Risk Perception and Adaptive Demands of Climate Change in Metropolis: A Case Study of Shanghai

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Abstract. This research put emphasis on the specific characteristics of climate risk as well as the impact factors of vulnerabilities in metropolis. Furthermore, grounded on the approach of participatory analysis, this research carried out the case studies in Shanghai, which reflected how different the stakeholders had the perception of climate risk and the demands of adaptation. The participatory stakeholder analysis in Shanghai depicted the different adaption demands. The research outcomes discussed the force driving factors of metropolitan climate risk including coastal geographic location, the population vulnerabilities (aging and high-density population), ecological vulnerabilities (the degraded ecological bearing capacities and resilience) and the vulnerabilities of economic structures. All in all, the metropolitan areas should build more incremental adaptive capabilities. In Shanghai' case, it should be highlighted of adaptive capabilities building in communicates and eco-logical environments.

Keywords: Climate risk perception · Metropolis · Adaptive capacity · Participatory stakeholder analysis · Shanghai · Vulnerability

1 Introduction

There are arguments about the definition of climate change risks, [1–4] which interwove a buck of impact factors including the frequency of hazard, socioeconomic conditions, population exposure, environmental vulnerability, and sanitation vulnerability [5, 6]. In this search, the definition of climate risk and vulnerability are cited from the IPCC [4] and Ellis [7], which claim that Climate change risks refer to adverse effects of climate change including climate variability and extremes. The direct climate change risks result from the natural hazard including heat, floods, droughts, storms and sea-level rising. Compared with that, the indirect of climate change risks are caused by the vulnerability of ecological and social systems in climate change such as crop production reduction, property loss and injuries of people. So the climate risks can be defined as a function of two main parameters: (1) the frequency of climate hazards and (2) vulnerability. Regarding vulnerability, some researches integrates physical vulnerability (P.V), exposure to hazards, and socioeconomic vulnerability [8]. For instance, Heijmans [9] finds that disaster response agencies are increasingly using 'the concept of "vulnerability" to analyze processes that lead to disasters and to identify responses', but at the same time,

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'agencies use the concept in the way that best fits their practice- in other words, focusing on physical and economic vulnerability. Safi [1] argued that vulnerability evolved from being centered on the physical vulnerability and became a comprehensive concept, within which both P.V. and socioeconomic conditions of threatened individuals or communities are intertwined. In this research, we still use the definition of vulnerability stated by IPCC [2] and Smit and Pilifosova [10]. IPCC report [2] describes vulnerability as a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. Smit (2003) argued that the vulnerability of a given community or system to climate change is specific to particular stresses or stimuli at particular locations and periods of time. There are two main factors: (1) exposure and (2) adaptive capacity. Just as aforementioned, climate risk may be represented as model (1).

$$\begin{aligned} \text{RISK} &= \text{f}\{\text{HAZARD}, \text{VULNERABILITY}\} \\ &= \text{f}\{\text{HAZARD}, \text{EXPOSURE}, \text{ADAPTIVE CAPACITY}\} \end{aligned} \tag{1}$$

From this formula to see, climate change risk results from three components. One is relating to natural hazard. Hazard may be represented as the long-term climate variation involving intense rainfall, rising sea level and the occurrences of extreme temperature, as well as the shot-term climate change such as the increased frequency of drought, flooding, typhoon, sandstorm, heat waves, acid rain and other environmental change.

The second factor refers to the exposure of regional system to hazard, particularly the exposure of population and socioeconomic condition [11]. The exposure refers to the probability or incidence of hazardous conditions relative to the presence of humans at a particular location at a particular time [12]. So the parameter of exposure is determined by the specific location, and the sensitivity of population and socioeconomic condition to hazard. For instance, the location near to floodplain or coastal zone may be easily harmed by flood or typhoon. The elderly, children, and people with disability are more sensitive to risks such as tornadoes, tsunamis, and earthquakes, where they have more difficulty in escaping and adapting to them. Furthermore, some industries such as agriculture, tourism, forestry and fishing are more sensitive than others to some hazards. Thereby, the region with high proportion of these sensitive industries may suffer with property loss [1, 13, 14].

Another factor is adaptive capacity, which refers to the ability of a system to cope with or survive from hazards. The adaptive capacity of a system reflects on the climate-proofing infrastructures and carrying capacity of environment. For instance, increasing forest coverage rate or dam reinforce may enhance the ecological adaptive capacity to flood. Adaptive capacity also involves the policy measures and institutional organization. The high perception of climate variation may increase the abilities of coping with hazard when it happened. Furthermore, some measures for raising awareness of climate risks such as setting up the system of meteorological disaster early warning, or providing self-help training and education for community would have great effort on preventing disasters and reducing damages.

In light of the conception of climate risks discussed above, climate risks have evident regional characteristics. The climate risks in metropolis may have more adverse impacts on population health as well as the social-economic system because of the agglomeration development. So this paper firstly focuses on the special characteristics of climate change risk in metropolis together with a case study of climate risk analysis in Shanghai. Four main vulnerabilities have been depicted in this part, involving the frequency of climate hazard happening, population factor, natural environment and economic structure. Generally, the aim of adaptation to climate change is to reduce vulnerability and increase resilience to impacts [10]. So promoting adaption capacity is the other task in this research. Adaptation capacities in a region depend on a variety of factors, including economic development condition, engineering measures such as building defensive infrastructures and other political measures such as public education or hazard insurance policies. Furthermore, the perceptions and action willingness of stakeholders to climate risks, especially the policy-makers in this region, have a significant role in building adaptation capacities. Thus ground on the climate risks analysis in Shanghai, this paper tried to analysis the different perceptions and adaptive demands among stakeholders in Shanghai so as to find the retrofit strategies for adaption to climate risks.

2 The Characteristics of Climate Change Risks in Shanghai

2.1 Main Climate Hazard

Shanghai is located midway along China's highly populated and generally prosperous Eastern seaboard. The city itself sits on mainly flat land at the confluence of the Yangtze and Huangpu Rivers, on the south-east edge of the Yangtze delta. The coastal lines of Shanghai is about 172 km, where is affiliated to Pacific Rim with multiple climate disasters especially rainstorm. In the Grounded on the meteorological data and disaster statistics from the Shanghai Meteorological Bureau, the main natural hazards in Shanghai point to typhoon, rainstorm and strong wind (Seen in Table 1). In these climate hazards, flood, typhoon and thunder happen in Shanghai most frequently than other climate hazards. However, the typhoon brings the most losses of economic losses, especially agricultural industry, resulting in economic losses about annual 1390.2 million$ and 8529 hm^2 areas of crops affected. Flood is the second worst hazard which cause the annual economic losses of 361.7 million$ and 6501.9 hm^2 areas of crops affected. The casualties mainly result from thunder and lightning, 3 or 4 people would die in this kind of climate hazard in every year, and about 2 or 3 people may be led to death by typhoon or tornado. The statistic data from Table 1 explains that the happing frequency of a certain hazard does not have linear relation with economic losses or casualty. The potential reason may be related to the adaption capacities or the perception of stakeholders to this kind of climate hazard, which will be discussed in detail later.

Table 1. Annual average losses resulted from different disaster in Shanghai

Category	Frequency (times)	Economic losses (million$)	Affected crops (hm^2)	Death population
Typhoon	143	1390.2	8529.0	2.4
Flood	163	361.7	6501.9	1.1
Strong wind	90	96.7	530.7	1.8
Tornado	48	68.4	756.5	2.0
thunder and lightning	142	23.4	231.8	3.4
Dense fog	35	0	0	1.3

**Shanghai Climate Center, Special assessment of climate change in Yangtze River delta urban agglomerations, 2012*

2.2 Ecological Environment Factors

Shanghai is an economic powerhouse in China that is already one of the world's major business cities. As the largest economic center in China, this city has kept sprawling rapidly with increasing consumption of energy and natural resources. Therefore, the intensive land utilization and high consumption of ecological sources bring great challenges to the ecological environment capacity, especially the ecological service functions of water resources, cultivated land and ecological diversity have decayed gravely [5]. Since 2003 the municipal government has paid more concern about increasing the ecological resiliency, which results in the ecological service value in the downtown of Shanghai restoring by 19.45 %. However, compared with the ecosystem before 1943, the ecological service value has dropped by 88 % [15]. Taken the water resource as the example, the rivers in Shanghai have been landfilled to increase the available land areas. So the water system has declined quickly in Shanghai. During the period from 1990 to 2009, the channel density had dropped from 6.5 km/km^2 to 3.4 km/km^2, which had fallen about 67 %. Especially, the small channels whose slop range from 200 to 1000 m dispersed most fast, which have accounted for 60 % of the whole dispersed rivers [16]. Similar to the water system, the increasing demand of land resources also triggers the irrational land utilization, which intensifies the deterioration of environment capacity. The data has shown that the temperature would elevate by 0.91°C resulting from heat island while the population in Shanghai grow per 1 million people.

2.3 Population Factors

The two factors of population have impacts on the climate risks, one related to the density; the other on the population structure. Shanghai is the city with the most population density in China. Until 2010, the density of population in Shanghai has swollen to 3632 people per kilometer square, increasing 40.3 % compared with the density of 2588 people per kilometer square in 2000. In addition, fifty percent of population has crowded in the downtown of Shanghai, which only account for one-tenth areas of the

whole Shanghai [17]. This kind of uneven population distribution brings more and more pressure to the central town not only in the infrastructure service but also the resource supplies, which intense the risk of population exposures to abnormal climate. Furthermore, the aging population structure also takes disadvantage to the exposure of climate risks. Generally, the poor or the age arranging from seventeen to sixty refer to the vulnerable population to climate risks such as heat wave, frozen and flooding. In Shanghai the vulnerable population has accounted for 33.8 percent of the whole population. The aging people over 80 years have kept growth in recent ten years. In China the social bonding in communities are weak. If the development of health care system cannot tag along with the trend of population structure change and provide enough social sources to care this vulnerable group, more and more population in the big city will be exposure in the threat of climate risks. Compared with the aging population, since 2002 the poverty has fallen and the adaptive capacities of the poverty to climate risk have been improved by increasing social insurance payments. Until 2007 the poverty group has reached 0.34 million people and the poverty rate is only 2.84 %.

3 Risk Perception of Different Stakeholders and Adaptive Capacities Analysis

Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behavior and in resources and adaptive technologies. [2] adaptive capacity is influenced not only by economic development and technology, but also by social factors such as social capital, social networks, values, perceptions, customs, and governance structures. Smith and Pilifosova (2003) argued that even though some region own rich resources or stay in a good economic condition, the climate vulnerability is higher than the poverty areas [10]. The main causes rely on the local poor cognition and deficient adaption measures. This study relies on a participatory action research approach to probe the impact of perception and adaptive demand on the design and implementation of effective adaptation strategies. So in the research, some approaches such as semi-structured interviews, scoring and ranking, will be applied to analyze the perception and action willingness of stakeholders.

The sampling design of this interview involved 53 participants, all of whom were the crucial policy-makers or actors in the implementation of local adaptation strategies. The participants would be divided into three groups. The first group refers to municipal officials from different sectors including departments of urban planning, water management, transportation, health care, forestry and disaster management. The second group belongs to meteorological experts who are engaged in independent researchers or consultants in meteorological agencies. The third group involves the community residents who mainly come from the downtown of Shanghai (Seen in Table 2).

Table 2. Number of interviewees and stakeholder groups represented

	Governmental, officials	The community residents	Academic, independent expert	Total
Interview participants	17	12	6	35
Scoring participants	14		4	18
Total	31	12	10	53

3.1 Risk Reception of Different Stakeholders to Climate Risk

The aim of this interview refers to understand their direct feeling or cognition about the climate risk through semi-interview with governmental officials, the meteorological experts and the residents in shanghai. Therefore, the interview question was designed as "what kinds of extreme climate events impressed you happened in Shanghai. The participants from three groups all perceived typhoon, rainstorm and heat wave as the main climate risks, which marches with the frequency of these climate hazards happened in Shanghai (Table 1). However, there were some divergences about the impacts caused by these hazards. Firstly, the meteorological experts paid more concern on the climate hazard itself, involving rainstorm, heat wave, flooding, frozen, draught and lightning. As the professionals, the direct perceptions from meteorological experts are more objective and specific. For instance, one of the most impressed extreme climate event to the experts was the rainstorm happened in August 1977, which cost the losses about 28 million dollars and 2 people dead. The experts cared more about exact extreme climate events rather than the impacts and damage resulting from the climate events. Secondly, the governmental officials concerned more about the impacts of climate risk on economic and social development. Taken the rainstorm as an example, the interviewed officials were impressed by the hazard impact on transportation operation, the crop losses and casualties resulting from the rainstorm. So the governmental officials care more about indirect climate risks such as waterlogging, infrastructure destroy, environmental impacts, economic losses and public health care. Thirdly, the perception of residents derived from their living experiences rather than the professional acknowledge. The residents, as rational-economic men, cared more about the short-term interest and their own losses in hazards. Usually they did not consider certain climate events as risks until their life or properties are threatened. Furthermore, one outcome from the interview with residents has drawn the attention. Though the residents are the important stakeholders in the climate adaptation, 76 % of the residents involved in this survey stated that even they do what they can for the adaption to climate risk, but it is useless or does not make a difference because their efforts are trifle compared with the systemic adaptive strategies. So the residents felt that the climate change was "governmental tasks and none of my business". From the outcome of the survey to analysis, the residents in Shanghai

have a low perception of climate risks, which not only bring dilemmas to adaptive action but also increasing the vulnerability of population in climate hazards.

3.2 The Analysis of Adaptive Demand in Shanghai

Climate adaptation refers to anticipating the adverse effects of climate change and taking appropriate action to prevent or minimize the damage they can cause, or taking advantage of opportunities that may arise [6]. Due to the different perception in climate risks, even in the same region, stakeholders would have distinct opinions in the adaptation demand. The adaptation demand may be multiple, but when the sources are limited, adaptation action should be carried out to satisfy the most emergent demands. In this study, the officials coming from different departments and the experts from meteorological agencies were required to indicate the urgency of climate vulnerabilities and rank their levels. The results have been shown in the Tables 3 and 4. In the opinion of meteorological experts, Typhoon is the most dangerous climate risk, to which the agriculture productions are very vulnerable as well as energy supply and causalities. Furthermore, the experts believed that rainstorm is the other risk which results in the urban waterlogging. Overall, the agriculture, urban drainage and energy supply are vulnerable to the climate risk. Compared with meteorological experts' opinion, the governmental officials deemed that the agriculture only account for little percent of GDP development in Shanghai, so they did not put the emphasis of adaptation on agricultural development, but treated rainstorm as the most emergency, which usually bring damage and threaten to transportation operation and energy supply. Typhoon is another primary climate risk in the official's perception, and they agreed the impact of typhoon on agriculture and energy supply. The heat wave is treated as the third climate risk in Shanghai not only to the experts but also governmental officials. But the expert argued that its impacts mainly focus on the energy supply, and the officials concerned its impact on agriculture. Though the threat of heat wave to population health has been noticed by both groups, they did not believe that the vulnerability pf population to heat wave is a serious problem.

Table 3. Evaluation results of climate vulnerabilities in Shanghai meteorological agency

effect / cause	A1	A2	A3	A4	A5	score
	20	12	11	10	8	
typhoon	1	16	7	3	8	
9	1	7	7	14	11	40
heat wave	26	0	0	6	3	
6	20	0	2	3	3	28
rainstorm	0	15	11	1	8	
6	0	14	2	4	6	36
score	27	31	18	10	36	

Table 4. Evaluation results of climate vulnerabilities in Shanghai municipal departments

	Rainstorm	Typhoon	Heat wave	Scores
Transportation	5	0	1	16
Energy supply	3	2	0	13
Losses of crops	0	2	3	7
Environment	0	1	1	2
Constructions	0	0	0	1
Casualties	0	1	1	2

**Institute for Urban and Environmental Studies Chinese Academy of Social Sciences, The investigation report of climate risks in Shanghai and its adaptive strategies, 2011*

Compared with the perception of the officials and meteorological experts in Shanghai, the participants from residents group felt through their direct living experiences that heat wave and rainstorm may bring more damage to their property or lives. However, regarding to the adaptive capacities for these two climate hazards, they felt satisfactions with the efforts of governmental adaption actions in minimizing the damage from rainstorm, but sounded the alert for preventing heat waves. The responders from resident groups reflected that they are easy to be stuck in the heat wave due to three action dilemmas. Firstly, the heat wave has turned to be an emerging climate disaster as the global temperature kept rising in recent years. But the residents in Shanghai still have not enough awareness of its hazard, so when they, especially the children or the old, take heatstroke or other disease caused by heat wave, the residents lack the related knowledge and experiences for timely medical aid. Secondly, the power and water supply for households still stay in the tension state, even though some factories and shopping centers in Shanghai have been restricted in the consumption of utilities on the hottest days of the summer. The power supply in Shanghai depends on the import of electricity from the other cities in Yangtze River Delta, where the energy tensions are also highlighted during the hot weather. Third dilemma is related to the medical care system. The residents in the interview described that it was difficult to call the ambulance or other medical aid services in the hottest days. The high temperature alert did not stir up enough attention to the medical care system, so the shortage of the medical reserves might delay the medical aid, which can be drawn a lesson from the heat wave disaster in Chicago during the July 1995.

Grounded on the distinct perception of potential climate risks, the stakeholders have different demands for engineering measures, technological innovation, policies or other adaptation measures for preventing the most threatening climate risks. The meteorological experts considered that weather forecast should involve the meteorological impact analysis in the health care, transportation, agriculture and other urban infrastructure operations so as to increase the capacities of anticipating potential damages and planning disaster prevention. Compared with the meteorological experts, the sectoral departments in Shanghai keep more interest and concerns in defense work for rainstorm flooding, which had hit shanghai frequently in the history and resulted in serious damage.

For instance, the urban drainage system engineering is one of the most important infrastructure development projects in Shanghai. Until 2010, the drainages have been built for 11488 km. Furthermore, since 2008 the drainages have been dredged for twice per year so as to improve the water discharge capacity. In the decade the drainage ability in Shanghai has increased obviously. Furthermore, during the interview, the governmental officials considered that the disaster warning system should be taken advantage to break an early alert for the vulnerabilities transportation. They deemed that rapid and unreasonable underground space uses brought more burdens and vulnerabilities to underground pipe system, which was prone to Waterlogging disasters. The digital management system for underground pipe network integrate with weather forecast information, which both are an important components in the urban disaster warning system, would minimize the impacts of climate risks such as rainstorm on the urban drainage systems

4 Conclusions

This research depicted the specific characteristic of climate risks in four aspects, which involved hazard itself and the vulnerability of population, economy and environmental capacity. Firstly, the most metropolis areas mainly lie in the coastal zones and are sensitive to the climate change. The increasing climate hazard in these locations such as the rising sea level, the rainstorm, and heat wave are threatening economic and social develop. Secondly, the aging population and the increasing population density in metropolitan areas have exposed more and more the old and vulnerable people to the climate hazard such as heat wave and flooding. The vulnerability of population has been outstanding in metropolitan climate risks. In addition, the climate hazard interweaved with the pressure of urbanization development has aggravated the environmental deterioration and the shortage of natural resources, as well as the degeneration of ecological rehabilitation capacity. Finally, the economic vulnerability to climate change has also been analyzed in this research.

Furthermore, this research probed in the risk perceptions and adaptive demands of different stakeholders in Shanghai through interview investigations. The perception level of stakeholders to climate risks determine if the adaption strategies can be planned exactly and the adaptive demands have a role in the priorities of various adaption actions. In this research, the outcomes of interviews showed that the main climate hazards such as typhoon, rainstorm and heat wave have been perceived by the stakeholders involving governmental officials, meteorological experts and the public. However, the adaptive demands among the stakeholders were distinct. The meteorological experts and local officials concerned more about the adaption on vulnerable transportation operation, urban flooding, agriculture development and energy securities in Shanghai. Compared with the former stakeholders, the public argued that the most emergent adaption action should be put into heat wave, which have turned to be a serious disaster in the decade and threatened the health of vulnerable people. So this research suggests that a disaster prevention system for heat wave should be set up as the priority adaption action, as well as the healthy services and insurances should be improved further.

In addition, from the analysis of the interview outcomes to see, both officials and metrological experts have noticed the necessity of taking adaptation measures for the climate change risks. Especially the vulnerabilities of urban flooding, energy supply, transportation and agriculture development have been put into the emphasis of adaptation action. However, the adaptation to environmental vulnerability in Shanghai has been ignored. For instance, even the vast investment has been contributed to the retrofit engineering of urban drainage so as to relief the risks of urban flooding, urban river channel keep dropping, which play a role of self-rehabilitation to digest the flooding.

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