

Empowering the Construction of Cultural Gene Maps and the Innovative Activation Design of Historical Districts Through Digital Intelligence

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ABSTRACT

In the context of rapid advancements in artificial intelligence and information technology, promoting industrial upgrade and innovation urgently requires the integration of digital intelligence technologies. For historic districts rich in traditional cultural heritage, the tension between preservation and development has become increasingly acute: it is essential to both safeguard deep cultural roots and leverage cutting-edge technologies to activate economic vitality. Therefore, there is an urgent need to establish a comprehensive theoretical framework and design scientifically grounded strategies to ensure sustainable protection and revitalization of these districts. This study, taking historic districts in southern Fujian, China, as a case example, integrates cultural gene theory with the concept of new-quality productive forces to propose effective revitalization strategies. Firstly, by combining cultural resource surveys, a scheme for constructing a cultural gene map empowered by digital intelligence is proposed. Subsequently, the study explores the application of advanced technologies such as digitalization, virtual reality, mixed reality, and human-computer interaction to formulate specific pathways for revitalization, including digital cultural tourism, intelligent guided tours, and cultural creative product development. The findings of this research not only provide theoretical support and practical guidance for the sustainable protection and revitalization of Minnan's historic districts but also offer valuable insights and reference for the regeneration of cultural heritage spaces in other regions.

Keywords: Historic districts, revitalization design, digital intelligence, cultural genes, new-quality productive forces.

INTRODUCTION

Research Background

The protection and development of cultural heritage sites have long been a topic of intense discussion among industry practitioners and scholars. In an era marked by rapid advancements in artificial intelligence and information technology, the development of related industries urgently requires the integration of AI and digital technologies to foster innovation and facilitate upgrading. China's significant national meetings, including the 20th National Congress of the Communist Party, explicitly emphasized the need to strengthen the protection and inheritance of cultural relics and historical heritage amid urban and rural development, advocating for the promotion of industrial innovation through technological breakthroughs and the cultivation of new-quality productive forces. Notably, in 2024, the concept of "Artificial Intelligence (AI)+" was formally incorporated into China's government work report for the first time. This reflects China's new era approach to heritage protection and cultural revival, which aims to preserve the deep cultural roots while leveraging the theory of new-quality productive forces to activate and innovate cultural sites through cutting-edge technologies such as AI.

The concept of new-quality productive forces (NQPF) is a strategic initiative in China, referring to an advanced productive state driven by revolutionary breakthroughs in technology, innovative allocation of production factors, and in-depth transformation and upgrading of industries. Its core revolves around innovation-driven development, aiming to move beyond traditional economic growth models. This paradigm emphasizes high technology, high efficiency, and high quality, aligning with the country's new development philosophy (National Development and Reform Commission, 2024a, 2024b). For Minnan's historic districts—whose long-standing cultural heritage embodies the essence of China's historical and cultural richness—there is an urgent crisis related to the loss of regional cultural continuity and the ongoing dilemma of balancing preservation with development. Addressing these challenges and seizing opportunities require in-depth exploration of cultural heritage, driven by the transformative power of new-quality productive forces to foster innovative revitalization.

Research Purpose

Given this context, the present study aims to provide effective strategies for the innovative revitalization of historic districts. By integrating cultural gene theory with the concept of new-quality productive forces, this research proposes design strategies for the digital intelligence-driven renewal of Minnan's historic districts.

This study begins by integrating and innovating through the theoretical frameworks of cultural genes and new-quality productive forces. It combines the mechanisms of "replication, selection, recombination, and mutation" from biological genetics with the processes of "inheritance, fusion, innovation, and activation" characteristic of historic districts. Furthermore, it links the concepts of "fusion, innovation, and activation" from cultural gene theory with the principles of "tech-driven innovation, reorganization of production factors, and industrial upgrading" from the theory of new-quality productive forces. The approach involves preserving the core cultural genes that represent the fundamental essence of historic districts, incorporating external genes—driven by technological innovation—and recombining these genes through innovative restructuring of production factors. This process aims to manifest a new form of revitalization characterized by industrial upgrading, thereby fostering a transformative and sustainable cultural and economic renewal.

This study then proposes a "cultural + technology" approach to the innovative revitalization of historic districts, termed "new-quality revitalization design." Building upon China's development trajectory of specimen-style protection, production-oriented development, and design-driven activation of historic districts, this approach leverages interdisciplinary and technological empowerment to enrich the application of design sciences across multiple fields. Central to this methodology is the construction of a cultural gene map, which provides a systematic design framework for the new-quality revitalization of historic districts. Specifically, it involves designing the cultural gene map of historic districts based on genetic inheritance mechanisms, while utilizing AI technologies to empower digital cultural tourism services, intelligent guided tour interactions, and cultural creative product designs, thereby fostering innovative and sustainable revitalization strategies.

LITERATURE REVIEW

Revitalization of Historic Districts

Since the publication of the "Historic Urban Landscape Recommendation" by UNESCO in 2011 (UNESCO, 2011) and China's "14th Five-Year Plan for the Conservation of Cultural Heritage and the Construction of Public Cultural Service System" in 2016 (Ministry of Culture and Tourism & State Administration of Cultural Heritage, 2016), research on the revitalization of historic districts has seen a continuous surge. Scholars have explored strategies and developmental pathways for the protection and transmission of cultural heritage within these districts. Analyses of their value assessment, challenges, and revitalization strategies from political, economic, social, and ecological perspectives have been extensively conducted (Della Spina, 2019; Yang, 2024; Zhu, 2023). Additionally, from the viewpoints of cultural and landscape planning, industrial development, and cultural products and services, researchers have examined evaluation frameworks, strategies for commercial district renewal, and approaches to shaping district images (Eyyamoglu, 2022; García-Hernández, 2017; Shehab El-Deen, 2024; He, 2020).

Cultural Genes

In the study of cultural heritage, the concept of cultural genes has attracted significant scholarly attention, mainly involving the development of theoretical systems and applied research. The foundational research in cultural gene theory can be traced back to Richard Dawkins' (1976) introduction of memetics in *The Selfish Gene*, which posits that cultural genes (memes) exhibit dynamic evolution and fusion during transmission processes (Dawkins, 1981, p. 48). Subsequently, scholars pointed out that cultural genes undergo a process of selection and elimination during inheritance, ultimately retaining gene forms that are adaptive to the characteristics of the times (Blackmore, 2001, pp. 12-14). Cultural genes act as carriers of cultural heritage transmission and preservation and may add or delete certain information during the process (Huang Yunhu, 2025). The theory of cultural genes has also been employed in constructing and designing genealogical systems of cultural heritage, providing frameworks for systematic classification and exploration (Wang Zixiao & Jia Qi, 2025).

Technological Empowerment in the Design of Historic Districts

The application of technological empowerment in the revitalization of historic districts has also become a prominent focus among scholars. Some researchers have innovatively integrated user experience concepts into the protection of cultural heritage within historic districts, developing digital applications based on interaction design and gamification principles (Tan, 2017). By adopting cross-scale research methods, they have applied digital technologies to architecture and landscape fields, constructing prototype design systems that encompass painting measurement, restoration, and regeneration processes, offering valuable references for heritage conservation and landscape reconstruction under contemporary technological contexts (Alici *et al.*, 2019, pp. 357–373). Additionally, scholars have discussed innovative design approaches for historic districts from perspectives such as design development pathways, social participation in design, and digital intelligence-driven design (Lin, 2018; Qian, 2024; Yao, 2024).

Research Gaps and Motivation

In summary, the research trends both domestically and internationally indicate that efforts to revitalizing historic districts increasingly focus on innovative design approaches that build upon preserving cultural gene inheritance while integrating new technologies. Existing studies have laid a necessary foundation; however, several key issues require further exploration. First, constructing comprehensive cultural gene maps for historic districts with distinct regional cultural features demands more in-depth investigation. Currently, most research on cultural genes concentrates on material culture or focuses on isolated contexts, with limited studies specifically examining region-specific districts like Minnan. Second, there is an urgent need to refine the application of the theory of new-quality productive forces in the design of historic district revitalization. Although scholars have increasingly explored technology-enabled protection and inheritance of cultural heritage, the integration of new-quality

productive forces into revitalization strategies needs deeper development. Third, the systematic construction of cross-disciplinary theoretical frameworks remains a promising area for further research.

While the revitalization design of historic districts has demonstrated an interdisciplinary trend, more systematic and comprehensive approaches are necessary. Therefore, studying Minnan's historic districts through interdisciplinary methods—focusing on constructing cultural gene maps and developing new-quality revitalization strategies—presents both significant theoretical challenges and broad application potential. This research aims to take Minnan's historic districts as a case study, establishing a theoretical foundation for constructing cultural gene maps and designing innovative revitalization strategies empowered by digital intelligence to foster sustainable development and dynamic renewal of these culturally significant sites.

CONSTRUCTION OF THE CULTURAL GENE MAP OF HISTORIC DISTRICTS

Field Investigation

In the preliminary stage of this research, a comprehensive survey was conducted on the cultural resources of Minnan's historic districts, including both tangible cultural heritage resources and intangible cultural assets. These resources were systematically categorized into material and intangible cultural systems. The study focuses on prominent Minnan historic districts with notable achievements in architectural conservation and commercial revitalization, such as Gulangyu Island (Figure 1) and Zhongshan Road (Figure 2) in Xiamen; the historic city area (Taiwan Road to Hong Kong Road) (Figure 3) and Qiaocun Dimei Ancient Village (Figure 4) in Zhangzhou; as well as Zhongshan Road (Figure 5) and Xijie Street (Figure 6) in Quanzhou. These districts represent typical, highly characteristic historic neighborhoods in three major southern Fujian cities—Xiamen, Zhangzhou, and Quanzhou (Figure 1). The research also examines the roles and interaction modes of various stakeholders involved in the activation process, including government agencies, cultural heritage management institutions, design teams, community residents, enterprises, and tourists. Emphasizing stakeholder roles and collaborative interactions is crucial for promoting sustainable heritage revitalization.



Source: Xiamen Gulangyu Administrative Committee.
Figure 1: Gulangyu Island, Xiamen City.



Source: Fujian Provincial Government Website.
Figure 2: Zhongshan Road, Xiamen City.



Source: Zhangzhou Municipal Bureau of Housing and Urban-Rural Development website.
Figure 3: The Historic District of Zhangzhou (Taiwan Road to Hong Kong Road).



Source: Zhangzhou Municipal Bureau of Housing and Urban-Rural Development website.
Figure 4: Dai Mei Ancient Village in Zhangzhou.



Source: Quanzhou Municipal People's Government website.
Figure 5: Zhongshan Road in Quanzhou.



Source: Quanzhou Municipal People's Government website.
Figure 6: Xijie (West Street) in Quanzhou.

Conceptual Framework

This framework integrates the theory of cultural genes with the concept of new-quality productive forces to construct a cultural gene map of historical districts. The process involves preserving the core cultural roots of the district's cultural genes, incorporating external genes (driven by technological innovation), and achieving gene recombination and innovation (restructuring production elements), thereby demonstrating a new dynamic of revitalization through industrial upgrading.

First, data-driven intelligent analytics enable the integration and analysis of diverse cultural resources in historical districts, transforming material and intangible cultural systems into explicit and implicit cultural elements. Second, decision-making-focused digital intelligence supports the development of a cultural gene map model, drawing on principles of biological gene inheritance—such as gene replication and external gene fusion—to select and recombine cultural genes within the district. Third, intelligent interactive and content-generating digital tools facilitate visual and interactive design, enabling human-computer collaboration in recomposing cultural genes, which inspires innovative revitalization through interaction, experience, and dissemination.

By combining the theories of cultural genes and new-quality productive forces, the framework for digitally empowering the construction of the cultural gene map and revitalization of Minnan (Southern Fujian) historical districts is illustrated in Figure 7.

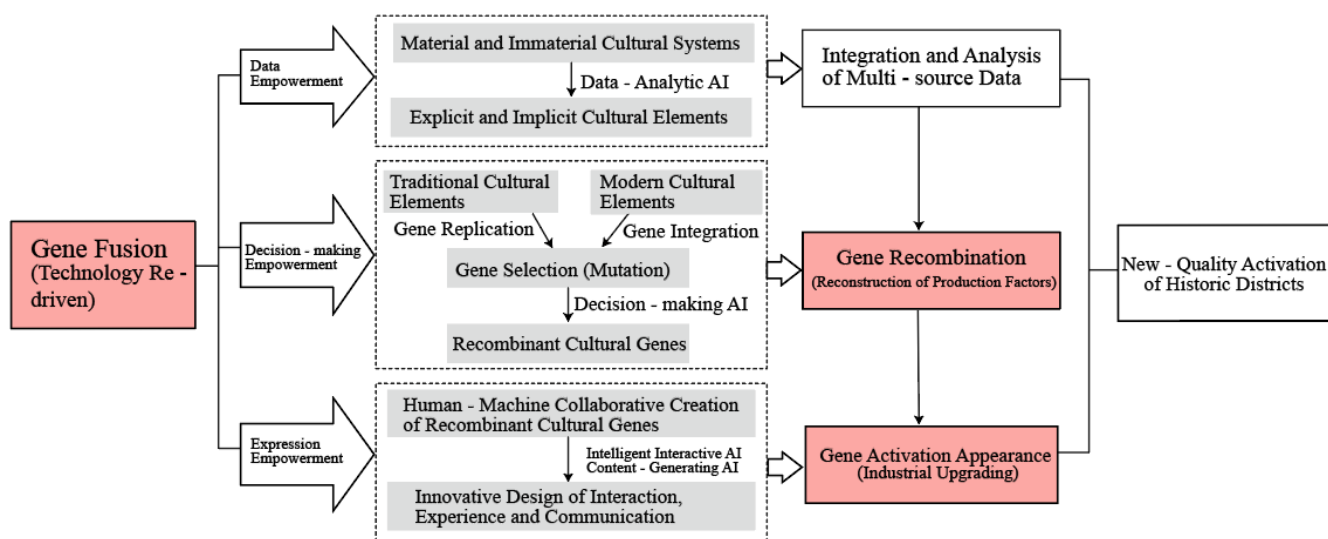


Figure 7: Analytical Framework for Constructing the Cultural Gene Map

STRATEGIES FOR DIGITALLY EMPOWERED NEW-QUALITY REVITALIZATION DESIGN OF HISTORIC DISTRICTS

Interdisciplinary Knowledge System Construction and Paradigm

This study is based on the principles of biological gene inheritance and integrates digital intelligence application technologies to promote interdisciplinary research in the construction of knowledge systems for cultural heritage preservation and inheritance. Building upon theoretical foundations, it proposes a paradigm for digitally empowered new-quality revitalization design of historic districts, as illustrated in Figure 8.

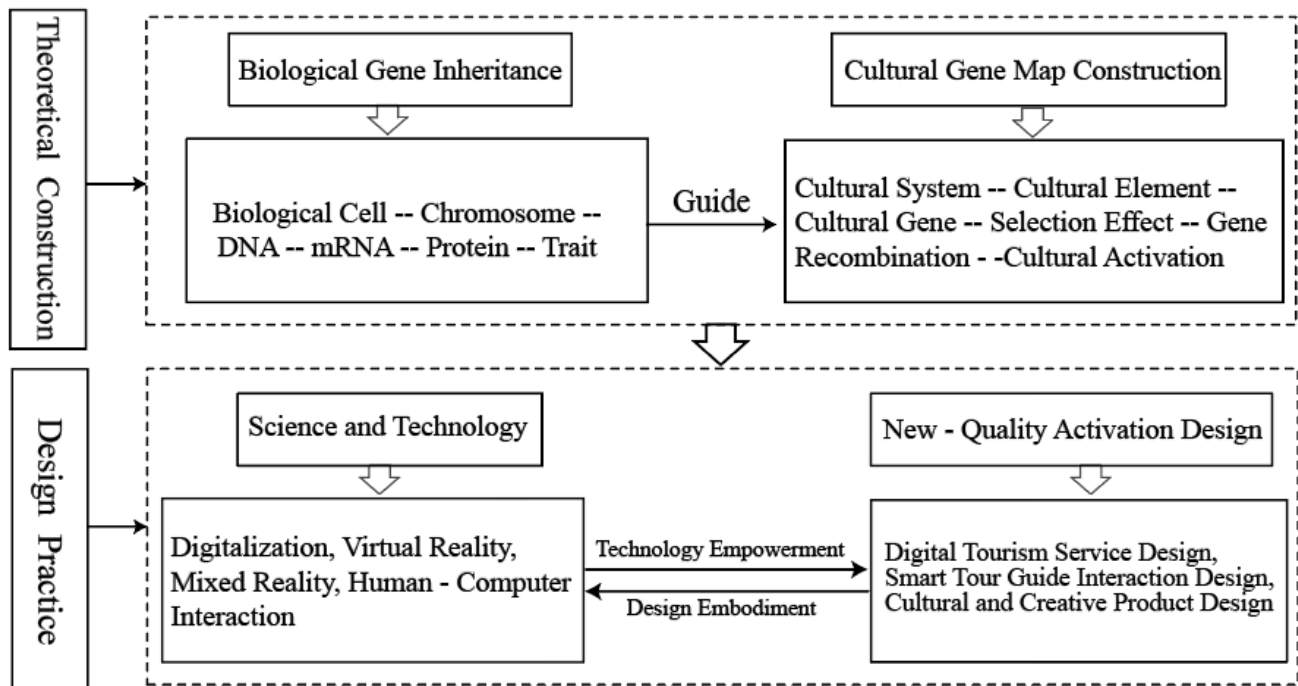


Figure 8: Theoretical Framework and Design Practice

New-Quality Revitalization Design Strategy

We propose leveraging scientific and technological advancements such as digitalization, virtual reality, mixed reality, and human-computer interaction to enable the new-quality revitalization design of historic districts. This includes digital cultural tourism service design, intelligent guided tour interactions, and cultural creative product development. The design process applies the concepts of “new-quality productive forces”—specifically technological innovation, restructuring of production elements, and industrial upgrading—through technological empowerment, human-computer collaborative design, and digital intelligence-driven cultural tourism scenarios. Grounded in the theory of new-quality productive forces and practical revitalization approaches of historic districts, this digital-powered new-quality revitalization model offers insights for the sustainable development of historic districts in the new era.

CONCLUSION

Research Summary

This study takes Minnan historical districts as a case study and systematically integrates the theories of “cultural genes” and “new-quality productive forces.” It proposes an overarching paradigm of “digitally intelligent empowerment for constructing cultural gene maps and designing new-quality revitalization of historical districts,” offering a practical theoretical framework and actionable pathways to address the dilemma between preservation and development. The main contributions and innovations of this research are reflected in the following three aspects:

(1) **Theoretical Integration:** This approach translates the biological mechanisms of “replication—selection—recombination—mutation” into a dynamic model of “inheritance—fusion—innovation—revitalization” for historical districts. It incorporates the concepts of technological breakthroughs, factor restructuring, and industrial upgrading from the “new-quality productive forces,” forming an interdisciplinary theoretical framework that fills the existing gap in research combining “cultural genes” and “new-quality productive forces” in the study of historic districts.

(2) **Methodological Innovation:** The study constructs a three-dimensional “cultural gene map” framework. In terms of data analysis, multi-source integration of material and intangible cultural resources is performed, with the extraction of explicit and implicit cultural elements. For decision-making, the map model facilitates the screening, recombination, and optimal allocation of cultural genes. In the realms of intelligent interaction and content generation, advanced technologies such as VR/MR, human-computer interaction, and generative AI are employed to realize immersive experiences, smart guided tours, and collaborative design of cultural creative products.

(3) **Practical Approach:** The study proposes a “tripartite” strategy of “digital cultural tourism services, smart guided tour interactions, and cultural creative products” in key areas including Gulangyu Island and Zhongshan Road in Xiamen, the ancient city of Zhangzhou and Däi Mei Ancient Village, as well as Zhongshan Road and Xijie in Quanzhou. This “new-quality

revitalization" approach aims to effectively transform technological innovation into sustainable productive forces and industrial value for the districts.

Limitations and Future Research

This study also has several limitations: firstly, the sample is limited to the Minnan region, and its applicability to other areas requires further validation; secondly, technological application faces barriers, posing challenges for broader dissemination and adoption; thirdly, there is a lack of long-term evaluation mechanisms. Future research should focus on three key areas: expanding the scope of study to test the model's adaptability across different regions; developing lightweight technological solutions to reduce application barriers; and establishing multi-stakeholder participation mechanisms to improve evaluation systems. These directions will promote the deepening of research on the revitalization of historic districts.

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REFERENCES

- Alici, A., Bonvini, P., Clini, P., Ferretti, M., Malinverni, E.S., Mariano, F., ... & Quattrini, R. (2019). Cultural heritage and landscape: Analysis, digitization and design aiming at a resilient future. *In The First Outstanding 50 Years of "Università Politecnica delle Marche" Research Achievements in Physical Sciences and Engineering* (pp. 357–373). Springer International Publishing.
- Blackmore, S. (1999). *The meme machine* (G. S. Gao & others, Trans.). Jilin People's Publishing House.
- Dawkins, R. (1976). *The selfish gene* (Y. Lu, D. Zhang, et al., Trans.). Science Press.
- Della Spina, L. (2019). Multidimensional assessment for "culture-led" and "community-driven" urban regeneration as a driver to trigger economic vitality in urban historic centers. *Sustainability*, *11*(24), 7237. <https://doi.org/10.3390/su11247237>
- Eyyamoğlu, M., & Akçay, A.Ö. (2022). Assessment of historic cities within the context of sustainable development and revitalization: The case of the walled city North Nicosia. *Sustainability*, *14*(17), 10678. <https://doi.org/10.3390/su141710678>
- García-Hernández, M., De la Calle-Vaquero, M., & Yubero, C. (2017). Cultural heritage and urban tourism: Historic city centres under pressure. *Sustainability*, *9*(8), 1346. <https://doi.org/10.3390/su9081346>
- Shehab El-Deen, A.S., Aboulsaadat, A.H., & Nour, W.A. (2024). Reviving the past: Urban strategies for renovating historic commercial streets in city centers. *Journal of Engineering and Applied Science*, *71*(1), 155. <https://doi.org/10.1186/s44147-024-00488-6>
- Tan, K.L., & Lim, C.K. (2017). Digital heritage gamification: An augmented-virtual walkthrough to learn and explore tangible cultural heritage. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, *9*(2-12), 125–129.
- UNESCO. (2011). *Recommendation on the historic urban landscape*. United Nations Educational, Scientific and Cultural Organization. Retrieved from <https://whc.unesco.org/en/hul/> (accessed 30 July 2024).
- National Development and Reform Commission. (2024). *Promoting high-quality development and achieving deep industrial transformation and upgrading*. Retrieved from http://www.ndrc.gov.cn/wsdwhfz/202402/t20240206_1363980.html (accessed 30 July 2024).
- National Development and Reform Commission. (2024). *The connotation and development direction of new-quality productive forces*. Retrieved from http://www.ndrc.gov.cn/wsdwhfz/202403/t20240301_1364322.html (accessed 30 July 2024).
- He, S. (2020). Landscape narrative perspective on gateway landscape design in historic cultural districts. *Urban Architecture*, *17*(17), 155–158. <https://doi.org/10.19892/j.cnki.csjz.2020.17.058>
- Huang, Y. (2025). A tripartite exploration of traditional crafts empowering rural revitalization—Based on cultural gene decoding and reproduction theory. *Journal of Zhengzhou University of Light Industry (Social Sciences Edition)*. Advance online publication.
- Lin, N. (2018). Source-based design journey: Participatory creation of "Our City" in the neighborhood. *Design*, *22*, 78–83.
- Qian, C., Wang, Y., Li, S., & Wang, J. (2024). An initial exploration of artificial intelligence in the protection of historic cultural districts. *Future Urban Design and Operation*, *9*, 43–48.
- Wang, Z., & Jia, Q. (2025). Construction and translation of the cultural gene lineage in Luoyang's cultural tourism district from an immersive experience perspective. *Agriculture and Technology*, *45*(14), 109–114.
- Ministry of Culture and Tourism & National Cultural Heritage Administration. (2016). *Plan for the protection of cultural heritage and the construction of public cultural service system during the 13th Five-Year Plan*. Retrieved from http://www.gov.cn/zhengce/content/2016-11/07/content_5127089.htm (accessed 30 July 2024).
- Yang, Y. (2024). Strategies for the revitalization and utilization of historic cultural districts under urban renewal. *Economic Forum*, *12*, 56–64.
- Yao, K. (2024). Creative design strategies for ancient city renewal under urban revival—Taking the Pingtang historic district of Gusu District, Suzhou, as an example. *Architectural Design Management*, *41*(1), 73–79.
- Zhu, H., Yu, H., & Wang, J. (2023). Perceptions of the effects of local cultural reconstruction in historic districts: A case study of Beijing Qianmen. *Geography and Geographical Information Science*, *39*(3), 137–144.