

Research on Social Resilience Construction and Climate Adaptation Strategies for Extreme Rainfall Risks

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ABSTRACT

In recent years, global climate change has led to an increase in the frequency and intensity of heavy rainfall, posing a significant threat to the survival and development of cities. Traditional disaster management methods are difficult to effectively solve the increasingly complex urban flood problems. From the perspective of rainstorm disaster, this paper analyzes the relevant measures and methods to enhance urban adaptability and improve climate resilience. On the basis of identifying new changes in extreme precipitation disasters and their impacts on existing systems at all levels, this article forms a main idea for cultivating social resilience from the perspectives of absorption capacity, adaptability, and resilience. Based on this, it explores countermeasures and suggestions for the coordinated response of engineering and non engineering measures to climate change, and finally proposes institutional arrangements and policy designs for the coordination of the two. In conclusion, enhancing regional resilience and actively adapting to climate change at a higher scale is one of the effective ways to reduce the risk of rainstorm disasters, and attention should be paid to the combination of concept updating, mechanism design and multi-party participation.

KEYWORDS

Extreme Rainfall; Social Resilience; Climate Adaptation; Risk Management; Urban Resilience.

1. INTRODUCTION

In recent years, under the trend of global warming, extreme weather and climate events have shown a trend of high frequency, wide geographical coverage, and increasing intensity, with short-term heavy rainfall as one of the main factors. They have the characteristics of suddenness, high disaster rate, and great destructive power, and have become one of the important disaster hazards affecting the safe development of cities and even regions. The July 20 rainstorm flood disaster in Zhengzhou and the heavy rainfall process in Beijing Tianjin Hebei region are typical examples. All of them expose the shortcomings and weak links of the existing disaster prevention and mitigation system in dealing with super heavy rainfall[1].

The purpose of this paper is thus to summarize, distill and present the risk characteristics and impacts of heavy rainfall; to create an appropriate social resilience framework for these kinds of event; to define what we mean by adapting to climate change; and explore opportunities for combining them to provide guidance on how society may better prepare for extremes in precipitation.

2. CHARACTERISTICS OF EXTREME RAINFALL RISK

The emergence and development of extreme rainfall risks also have obvious temporal characteristics. From a meteorological perspective, extreme rainfall mainly comes in two forms: short-term heavy

rainfall and long-term cumulative rainfall, both of which exhibit increasing intensity and frequency[2]. In terms of risk development, extreme rainfall is not usually caused by a single factor, but also closely related to urban topography, underlying surface conditions, infrastructure conditions and other factors, leading to the occurrence of disaster chains such as rainstorm waterlogging, flash floods and landslides, and power cut.

3. BUILDING SOCIAL RESILIENCE: A CORE FRAMEWORK FOR COPING WITH EXTREME RAINFALL

Integrating social resilience theory into research to more comprehensively analyze the ability of cities to face the risk of heavy rainfall. On the basis of the connotation of social resilience, it can be divided into three basic forms: absorptive force, elasticity and regenerative force. These three basic forms constitute the basic connotation of cities facing rainstorm and waterlogging disasters.

3.1. Absorption Capacity: Construction of Infrastructure Robustness and Redundancy

Absorption capacity refers to the ability of a system to absorb disturbances without undergoing fundamental functional changes when subjected to extreme rainfall impacts. The physical robustness of infrastructure is the fundamental guarantee for absorption capacity, including improving the design standards of drainage networks, strengthening the maintenance and management of flood control facilities such as embankments and pumping stations, and enhancing the waterproof and flood prevention levels of key buildings.

At the same time, attention should be paid to redundancy construction[3]. The so-called redundancy refers to the backup of key nodes or critical functions in the system. Once one link fails, another link will replace it to ensure the normal operation of the entire system. For example, alternative evacuation route design in transportation systems, decentralized energy and microgrid system construction in power systems, emergency communication backup networks in communication systems, etc. The above methods can improve the resilience level of rainstorm disaster resistance of the system.

Sponge city construction is a case of improving absorption capacity, using dispersed methods such as permeable paving, rain gardens, and sunken green spaces to enhance the ability of ground rainwater infiltration and storage. While alleviating the drainage burden of the pipeline system, it also achieves the utilization of rainwater resources, which is a combination of grey infrastructure and green infrastructure.

3.2. Adaptability: Flexibility and Resource Allocation of Social Systems

Resilience means that when facing the threat of rainstorm disaster, the system can flexibly change its own state according to different situations to reduce the degree of damage. Among them, flexibility is the key element, which means that the response mode of the system to the threat of rainstorm disasters can change with the change of disasters.

The improvement of adaptability cannot be separated from the construction of multi-party collaborative governance mechanisms[4]. The response to extreme rainfall involves multiple government agencies such as meteorology, water conservancy, emergency response, transportation, and housing construction, as well as multiple entities such as enterprises, communities, social organizations, and residents. It is necessary to establish a normalized cross departmental communication and coordination mechanism, clarify the responsibilities and cooperation processes of each entity, and form a joint force when risks occur. In addition, market entities are encouraged to enhance their resilience, support the development of catastrophic insurance products in the insurance

industry, encourage social organizations to participate in emergency management and social assistance, and form a situation of political and social co construction, governance, and sharing.

Risk based national spatial planning is an adaptive manifestation at the land use scale. When formulating national spatial planning, it is necessary to consider the spatial distribution of extreme rainfall risks and determine corresponding flood risk control lines. When planning urban development boundaries, it is necessary to avoid high-risk areas where heavy facilities are concentrated and large populations are gathered; For high-risk areas that have already been constructed, efforts should be made to cooperate with urban renewal to alleviate or strengthen their prevention capabilities.

3.3. Recovery Capability: Post disaster Reconstruction and Learning Transformation

Resilience refers to the degree to which a city can quickly recover to a normal state after experiencing heavy rainfall events and summarize experience and improve systems during the disaster response process. Resilience first emphasizes rapid response and recovery, that is, rescuing and resettling people as soon as possible after a disaster, repairing and rebuilding infrastructure, and restoring daily life order; This requires sufficient emergency material reserves, professional emergency rescue forces, and smooth channels for emergency information dissemination.

The second is institutional feedback on post disaster evaluation and experience. Every heavy rainstorm is an opportunity to learn. It is necessary to summarize the disaster process, disaster causing mechanism and the gains and losses of the measures taken[5]. This is not just a technical evaluation, but should be reflected from the aspects of institutional arrangement, organizational operation and social participation. The evaluation results should be promptly fed back to the plan revision, standard revision, plan optimization, and personnel training, and form a virtuous mechanism for continuously strengthening disaster reduction and relief capabilities.

Resilience also includes two aspects: mental health and social relationships. Heavy rainfall disasters can cause varying degrees of psychological harm to affected people, and necessary psychological counseling and support are needed; Heavy rainfall disasters can also damage or rebuild neighborhood relationships. Post disaster reconstruction can strengthen the connections between neighbors and help build a community of solidarity and mutual assistance.

4. CLIMATE ADAPTATION STRATEGIES FOR EXTREME RAINFALL RISKS

4.1. Engineering Adaptation Measures: Combining Natural Solutions with Grey Infrastructure

Engineering control measures are the fundamental guarantee for addressing the risk of excessive precipitation. Traditional grey infrastructure includes pipeline systems, pump stations, water storage tanks, and embankment protection. Its advantages are clear functions, predictable effects, and the ability to handle precipitation within certain standards. However, with the increase of excessive precipitation, relying solely on grey infrastructure cannot completely reduce risks, and large-scale construction and expansion face practical constraints such as land scarcity and huge investment[6].

Nature based solutions refer to utilizing the processes and functions of natural ecosystems for risk regulation, protecting and restoring the natural regulation and storage functions of rivers and lakes at the urban scale, constructing waterfront ecological buffer zones, and leveraging the role of wetlands in flood control and water purification; Green roofs, rain gardens, permeable paving and other methods are adopted at the community scale to achieve source reduction and process control of rainwater. At the regional scale, protect and restore the conservation forest land in mountainous areas, improve the soil infiltration rate, and reduce rainstorm runoff at the source.

The second is to combine nature based solutions with grey infrastructure to form a functionally complementary engineering ensemble, such as setting up ecological storage ponds at the end of the drainage system to achieve dual functions of peak shaving and shifting in rainy days and landscape ecology in normal times; Considering both the functional guarantee of engineering measures and the ecological and social benefits.

4.2. Non Engineering Adaptation Measures: Systems, Planning, and Behavioral Guidance

The disaster reduction management strategy mainly intervenes in policy and regulation formulation, spatial planning, public activities, and other aspects to reduce the vulnerability of the system. Firstly, in terms of policies, the frequency and scope of extreme precipitation should be evaluated and revised in a timely manner to form corresponding risk maps as important references for urban planning and disaster prevention plans; Secondly, improve the early warning system, enhance the level of disaster forecasting and early warning, expand the release methods, and ensure that notifications are promptly conveyed to every potentially affected family member.

Macro control is manifested in integrating climate adaptation ideas into various levels and links of urban and rural planning, reasonably determining the size and spatial structure of cities at the overall planning level, and avoiding high-intensity development in high-risk areas; Determine the rainwater control indicators for the plot at the regulatory level and require new projects to implement the requirements for sponge city construction; In construction and construction, climate building suitability guidelines should be developed to provide requirements for underground space waterproofing and flood prevention, as well as water blocking measures for building entrances and exits[7].

The second is to strengthen public risk awareness and behavior guidance. Through regular science popularization, education and drill activities, the public can master the common sense of extreme rainfall risks, learn the skills and methods of self rescue and mutual rescue in rainstorm and waterlogging, form the habit of paying attention to weather forecast and early warning, cultivate community emergency backbone in the community, and carry out community risk and hidden danger investigation and emergency preparedness. Create an atmosphere of mutual assistance among neighbors.

4.3. The Core Role of Nature based Solutions in Adaptation

Nature based solutions have become an increasingly important core option in the field of climate adaptation, and their significance lies not only in the value of technological means, but also in the value of concepts and methods. Firstly, the concept based on nature emphasizes that the relationship between humans and nature is harmonious, recognizing the self regulating function of nature's own ecosystem, respecting the process of nature without attempting to transform it, which is also very different from traditional engineering thinking.

Thirdly, nature based solutions possess multifunctionality and collaborative gain features. A measure can often achieve multiple functions such as rainwater management, water quality improvement, biodiversity conservation, carbon sequestration increment, and leisure and recreation, with a higher investment return ratio than grey facilities with a single function. For example, the construction of urban river landscape can not only improve the flood discharge capacity, but also optimize the waterfront environment, increase the output value of surrounding land, and help improve the quality and efficiency of urban renewal.

Adaptability: Nature based solutions are dynamic adapted. The nature system itself is adaptable, which can respond correspondingly to the climate change;However, grey infrastructure tends to be rigid in mathematical sense and can not be modified after being completed[8]. It has the potential for

failing if climate risks move out of the designed range. Thus, making nature-based solutions the first point of reference, and principal tool for climate adaptation, would be a sensible option in order to improve the sustainability and resilience of adaptation options.

5. INTEGRATION PATH OF SOCIAL RESILIENCE CONSTRUCTION AND CLIMATE ADAPTATION

Adaptation means adaptive action in response to the impact and risk of climate change; Social resilience focuses on the system's capacity to withstand pressure through the whole process, so climate change adaptation and disaster risk reduction have much in common with each other and may be used together to address the risks from extreme rain events.

5.1. The Conceptual Shift from Passive Response to Active Adaptation

The prerequisite for integration is a change in ideological concepts. The traditional approach to disaster prevention and reduction is event oriented, starting emergency rescue work after a disaster occurs, implementing rescue and relief actions, and carrying out post disaster reconstruction, which has a clear passive characteristic; In this situation, there is often a phenomenon of exhaustion and inability to cope with frequent and intense extreme rainfall risks.

Proactive adaptation means integrating the concept of risk prevention into daily life and development processes, actively facing the impact of extreme heavy rainfall in urban development, engineering construction, industrial layout, and other aspects, and making preparations in advance to reduce potential damage[9]. This requires both policy guidance from the central to local levels and concrete practice from the grassroots level. The concept of proactive adaptation needs to be implemented in the development ideas of governments at all levels, and it also relies on propaganda and education to become a common understanding of the whole society.

5.2. Incorporating Resilience Indicators into the Entire Process of Urban Planning and Project Approval

The implementation of ideas requires institutional support. Incorporating resilience indicators into urban planning and approval is an important measure to promote the integration of social resilience and climate adaptability. In national spatial planning, resilience city goals and indicators are formulated, such as rainwater pipe network standards, urban permeable area ratios, emergency shelter coverage rates, and redundancy rates of important facilities.

The second is to strengthen resilience requirements in the planning and construction approval process, introduce a climate adaptation assessment mechanism in the construction project review process, and require feasibility studies of major project construction to analyze the impact of extreme heavy rainfall risks and propose mitigation measures; Strictly approve or require higher disaster prevention standards for projects located in high-risk areas with heavy rainfall. Through planning and construction approval checks, resilience requirements are integrated into the entire process of urban planning and construction from the source.

5.3. Establish a Cross Departmental and Cross Regional Climate Risk Joint Prevention and Control Mechanism

Heavy rainfall generally has watershed and regional characteristics, and a single administrative region cannot cope alone. Establish a joint prevention and control mechanism between departments and regions to provide organizational support for improving response efficiency. From the perspective of the watershed, there should be information exchange and unified scheduling mechanisms between the upstream and downstream, as well as on the left and right banks[10]. The reservoirs should be

arranged for staggered flood control and river drainage to prevent the transfer of risks and escalation of conflicts caused by individual efforts.

From a departmental perspective, it is recommended that meteorological, hydrological, emergency, planning, transportation, housing and other departments strengthen data sharing and business linkage, establish a risk assessment warning emergency response post disaster assessment work chain, and try to establish a regional emergency resource coordination and allocation mechanism. When a region encounters extreme heavy rainfall, adjacent areas can provide support and assistance in terms of manpower, material resources, machinery, etc.

5.4. Financial Security and Innovation of Diversified Investment and Financing Mechanisms

Enhancing social resilience and promoting climate adaptation both require long-term financial support. The existing fiscal funding supply model is no longer able to meet the growing demand for funds. It is necessary to reform the investment and financing mechanism, expand diversified financing channels, prioritize social resilience and climate adaptation in public finance investment areas, increase special fund investment, and (4) ensure basic construction expenditures.

In terms of introducing social capital, it is possible to study the issuance of special bonds for resilient city construction, guiding long-term capital investments such as insurance funds and social security funds to build resilient projects; Encourage banks and insurance institutions to innovate climate adaptive financial products and services, and support enterprises and individuals in carrying out adaptation actions. Research the construction of a disaster insurance system to better enable insurance to play a role in risk diversification and economic compensation, and use price leverage to incentivize insured individuals to actively engage in risk prevention and control.

6. CONCLUSION

The increasing frequency of extreme heavy rainfall events is an unavoidable fact in the context of global warming. In the context of the increasing probability of extreme heavy rainfall events, the traditional passive resistance based engineering protection concept is no longer applicable. More efforts should be made to enhance the overall ability to withstand, adapt, and recover from disasters. Enhancing social resilience refers to the ability of a social system to accept and digest shocks from the environment, adapt to changes in the environment, and quickly recover to normalcy; Climate adaptation means that people can actively find potential adverse effects and take precautions in advance. The two complement each other to form a rainstorm disaster prevention system.

Looking ahead, there are still many issues worth exploring regarding social resilience and adaptability under extreme rainfall exposure, such as how to evaluate resilience levels in different regions? How to calculate the adaptation cost? Who will be the coordinator of adaptability? We believe that more research and action will provide more knowledge reserves and practical experience for this field, and work together to create a safer, more resilient, and sustainable living space.

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