Construction of Urban Infrastructure Resilience

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Abstract: Resilient infrastructure refers to infrastructure projects that can absorb the impact of disasters and maintain or restore basic functions as soon as possible by adapting to disasters. Through buffering strategy, redundancy strategy, diversity strategy, multi-function strategy and adaptive strategy, the absorptive capacity and adaptability of urban infrastructure can be improved, so as to enhance its resilience.

1. Introduction

Traditional protection strategies focus on how to prevent the occurrence of disasters or avoid the impact of disasters before they occur. It is undeniable that this is an important way to ensure the safety of urban infrastructure. However, with the increase of risk uncertainty and unpredictability, urban disasters are difficult to be completely avoided. In this case, it is also important to think about how to maintain or restore the function of urban infrastructure as soon as possible after the disaster. The construction of resilient infrastructure is an innovative way to enhance the city's comprehensive ability of disaster prevention and mitigation and ensure the safe operation of the city.

2. Connotation of Urban Resilient Infrastructure Construction

The so-called “resilient infrastructure” is an infrastructure project with strong resilience. It can absorb the impact in the face of disaster disturbance and maintain or restore its basic functions as soon as possible through adaptation and transformation. The disaster mentioned here does not only refer to natural disasters, but also refers to all destructive events threatening the safety of infrastructure. Therefore, if an infrastructure project can maintain or quickly restore its basic functions after being hit by disasters, it means that it is resilient; On the contrary, it shows that toughness is insufficient.

For example, on October 29, 2012, hurricane “Sandy” hit New York, causing nearly two million households to lose power. However, it took a week for New York City to fully restore power supply. At the same time, the long-term power failure caused the interruption of the gasoline supply chain, which greatly affected the safe operation of the whole city[1]. By comparison, it can be simply concluded that under the impact of wind disaster, the resilience of power supply facilities in Haikou is stronger than that in New York.

Specifically, “resilient infrastructure” requires to improve the resilience of infrastructure projects, that is, to enhance the absorptive capacity and adaptability on the premise that disasters can not be completely avoided. Absorptive capacity refers to the ability of infrastructure projects to effectively withstand the impact of disasters without obvious deviation from normal operation. Specific strategies of absorptive ability include buffer strategy and redundancy strategy. Adaptability refers to the ability of infrastructure projects to adapt to environmental changes and continue to play a role after disasters. Specific strategies of adaptability include diversity strategy, multi-functional strategy and adaptive strategy. Obviously, the stronger the absorptive capacity and adaptability of infrastructure, the stronger its resilience and the higher its security.

3. Absorptive Capacity Construction of Urban Resilient Infrastructure

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3.1 The Buffering Strategy

The buffering strategy makes the project absorb the impact of disasters through specific design to reduce the consequences of disasters, so as to maintain the functionality as much as possible. In theory, researchers often describe disaster risk as a function of threat (T), vulnerability (V) and consequence (C), that is, risk = f (T, V, C). Buffering strategy holds that although the threat (T) can not be changed when the disaster cannot be avoided, the disaster risk can be reduced by reducing the vulnerability (V) of the project itself and the consequence (C) of the disaster impact as well. For example, previous disaster events show that the progressive collapse of engineering buildings will not only cause a lot of casualties and property losses, but also lead to the destruction of the whole project. The so-called “progressive collapse” refers to the chain reaction of other parts caused by the local damage of engineering buildings, which eventually “leads to the collapse of the whole structure or a large area”. The progressive collapse in the federal building explosion in Oklahoma, USA in 1995 and the World Trade Center impact in New York in 2001 exacerbated the consequences of the events. In order to avoid the occurrence of progressive collapse, a variety of anti progressive collapse design methods have emerged in the engineering field, most of which essentially use the buffer strategy to reduce the impact of disasters on engineering buildings. In addition, the installation of fireproof foam on the facade of some infrastructure projects also reflects the buffer strategy. The main purpose of fireproof foam is not to avoid fire, but to absorb the impact of fire after the fire, so as to reduce the impact of fire. Therefore, consciously applying these buffer strategies in the process of infrastructure construction can enhance the resilience of related projects.

3.2 Redundancy Strategy

Redundancy strategy improves resilience by increasing backup system. When infrastructure projects are affected by disasters, standby system can be enabled to ensure normal function or function recovery as soon as possible. In 2012, the city learned the lesson of “Sandy” hurricane, which made the New York City gas station system unable to provide services due to power failure. After the hurricane, New York City has equipped backup generators for most gas stations to avoid repeating the same. Redundancy requires that the infrastructure must have spare components or alternatives. The standby system can be identical, such as establishing two or more waterworks for a city, so that even if one plant is hit by a disaster, other waterworks can be activated to ensure the city's water supply. In addition, the standby system can be a different option to perform the same function. At present, some cities are also actively using renewable energy to generate electricity distributed and build small-scale and decentralized micro grid projects in addition to the main power grid. This kind of micro grid can operate independently and connected with the external network. Therefore, in case of disturbance or failure of the main network, it can maintain normal power supply, thus improving the toughness of the overall power supply facilities. Unlike versatility, redundancy seems to increase costs in the short term and therefore “uneconomic”. However, if the perspective is changed, it can improve the resilience of urban infrastructure projects in a long period of time, not only to cope with risks and uncertainties, but also to the long-term cost saving.

4. Construction of Adaptability of Urban Infrastructure

4.1 The Diversity Strategy

The diversity strategy in resilience construction is inspired by the diversity of biological system response. Ecologists have long found that when faced with external pressure and disturbance such as climate change, environmental pollution and disease, functional groups composed of different species will have different responses. In this case, functional groups have stronger ability to recover from disturbance, and the conditions for their overall sustainability will be more extensive. Similarly, as far as the security of urban infrastructure system is concerned, if each basic function is undertaken by a variety of projects, the response diversity of the whole system will be enhanced, thus enhancing the overall resilience of urban infrastructure. Diversity strategy requires planners and designers to have systematic thinking, and form a diverse engineering system by designing different projects to meet the same function. From 23:00 on November 23 to 18:00 on November 27, 2005, affected by Songhua River water pollution, Harbin waterworks was forced to stop supplying water for 91 hours. Although the crisis has caused some panic and rush buying, the water demand of more than 3 million urban people has been basically guaranteed. The reason is that in addition to the waterworks, there are 918 underground wells in the city that can provide emergency water supply. This case shows that due to the existence of diversified water supply projects, the water supply system of the whole city has strong resilience, and the core function of water supply can be maintained when it is impacted by disasters. On the contrary, lack of diversity will lead to the decline of infrastructure resilience. After World War II, European countries vigorously developed air transportation. However, the volcanic eruption in Iceland in 2010 led to the paralysis of the air transportation industry in Western Europe, which caught Western European countries by surprise and greatly affected the transportation system, exposing the weakness of its lack of resilience.

4.2 The Multi-Functional Strategy

The multi-functional strategy emphasizes the integration of multiple functions in an infrastructure project, and aims to enhance the adaptability of the overall infrastructure system to the impact of disasters through the interweaving, combination and superposition of functions. Versatility can not only enhance the economic and spatial benefits of the project, but also enhance the overall resilience of infrastructure. For example, some expressways in Sweden can take off and land airplanes in addition to the function of driving, so as to ensure that airplanes can still take off normally after being hit at the airport[2]. Similarly, some sections of Shenda Expressway and Zhengmin Expressway in China also have runway functions, which can provide emergency take-off and landing services for passenger and cargo aircraft and military aircraft when necessary[3]. This multi-functional design helps to improve the adaptability and transformation ability of urban infrastructure system to the environment, and maintain or restore the function as soon as possible after the disaster. At present, aiming at the uncertainty and unpredictability of disaster risk, people have more consciously applied the multi-functional strategy in the design and construction engineering. In Lasbah, Denmark, in response to the flood risk brought by climate change, a flood park was designed and built by the designer and local residents. The park not only has general exercise and recreation facilities, but also has three reservoirs, so it has multiple functions such as viewing, exercise, recreation and flood storage, which can help it absorb and adapt to the impact of rainfall, flood and other disasters, and enhance its toughness as well[4].

4.3 The Adaptive Strategy

The adaptive strategy emphasizes that the system should be flexible on the premise that it is unable to accurately recognize the future changes, shocks and disturbances. It is necessary to improve its survival and adaptability through “adapting to changes” and “learning from practice”. As far as infrastructure is concerned, adaptability emphasizes that infrastructure engineering can automatically adapt to environmental changes, especially negative changes. The small-scale flood control project designed by researchers from Nottingham Trent University and a commercial company embodies the “adaptive strategy”. The core device of the small-scale flood control project used to protect low-lying areas is SELOC (self-intercepting low-cost barrier) system, which can rise with the rise of water level without artificial change, therefore, it has stronger toughness to deal with the disturbance and the change of external conditions[5]. In addition to self adaptation, some designers also try to research and develop self-healing technology for infrastructure projects under impact. If it can be successfully applied in practice, it will obviously help to enhance the resilience of infrastructure.

5. Conclusion

The thought of resilience originated from natural ecology pays attention to the ability of system to absorb, adapt to and change the impact of disasters, so as to maintain or restore its own function as soon as possible. This idea opens up a new perspective for the security of infrastructure. From the perspective of resilience, building resilient infrastructure and enhancing the ability of infrastructure projects to absorb, adapt to and transform the impact of disasters are conducive to maintaining or restoring functions as soon as possible after disasters, which is also helpful to ensuring the safe operation of the urban system. Therefore, the construction of resilient infrastructure is an innovative way to enhance the city's comprehensive ability of disaster prevention and mitigation and ensure the proper operation of the city. In practice, the strategies of buffering, versatility, redundancy, diversity and adaptability should be applied to the planning, design and construction of infrastructure projects.

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