metropolis, and the degree of population density has a great impact on the security of metropolis. It also shows that the new disaster problems have some commonalities among large cities. How to ensure urban security in high-density environment is the primary problem faced by metropolis.

3. Disaster prevention systems in high-density urban environment

Generally speaking, the construction of disaster prevention system mainly follows the following three principles [4]:

- Planning and design can reduce the inherent hazards of urban disasters and avoid the induced human disasters in the construction process;
- Early warning of possible disasters and measures for eliminating or resisting disasters;
- Enhance the ability of building and urban environment to respond to disasters, and ensure the safety of personnel during disasters.

Guided by the above principles, and combined with the normal disaster prevention planning system of high-density central area proposed by Wang Q. [4], the following studies are carried out from 5 aspects (Figure 3). The authors try to put forward disaster prevention strategies to improve the overall level of disaster prevention in high-density urban environment.
3.1. Land use layout in high-density urban environment

3.1.1. Land use layout based on ecological principles. Firstly, from the perspective of ecosystem harmony, we should retain the original ecological elements of the city, and select the urban land scientifically which is beneficial to disaster prevention. New urban areas should choose the most favorable location for disaster prevention, and old urban areas should avoid disaster-prone directions according to regional characteristics. Secondly, the suitability of land use for disaster prevention should be evaluated in the early stage of urban construction. Through the comprehensive evaluation, the potential disaster risk of the region is avoided, and the function of urban land is reasonably arranged.

3.1.2. Land use layout based on stock control. The disaster risk of high-density urban environment will multiply with the growth of urban scale. Reasonable control of urban scale can reduce the risk of disasters caused by high density. On the other hand, it can improve the controllability of urban disasters, which is conducive to effective control of early disasters. In addition, the mixed layout of urban construction land is easy to break the single functional space, shape diversified urban space and living environment, reduce social security risks such as crime, and form different disaster-bearing environment when disasters occur.

3.2. Open spatial patterns in high-density urban environment
The rational layout of open space is conducive to improving the city's high-density environment and the formation of disaster prevention system. Open space, as a soft space, has the functions of shock absorption, fire prevention, windproof and blocking the source of bacteria. It can prevent the spread of disasters and form a natural barrier. The "Green corridor" proposed by Japan in the "Fibercity" plan is a typical open space disaster prevention strategy (Figure 4). "Green corridor" refers to the green and open space connected in series at different scales in a city. Fire prevention zoning is divided into irregular networks, which can control the spread of fire [5]. In addition, the construction of urban disaster prevention parks combined with disaster relief plays an important role in urban security, and has become an important part of urban disaster prevention planning.

3.3. Road patterns in high-density urban environment
High-density urban area has large traffic flow and complex traffic modes, which is liable to produce serious "tidal" traffic. According to the characteristics of dense traffic, choosing chessboard road network is the best choice for high-density cities [7]. Chessboard road network can provide traffic participants with a variety of road choices, the shortest distance and the most along-street interface. When some streets are damaged in traffic congestion or disaster, the high connectivity and homogeneous distribution of chessboard road network are conducive to rapid evacuation and refuge. For the built urban central area, on the basis of maintaining the original road texture, narrow and dense roads and smaller blocks can be formed by increasing the density of road network and road redundancy.

3.4. Building space and surroundings in high-density urban environment
The high-density urban environment is dominated by the building groups, and its building density and height are generally higher. Therefore, it is possible to start from building space and surroundings, reduce the disaster-causing factors and strengthen the disaster prevention measures. In the initial stage
of construction, it is necessary to avoid unsuitable construction areas such as geological hazard-prone areas, so as to make the building space and environmental elements constitute an organism. Secondly, the density of road network and building face should be increased appropriately to ensure the necessary spacing between buildings and provide a variety of evacuation channels. Finally, the strategy of landscape facilities, sight design and safe lighting can be combined with disaster prevention system.

3.5. Infrastructure layout in high-density urban environment

In recent years, many domestic and foreign cities have suffered frequent disasters in transportation, electricity, energy and drainage systems, etc. Urban infrastructure has shown serious vulnerability in the continuous disaster testing. Infrastructure disasters are mainly divided into two types: accidents caused by the facilities aging, faults, damages and other self-failures, and secondary disasters caused by the destruction of facilities owing to external causes. Therefore, on the one hand, we should improve the defence standard of lifeline system, enhance its own stability and ability to resist disasters, and ensure the normal operation of urban functions during disasters. On the other hand, we should increase redundancy and optimize the overall arrangement of branches in the facility system to ensure that the whole lifeline system will not be paralysed due to the damage of any local facility in the event of disasters [8]. In addition, it is necessary to upgrade the scientific and technological level of infrastructure system and accelerate the construction of underground utility tunnel (Figure 5).

4. Conclusion

The study of disaster prevention planning in high-density urban environment is an urgent need for eliminating hidden hazards of disasters and ensuring the safety of cities and towns. It is also a necessary prerequisite for the sustainable development of urban ecosystems. However, there is still a gap in the study of disaster prevention under high-density characteristics in China. In a time of multiple disasters around the world, the author believes that we should set up the correct thought of urban disaster prevention, optimize the urban spatial structure from the perspective of normalized disaster prevention, realize the dynamic balance between urban construction and ecological environment, and promote the healthy and orderly development of cities.

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