International Journal of Urban Management and Energy Sustainability (JUMES)

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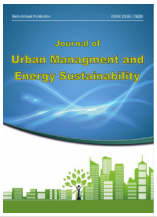

CASE STUDY RESEARCH PAPER

Explaining the effective indexes in the restoration of the natural landscape (Case Study: ancient Iranian historical bridges)**

Fatemeh Rostami, Ghazal Keramati*, Hossein Soltan Zadeh

Department of Architecture, CT.C., Islamic Azad University, Tehran, Iran

ARTICLE INFO

Article History:
Received 2025-04-27
Revised 2025-06-22
Accepted 2025-08-08

Keywords:
Bridges of ancient Iran, historical bridges, indexes of natural landscape restoration, landscape, natural landscape and architecture

ABSTRACT

Historical buildings, especially architectural structures such as bridges, hold a special place in architecture and the natural landscape, reflecting humanity's ability to combine art and function. Currently, many restoration projects in third-world countries are carried out without adequate attention to natural landscape and architectural indexes, leading to a decrease in the cultural and aesthetic values of the monuments. Meanwhile, throughout history, the architecture of ancient Iranian bridges has played a significant role not only as functional structures but also as cultural and artistic symbols in shaping the natural and cultural landscape of the region. The aim of this study is to examine and develop effective indexes for restoring the natural landscape of ancient Iranian historical bridges. This research is analytical with a practical purpose. The paradigm of the study is interpretive, and the research design is qualitative. Data collection was conducted through library and documentary methods. Initially, content analysis and inductive reasoning were used, followed by a participatory decision-making approach utilizing the fuzzy Delphi model. The findings indicate that conservation of architectural elements, restoration standards, and resilient materials rank highest, with scores of 23.4, 19.4, and 16.4, respectively, in finalizing the model. The conclusion is that the identified indicators should be assessed collectively and simultaneously so that restoration projects can maintain their durability, sustainability, and cultural identity in the long term, and the natural landscape of historic bridges can be properly preserved and restored. Future studies could explore the internal and structural relationships among the indicators.

DOI: 10.22034/ijumes.2025.2063285.1315

Running Title: Restoration of the natural landscape of ancient Iranian historical bridges

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
22	02	09

*Corresponding Author:
Email: *gh.keramati@iauctb.ac.ir*
Phone: +989122056174
ORCID: https://orcid.org/0000-0002-1029-2495

**This article is taken from Fatemeh Rostami's doctoral dissertation thesis entitled: "Compilation of Guidelines for the Reconstruction of Natural, Architectural and Historical Landscape of Ancient Iranian Bridges" which is currently being conducted at the Islamic Azad University of Tehran Center (CT.C, Tehran, Iran) under the guidance of Dr. Ghazal Keramati and the advice of Dr. Hossein Soltan Zadeh.

INTRODUCTION

Cultural heritage is considered the enduring symbols of a nation's identity and history, playing a fundamental role in preserving and transmitting core values, beliefs, and arts (Nejad Ebrahimi et al., 2020). Among various types of this heritage, historic buildings and especially architectural structures like bridges hold a special place in architecture and the natural landscape, reflecting human ability to combine art and functionality (Morooj Torbati and Pournadery, 2013). In ancient Iran, bridges were not only pathways but also cultural and architectural symbols of the era, shaping regional cultural identity and the public landscape through natural and structural elements (Pour Bahador and Fadaei Nejad, 2013). According to numerous studies, these bridges serve as key elements in natural landscape design, contributing to the balance between environmental structures and nature (Pour Yusef et al., 2021). Several factors, including the passage of time, natural influences, urban development, and human activities, have led to deterioration, destruction, and damage to these structures (Kazemi, 2017). Neglecting the preservation of landscape systems results in a decline in the aesthetic, historical, and cultural values of these monuments, emphasizing the importance of their restoration and conservation (Ghani et al., 2023; Jensen et al., 2009). In the process of cultural heritage restoration, reliance on specific indicators and criteria is vital for more precise and scientific conservation and for ensuring their continuity and credibility (Ahmadi and Fattahianpour, 2016). These indicators essentially serve as mirrors that assess the value, condition, and capabilities of a historic site, guiding the design and implementation of restoration processes (Pour Mohammadi et al., 2020). Regarding the natural landscape, indicators such as harmony with the environment, authenticity, continuity, and sustainability are particularly important, influencing restoration projects (Taylor, 2008; ESF, 2010; Guo et al., 2010). These indicators not only aid in maintaining the appearance and function of the structure but also play a key role in reviving its cultural and aesthetic significance (Taylor and Lennon, 2011; Head, 2007). Given the importance of landscape perspective and aesthetic considerations in heritage conservation, many studies have focused on using visual, spatial, and perceptual indicators to simultaneously preserve and revive cultural heritage and natural landscape (Torkashvand et al., 2017). Currently, many restoration projects in third-world countries are carried out without sufficient attention to natural landscape and architectural indicators, leading to a reduction in the cultural and aesthetic values of the monuments (Pir Hiyati and Anisi, 2021). Throughout history, the architecture of Iran's ancient bridges has played a significant role not only as functional structures but also as cultural and artistic symbols shaping the natural and regional cultural landscape (Morooj Torbati and Pournadery, 2013). Notable examples of such structures include the Daryacheh Bridge in Kermanshah and the Marunn Bridge in Isfahan, each holding a special place in Iran's history and regarded as symbols of architectural and scenic heritage (Fig. 1 and 2).

Considering the importance of these examples, many studies have been conducted in the field of cultural heritage restoration and preservation. However, most of these studies have focused on the physical and architectural structure of the monument, with less attention given to the natural landscape and the indicators influencing its reconstruction. As a result, restoration processes often neglect specific considerations of the natural landscape and its impact on the cultural and aesthetic function of the monument, leading to a decline in its cultural and natural landscape values. One significant gap in the research domain is the lack of a comprehensive and scientific approach to developing effective indicators for restoring the natural landscape of these monuments. Many projects are carried out conventionally without clear and scientific criteria, which not only diminishes the cultural heritage value but also damages the natural landscape and indigenous

Figure 1: View of the ancient Dokhtar Bridge in Pol-e-Dokhtar County

Figure 2: View of the ancient Marnon Bridge in Isfahan city

identity of the monument. (Labadi et al., 2021, Lan et al., 2021) Alongside these research gaps, advances in modern technologies in design and restoration offer new opportunities to develop and utilize effective indicators. However, the absence of a coherent and practical framework in this field continues to hinder the development of projects based on scientific principles. Therefore, the need for comprehensive research to identify and develop key and effective criteria and indicators for the natural landscape reconstruction of Iran's historic bridges is increasingly felt. Case studies, like the restoration of the Khaju Bridge in Isfahan, can serve as reference models and scientific guides for other restoration processes. Additionally, a new approach based on multi-dimensional analyses, including architectural, aesthetic, natural, and cultural indicators, should be considered to improve restoration operations. This approach can help enhance the quality of restoration projects and improve the protective and sustainable level of the monument (Palang et al., 2005; Plieninger and Pulido, 2009). The main issue is that the lack of scientific models and practical standards has challenged the restoration and reconstruction processes of the natural landscape of historic bridges, necessitating comprehensive and practical research to address these gaps. (Dong shu et al., 2024, Qiang, 2024) Furthermore, better understanding of case examples and analysis of damages and opportunities in these projects can provide a suitable framework for the future and prevent the repetition of past damages. This research aims to answer the question of which indicators can influence the natural landscape reconstruction of Iran's historic bridges and how these indicators can be integrated into restoration processes to develop a comprehensive operational model and framework.

Therefore, developing effective indicators enables restoration processes to be guided by a scientific and coherent approach, ensuring the preservation of the monument over time (Palang and Fry, 2003). By focusing on case studies of Iran's historic bridges, key components and specific indicators that influence natural landscape restoration can be identified. This study aims to propose functional and impactful indicators through precise and scientific analysis, and to present an operational framework. Consequently, the ultimate goal is to develop basic criteria and actionable indicators that can improve the restoration of historic sites and preserve their natural landscape in a sustainable and aesthetically pleasing manner. To achieve this goal, the main question is which architectural landscape indicators play a key role in the reconstruction process of Iran's historic bridges and how they can be effectively applied in restoration projects. The overall aim is to design a scientific and practical framework that, through a deep understanding of cultural, natural, and architectural needs, guides the restoration process towards sustainability, cultural identity preservation, and aesthetic enhancement. Subsequently, the importance of these indicators and the proposed framework in improving the management and continuity of Iran's cultural heritage becomes clear, ultimately offering practical and scientific solutions for future projects. Based on this, an initial conceptual model of key components can be proposed. This model includes four main components, each comprising several important indicators. (Tab. 1)

For each component, several key indicators are defined that can guide evaluation, analysis, and decision-making in the restoration and reconstruction process. Architectural and structural indicators include: compatibility of new materials with historic materials, resistance to earthquakes and natural factors, preservation of the original form and shape of the monument, and structural cohesion and durability. For visual landscape indicators: the degree of conformity and harmony with the natural landscape, spatial and perceptual quality of the monument, the extent of preserving and enhancing visual appeal, and measurement of the impact on the regional landscape. For natural and ecological indicators: the extent of preservation and improvement of the surrounding ecosystem health, compatibility of the natural setting with the restorative effect, reduction of negative impacts on the biotope, and sustainable utilization of natural resources in the restoration process. For cultural and identity indicators: preservation of the cultural and architectural authenticity of the monument, impact on the region's cultural identity, the degree of people's understanding and sense of belonging to the monument, and effective connection of the monument with local life and cultural heritage. (Tab. 2) (Fig. 1)

MATERIALS AND METHODS

Research Background

In the field of study and research on the restoration and reconstruction of the natural landscape and cultural heritage of Iran's historic bridges, numerous researchers have adopted various approaches. For example, Karmi (2006) in the article "Revisiting the Engineering of Khaju Bridge" aimed to examine the technical and cultural issues of this monument using qualitative analysis, and the findings showed that neglecting aesthetic and natural considerations has led to a decrease in the cultural value of the monument. Shohany (2013) in the study "Examining the Role of Landscape in Bridge Restoration" aimed to investigate the impact of the natural landscape on the restoration process using comparative analysis and sampling methods, concluding that simultaneous attention to natural elements and landscape in restoration projects enhances cultural identity and sustainability of the monument. Farzaneh et al. (2011) in the article "Exploring the Manifestation of Sadralian Wisdom in Isfahan's Architecture during the Safavid Era" focused on structural and architectural form analysis, applying architectural and

Table 1: Natural landscape components of historical bridges

Component	Importance in Heritage Preservation	Assessment Tools	Main Responsibilities
Architectural and Structural Component	Very High	Material tests, sampling, imaging	Architectural engineers, material scientists, restoration technical team
Aesthetic and Visual Landscape Component	Moderate importance for visual appeal	Photography, surveys, visual evaluation	Landscape designer, architect, visual expert, sociologist
Natural and Ecological Component	Vital for sustainability of the monument	Biological assessments, ecosystem health measurement	Environmental specialists, ecologists, natural resources officials
Culture and Identity Component	Very High	Interviews, cultural studies, heritage analyses	Cultural experts, sociologists, cultural managers

Table 2: Effective components and indexes in restoring the natural landscape of historic bridges in ancient Iran

Components	Key Indicators	Descriptions
Architectural and Structural	Compatibility of materials with historic artifacts	Preservation of architectural identity and original materials of the monument
	Structural resistance and durability	Resistance to earthquakes, wind, and natural factors
	Preservation of original form and dimensions	Maintenance and restoration of the historic shape of the monument
	Structural cohesion	Structural stability and prevention of secondary damages
Visual Landscape	Compatibility with natural landscape	Harmony and coordination with the surrounding environment
	Visual quality	Visual impact and attractiveness of the monument in the regional landscape
	Preservation of spatial integrity	Balance and alignment of landscape elements and the monument
	Visual appeal	Enhancement of aesthetic beauty and visual attractiveness of the monument
Natural and Ecological	Preservation and enhancement of ecosystem health	Maintaining the riverbed and surrounding ecosystem
	Minimizing negative impacts on biota	Reducing human interference and damages
	Sustainability of natural resources	Sustainable utilization during restoration operations
	Alignment with natural structure	Compatibility between the structural form and natural environment
Cultural and Identity	Preservation of cultural authenticity	Maintaining cultural elements and historical values
	Strengthening local identity	Impact on the sense of belonging and enduring heritage
	Connection with national heritage	Preservation of cultural and historical principles and norms
	Community impact	Local participation and awareness raising

historical analysis methods, revealing that durable structures and historic forms can be effective in the restoration process. Pir hayati and Anisi (2021) in their research "Defining Principles of Cultural Landscape Preservation of the Karkhan River Historic Bridges in Lorestan" aimed to develop landscape design principles for restoration projects; through reviewing global experiences and interviews with restorers, they concluded that recreating the natural landscape enhances aesthetic appeal and the monument's identity. Azizi (2023) in the study "Evolution of Bridge Construction in the Architecture of Historic Bridges" aimed to evaluate suitable materials for preservation and durability, introducing resistant options compatible with the old structure through technical tests. Hassanpour et al. (2022) in the article "Typology and Influential Factors in the Formation of Architectural Bridges in Gilan Province, with a Focus on the Safavid and Qajar Eras" aimed at environmental protection, assessing the impact of restoration operations on surrounding ecosystems, showing that design based on biological indicators and sustainable architecture leads to better protection of the monuments. Karimian (2022) in the article "The Role of Architectural Elements in Preserving the Historic Identity of Bridges" aimed to examine the relationship between form and architectural elements with cultural identity, and through analyzing historic examples, demonstrated that matching modern architecture with old elements directly enhances the sense of belonging. Rahimi (2023) in the research "Aesthetic Indicators in Restoration Operations" aimed to develop aesthetic indicators and employed visual analysis methods, indicating that balancing natural and structural elements results in higher social satisfaction. Torbati and Pour Naderi (2023) in the study "Continuity of Effective Traditions in the Formation of Khaju Bridge Based on Comparative Study of Historic Bridges in Isfahan" aimed to develop sustainable restoration models, concluding from comparative analysis of domestic and foreign examples that adherence to sustainability indicators guarantees the quality of restoration operations. However, Valibeyg and Jahangard (2023) in the article "Visual Representation of the Morphological Changes of Si O Seh Bridge Based on Analysis of Historical and Visual Documents, with an Emphasis on Modeling Bridge Nooks" aimed to enhance community participation and cultural promotion; As a case study of several projects, it showed that active local participation leads to cultural sustainability and community support. Smith (2010) in the article "Heritage Conservation and Landscape Integrity" aimed to examine the relationship between heritage architecture and natural landscape through a comparative analysis approach.

Results showed that integrating natural landscape elements with architecture in the restoration process helps preserve cultural identity and ensures the sustainability of the monument. Johnson (2012), in the study "Sustainable Restoration Methods," using case study methods and data analysis, demonstrated that utilizing local materials and modern technologies in restoring historic buildings increases durability and reduces costs. Brown (2013), in the article "Cultural Landscape Management," aimed to evaluate management strategies for cultural landscapes. The findings indicate that community participation and the use of cultural indicators significantly influence the effectiveness of the restoration process. Martin (2014), in their study "Structural Analysis of Historic Bridges," focused on the structural analysis and reinforcement of such bridges, and proposed safe and compatible restoration strategies using digital technologies and material analysis. Lee (2015), in the article "Environmental Impacts of Restoration Operations," examined how restoration activities should align with environmental indicators. The conclusion revealed that an ecological approach ensures ecosystem health and landscape preservation. Walker (2016), in research titled "Heritage Site Branding and Community Engagement," aimed to enhance local attachment and participation through cultural advertising and

community interactions; the study showed that community ownership feelings strengthen the sustainability of the restoration process. Carter (2017), in the study "Innovations in Materials for Heritage Conservation," focused on developing resistant materials and modern technologies for restoring historic buildings, demonstrating through laboratory research that using these materials significantly impacts the durability and delicacy of restoration. Miller (2018), in the article "Visual Impact of Heritage Restoration," examined aesthetic indicators and the impact of restoration on the public landscape. Findings indicated that harmonizing natural and architectural elements enhances the visual value of the monument. David (2019), in the research "Integration of Modern Technologies in Heritage Sites," reviewed digital technologies for recording, documenting, and restoring historic artifacts; using 3D modeling and virtual reality increases the accuracy of restoration processes. Wilson (2021), in the article "Adapting to Climate Change in Historic Sites," studied the impact of climate change on these sites and developed resilient strategies with scientific approaches, showing that such approaches reduce the adverse effects of climate change and guarantee the sustainability of artifacts. Martin (2022), in the research "Material Durability and Aesthetics in Restoration," examined the longevity of materials and the preservation of aesthetic beauty in cultural works, demonstrating that resistant materials, together with maintaining historical appearance, enhance the final quality of the monument. (Tab. 3)

Table 3: Research background review

Researcher Name	Year	Topic	Method	Type of Research	Systematic Approach	Findings	Conclusion
Karmi	2006	Revisiting Khaju Bridge Engineering	Qualitative Analysis	Case Study	Qualitative Analysis	Ignoring aesthetic and natural considerations reduces cultural values of the monument	Neglecting aesthetic and natural factors diminishes cultural significance
Shohany	2013	Examining the Role of Landscape in Bridge Restoration	Comparative Analysis	Comparative Study	Sampling and Comparative Analysis	Impact of natural landscape on the sustainability and cultural identity of the monument	Attention to natural landscape is important in restorations
Farzaneh et al.	2011	Manifestation of Sadralian Wisdom in Isfahan's Architecture during the Safavid Era	Structural and Historical Analysis	Deep Architectural and Historical Analysis	Structural and historical analysis	Durable structures and historic forms are effective in restoration	Structural elements and forms are essential in effective restoration
Pir hayati and Anisi	2021	Principles of Cultural Landscape Preservation of Karkhan River's Historic Bridges in Lorestan	Review of Global Experiences	Comparative Study	Review and analysis of global experiences	Recreating natural landscape completes the monument's restoration	Natural landscape plays a key role in restoration
Azizi	2023	Evolution of Bridge Construction in Historic Bridges Architecture	Technical Tests	Testing and Evaluation	Material and Structural Tests	Resistant materials compatible with the old structure identified	Appropriate materials significantly impact durability

Researcher Name	Year	Topic	Method	Type of Research	Systematic Approach	Findings	Conclusion
Hassanpour et al.	2022	Ecosystem Conservation During Restoration of Historic Sites	Ecological Impact Assessment	Field Study	Ecological Indicators Evaluation	Design based on ecological indicators ensures better protection	Environmental protection should be prioritized
Karimian	2022	The Role of Architectural Elements in Preserving the Historic Identity of Bridges	Analysis of Historic Examples	Architectural Analysis	Comparative and Field Analysis	Modern architecture matching old elements is effective	Matching architectural elements affects the monument's identity
Rahimi	2023	Aesthetic Indicators in Restoration Operations	Visual and Indicator Analysis	Analytical Study	Image Analysis and Indicator Mapping	Preservation of balance between natural and structural elements is satisfactory	Elemental balance has a positive impact
Torbati and Pour Naderi	2023	Continuity of Effective Traditions in the Formation of Khaju Bridge Based on Comparative Study of Historic Bridges in Isfahan	Case Study	Workshop Study	Qualitative Analysis and Field Observation	Active local participation leads to better sustainability of the monument	Community participation is essential
Valibeyg and Jahangard	2023	Visual Representation of Morphological Changes of Si O Seh Bridge Based on Analysis of Historical and Visual Documents with Emphasis on Modeling Bridge Nooks	Technical Tests	Material Evaluation	Environmental and Mechanical Testing	New materials compatible with old structures identified	Resistant and compatible materials are important
Smith	2010	Heritage Conservation and Landscape Integrity	Comparative Analysis	Case Study	Comparative and Case Study Analysis	Reuse based on new functions preserves cultural and functional value	Adaptive reuse is effective in restoration
Johnson	2012	Methods of Sustainable Restoration	Climate Impact Assessment	Experimental Study	Impact Assessment and Modeling	Designing resistant structures against climate change is important	Need for climate-resilient design
Brown	2013	Cultural Landscape Management	Novel Material Testing	Testing and Evaluation	Laboratory and Modeling	New materials have longer durability and compatibility	Resistant materials are key in preserving monuments
Martin et al.	2014	Structural Analysis of Historic Bridges	Field and Sample Analysis	Comparative Study	Sample and Comparative Analysis	Natural landscape design enhances cultural and natural value	Effective landscape planning is beneficial

Researcher Name	Year	Topic	Method	Type of Research	Systematic Approach	Findings	Conclusion
Lee	2016	Heritage Site Branding and Community Participation	Case Study	Qualitative Study	Active Community Engagement	Community involvement guarantees the sustainability and preservation of the monument	Community collaboration is fundamental
Walker	2016	Heritage Site Branding and Community Engagement	Digital Technologies	Technology Research	Development of Software and New Technologies	Digital documentation enables rapid and precise analysis of monuments	Technology increases restoration efficiency
Carter	2017	Material Innovation in Heritage Conservation	Cultural Analysis	Comparative Study	Cultural Value Assessment	Proper understanding of cultural values leads to more effective restoration and preservation of authenticity	Cultural values impact restoration
Miller	2018	Visual Impact of Heritage Restoration	Structural Measurement	Experimental Study	Structural Monitoring Systems	Monitoring systems increase the lifespan and safety of bridges	Structural health monitoring is effective for maintenance
David	2019	Integration of Modern Technologies in Heritage Sites	Policy Evaluation	Analytical Study	Technology and Policy Analysis	Natural and green technologies reduce environmental impacts and cost	Sustainable strategies are key
Wilson	2021	Adapting to Climate Change in Historic Sites	Economic and Cultural Analysis	Case Study	Economic and Behavioral Analysis	Landscape-based tourism promotes preservation and sustainable income	Tourism is an effective preservation tool

In reviewing the research background in the field of natural landscape and cultural heritage restoration of historic bridges, the role of modern technologies, resistant materials, and community participation methods are identified as key factors. Domestic studies emphasize the importance of preserving cultural identity, architectural elements, and natural values during the restoration process, while foreign research focuses more on digital technologies, structural reinforcement, and the development of sustainable policies. This synergy indicates that the restoration of historic sites requires multidimensional approaches incorporating a wide range of technical, cultural, and managerial tools. Additionally, comparative analyses between global and domestic experiences show that tailoring efforts to local contexts and understanding the values involved play significant roles in achieving successful restorations, highlighting the importance of community participation for project sustainability. Furthermore, the use of new materials and digital technologies has been implemented in many projects due to cost reduction and increased accuracy, yet maintaining cultural authenticity and harmony with historic structures remains a challenge. On the other hand, studies indicate that natural landscape and historic site restoration should be integrated with environmental preservation and economic development to ensure both cultural sustainability and sustain-

able growth. These points suggest that the field of restoration needs ongoing interdisciplinary research, and leveraging advanced technologies alongside valuing culture and art can lead to a promising future. There is also a need for more comprehensive research on integrating modern technologies, compatible materials for old structures, and the role of culture in the restoration process. For example, developing technologies such as structural monitoring systems and digital mapping can make restoration processes faster and more precise. Additionally, utilizing smart technologies and innovative materials can enhance structural durability and reduce maintenance needs. Simultaneously, further research on community participation, stakeholder collaboration, and the role of cultural values in decision-making is essential. These approaches not only guarantee the preservation of cultural identity but also contribute to the social and economic sustainability of restoration projects. Therefore, current research should focus on advancing digital technologies, sustainable materials, and valuing cultural assets. This study, centered on the restoration and reconstruction of natural landscapes and the cultural heritage of historic bridges, can help address challenges related to maintaining authenticity. By employing advanced technologies, this research can propose smart and sustainable restoration plans that improve structural lifespan while preserving cultural and natural values. Additionally, by emphasizing active community involvement, it will develop innovative solutions to foster ownership and social sustainability, which are crucial in the restoration process. Examining the role of new materials and digital technologies in old structures can improve implementation processes and reduce costs while maintaining cultural sensitivity. Moreover, this research can provide management and policy models for the sustainable protection and utilization of heritage monuments aligned with international approaches. As a result, existing technical and cultural gaps in the field of historic bridge restoration will be addressed, providing a scientific and practical framework for future restorations. One of the strengths of this study is its focus on integrating technology with cultural values, as solely applying technology or cultural preservation alone has often been inadequate. This research can combine innovative technological solutions with the preservation of cultural authenticity to offer a practical model for restoring historic bridges. This approach not only preserves functional and symbolic values but also enables better utilization and continuous management of the site.

Methodology

The current research is of an analytical nature with an applied objective. The research paradigm is interpretive, and the research design is qualitative. The data collection method is library and documentary, utilizing content analysis and inductive reasoning. Initially, content analysis is used for a systematic and detailed review of documents, methods, and restoration experiences. This stage involves collecting a set of documents, articles, project reports of internal and external restoration efforts, and past restoration records, then coding and categorizing topics related to the restoration of historic sites. After identifying the needs and challenges, a fuzzy Delphi method is employed to gather expert opinions and insights. This method includes selecting experts and specialists in cultural heritage and natural landscape restoration based on their expertise, experiences, and relevant knowledge; designing preliminary questionnaires with options and ambiguous spaces to collect diverse expert opinions; conducting multiple rounds of questionnaires, analyzing results and refining opinions, converging perspectives. Following the collection of expert opinions, modeling and prioritization methods are used, including combining content analysis results and fuzzy Delphi opinions within multi-criteria decision-making models to identify the top strategies, applying weighting indices, and performing multi-criteria decision analysis to rank proposed options;

finally, a comprehensive evaluation based on technical, cultural, economic, and sustainability criteria, along with recommendations for the best methods and materials for restoring historic bridges. In the end, the designed model and proposed strategies can be evaluated through case studies or pilot projects in future research. Consequently, the proposed methodology is an integrated approach that leverages content analysis for deep understanding, fuzzy Delphi for expert consensus, and decision modeling for prioritization and implementation. This comprehensive, multi-level approach addresses the research questions and objectives in the fields of historic site restoration and natural landscape preservation.

DISCUSSION AND FINDINGS

Based on the initial findings in the research sections, a table has been prepared listing 18 main factors influencing the restoration and reconstruction of natural landscapes and cultural heritage of historic bridges. This table organizes the key factors according to the factor name, component, criterion, and relevant explanations. (Tab. 4)

The process of implementing the Delphi method to develop effective indexes in the restoration of the natural landscape of historical bridges in ancient Iran

Findings from implementing the Delphi method

In the first round, the panel members identified 12 out of 18 factors extracted from successful research as having a high or very high impact on

Table 4: Proposed factors derived from content analysis in developing effective indicators for restoring the natural landscape of ancient Iranian historic bridges

Factor	Explanation	Component	Criterion
Resistant Materials	Materials should be resistant and compatible with the historic structure.	Type of materials, durability, compatibility with old structures	Durability, compatibility, aesthetics
Digital Technologies	Utilizing modern technologies for better management of restoration.	Documentation, mapping, structural monitoring	Accuracy, speed, cost
Principles of Natural Landscape Design	Landscape design should align with the natural environment and historic structure.	Harmony with environment, surveillance, visual coherence	Harmony, beauty, sustainability
Local Community Participation	Active community involvement is essential for maintenance and protection.	Information, engagement, education	Participation, trust, sustainability
New and Sustainable Materials	New materials should be green, economical, and structurally compatible.	Eco-friendly, environmentally friendly materials	Sustainability, compatibility, cost
Protection of Architectural Elements	Preserving architectural elements is crucial for site recognition and authenticity.	Iconic elements, forms, architectural details	Aesthetics, identity, coherence
Reinforcement Technologies	Using reinforcement technologies against natural disasters.	Strengthening systems, shock absorbers, structural reinforcement	Resistance, safety, durability
Biological and Environmental Protection	Preserving biological resources and environmental compatibility in restoration.	Ecosystem evaluation, natural resource conservation	Sustainability, environment, biodiversity
Restoration Process Design	Logical and organized processes for implementing restoration projects.	Planning, scheduling, cost estimation	Effectiveness, efficiency, cost-saving
Restorative Standards	Adherence to national and international standards during restoration.	Documentation, regulations, quality criteria	Quality, compliance, assurance

Factor	Explanation	Component	Criterion
Cultural Values	Maintaining and enhancing cultural values aligned with local and global identity.	Symbols, historical documents, cultural significance	Identity, authenticity, meaning
Modern Technologies in Materials	Modern materials should perform well and be visually appealing.	Smart materials, corrosion-resistant	Durability, aesthetics, compatibility
Risk and Crisis Management	Planning to address natural and human-made crises.	Risk assessment, emergency plans	Sustainability, security, preparedness
Aesthetic Standards	Following visual standards and harmonious design in landscape restoration.	Visual indices, balance, element alignment	Attraction, identity, harmony
Structural Monitoring Technologies	Continuous monitoring of structural health and timely corrections.	Measurement systems, supervision, monitoring	Accuracy, speed, efficiency
Indigenous and Traditional Architecture	Using indigenous and traditional architecture in restoration and reconstruction.	Local design principles, indigenous materials, native forms	Identity, authenticity, compatibility
Economic and Tourism Development	Economically exploiting sites sustainably without damaging the site.	Tourism vitality, sustainable income, economic impacts	Sustainability, profitability, attract tourists
Modern Environmental Technologies	Employing new technologies to preserve the environment related to landscapes.	Renewable technologies, reducing environmental impacts	Compatibility, sustainability

developing the framework for effective indicators in the restoration of the natural landscape of ancient Iranian historic bridges. The detailed and comprehensive results related to the implementation of the first round of questionnaire distribution are provided in the table below. The factors of digital technologies, modern and sustainable materials, new technologies in materials, structural monitoring technologies, economic and tourism development, and new environmental technologies were excluded due to having an average importance score of less than 2.5 in the Delphi process. (Tab. 5)

After implementing the first phase of assessment and evaluation of expert opinions, and based on the theoretical foundations as well as receiving suggestions from the panel members, in this round, to exercise caution, all factors derived from the theoretical foundations along with the average opinions of members in the first round and each member's previous opinion were provided to all panel experts. The panel members identified 8 factors out of 12 proposed in the second round as having a high or very high impact (with an average score greater than 3) on the effective framework for restoring the natural landscape of ancient Iranian historic bridges. Accordingly, the factors of local community participation, reinforcement technologies, cultural values, and risk and crisis management are detailed in the comprehensive results related to the second round of questionnaire distribution in the table below. The Kendall's coefficient of agreement for responses regarding the ranking of factors that had a high or very high impact in this round was 0.766. (Tab. 6)

In the third round of developing the proposed framework of indicators for effective restoration of the natural landscape of ancient Iranian historic bridges, the opinions of panel members, including the average opinions from the second round and each member's previous opinion, were provided to all experts. The detailed and comprehensive results related to the third round of questionnaire distribution are presented in the table below. The Kendall's coefficient of agreement for the responses regarding the ranking of the six factors was 0.789. (Tab. 7)

Table 5: The first phase of the fuzzy method in developing the proposed indexes for effective restoration of the natural landscape of ancient Iranian historic bridges

Row	Factors	Number of Responses	Average	Standard Deviation	Minimum	Maximum
1	Resistant Materials	15	3.85	0.35	1	5
2	Principles of Natural Landscape Design	15	3.75	0.37	1	5
3	Local Community Participation	15	2.85	0.37	1	5
4	Protection of Architectural Elements	15	3.91	0.45	1	5
5	Reinforcement Technologies	15	2.95	0.37	1	5
6	Biological and Environmental Conservation	15	3.80	0.40	1	5
7	Design of Restoration Processes	15	3.75	0.35	1	5
8	Restoration Standards	15	3.87	0.37	1	5
9	Cultural Values	15	2.96	0.45	1	5
10	Risk and Crisis Management	15	2.63	0.52	1	5
11	Aesthetic Standards	15	3.65	0.65	1	5
12	Indigenous and Traditional Architecture	15	3.54	0.52	1	5

Table 6: The first stage of the fuzzy method in developing the proposed indicators of effective indicators in restoring the natural landscape of historical bridges in ancient Iran.

Row	Factors	Number of Responses	Average	Standard Deviation	Minimum	Maximum
1	Resistant Materials	15	4.01	0.33	2	5
2	Principles of Natural Landscape Design	15	3.91	0.35	2	5
3	Protection of Architectural Elements	15	4.07	0.42	2	5
4	Biological and Environmental Conservation	15	3.96	0.39	2	5
5	Design of Restoration Processes	15	3.90	0.37	2	5
6	Restoration Standards	15	4.03	0.32	2	5
7	Aesthetic Standards	15	3.81	0.56	2	5
8	Indigenous and Traditional Architecture	15	3.70	0.49	2	5

Table 7: The first stage of the fuzzy method in developing the proposed indicators of effective indicators in restoring the natural landscape of historical bridges in ancient Iran.

Row	Factors	Number of Responses	Average	Standard Deviation	Minimum	Maximum
1	Resistant Materials	15	4.16	0.31	3	5
2	Principles of Natural Landscape Design	15	4.07	0.30	3	5
3	Protection of Architectural Elements	15	4.23	0.35	3	5
4	Biological and Environmental Conservation	15	4.12	0.33	3	5
5	Design of Restoration Processes	15	4.06	0.32	3	5
6	Restoration Standards	15	4.19	0.29	3	5
7	Aesthetic Standards	15	3.97	0.45	3	5
8	Indigenous and Traditional Architecture	15	3.86	0.42	3	5

Reasons for stopping the survey

- The results of the three rounds of the Delphi method in the research indicate that consensus has been reached among panel members for the following reasons, and the repetition of rounds can be considered complete:
- In the second round, more than 50% of members selected 12 influential factors in developing the socioeconomic indicators for affordable housing, with an emphasis on the housing ownership syndrome, all of which had an average score greater than 2.5.
- The standard deviation of members' responses regarding the importance of factors in the third round decreased significantly compared to previous rounds.
- The Kendall's coefficient of agreement for responses regarding the ranking of factors in the third round is 0.789. Given that the panel had more than ten members, this level of Kendall's coefficient is considered highly significant.
- The Kendall's coefficient of agreement for the ranking of the six influential factors in developing effective indicators for restoring the natural landscape of ancient Iranian historic bridges increased only slightly to 0.023 from the second to the third round, indicating no considerable growth in consensus between the members across consecutive rounds.
- The scores assigned to factors by experts and elites indicate that the highest scores—and thus the greatest impact belong to indicators of protection of architectural elements, restoration standards, resistant materials, and biological and environmental conservation. These are the key indicators in defining the final effective indicators for restoring the natural landscape of Iran's ancient historic bridges. (Tab. 8)

Table 8: Indicator, sub-indicator and evaluation tool intended to compile the final indicators of effective indexes in the restoration of the natural landscape of historical bridges in ancient Iran

Topic	Indicator	Sub-indicator	Evaluation Tool
Effective Indicators for Restoring the Natural Landscape of Iran's Ancient Bridges	Resistant Materials	Resistance to climatic conditions (rain, wind, earthquakes, temperature variations)	Quantitative
	Principles of Natural Landscape Design	Harmony with the natural environment and bioregion, preservation of biodiversity and ecological values, maintaining balance and sustainability in landscape elements	Qualitative
	Protection of Architectural Elements	Continuous maintenance and restoration of historic elements, prevention of unauthorized changes and physical damages, adherence to principles of authenticity and identity in preservation and restoration	Qualitative
	Biological and Environmental Conservation	Preservation of biodiversity and local ecosystems, reduction of biological and environmental pollution, and sustainable and responsible use of natural resources	Qualitative
	Design of Restoration Processes	Precise analysis of the condition and needs of the restoration process, selection of appropriate methods and materials based on technical and cultural values of the structure, and planning of phased and timely restoration	Quantitative-Qualitative
	Restoration Standards	Adherence to national and international standards for restoring historic buildings, use of materials and methods compatible with cultural and technical values, thorough documentation of restoration operations, and preservation records	Quantitative-Qualitative
	Aesthetic Standards	Coordination of design elements with aesthetic principles, creation of visual balance and harmony in landscape and architecture elements, and consideration of visual and cultural trends in design and implementation	Quantitative-Qualitative
	Indigenous and Traditional Architecture	Preservation and promotion of local and cultural architectural elements and styles, use of traditional materials and technologies suitable for the region, and enhancement of cultural identity in design and execution based on indigenous values	Qualitative

RESULT AND CONCLUSION

This comprehensive table depicts a deeper analysis of the importance of primary and secondary factors and specifies the role of each in the decision-making process for the final indicators. The process of restoring and restoration historic bridges, the use of materials resistant to earthquakes, erosion and environmental factors is of great importance. These materials, in addition to being strong, must be adjacent to the appearance and cultural values and local architecture. Experts emphasize the importance of this factor, because the durability and sustainability of historic structures depend on the quality of the materials used. If the materials are not resistant, the project may be vulnerable in the short term and require frequent repairs, which is costly and threatens the sustainability of the project. The principles of natural landscape design are among the key factors in establishing a balance between natural and cultural values. These principles help to adapt the restored structures to the natural context, and bridges located in the heart of natural environments, their visual and biological perspectives are preserved. This element is in line with the preservation of natural landscapes and their role in cultural identity and historical heritage, and from the perspective of the elite, its importance is much higher than the technical elements. The participation of the local community is one of the crucial factors in the long-term success of restoration projects. The elite believe that the indigenous community has valuable intellectual and management assets that should be included in the restoration and protection of cultural heritage. In this way, the use of local knowledge, the opinions of residents, and increasing public awareness of the project ensures that cultural heritage is preserved in the long term and destruction is prevented. This factor is the main element in the acceptance and care of heritage and its absence usually carries the risk of premature destruction of heritage. Biological and environmental protection, along with other factors, plays a very important role in ensuring the continuity and health of ecosystems around historic bridges. Reducing destructive impacts and preventing environmental pollution and destruction are among the issues that must be observed in the design and implementation of projects. Experts believe that ignoring this factor can lead to the destruction of natural values and even serious damage to structures, which results in a decrease in the quality and efficiency of the project. Designing restoration processes is considered the core of operational strategies. These processes should be based on global standards and sensitive to cultural and historical values. Experts believe that developing and following comprehensive restoration processes ensures the quality level of restorations and the sustainability of historical structures. In this process, a careful assessment of the condition of each structure, determining restoration priorities, and determining appropriate technologies play an important role in the success of the restoration process. Cultural values, identity, and spiritual relics are the most fundamental elements in the restoration of cultural and historical heritage. Any change or reconstruction should not affect or diminish cultural values. Experts believe that preserving these values is important, not only in appearance but also in the spirit and identity of the project. In other words, every action must be carried out with deep respect and understanding for cultural heritage, otherwise, the project will distance itself from its original values and lose its effectiveness and acceptance among society. Native and traditional architecture, as one of the main design indicators, plays an important role in adapting to the environment and cultural identity. This type of architecture, authentic symbols and construction methods are adapted to the climate and lifestyle of each region and for this reason it has a special value. Using this architecture in restoration and reconstruction not only helps to preserve historical identity, but also leads the process towards a project compatible with the natural and cultural environment.

From the perspective of the elite, this approach is the main key to preserving and transmitting cultural heritage. Alongside these

factors, retrofitting technologies also play an important and complementary role. These technologies, by enhancing the resistance of the structure to earthquakes, environmental factors and natural damage, help improve the overall strength and durability of restored structures. Although these technologies are of great importance, the elite believe that one cannot rely solely on retrofitting technologies and that they should be placed alongside fundamental factors and cultural and natural values. The intelligent use of retrofitting technologies can guarantee the long-term sustainability of historical heritage, but they should never replace natural, cultural and social conservation, but should complement them so that historical structures become more resilient to unforeseen events. In this regard, restoration standards are of great importance; these standards play a guiding role in ensuring the quality and coordination of restoration operations with heritage values. By adhering to these standards, projects are prevented from being damaged during the maintenance process, and the quality level of restoration is maintained. Experts believe that ignoring these standards may cause irreparable damage and destruction to the heritage, which will also cause the loss of valuable cultural assets. Therefore, some believe that these standards should be observed at all stages of restoration and should be considered as the final criterion determining the quality of work. Another factor that plays a vital role in long-term sustainability is risk and crisis management. This management includes planning for rapid response to natural disasters such as earthquakes, floods, and strong winds. Experts believe that by making the necessary predictions, developing emergency solutions, and educating the local community, the possibility of reducing damage to cultural heritage is greatly increased. Ignoring this factor can cause sudden and irreparable destruction, and as a result, historical and cultural assets are at risk. Therefore, a focus on crisis management should be a central part of the overall restoration strategy. Finally, beautification and lighting standards also play an important role in attracting visitors and enhancing the visual appeal of the works. These standards should be developed and implemented in order to preserve the visual and artistic values of cultural heritage. Although these criteria are valuable to the elite, their importance is at the final stage of the restoration operation and should not be replaced by fundamental factors. From the experts' point of view, maintaining a balance between aesthetics and core cultural values is the key to success in restoration projects, and these factors should be considered simultaneously with other indicators to maintain a living and attractive heritage. Taken together, these factors provide a comprehensive roadmap for the restoration and reconstruction of historic bridges. Each has a specific and important role in the health and durability of cultural heritage, and if properly combined and given coordinated attention, a sustainable and long-lasting future can be drawn for these valuable works. Recognizing the importance of each factor and prioritizing them correctly is the key to the success of restoration projects and must be carefully considered in planning and implementation. (Tab. 9)

The result, the study of the set of factors related to the restoration and conservation of cultural heritage shows that a combination of technical, natural, social and managerial factors play a vital role in ensuring the durability and sustainability of historical structures. Each of these factors must be carefully evaluated and considered in the restoration process in order to achieve a desirable effect in preserving cultural, artistic and environmental values. The most important results of this analysis are given below.

- Resistant and durable materials, as the most basic technical factor, guarantee the strength of restored structures against natural disasters and environmental factors. Laboratory assessments and quality control before and during the project ensure the final quality of the structure and prevent premature failures.

Table 9: Proposed research framework for future studies in the field of case study evaluation

Final index	Factor Type	Evaluation Method	Metrics	Measurement Tools	Responsible Person	Timing	Level of Importance
Durable and Resistant Materials	Technical	Material tests and strength experiments	Tensile, compressive resistance, durability against environmental conditions	Material testing devices, sampling	Materials Engineers	Before project start, during implementation	Very High
Principles of Natural Landscape Design	Natural	Compatibility analysis with natural bed, visual assessment	Visual harmony, preservation of natural landscape	Drawing, photography, local surveys	Landscape Designer, Architect	Design phase and post-implementation	High
Local Community Participation	Social	Interviews, surveys, consultation meetings	Participation level, community satisfaction	Questionnaires, field reports	Project Manager, Social Expert	During project and maintenance operations	Very High
Biological and Environmental Protection	Biological	Bio-environmental impact assessment	Reduction of harmful effects, Biodiversity	ICAO, GIS, Biological sampling	Environmental Experts	During implementation and maintenance	High
Standard Restoration Processes	Technical	Compliance evaluation with international standards	Restoration quality, adherence to regulations	Technical reports, checklists	Technical Manager, Supervisors	During project execution	Very High
Innovative Reinforcement Technologies	Technical	Quality control tests, laboratory experiments	Earthquake resistance, climate change adaptation	Laboratory equipment, smart sensors	Technical Engineers, Technology Team	Before installation, throughout the structure's lifespan	Very High
Risk and Crisis Management	Managerial	Review of prevention and rapid response plans	Damage reduction, emergency preparedness	Performance assessment, practical drills	Crisis Management Team, Local Officials	Periodic, post-implementation	Very High

- Natural landscape design principles play an important role in the harmony between restored structures and the surrounding environment. The use of imaging technologies and conformity assessments ensures that projects are compatible with the natural and cultural context of the region and strengthen the sense of preserving natural and cultural identity.
- Local community participation is a fundamental principle in the restoration process. In addition to creating a sense of ownership, active consultation and participation of local people leads to continuous care and better maintenance of the monuments and prevents boredom and indifference.
- Biological and environmental protection plays a vital role in preventing environmental damage and the destruction of ecosystems around historical heritage. Assessing biological impacts and implementing preventive measures are among the most important measures to maintain the health of the environment and the structure.
- Following standard restoration processes and observing regulations increases the quality of the project and ensures that restoration operations are carried out according to global best practices. Continuous control and regular assessments reduce possible errors.

- Modern retrofitting technologies allow for the improvement of the resistance of structures to earthquakes, floods and climate change. The use of smart sensors and permanent tracking technologies provides real-time control of the condition of the structure.
- Risk and crisis management plays a key role in reducing losses and quickly returning to normal. Operational exercises, public education and emergency plans ensure organization in the face of unforeseen events.
- Beautification and lighting standards should focus on visual appeal and attracting the attention of spectators, in addition to preserving cultural values. Harmonizing these standards with cultural elements enhances the visual value of the heritage.
- Training and empowering human resources is a fundamental factor in improving the quality of restoration. Organizing specialized workshops, practical training and keeping specialists up to date helps to increase the skills and knowledge of restorers.
- Continuous maintenance and supervision ensure the long-term durability of the project. Periodic inspections, preventive repairs and careful documentation prevent possible deterioration and damage.
- International cooperation and partnerships with organizations such as UNESCO institutionalize global standards for domestic projects and facilitate the transfer of new technologies and global experiences.
- Scientific research and development of new technologies play a leading role in improving the restoration process. The establishment of research centers and documentation archives enhances the scientific and practical level of projects.
- Supportive policies and laws provide the necessary legal framework for the protection and restoration of heritage. The development of sustainable laws and continuous review guarantee effective protection in the long term.
- Providing financial resources is a key factor in the effective and unrestricted implementation of projects. The use of public, private and international funds creates a sustainable economic structure.

As a result, the set of factors affecting the restoration and conservation of cultural heritage should not be limited to technical aspects alone, but the role of natural, social, managerial, and cultural factors should also be considered. These factors should be evaluated in an integrated and simultaneous manner so that restoration projects can maintain their long-term durability, sustainability, and cultural identity. Therefore, cooperation between expert teams, careful planning, the use of modern technologies, and compliance with international standards, along with the active participation of the local community, are the keys to success in the conservation of cultural heritage. Paying attention to continuous evaluation processes and continuous improvement based on the results obtained ensures a dynamic and flexible process in the face of environmental changes and new technologies. Taking all these factors in a balanced manner, in addition to preserving cultural values, provides for sustainable development and cultural tourism. Ultimately, this comprehensive and multifaceted approach can preserve and transmit the country's rich heritage to future generations. A scientific and standardized approach to restoration operations is a prerequisite for improving the scientific and practical level of projects and gaining greater trust from society and international institutions. For this reason, paying attention to all effective factors and aligning different strategies requires careful planning, continuous training, and well-founded scientific research. As a result, giving importance to all these dimensions not only ensures the physical preservation of the works, but also keeps them as cultural and identity symbols, lasting and influential in society, and preserves cultural heritage as a national and global asset.

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HOW TO CITE THIS ARTICLE

Rostami, F. , Keramati, G. and Soltan Zadeh, H. (2025). Explaining the effective indexes in the restoration of the natural landscape (Case Study: Historical bridges of ancient Iran). (e728224). International Journal of Urban Management and Energy Sustainability, (), e728224

DOI: 10.22034/ijumes.2025.2063285.1315