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Analysis on Influence of Urban Spatial Pattern Changes on Social Vulnerability

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ABSTRACT

This paper studies and analyses the formation and evolution of the urban spatial pattern of Harbin, a waterfront city in northern China. Considering the history and culture of this city, as well as the impetus of modern urbanization, and performing Pearson's correlation analysis it is concluded that the modelled social vulnerability score and the flood damage in certain periods are highly correlated. The results indicate, 1. that the change of spatial pattern and the social vulnerability to disasters are in a high coupling relationship, 2) that the social vulnerability is closely related to the terrain of the disaster source, and the urban civilians, handicraftsmen and businessmen in Daoli District and Daowai District of the first stage of terrain are the population with the highest social vulnerability, and 3) that there is no apparently time-varying change of socially vulnerable groups. This paper innovates to combine the research on the dynamic change of the urban spatial pattern and the research on social vulnerability, in order to supplement and perfect the assessment system for social vulnerability influencing factors, and to provide reference for the establishment of the social policy as relevant.

INTRODUCTION

Since the beginning of the 20th century, natural disasters in China have come to an explosion period in terms of not only type and frequency, but also the loss caused from damage. As disaster causes more and more damages, disaster risk has become one of the greatest obstacles that hinder the sustainable development of human society. With the development of disaster prevention and reduction works to the depth in each country, both the academic and the industrial fields have turned the attention from the traditional view that took disaster-inducing factors as the core of research to a new one that focuses on the social vulnerability of human society itself. The scholars hold different views on the meaning of social vulnerability: Burton et al. (1978) suggested that it means the susceptibility to the destruction and damage from natural disaster. Timmerman (1981) took it as the degree of the adverse impacts of disaster event on social system. Mitchell (1989) pointed out that social vulnerability is a potential loss. Smith (1992) pointed out that it is the comprehensive metrics of the risk of disaster, and that of the social and economic ability to handle disaster events. Blaikie et al. (1994) believed that it is the ability of individuals or community to predict, handle, withstand and recover from disasters, which involves diverse factors to describe how natural or social disasters threaten our lives. In order to solve the threat of the social vulnerability to disaster risk, they put forward a disaster pressure and release model. Hewitt et al. (1997) expanded the research on social vulnerability to the fields of nature, technology and man-made disasters fields, as well as influencing factors of disaster mitigation. Through the research on social vulnerability, we gradually come to the point that the nature of disaster is the destruction or damage to human beings and human society itself. This potential risk would pose a threat to human society in future to a great extent, that it not only puts great pressure to the current environment of human's survival, but also is likely to cause a huge loss to individuals, even the entire society (Guo 2005). The research on social vulnerability to natural disasters involves many intricate and complex factors closely linked to human society, such as life safety and social wealth, which are related to the survival of human beings and social development.

At present, this subject has become the new pattern and the new trend in the research on disaster risk management. Reducing the damage and impact from disaster calls for analysing and handling various influence factors in a comprehensive way. These factors include the disaster-formative environment and the disaster-causing factors, while the cultural and social environments of the disaster-affected region should be included too, among which its spatial pattern resulted from its special history, social culture, economy and other factors play a crucial role in the social vulnerability of this region. In 2008, Wenchuan in Sichuan, China (Fig. 1) suffered a devastating strike in the "5.12" earthquake, which is one of the typical cases explaining this process, and one of the most important influencing factors is the urban spa-

Fig. 1: Urban spatial pattern of Wenchuan, Sichuan, China.

tial pattern of Wenchuan due to its special geographical position.

Research on Relation between Urban Location Change and Vulnerability and its Significance

There is a special formation mechanism of the occurrence and the development of natural disasters. The first one who researched the occurrence process of natural disaster from the perspective of social vulnerability is Disaster Research Center, University of Bradford, England leaded by Westgate and other scholars. This research organization took social vulnerability as the breakthrough point to carry out intensive field investigation and research on the types of natural disaster risks and their characteristics. In terms of international cooperation against natural disaster risks, UNESCO clearly mentioned in the Intergovernmental Conference on the Assessment and Mitigation of Earthquake Risk held by it, that the cultural environment, changes in history and economy and social development are the important reality references that influence the higher frequency of natural disasters including earthquake, flood and debris flow in so many developing countries (Westgate & Keefe 1976). In 1945, Gilbert F. White (Buton et al. 1993) put forward the concept "adaptation and adjustment" based on the research on flood disasters in Mississippi basin and taking into consideration the findings in field investigation, and pointed out the main principles in understanding the disaster-inducing factors and adjustment to natural extremes; then he combined this concept and the changes of geographical environment for comprehensive consideration, and found that the main cause for the aggravation of flood disaster in this region was the vulnerability of the human-earth system in this region. Later, Kates et al. (1993) mentioned that it was necessary to take into consideration the typical characteristics of social vulnerability for systematic fitting analysis of the types of different natural disasters (Kates et al. 2001). In 2000, Downing T. E. put forward that it was necessary to regard social vulnerability as the major research direction of vulnerability science, and concluded that it was necessary to define its fundamental features and research objectives as a research direction (IHDP 2001). After these researches, the scholars came to a consensus that the traditional research pattern that focused on the inducing factors of natural disasters was broken through; it was required to intensify the consideration of comprehensive indexes, such as the social capability of bearing and adapting to disasters and its adjustment ability; and the research and discussion on social vulnerability under the background of natural disasters should be one of the developing direction of this science. So far, more and more scholars and related researchers have started to focus on social vulnerability, and have used it as reference to observe and analyse different natural disasters, and to discuss the influences of social, economic and cultural factors (such as population shift, social macro and micro-structure and regional historic development) on natural disasters. Then we gradually realized that the occurrence of disaster is not only a natural phenomenon, but also a social problem.

Disaster science is an empirical research field. A research on a U.S. community carried out by Bankofft in 2007 found that there was a huge difference in values and intervention capacity to natural disasters between different levels (especially social vulnerable levels) due to their difference in financial level (Bankofft 2007). These classic cases tell us from an aspect that comprehensive consideration of the causes for social vulnerability to natural disasters and the social indexes of influencing factors has been included in research scope, and this research will impose important and far-reaching influence on reducing regional disaster risk, increasing anti-disaster ability and recovering ability.

When reviewing the evolution of urban spatial pattern in the West, it is not difficult to find that industrial revolution caused the deep change in the field of socio-economy, brought the West into the process of rapid urbanization, and broke up the traditional urban spatial pattern which had taken

family and small workshop economy as module, thus the cities started to feature large-scale centralization represented by industrial park, residential area, business service area and administration area, as well as scalization. Compared to the urban pattern style of rapid development, there was a special social vulnerable group formed in a special urban region, which was mainly composed of the urban poor or social aid recipients, namely "slum". The occurrence of this social phenomenon has attracted the attention of some scholars in the field of social improvement, who have discussed this phenomenon, and proposed a research pattern based on the differentiation of social vulnerable groups after the evolution of urban pattern. Moreover, it is worth mentioning that in the middle of 1990's, Cutter concluded the existing research and put forward the regional disaster model, which introduces the influence of different geographical environments and social backgrounds on natural disaster risk in details. He believed that any change of any factor that is easy to be ignored, such as biocoenosis and physical spatial structure, might cause great change of regional vulnerability (Cutter et al. 2003). In 2004, Dwyer analysed the disaster-inducing mechanism based on the interaction between the risk of disaster-inducing factor, the extent of exposure to disaster-formative environment and the vulnerability of the disaster-affected region, and put forward a disaster risk evaluation model (Dwyer et al. 2004). In the same year, Smith puts forward a disaster risk matrix model based on the contrary relation between physical exposure to natural environment and the vulnerability of human beings (Smith 2004). This theory is a response to Castells, who puts forward in 1972 the theoretical framework of social system based on spatial structure, political economy and ideology (Kung-Hung 1991).

It can be concluded according to the discussion above that there are many factors influencing social vulnerability, and in order to understand the relation between natural disaster risk and social vulnerability, more and more scholars tend to look for the answer through rational discussion of human society itself and self-cognition. With the rapid development of inter-urban or inter-regional communication and urbanization, the influence of the important location of our living, learning and working, namely the city, as well as the urban spatial structure that is changing rapidly to social vulnerability, must be an important angle for relevant scholars to focus on and research.

CONTENTS OF THIS RESEARCH

Research background of the sample city: China is a country suffering from flood and drought almost every year, but at different severity levels, which changes in a rhythmical manner. The 1998 flood swept a greater part of China, 8 million soldiers and citizens carried out a desperate fight against the water rising fiercely in Yangtze River, Songhua River, Nen River and other rivers from northern China to south China.

This paper takes Harbin, an important city in northern China, and Songhua River, a river flooding frequently, as an example for the analysis. Harbin is in the north part of northeast China and in the south of Heilongjiang Province, with longitude spanning 125°42'-130°10' E and latitude 44°04'-46°40' N. Its administration area consists of 8 districts and 11 counties, with a total land area of 53,000 km^2, and a total population of 9,686,100 (Zhen 2005). The area of its proper city is 1,637 km^2, in which the urban built-up area is 220 km^2, with a population of 3,382,000. Harbin is the biggest transportation hub in northeast China, an important communication center on the Eurasian continent and the biggest inland port. Geographically, Harbin is located in a flat bottom land, mainly in the midstream and downstream of Songhua River, covering a large area. For the urban area, the threat of flooding mainly comes from the main stream of Songhua River. The flood before the Harbin section of Songhua River mainly comes from Nen River, and then from Songhua River and Lalin River. Thus, Harbin is a typical floodplain city with river hazard, as shown in Fig. 2. According to history, there were three recorded great floods in the city of Harbin, namely in 1932, 1957 and 1998, with their threats and losses caused as shown in Fig. 3 and Table 1:

Formation and Evolution of Urban Spatial Pattern of Sample City

The main areas subject to flooding in Harbin are along the south bank of Songhua River, namely Daoli District and Daowai District which are in lower position, and the population in this area is the main vulnerable group. Historically, the evolution of this area's urban spatial pattern can be roughly divided into three periods:

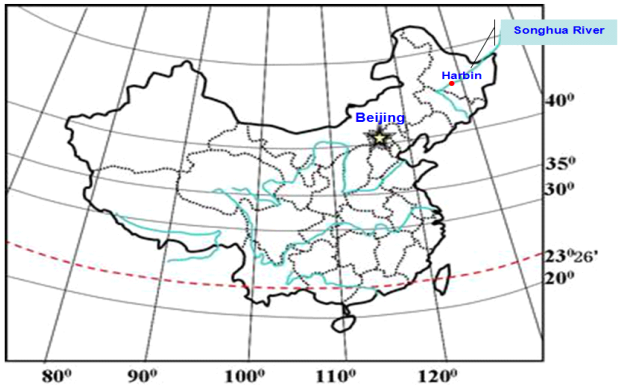

Fig. 2: Songhua River basin and the position of Harbin.

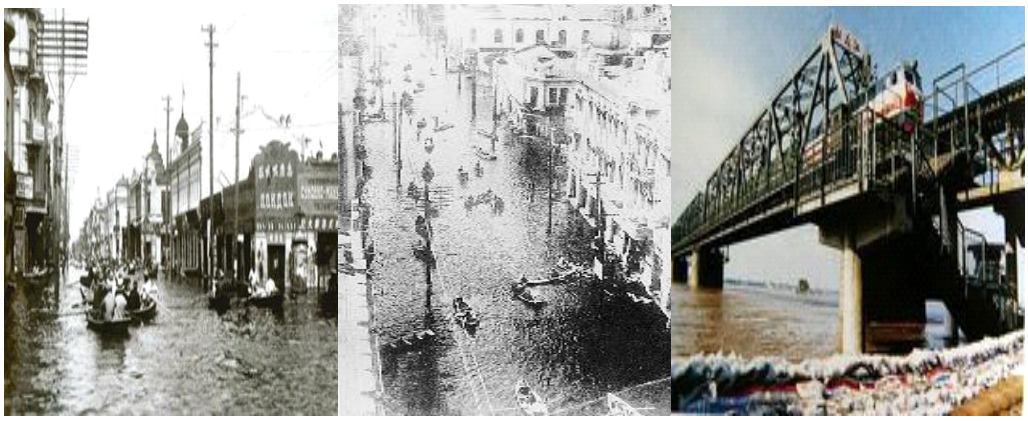

Fig. 3: Disaster situations along Songhua River in Daoli District, Harbin, in 1932, 1957 and 1998.

Table 1: Statistics of main losses of Harbin caused by these three floods.

Date	Highest water level (meter above the sea level)	Population affected (million)	Economic loss (RMB million)
1932.8.12	119.72	23.8	2.38
1957.9.6	120.06	30.1	240.1
1998.8.19	120.67	81.19	4000

Table 2: Statistics of social vulnerabilities.

Year	Social vulnerability score
1932	0.061
1957	0.125
1998	0.325

The first period is from the end of the 19th century to the time around the construction of the Chinese Eastern Railway. According to the historic records, the city of Harbin was established on the low-lying beach of Songhua River, taking Butou (currently Daoli District) and Fujiadian (currently Daowai District) as the city proper where there was the densest population, mainly fishers, handicraftsmen, the homeless and the urban poor, generally with a low level of education, surrounded by Xiangfang, Sijiazi, Guxiangtun and nearly a hundred Bannermen villages on the north bank of Songhua River, including Majiachuankou and Shuangkoumian, with a total population of three to five thousand. In April, 1898, when Imperial Russia started the construction of the Chinese Eastern Railway, the advance team of the railroad construction team of Imperial Russia arrived at Tianjiashaoguo of Harbin (currently the region around Xiang fang), where they settled down as the post of Railway Engineering Bureau. After the completion of this railway, a large number of white emigres and rich Jewish merchants had moved to Harbin escaping from the persecution of newly-built Soviet Union since the October Revolution. Later they settled down where today is the Daoli District , due to the convenient waterway transportation and port opening permission of Qing government, and became the main population of Daoli District. Before Japanese invasion of China, urban spatial pattern of Harbin had come to an early form basically.

The second period was from the establishment of the puppet state of Manchukuo to the early stage of People's Republic of China, when Japan's urban planning was directing the development and evolution of Harbin's urban spatial pattern, which highlighted function partition, planned the pattern of residence areas in ratings and restricted population flow. At the same time, the pattern in this period took the road vertical to the railway station as the axis, based on which, Daoli District on the north side of the railway station extended to the upstream of Songhua River and became the center of economy; the area on the south side of the railway station became the center of politics, where there came a lot of business institutions and administrative organizations, forming the new core of the city; and Daoli District extended to the downstream of Songhua River, where the urban civilians mainly lived. This urban pattern was basically kept after new China was founded.

The third period was from the establishment of new China to today, especially along with the reform and opening-up. The change of social environment and the acceleration of urbanization has driven the sharp increase of population density, which has brought new challenges to the development and planning of Harbin. Based on the pattern formed in the second period, this city is speeding up changing the cultural and ecological environment. The economic factors have brought along the formation of a new urban pattern, that more

Table 3: Statistics of correlation between social vulnerability and flood damage. Pearson's correlation coefficient between social vulnerability and flood event.

Pearson Correlation		The indictors of flood event	
The coverage social Vulnerability score	Correlation coefficient Sig. (2-tailed)	The number of people affected 0.991** 0.073	The economic losses(Million Yuan) 0.974** 0.05

*Correlation is significant at the 0.05 level (1-tailed); **Correlation is significant at the 0.05 level (2-tailed).

and more landscape view buildings are being built along Songhua River. The establishment of Qunli New District (Fig. 4) is a typical example of this period.

Terrain Feature of the Sample City

The city proper of Harbin can be divided into three stages of floodplain formed by Songhua River. With an elevation between 118 and 120 m and a flat and low-lying terrain, the first stage includes Daoli District and Daowai District, and is the important business and trade zone in Harbin, as well as the main living area of urban residents. With an elevation between 125 and 155 m and a smooth transition from the first stage but a clear boundary between, the second stage mainly includes Nangang District and most of Xiangfang District, which covers a large area but has suffered from a long history of erosion from running water. It has slight ups and downs, thick and fertile soils, so that it is the important agricultural area of Harbin. With an elevation between 160 and 200 m, the third stage mainly includes Huangshanzuizi, the south part of Pingfang District and other regions, gradually blending with the remainder of Zhangguangcai Range on the southeast, which is classified as hilly area.

When compared to Table 1, it is not difficult to find that this terrain feature made almost all of the first stage be exposed to and submerged in flood whenever the flood crest reached the highest level, which undoubtedly aggravates the vulnerability of this area. Therefore, terrain is the objective factor determining the vulnerability, which was formed along with the evolution of the urban spatial pattern through different periods stated above.

Research Method and Data Processing

Method: The method used in this paper is to perform correlation analysis for the social vulnerability scores of Harbin and the flood damage in different periods, by which it is available to obtain the degree of correlation between the two variables, and to understand the influence of social vulnerability on the flood damage in certain periods in the history of Harbin. The typical method is linear correlation analysis. Based on the level of measurement of the variables, different correlation analysis methods can be used, and the degree of correlation between the two variables is normally expressed as r, the range of which is $-1 \le r \le 1$. The closer r is to 1, the more correlated are the two variables; otherwise, the closer r is to 0, the less correlated are the two variables.

Data processing: Based on the actual situation, the data can be processed as follows:

1. Building mathematical model:

$$E_{i,j} = \frac{P_{i,j}}{D}$$

where, $E_{i,j}$ is the social vulnerability score, $P_{i,j}$ is the ratio of actual built-up area and that planed on a certain stage of terrain in a certain period; and D is the mean distance of the stage from Songhua River.

2. Nondimensionalizing indicators: To nondimensionalize the indicators to be assessed, and to normalize their ranges of variation. For indicators to which social vulnerability is in direct proportion, they can be normalized as follows:

$$x(i,j) = [x^*(i,j) - x_{\min}(j)] / [x_{\max}(j) - x_{\min}(j)]$$

For indicators to which social vulnerability is in inverse proportion, they can be normalized as follow:

$$x(i,j) = [x_{\max}(j) - x^*(j)] / [x_{\max}(j) - x_{\min}(j)]$$

3. Calculating social vulnerabilities with results presented in Table 2. According to Table 2, there are great changes in the risk of social vulnerability between different years, and it shows a rising trend across the three periods.
4. Performing correlation analysis for the social vulnerability scores and the flood damage in different periods: Both the social vulnerability and the flood damage in certain periods are variables with a level of measurement higher than scale variable, therefore product-moment correlation, namely Pearson's correlation coefficient, is applied. The output obtained by SPSS 15.0 is shown in Table 3. As given in Table 3, the social vulnerability and flood damage are highly correlated, which is verified by the two tailed test at 0.05 significance level, indicating that social vulnerability has a significant influence on flood damage.

Fig. 4: Different district of Harbin in three periods.

Data sources: The data come from Harbin Statistical Yearbook (2011), China City Statistical Yearbook (2011), China Population Statistical Yearbook (2011), the report of the city survey group of Harbin, relevant literatures and Internet.

RESULTS

The region with the highest risk of flooding in Harbin has the greatest social vulnerability. According to the analysis above, Harbin has developed along the south bank of Songhua River due to historical reasons, which makes Daoli District and Daowai District exposed to the risk of flooding from Songhua River. Therefore, the region on the first stage of terrain has become the key area of flood-fighting and emergency rescue in Harbin. All of the three recorded floods (1932, 1957 and 1998) occurred in Daoli District or Daowai District, especially the flood in 1932, which was described like a beast of prey and killed about 20 thousand citizens, while the total population of Harbin at that time was 380 thousand. Due to the inefficiency of the Manchukuo government, there was an outbreak of plague in this city, and the number of victims was up to 238 thousand, which was 62.2% of the total population. This flood resulted in direct and indirect economic loss up to 23 million in Manchukuo yuan. Under the strike of the catastrophic flood in 1957, most of the buildings along Songhua River in Daoli District and Daowai District suffered from piping and seeping problems, with the danger of collapsing and dike burst. Meanwhile, 12.3 thousand mu of agricultural land was flooded, and 75 people were killed. In 1998, the flood peak came earlier than the previous two did, which caused serious damage to Harbin, resulting to 811.9 thousand victims, among which, 229.5 thousand people had to be evacuated. Daoli District and Daowai District, which are in lower position, were the main areas flooded. For the city in whole, 98.2 thousand houses were destroyed, and 4,037.3 thousand mu of crops were ruined. The economic damage resulted from flooding and waterlogging, including the costs of flood fighting and emergency rescue, was about RMB 4 billion.

Social vulnerability is closely related to the terrain structure of disaster source. The sample city has clear terrain stages, and the first stage, where Daoli District and Daowai District are located, is exposed to higher risk of flooding, with a much greater social vulnerability to flood than the other two stages. As there is a distinct boundary between the first stage and the other two stages, the impact of flooding is not significant for these two stages.

CONCLUSIONS

The change of urban spatial pattern and the social vulnerability to disasters are in a high coupling relationship. Usually, the urban spatial pattern of a city is the result of different factors that are interacting with each other. Our analysis on the spatial evolution of Daoli District and Daowai District of Harbin shows that history, culture and economic interest during urbanization are the main causes for the current pattern of these areas, as well as its evolution. The first stage, which mainly consists of Daoli District and Daowai District, is the high-exposure area in flooding, and has a higher social vulnerability. Therefore, the evolution of spatial pattern of Daoli District and Daowai District and the social vulnerability of these areas are in a high coupling relationship.

Research on the dynamic change of the social vulnerability from the view of social spatial pattern. The previous researches paid no attention to the research on the dynamic change of social vulnerability. This paper takes the three recorded floods (1932, 1957 and 1998) in the history of Harbin as our examples to study the formation and evolution of the unique spatial pattern of this city, and analyses the change of social vulnerability of the high-exposure areas from a dynamic view. The data indicate that the social vulnerability of these areas shows a rising trend.

Risk reduction includes the improvement of engineering measures, fund raising and early-warning system, and it calls for focusing on the change of urban spatial pattern. As a systems engineering, risk reduction includes the construction of infrastructure and engineering facilities, and the improvement of personnel allocation, fund raising and early-warning system; meanwhile, it should also include understanding the change of environment and that of culture which is intangible. This paper gives a try to analyse the evolution of urban spatial pattern, which provides a good perspective for further researches.

The social vulnerable groups do not change significantly with time. According to the history of Harbin in about a hun-

dred years, and the formation of the urban spatial pattern of this city, the closer to Songhua River the area is, the higher risk of flooding it faces, especially Daoli District and Daowai District. For Daowai District, the main population under the threat of flooding are the urban poor, handicraftsmen, freelancers and the homeless, who are in lower class with less income and fewer educational resources, and have limited recovery and self-building capability. For Daoli District, which is the main business zone, the main population under the threat of flooding are rich merchants or those in higher class, who have adequate recovery capability, however, their social vulnerability is still great as they are on the stage of terrain which is in the special terrain exposure zone. According to the data about the three recorded floods, the vulnerable groups do not change with time.

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