Evaluation of Fire Safety Resilience in Urban Communities: A Case Study of Tangshan City

Shuo Liu, Jiefang Tian

School of civil engineering, North China University of Science and Technology, Tangshan 063000, China

Abstract

With the acceleration of urbanization, urban communities are an important place for people's daily life, and their fire safety issues are becoming increasingly prominent. In the face of the threat of emergencies such as fires, improving the resilience of community fire safety, that is, the ability to adapt and recover in response to fires, has become a key issue that needs to be solved urgently. The purpose of this study is to explore the evaluation indicators and methods of fire safety resilience in urban communities, and to provide new ideas and directions for community fire safety construction. The concept of resilience, which emphasizes the self-regulation and resilience of the system in the face of external shocks, has gradually been widely recognized in the field of disaster prevention. As the basic unit of the urban system, the resilience level of the community is directly related to the disaster resilience of the city as a whole. Therefore, from the perspective of resilience, it is of great theoretical significance and practical value to evaluate and study the fire safety of urbancommunities. This study will first sort out the relevant theories of resilience and community resilience, and clarify the connotation and importance of fire safety resilience in community disaster prevention. On this basis, through the study of the existing community resilience index evaluation system at home and abroad, combined with the actual characteristics of urban communities in China, a fire safety resilience evaluation index system suitable for urban communities in China is constructed, and the resilience level of communities in response to fires is strodied. In addition, this study will also use empirical research methods to select communities built in different periods of Tangshan City for case analysis, so as to verify the scientificity and effectiveness of the constructed fire safety resilience evaluation index system. By comparing and analyzing the resilience level and influencing factors of different communities, this paper aims to provide targeted strategies and suggestions for improving the fire safety resilience of urban communities. In conclusion, the evaluation of fire safety resilience of urban communities is of great significance for promoting community fire safety construction and improving the overall disaster prevention capacity of cities. This study will be committed to constructing a scientific and practical evaluation index system, providing theoretical support and decision-making reference for relevant practices, in order to contribute to the sustainable and safe development of urban communities in China.

Keywords

Community Resilience; Fire Safety; Evaluation System Introduction.

1. Research Background

With the continuous acceleration of urbanization [1], the rapid growth of urban population and the dense layout of buildings, the fire risk faced by urban communities has significantly increased. As the core place for the daily life of urban residents, the fire safety situation of

communities not only concerns the life and property safety of individuals, but also has a profound impact on the overall safety and stability of the city.

The "Outline of the 14th Five-Year Plan and Long-Range Objectives Through the Year 2035 for National Economic and Social Development of the People's Republic of China" [2] proposes: "Adapt to the new concepts and trends of urban development, carry out pilot demonstrations of urban modernization, and build livable, innovative, smart, green, humanistic and resilient cities." Building resilient cities has become a new paradigm for urban safety development in the new era. Communities are the most basic units of a city [3]. Fire safety, as an important part of urban safety, enhancing the resilience of community fire safety is of great significance for building resilient cities.

According to the data released by the Fire Rescue Bureau of the Ministry of Emergency Management, the national fire situation in residential areas over the past decade shows that from 2012 to 2021, there were 1.324 million residential fires in China, resulting in 11,634 deaths, 6,738 injuries, and direct property losses of up to 7.77 billion yuan. This indicates that once a fire occurs in a residential area, it often leads to irreversible serious consequences. The frequent occurrence of fire accidents not only reveals many hidden dangers in community fire safety management, but also reflects that traditional fire safety measures may not be sufficient to meet the increasingly complex fire safety needs of cities in the rapid urbanization process [4]. Therefore, it is particularly important to deeply evaluate the resilience of community fire safety. The resilience of community fire safety not only refers to the ability of the community to maintain the minimum life operation after suffering from fires and other emergencies, but also includes its ability to identify and respond to potential risks before a fire occurs.

Through a systematic assessment of the resilience of community fire safety, potential fire safety hazards can be discovered and resolved in a timely manner, and more scientific fire safety management strategies and emergency plans can be formulated, thereby improving the overall ability of the community to deal with fires and other emergencies. In addition, research on the evaluation of community fire safety resilience can also promote policy formulation and implementation, enhance public fire safety awareness, and ultimately achieve continuous optimization and improvement of community fire safety. Therefore, the evaluation of the resilience of community fire safety not only has important theoretical significance, but also has profound practical value, providing a solid foundation for ensuring the life and property safety of residents and social harmony and stability.

2. Research Significance

2.1. Theoretical Significance

Through the research on the evaluation of urban community fire safety resilience, the connotation of resilience can be further explored, enriching the content of resilience theory.

Fire safety is an important category in the field of urban disaster prevention, and community fire safety is the basic guarantee of urban fire safety. Therefore, the research on the evaluation of urban community fire safety resilience helps to promote the in - depth development of community resilience evaluation research.

2.2. Practical Significance

By evaluating the fire safety resilience of communities, potential risks in community fire safety can be identified, providing a scientific basis for formulating targeted improvement measures. The implementation of these measures will effectively improve the fire safety level of communities, reduce the occurrence of fire accidents, and protect the lives and property safety of residents.

Through the research on fire safety resilience evaluation, fire safety management models and methods suitable for urban communities can be explored, providing new ideas and directions for urban fire safety management.

When the government and relevant institutions formulate policies related to the fire safety of old communities, they need to fully understand the current fire safety situation and needs of communities. The research on the evaluation of urban community fire safety resilience can provide a scientific basis for policy - making, ensuring the pertinence and effectiveness of policies.

3. Research Status of Resilience Theory

3.1. Resilience Research

The term 'resilience' originates from the Latin word 'resilire', which refers to the ability of a system or individual to recover from impacts or disturbances[5]. Ecologist Holling [6] applied the term "resilience" to the field of ecology during relevant research stages, using it to describe the ability of ecosystems to automatically recover. Subsequently, the Resilience Alliance expanded the concept of "ecological resilience" to interdisciplinary fields, leading to the continuous development of resilience theory.

As the exploration of resilience theory continues to advance and deepen, the concept of "resilience" is gradually being introduced into the urban domain. In the urban field, resilience theory provides a new concept and approach for cities to cope with complex and changing challenges such as natural disasters, social conflicts, and economic fluctuations[7].

Ahern [8] explores the sustainability and resilience of cities, proposes the concept of "safety failure" through interdisciplinary collaboration and adaptive design, and provides an innovative perspective for urban sustainable development. It emphasizes the necessity of adaptability and resilience, and provides theoretical basis and practical guidance for future urban planning.

Meerow et al. [9] provided a comprehensive description of urban resilience, stating that it refers to the ability of urban systems and their social, ecological, and technological networks to maintain their original state or quickly restore their ideal state and adapt to changes when disturbed. This ability enables urban systems to quickly adapt in different temporal and spatial dimensions to overcome the challenges they need to face.

Resilience theory, as an important and widely influential theory, not only has practical applications in urban planning and development, but also has extremely wide application space in many other fields.

Bruneau [10] first proposed the concept of earthquake resilience, which refers to the ability of ecosystems to remain unchanged in the event of earthquake damage, as well as the ability of systems to self repair after an earthquake.

Walker [11] explored the resilience of social ecological systems through comparative resilience research and theoretical development, and proposed different methods of resource management and governance based on resilience.

3.2. Community Resilience Evaluation

Kammouh O et al[12]. proposed an index method based on the PEOPLES framework, aiming to measure the seismic resilience of urban communities. This method constructs a comprehensive function curve through weighted function functions and matrix - dependent techniques to dynamically evaluate resilience. Taking San Francisco as a case study, it fills the gap in the current quantitative research on community resilience.

Alshehri S A et al[13]. combined the Delphi method with the Analytic Hierarchy Process (AHP) to construct a new framework for evaluating the disaster resilience of Saudi Arabian communities. This framework innovatively proposed a weight system based on expert consensus, achieving both quantitative and qualitative evaluations of community resilience. This not only fills the gap in community resilience assessment tools but also provides a practical assessment tool for enhancing community disaster response capabilities.

Gerges F et al[14]. introduced the Community Intrinsic Resilience Index (CIRI), aiming to quantitatively measure the absolute resilience level of communities in key areas such as transportation, energy, health, and social economy in real - time. With the help of the GIS platform, they strive to make up for the deficiencies in the attribute weight allocation and cross - political - boundary assessment of existing resilience indicators. The ultimate goal is to help decision - makers more effectively evaluate and enhance the ability of communities to respond to natural disasters and accelerate the post - disaster recovery process.

Fox - Lent C[15] proposed a stakeholder - oriented RM framework for evaluating community resilience. By combining qualitative and quantitative data and allowing communities to select their own indicators, this framework enhances the applicability and practicality of the evaluation. At the same time, by cooperating with community professionals, promoting education and participation, and finally presenting the evaluation results in an intuitive visual way, it facilitates project development and decision - making.

4. Research Status of Fire Accidents

4.1. Fire - related Research

Jonathan Corcoran et al[16]. used spatial analysis techniques to deeply analyze the spatial changes of fire events and their relationships with social and economic factors. Filling the gap in fire data analysis in the UK, they used multiple regression and GIS technology to explore the relationship between various types of fires in South Wales and the 2001 population data, providing guidance for fire policy - making. They also expanded the analysis of fire types, thus promoting the development of related fields.

Johansson N et a[17]l. explored the current application status and future potential of fire dynamics theory in fire services through a systematic literature review and interview research. They pointed out that although fire dynamics is widely applied in the prevention and investigation fields, its application in the operational field still needs to be strengthened, especially when dealing with complex building fires. They emphasized the importance of combining theory with practice and the room for improving theoretical knowledge, hoping to promote the development of intelligent fire - fighting technology.

M Taylor et al[18]. analyzed the residential fire injury data of the UK Fire and Rescue Service through chaos theory, aiming to reveal the complex patterns, repetitiveness, interconnection, and sensitivity to initial conditions of fire accidents and injuries, thus filling the gap of traditional statistical methods and enhancing the effectiveness of fire prevention strategies.

4.2. Fire Safety Resilience Evaluation

Yi G W et al[19]. evaluated the fire risk of high - rise buildings using fuzzy characteristic quantities, determined the indicator weights through the Analytic Hierarchy Process (AHP), and applied a comprehensive evaluation model based on fuzzy pattern recognition to establish an evaluation method that can more accurately reflect the fire risk situation of high - rise buildings, providing a basis for performance - based fire protection design and safety management.

Xu M et al[20]. proposed an adaptive fuzzy - RBFNN model combining fuzzy theory and Radial Basis Function Neural Network (RBFNN) for the fire safety assessment of high - rise buildings.

Aiming to improve the efficiency, accuracy, and reliability of the assessment, it solved the problems of qualitative analysis and local minimum traps in traditional methods. Through expert sample training, it verified its ability to quickly and accurately simulate the reasoning process of fire safety experts.

Bai M H et al[21]. established a theoretical framework for urban safety resilience assessment based on a triangular model, combined three indicator systems of fire risk, regional characteristics, and fire resilience, and used the entropy weight method and cloud model for quantitative assessment, filling the gap in urban fire safety resilience research and providing a reference for policymakers.

5. Research Review

By sorting out relevant domestic and foreign literature, it is found that the research on resilience theory mainly focuses on multiple fields such as urban resilience, ecological resilience, and engineering resilience. The research on resilience evaluation mainly focuses on urban resilience evaluation and seismic resilience evaluation. However, the research on the evaluation of urban community fire safety resilience is relatively scarce.

Therefore, this paper takes urban communities as the research object. Based on the characteristics of communities in China, a set of index systems for evaluating the fire safety resilience of urban communities is constructed, aiming to provide a systematic evaluation framework to support the enhancement of the fire safety resilience of urban communities.

References

[1] Cheng Jiao Analysis of the Main Problems and Countermeasures in China's Urbanization Process [J]. Modern Marketing (Next Issue), 2020, (11):7-9.

[2] People's Publishing House The 14th Five Year Plan for National Economic and Social Development of the People's Republic of China and the Long Range Objectives for 2035 [M]. People's Publishing House, 2021

[3] Wu Zhiqiang, Wu Jiang, Zhang Jiali, etc Academic Discussion on the Implementation Mechanism of Renovation and Transformation of Old Urban Residential Areas [J]. Journal of Urban Planning, 2021, (03):1-10.

[4] Zhang Hui Analysis of Problems and Countermeasures in Community Fire Protection Construction [J]. China Science and Technology Wealth, 2010 (16): 297-298

[5] ROSE A. Economic resilience to natural and man-made disasters: Multidisciplinary origins and contextual dimensions[J]. Environmental Hazards, 2007, 7(4): 383-398.

[6] C S Holling. Resilience and Stability of Ecological Systems[J]. Annual Review of Ecology and Systematics, 1973, 4

[7] WALKER B, HOLLING C S, CARPENTER S R, et al. Resilience, adaptability and transformability in social-ecological systems[J]. Ecology and Society, 2004, 9(2): 5-12.

[8] AHERN J. From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world[J]. Landscape and Urban Planning, 2011, 100(4): 341-341.

[9] MEEROW S, NEWELL J P, STULTS M. Defining urban resilience: A review[J]. Landscape and Urban Planning, 2016, 147: 38-49.

[10] BRUNEAU M, CHANG S E, EGUCHI R T, et al. A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities[J]. Earthquake Spectra, 2003, 19(4): 733-752.

[11] WALKER B H, ANDERIES J M, KINZIG A P, et al. Exploring resilience in social-ecological systems through comparative studies and theory development: introduction to the special issue[J]. Ecology and Society, 2006, 11(1): 12.

[12] Kammouh O, Zamani-Noori A, Cimellaro G P, et al. Resilience Assessment of Urban Communities[J]. Collection of Technical Papers - AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 2019, 5(1):04019002.

[13] Alshehri S A , Rezgui Y , Li H .Disaster community resilience assessment method: a consensus-based Delphi and AHP approach[J].Natural Hazards, 2015, 78(1):395-416.

[14] Gerges F, Nassif H, Geng X L, et al. GIS-based approach for evaluating a community intrinsic resilience index[J]. Natural Hazards, 2021.

[15] Fox-Lent C, Bates M, Linkov I. A matrix approach to community resilience assessment: an illustrative case at Rockaway Peninsula[J]. Environment Systems and Decisions, 2015.

[16] Jonathan Corcoran,Gary Higgs,Chris Brunsdon et al.The use of spatial analytical techniques to explore patterns of fire incidence: A South Wales case study.Computers, Environment and Urban Systems,2007

[17] Johansson N, Svensson S. Review of the Use of Fire Dynamics Theory in Fire Service Activities[J]. Fire Technology, 2018.

[18] Taylor M, Francis H, Fielding J, et al. A chaos theory view of accidental dwelling fire injuries[J]. Fire and Materials, 2024.

[19] Yi G W, Qin H L. Fuzzy Comprehensive Evaluation of Fire Risk on High-Rise Buildings[J]. Procedia Engineering, 2024.

[20] Xu M, Peng D. Fire Safety Assessment of High-Rise Buildings Based on Fuzzy Theory and Radial Basis Function Neural Network [J]. Journal of Physics: Conference Series, 2020.

[21] Bai M H, Liu Q. Evaluating Urban Fire Risk Based on Entropy-Cloud Model Method Considering Urban Safety Resilience[J]. Fire, 2023.