ISSN: 2538-3019, EISSN: 2676-4806
DOI:
Journal of Architectural Thought, Volume 8, Issue 15, Spring and Summer 2024

Optimal selection in the adaptive reuse of historic buildings based on the Analytic Hierarchy Process
(Case study: Khadivi Historic House in Zanjan, Iran)

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Submitted: 17/7/2024

Accepted: 20/9/2024

Abstract

Research Problem: The multifaceted nature of the adaptive reuse of historic buildings concept and its complexity with numerous and diverse influencing factors in the field of action, including the multiplicity of possible alternatives, the variety of evaluation criteria, and the possible conflict in the opinions and expectations of stakeholders, has made the field of decision-making in this arena perplexingly complicated. In this regard, the need to adopt a scientific method requiring that the Analytic Hierarchy Process be used concerning its efficiency in multi-criteria and multi-alternative environments so that by relying on the comparative judgments of experts, a consensus can be reached in determining the optimal alternative. The selection of the Khadivi Historic House also provides an objective basis for testing the generalization of the method above, in the domain of locally valuable buildings by relying on its ability to be reused.

Research Question: How can the Analytic Hierarchy Process be applied to choose the optimal alternative for adaptive reuse of historic buildings?

Research Objectives: This article is based on explanatory research that was done to create a decision-making model in the adaptive reuse of historic buildings based on the Analytic Hierarchy Process to provide the possibility of choosing the optimal alternative based on it.

Research Method: This article's methodological framework is based on a quantitative approach based on the Analytic Hierarchy Process and consistent with mathematical logic. According to the nature of the data, the respondents were defined as an expert group of nine people and a group of forty-one people. In this regard, Data collection was conducted using the documentary method to identify the criteria and sub-criteria, while the field method was employed to determine the alternatives and construct a pairwise comparison matrix. Also, Data processing employed a three-step hierarchical analysis: decomposition and structuring, measurement, and synthesis, using Expert Choice Software Version 11.

The Most Important Results and Conclusions: Determining the relationship between the essential elements of decision-making showed that the adaptive reuse of Khadivi Historic House as a "house museum" is the optimal choice, and the architectural, cultural and economic criteria are the most critical factors in this selection, respectively. In addition, the conceptual model of adaptive reuse of historic buildings based on the four concepts of Transformation, Evolution, Continuity, and Adaptation, as well as the system of criteria, sub-criteria, and evaluation indicators in this approach, are implicit results of this research.

Keywords: Adaptive Reuse, Analytic Hierarchy Process (AHP), Optimal Alternative, Historic Building, Khadivi Historic House.

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1. Introduction

Adaptive reuse is one of the complex and multi-faceted approaches to historic buildings, which confronts the decision-making process in this field with various challenges. One aspect of this complexity is the need to make a well-considered and prudent decision that encompasses the optimal choice among the possible alternatives in the adaptive reuse of historic buildings. The realization of this necessitates that the decision-making process balances multiple and often contradictory criteria while fostering consensus among stakeholders. Therefore, the experiences of the past two decades to adopt a scientific method, have turned to the use of Multi-Criteria Decision-Making (MCDM) methods and the Analytic Hierarchy Process (AHP) to provide a suitable solution for this challenge by referring to its capabilities.

The Analytic Hierarchy Process is an efficient method in Multi-Criteria and Multi-Alternative environments, which provides the possibility of optimal selection by comparing possible alternatives to criteria and sub-criteria. The mentioned method, by decomposing the decision problem and structuring it into a hierarchy, creates the necessary context for measuring the relative importance of decision elements and prioritizing them so that based on the obtained prioritization, it becomes possible to rank the alternatives and make the optimal selection.

The research underlying this article aims to develop a decision-making model in the adaptive reuse of historic buildings; how, to apply the Analytic Hierarchy Process in selecting the optimal alternative has been examined to provide the possibility of improving the evaluation and decision-making process in the local community by generalizing the existing experiences in a case with local values.

In this regard, the historical house of the Khadivi of Zanjan from the first Pahlavi period has been selected as a case study to create an objective context for testing the method mentioned above. In addition to leading to the practical development of the Analytic Hierarchy Process in the adaptive reuse of historic buildings of local value in line with the main goal of the research and providing a practical solution to resolve a real problem, the advancement of the above process, supported by the theoretical framework and the development of a conceptual model, as well as the development of a system of criteria, sub-criteria, and indicators derived from it, provides theoretical and operational insight towards the development of an approach to the adaptive reuse of historic buildings.

On this basis, after the introduction, the article's structure is organized into five main sections. In line with that, the first part provides an overview of the background of the application of the Analytic Hierarchy Process in the adaptive reuse of historic buildings to determine the relationship of this research with the existing literature. Following that, the framework for the research method, including methodology, respondent selection, data collection, and hierarchical analysis, has been established to guide the implementation of the research. Subsequently, the theoretical framework and the conceptual model derived from it are presented to further develop the concept of adaptive reuse. The continuation of the above process has been accompanied by the description of the materials and the classification of the main research data in

the studies and reviews section, which has progressed in the direction of introducing the Khadivi Historic House and possible Alternatives, as well as the system of criteria, sub-criteria and evaluation indicators. Finally, the follow-up of the content structure has been completed by explaining the results to identify the critical success factors and determine the best alternative for the adaptive reuse of the Khadivi Historic House, as well as their discussion and by summarizing the topics in the conclusion section, it is possible to leave the discussion.

2. Research Question

How can the Analytic Hierarchy Process be applied to choose the optimal alternative for adaptive reuse of historic buildings?

3. Research Hypothesis

In the framework of the Analytic Hierarchy Process, by prioritizing the relative importance of decision-making elements including criteria, sub-criteria, and alternatives, and then synthesizing the mentioned priorities, the optimal alternative in the adaptive reuse of historic buildings can be selected.

4. Research Background

The use of the Analytic Hierarchy Process in existing literature indicates a growing trend in its application for the adaptive reuse of historic buildings (Nadkarni & Puthuvayi, 2020, pp. 5,9). This method, introduced in the 1970s by Thomas L. Saaty, is a prominent multi-criteria decision-making approach that is widely used for assessing criteria weights and ranking or selecting alternatives in adaptive reuse[1].

An example of these experiences is the research by Wong and Zeng in 2010 (Wang & Zeng, 2010), as well as the research by Nesticò and Soma in 2019 (Nesticò & Somma, 2019), who used the mentioned method to assess criteria weights. Alternatively, studies have used this method to choose the best alternative for adaptive reuse of historic buildings. Such as Murano et al.'s research in 2016 (Morano, Locurcio, & Tajani, 2016) as one of the first examples in determining the best use for Rocca Stense Castle in Finale Emilia Italy or Claver et al.'s work in 2018 (Claver, García-Domínguez, & Sebastián, 2018) for the reuse of industrial assets, as well as the work of Haroun and Colleagues in 2019 (Haroun, Bakr, & Hasan, 2019) in the adaptive reuse of Azizah Fahmi Palace in Alexandria, Egypt. Also, several investigations by Ribera, Coco, Nestico, and Mosley have been done from 2020 to 2024 in this direction (e.g. Ribera & Cucco, 2020; Ribera, Nesticò, Cucco, & Maselli, 2020; Cucco, Maselli, Nesticò, & Ribera, 2023; Maselli, Cucco, Nesticò, & Ribera, 2024).

The accumulation of these experiences, which have enhanced the decision-making process in the field for over a decade, not only illustrates the increasing use of the Analytic Hierarchy Process but also highlights its potential for the adaptive reuse of historic buildings.

5. Research Methods

The process of achieving the goal in this research is based on making decisions in four main axes, which are related to research methodology, selection of respondents, data collection, and hierarchical analysis, which are organized as follows:

5.1 Research Methodology

This article's methodological framework is based on a quantitative approach based on the Analytical Hierarchy Process and consistent with mathematical logic. This approach, about the goal and

question, is applied research that has been carried out to develop the capabilities of the process as mentioned above, in improving the decision-making process in the adaptive reuse of historic buildings and optimal selection. Also, concerning the data collection method, it is considered a non-experimental study carried out through a survey and based on a cross-sectional method. The implementation of this method focuses on data obtained from experts and by inquiring with stakeholders. The other part of the data, which was qualitative, has been collected through documentary methods and a systematic literature review of key sources. In line with the above methodology, a framework has been provided to implement the research method of this article to collect and analyze data in detail, as outlined below.

5.2 Selection of Respondents

The study's respondents were defined into two groups: experts and stakeholders, based on the nature of the data. The experts consisted of nine people[2] from Zanjan City who were selected to complete expert questionnaires and make comparative judgments within the framework of the Analytic Hierarchy Process. These individuals were purposefully selected from among experts from the General Office of Cultural Heritage, Tourism and Handicrafts of Zanjan Province, faculty members of the University of Zanjan, Managers of cultural heritage and urban development of Zanjan, and an activist in the field of cultural heritage. The selection of these individuals was based on their expertise in the adaptive reuse of historic buildings, determined by education, experience, relevant background, and participation in decision-making forums. Stakeholders were selected based on the classification by Mısırlısoy and Günce (Mısırlısoy & Günce, 2016, P. 95), consisting of 41 individuals from various groups, including investors, producers, regulators, and users, who are familiar with the current and past status of the Khadivi Historic House.

5.3 Data Collection

This research was conducted based on three data groups, referring to the initial step of the Analytic Hierarchy Process,

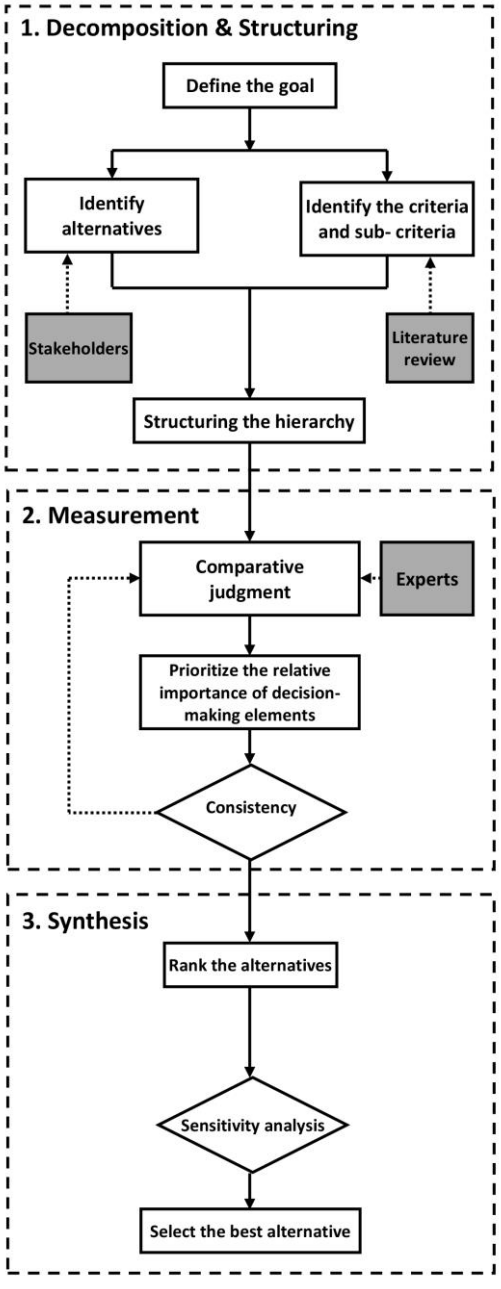

Figure 1. AHP Flowchart. (Developed by the author based on existing literature)

which decomposes the main problem into sub-elements including goal, criteria, sub-criteria, and alternatives. On the one hand, the data of the first group were collected in a documentary method to develop the criteria and sub-criteria; on the other hand, the data were collected in a field method to identify possible alternatives for the adaptive reuse of Khadivi Historic House as the second group, and the other one included the above two groups, which resulted in the third group of data as a result of pairwise comparisons.

The data of the first group, in order to identify the criteria and sub-criteria for evaluation based on the theoretical framework of research and development of the conceptual model of adaptive reuse of historic buildings, was conducted by a systematic literature review of fifty-seven key sources, including forty-five reputable scientific articles, five relevant international reference institutions, and seven green building rating systems, which led to the identification and development of six criteria, thirteen sub-criteria, and thirty-nine indicator groups in the form of Table 1.

The data of the second group, which was provided to identify possible alternatives for the adaptive reuse, was initially achieved through a survey of stakeholders, as a result of which twelve alternatives were identified in the first stage, then by presenting the alternatives as mentioned earlier to experts and also by surveying the building owner, finally, Five alternatives were finalized, including house-museum, art gallery, mixed Use (included a boutique gallery, exhibition and a conference hall), boutique hotel, and traditional Restaurant.

The data of the third group were also collected to provide the possibility of forming pairwise comparison matrices by distributing three types of expert questionnaires and a survey of the experts. These questionnaires, structured and designed with pairwise comparison questions between decision-making elements, were organized in the usual format of Analytic Hierarchy Process questionnaires based on the fundamental scale in a nine-value scale. In this context, the first questionnaire posed two questions: "Which criterion is more important?" and "How important is it compared to the other?" This resulted in 15 pairwise comparisons among the six main criteria. The second questionnaire, by asking the same questions, made 78 pairwise comparisons between the 13 sub-criteria. The third questionnaire asked two questions: “Which alternative is preferable for each sub-criteria? Furthermore, how much is its preference to the other?”, and organized 130 pairwise comparisons between the options.

5.4 Hierarchical Analysis

In the research supporting this article, the data analysis was carried out based on the Analytic Hierarchy Process and by Expert Choice software version 11. This approach was adopted due to its effectiveness of the method mentioned above, as a "decision analysis paradigm" (Forman & Gass, 2001, p. 485) aimed at the resolution of choice problems in a multi-criteria environment, which was in line with the main problem of this article. For this purpose, referring to the opinion of Forman and Gass, who introduced the prime use of the method as mentioned above, in “structuring complexity”, “measurement on a ratio scale”, and “synthesis” (Forman & Gass, 2001, p. 469), as well as Saaty and Vargas, who mentioned the three steps of “decomposition, or the structuring of the problem into a hierarchy”, “comparative judgment”, “synthesize the priorities” (Saaty & Vargas, 2012, pp. 12-16), the research process was organized under Figure 1 in three stages of “decomposition & structuring”, “measurement”, and “synthesis”.

In the decomposition & structuring stage, decision elements were organized hierarchically into four levels including the main goal, six criteria, thirteen sub-criteria, and five alternatives, as shown in Figure 2. In the measurement stage, the elements of the above system were linked together based on the principle of comparative judgments by determining the potency of various elements at one level on elements at the next higher level, to enable the computation of the relative strengths of the impacts of the elements of the lowest level on the main goal. In this regard, the questionnaire data completed by the experts were organized in the form of a pairwise comparison matrix so that the relative importance of each decision-making element, including all criteria, sub-criteria, and alternatives, could be calculated using the eigenvector method. The above process, based on a mathematical operation in determining the geometric mean of each row of the matrix, normalizing them, and obtaining the eigenvector, ultimately led to the prioritization the relative importance of the criteria, sub-criteria, and alternatives. The consistency ratio calculation was controlled as the final step of this stage to ensure consistency between pairwise comparisons and minimize errors. This rate is determined to be equal to or less than 0.10 according to Saaty's recommendation, indicated a consistent and reassuring situation in all judgments (SAATY, 1980, pp. 6-10, 179-190). In the synthesis stage, the set of priorities at all hierarchical levels was combined based on "the principle of hierarchic composition" and in a "distributive mode" to derive the composite or global priorities. The final step in this process was related to sensitivity analysis, which, according to Dantzig, was performed to "assess the stability of an optimal solution under changes in the

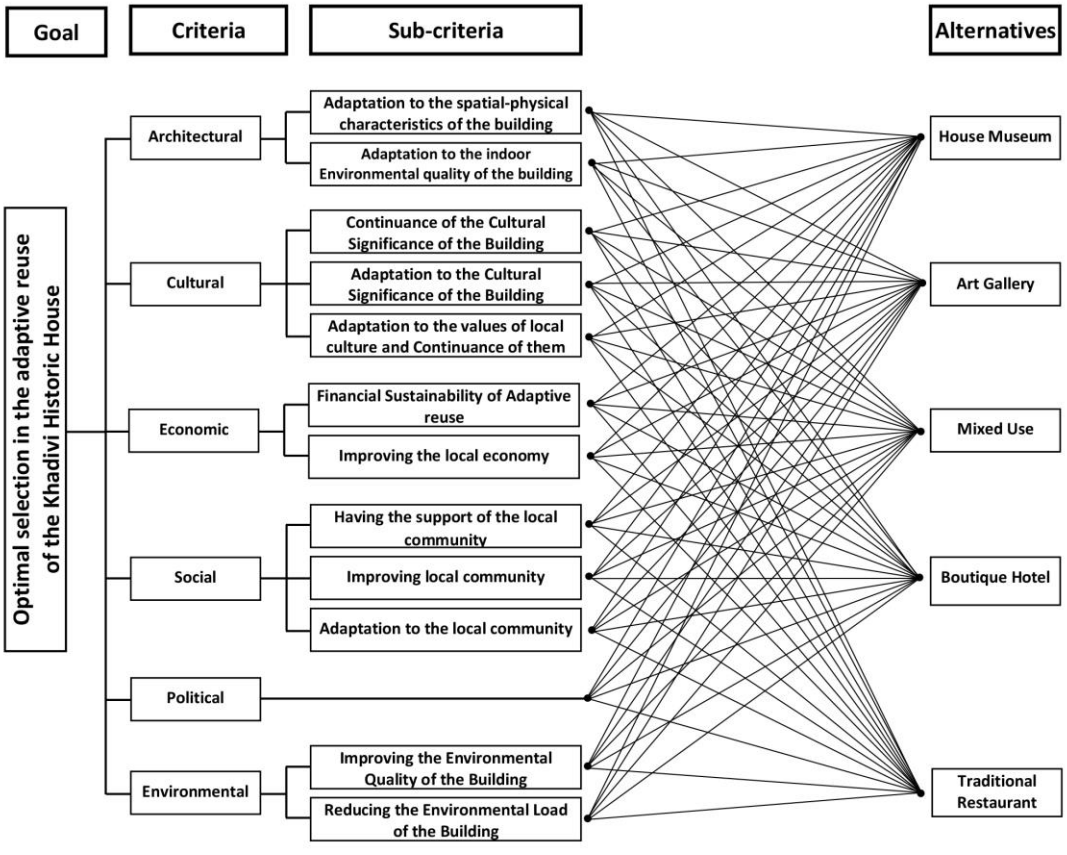

Figure 2. Hierarchy Structure of AHP for Optimal Selection in the Adaptive Reuse of the Khadivi Historic House

parameters" (Triantaphyllou & Sánchez, 1997, p. 37); as a result of which, in addition to performing a sensitivity analysis on the weights of the decision criteria and the performance values of the alternatives expressed in terms of the decision criteria, sensitive criteria were also identified.

6. Theoretical Foundations

The growing literature that has developed in recent years on the adaptive reuse of historic buildings has expanded its theoretical scope across various sciences. The scientific support obtained has provided a valuable opportunity to improve the conceptual model of this field on a comprehensive and inclusive level. In this context, the theoretical framework of this research has been developed by referencing two paradigms in conservation and development to create a conceptual model. On this basis, a system consisting of four concepts of transformation, evolution, continuity, and adaptation has been established following Figure 3, based on which adaptive reuse has emerged as a multifaceted approach. In this view, adaptive reuse is a "transformative" action that "evolves" the historic building based on its "adaptation" ability towards effective use and role-playing and guides it towards "continuity of life". By giving a central position to the concept of transformation, the proposed model explains, on the one hand, its direction, scope, and level, and on the other hand, the possibility and capacity of the building to accept it within the scope of the concepts mentioned above, as follows, to provide a theoretical basis for the adaptive reuse of historic buildings.

"Transformation" about meaning implies change. this concept, in the scope of theory and practice of the adaptive reuse of a historic building, reflects change in its dimensions and contexts. The derivation of the concept mentioned above, from the literature in this field focuses on the descriptions and definitions of adaptive reuse. When Machado, based on the palimpsest metaphor, considers this action as rewriting (Machado, 1976, p. 46), whereas Cherchi, considers it as a "shift" and a "transformative process" towards creating a new asset as a "typological shift" in the building (Cherchi, 2016, p. 21), or Stone, who explains it in connection with the priorities, needs, and wants of society (Stone, 2019, p. 4). Also, definitions that are interpreted by referring to concepts such as "change" (Douglas, 2006, p. 1), (PLEVOETS & CLEEMPOEL, 2019, p. 23), (Brooker & Stone, 2004, p. 11), (ICOMOS Australia, 2013), (ICOMOS New Zealand, 2010), **"transforming"** (Berger, Hermann, & Wong, 2009), (Wong, 2017, pp. 30, 32) and **alteration** (Scott, 2008). On this basis, in this study; adaptive reuse has been considered a transformative process that is realized by making changes in historic buildings.

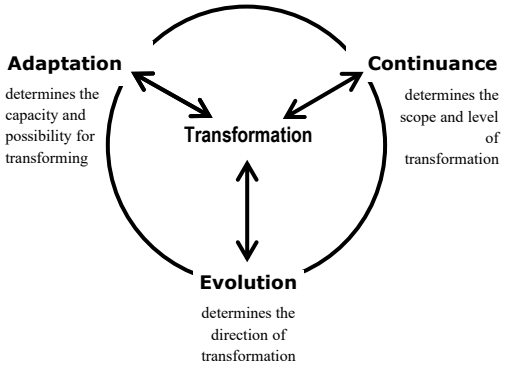

Figure 3. The Conceptual Model of Adaptive Reuse of Historic Buildings

"Evolution" is a fundamental aspect of adaptive reuse that, about other aspects, determines the "direction of transformation" to guide it towards the usefulness of the historic building. In this view, usefulness means providing the possibility of the historic building

playing a role in contemporary life and connecting with its mechanisms, which is realized as a result of the transformation of the building and its outcomes and effects. In this process, a contemporary layer is added to the building, forming another stage of its evolution, which in most cases is accompanied by the improvement of physical/spatial standards and the social, economic, and environmental impacts resulting from the change in function. In this regard, there is a broad consensus that adaptive reuse is an effective approach to addressing issues related to sustainable development[3]. Thus, adaptive reuse, relying on the aspect of evolution and in an innovative process, allows the historic building to evolve so that it is effective in a modern format and plays a sustainable role in development.

“Continuance” is another aspect of the adaptive reuse approach that determines the “scope and level of transformation” to conserve the cultural significance of the historic building. This concept, implying continuity and permanence, realizes the idea of heritage that relies on essential links between the past, present, and future. In fact, continuance is related to responsible action and a moral commitment towards cultural heritage, which has been reflected in the Venice Charter as a common responsibility to safeguard historic monuments for future generations and hand them in the full richness of their authenticity. Existing literature has supported the concept mentioned above, by relying on concepts such as cultural significance, cultural heritage value, the continuity of life in the physical environment, or its reference in analogy to the act of translation or the second violin in an orchestra[4]. Accordingly, adaptive reuse based on the pillar of continuity acts as a strategy to guide the transformation towards conserving the heritage values of the historic building.

"Adaptation" is another aspect of adaptive reuse that determines the "capacity and possibility" for transforming a historic building based on the idea of "adaptability", in the direction of evolution and within the framework of continuity. This aspect emphasizes a cautious view in implementing changes to ensure a low-risk and reliable outcome for continuity and evolution so that the probability of unforeseen negative effects is reduced, while at the same time, the probability of success and positive results is increased. According to this principle, the historic building changes and adapts to the new use. In addition, the new use of a historic building is also selected in circumstances that are compatible and appropriate to the context. In this regard, there is a variety of sources that developed this aspect within the frameworks of concepts such as cultural significance, cultural heritage values, performance, and environmental and socio-economic benefits[5]. adaptive reuse, relying on the aspect of adaptation, is based on the adaptability of the building in accepting new functions on the one hand, and on the other hand, it goes beyond the building, towards adapting its functionality to the environmental, economic, social, cultural and political contexts.

Thus, relying on the proposed conceptual model, the idea of adaptive reuse is considered as a transformative factor that transforms the historic building in the aspect of adaptation, relying on adaptability, so that, it modernizes towards the utility based on the aspect of evolution and based on the aspect of continuity, it remains within the framework of its values. In other words, adaptive reuse will be a transformation in the evolution of the historic building that relies on the potential for change in the building, the possibility of continuing life, and transferring its values to contemporary and future generations. The insight gained, and the proposed

conceptual model provides a basis for action in all stages of the adaptive reuse process, including determining criteria and decision-making indicators in selecting a new use for a historic building.

7. Studies and Reviews

The primary studies and investigations in the research supporting this article are, on the one hand, aimed at identifying the Khadivi Historic House and, on the other hand, are related to the identification of decision-making elements, including alternatives and the system of criteria, sub-criteria and indicators, which are as follows:

7.1 Khadivi Historic House

The example studied is a building from the first Pahlavi period, belonging to Mirza Hassan Naser Khadivi, also known as Naser Nizam. It is located on Naser Nizam Street, now known as Haft-e Tir Street, in the "Dalan Alti" neighborhood.

The mentioned building, with an area of 800 square meters on two floors and a courtyard of 200 square meters, is the only remaining part of Naser Nizam's residential complex and one of its eight registration plates with endowment ownership that was registered in the National Monuments List in 2000. This building was a residence for Naser Khadivi's family members until 2014, but since then, it has been abandoned. In its current state, despite the numerous decays and damages, the mentioned building has retained its authenticity and integrity to a considerable extent, And the associations and meanings associated with it have continued. The urban context of the building, belonging to the Sabzeh-e-Meydan complex, places this historical house in connection with elements of the city's structural system that have an economic, social, and cultural nature. The concentration of significant historic places and tourist attractions in this urban area, including the tourist route of the Rakht-Shouy Khaneh - Zolfaqari

Figure 4. Photos, Floor Plan, and Location of Khadivi Historic House
1. North elevation of Khadivi historic house, 2. Ground floor plan of Khadivi historic house, 3. South elevation of Khadivi historic house, 4. Khadivi historic house, 5. Zolfaqari mansion (Archaeological Museum), 6. Daraie mansion (Handicraft Museum), 7. Asaadi historic house, 8. Jamali historic house, 9. Zeynabiyeh mosque, 10. Khanum mosque, 11. Jame mosque of Zanjan, 12. Zanjan historic Bazaar complex, 13. Agha Seyed Fathollah mosque, 14. Enghelab Square, 15. Rakht-Shouy Khaneh (Anthropology Museum)

Mansion- Historic Bazaar complex, has strengthened the touristic nature of the location mentioned above, which can be seen in Figure 4.

7.2 Adaptive Reuse Alternatives

The possible alternatives for the adaptive reuse of the Khadivi Historic House, were finalized in five types, including House- Museum, Art Gallery, Mixed Use, Boutique Hotel, and Traditional Restaurant, each bringing a different quantity and quality to the occupation of the spaces of the building in line with its purpose and based on its functional system. On this basis, in the House-Museum alternative, to present a narrative of the house's social history and architectural culture and current life in it, all spaces are allocated to public viewing, and limited service and support functions are considered. In the Art Gallery alternative, a set of spaces is also allocated to the display and presentation of works of visual and traditional arts, and as in the above case, service and support functions are provided at a limited level. The alternative related to the Mixed Use with a cultural-commercial purpose includes three functions: a conference center for holding limited and meetings, a boutique gallery for presenting special works of art and antiques, and a book cafe. In the Boutique Hotel alternative, to create a unique experience of accommodation and provide exceptional and high-standard services, in addition to accommodation and providing a high standard of comfort, part of the spaces are allocated to particular and high-quality service and support functions. The Traditional Restaurant alternative also has acceptable comfort facilities to provide local food and drinks, in addition to catering. It includes a set of service and support functions such as a kitchen, storage of consumables, cold stores, dishwashers, and the like.

7.3 The System of Criteria, Sub-Criteria and Indicators

The assessments in this study were based on criteria systematically derived from the adaptive reuse literature, consistent with the conceptual model. In this regard, items from the existing literature related to the four pillars of Transformation, Evolution, Adaptation, and Continuity were distinguished as evaluation indicators to form the initial components. The indicators above, were grouped and classified into homogeneous and congruent groups, a set of sub-criteria, and in a similar process, the main criteria were organized in terms of belonging to a comprehensive whole consisting of six social, economic, environmental, cultural, architectural, and political systems to form the evaluation framework following Table 1. Accordingly, the criterion for determining the best alternative for adaptive reuse of Khadivi Historic House under the framework was based on the quality of role-taking and role-creating of each alternative in the systems as mentioned above,.

8. Results and discussion

The research process based on data measurement in the second stage and synthesizing priorities in the third stage led to findings that aligned with the expected goal. The findings mentioned above, were aimed at prioritizing criteria, sub-criteria, and alternatives on the one hand, and at determining the optimal alternative on the other hand, each of which had a level of significance that has been mentioned and interpreted as follows:

8.1 Optimal Alternative in the Adaptive Reuse of Khadivi Historic House

This research aimed to test the Analytic Hierarchy Process in improving the decision-making process aimed at the

adaptive reuse of historic buildings, which was pursued in connection with the Khadivi Historic House of Zanjan as a study sample. The findings, as shown in Figure 5, showed that the reuse of the aforementioned building as a "House-Museum" has the highest priority over other alternatives. This finding, which was obtained as a result of synthesizing the relative importance of the alternatives, sub-criteria, and criteria concerning the objective, placed the alternatives of Art Gallery, Mixed Use, Boutique Hotel, and Traditional Restaurant in the following priorities, respectively. During this process, the repetition of the above process at two levels related to the alternatives and

Table 1- The System of Criteria, Sub-Criteria and Indicators in the Adaptive Reuse of Historic Buildings

Criteria and sub-criteria	indicators	References
Architectural		
Adaptation to the spatial - physical characteristics of the building	Compatibility with original layout of the building	[29], [35], [36], [81], [91], [92]
	Compatibility with the structural capabilities of the building	[10], [29], [30], [35], [36], [37], [81], [91], [92]
	Compatibility with the technical performance and durability of the fabric	[10], [36], [81], [91], [92]
Adaptation to the indoor Environmental quality of the building	Minimum need to major new services and equipments	[36], [37]
Cultural		
Continuance of the Cultural Significance of the Building	Minimum changes to significant fabric	[14], [29], [30], [35], [36], [69], [70]
	Minimum impact on significant interiors, interior planning (circulation patterns and use of rooms) and decorative schemes and finishes	[36]
Adaptation to the Cultural Significance of the Building	good fit between the old and new function of the building	[29], [36]
	Respect for the associations and meanings associated with the building	[14], [35], [36], [69]
Adaptation to the values of local culture and Continuance of them	The correlation with important historical events and historical personage	[49], [69], [89]
	Enables to display its regional and folk art features	[14]
	aptitude to express the cultural peculiarities of the reference territory	[14], [35], [63], [65], [70]
Economic		
Financial Sustainability of Adaptive reuse	Capital Cost (acquisition cost, labor and construction materials, consultant's fees, building permits, development charges, legal fees, etc.)	[11], [23], [24], [35], [65], [81], [82], [83], [90], [91], [92], [94]
	Benefits of adaptive reuse for owner and investor (Return on capital, profitability, long-term value, ease of letting or selling, etc.)	[24], [28], [35], [63], [65], [81], [82], [90], [91], [92], [94]
	Operating Expenses	[4], [24], [81], [82], [90], [91], [94]
Improving the local economy	job creation	[4], [24], [46], [53], [58], [62], [71], [72], [73], [89]
	Tourism (Cultural) Economic Growth	[4], [24], [46], [58], [62], [71], [72], [73], [89]
	Local Business and Market Creation	[4], [24], [62], [71], [89]
	Impact on downtown revitalization	[4], [24], [62], [71], [72], [73], [89]
	Increasing Property Values	[2], [4], [14], [24], [53], [58], [62], [71], [72], [73], [89]
Social		
Having the support of the local community	Acquire benefits for all stakeholders	[8], [9], [11], [29], [43]
	Social collaboration	[60], [83]
	Associated with social networks in the community	[23], [25]
	Enhancing the role of communities	[5], [17], [43], [60], [70], [83], [89], [90], [91]
Improving local community	Improve the ability, opportunities, and dignity of all	[64], [86]
	The satisfaction of basic needs and improvements in the quality of life for all segments of the population	[1], [5], [8], [17], [48], [54], [64], [83], [86], [89]
	Promote public interests	[14], [65]
	Increasing public awareness, involvement and support	[14], [35], [90], [91]
Adaptation to the local community	Respect to the beliefs, values and norms of the local community	[35], [49], [82], [86], [90], [91]
	Respect the rights and aspirations of others	[64]
	Public interest and support	[10], [82], [91]
	Security for new users	[5], [17], [19], [25], [64], [89]
Political		
Adaptation to building codes, legislation and regulations	Compatibility with the building codes, legislation and regulations (Fire Safety, Disability Access, Health & Safety, Security, Energy Efficiency, ...)	[10], [11], [18], [29], [36], [68], [81], [92]
	Compatibility with urban development plans	[11], [18], [36], [37], [81], [82], [91], [92]
	Compatibility with cultural heritage management plans	[11], [18], [36]
Environmental		
Improving the Environmental Quality of the Building	Indoor Environment (Noise & Acoustics, Termal Comfort, Lighting & Illummination, Air Quality)	[6], [11], [21], [29], [33], [34], [36], [42], [59], [78], [87]
	outdoor Environment on site (Preservation & Creation of Biotope, Townscape & Landscape, Local Characteristics & Outdoor Amenity)	[4], [6], [14], [21], [26], [33], [34], [59], [78], [87]
Reducing the Environmental Load of the Building	Energy (Building Termal Load, Natural Energy Utillization, Efficiency in Building Service System, Efficient Operation System)	[4], [6], [11], [14], [21], [26], [33], [34], [36], [42], [59], [78], [81], [87], [89]
	Resource and Materials (Water Resources, Reduction of Non Renewable Material Use, Materials with Low Health)	[4], [6], [11], [14], [21], [26], [33], [34], [36], [42], [59], [78], [81], [87], [89]
	Off- site Environment (Global Warming, Local environment, Surrounding environment)	[4], [6], [11], [14], [21], [26], [33], [34], [36], [42], [59], [65], [81], [87], [89], [91]

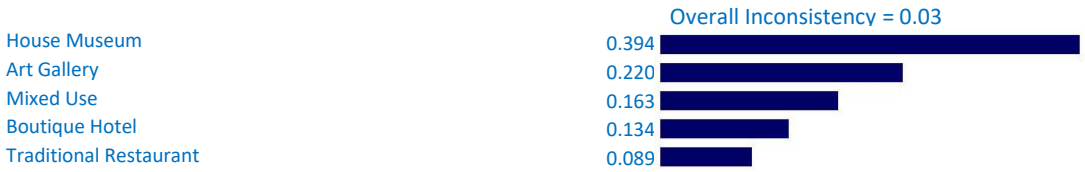

Figure 5. Ranking Alternatives in the Adaptive Reuse of the Khadivi Historic House

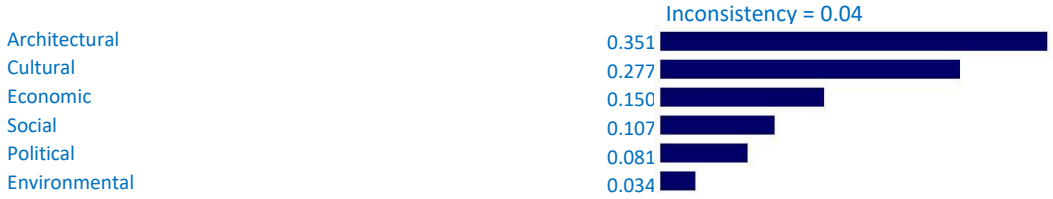

Figure 6. Prioritizing the Relative Importance of Adaptive Reuse Criteria for the Khadivi Historic House

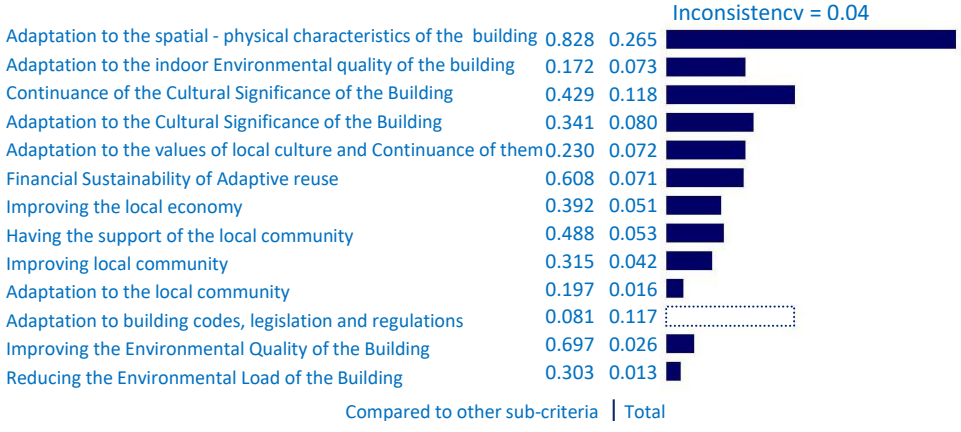

Figure 7 - The Relative Importance of Sub-Criteria for the Adaptive Reuse of Khadivi Historic House Compared to the Other Sub-Criteria and Total

sub-criteria that were carried out concerning to the criteria, according to the results reflected in Table 2, the alternative of House- Museum had the highest priority in five architectural, cultural, social, political and environmental criteria. This situation was repeated based on pairwise comparisons between alternatives based on sub-criteria, with the House-Museum alternative ranked highest in eleven cases.

In addition, according to the comparative judgments, the architectural criterion was given high relative importance compared to other criteria, followed by cultural, economic, social, political, and environmental criteria, in order of priority, as shown in Figure 6. In this regard, the sub-criterion "Adaptation to the spatial- physical characteristics of the building" about the architectural criterion, followed by the sub-criterion "Continuance of the Cultural Significance of the Building" concerning the cultural criterion, had the highest relative importance, and the other sub-criterions were placed in subsequent priorities, as shown in Figure 7.

8.2 Interpretation of Findings

In line with the above, the sensitivity analysis shows that reducing the weights of the criteria does not impact the ranking of the alternatives. However, increasing

the weight of the economic criterion, as illustrated in Figure 8, can lead to a change in the rankings. Specifically, when the weight of the economic criterion increases, the Boutique Hotel may rise to first place, the House-Museum could move up to second place, and the Traditional Restaurant may fall to third place. Also, according to Figure 9, increasing the weight of the political criterion causes a change in the position of the Traditional Restaurant and the boutique hotel about each other. In this sense, the economic and political criteria are considered sensitive criteria. These changes, particularly regarding the economic criterion that can alter the status of the preferred alternative, necessitate a 140% increase in the weight of this criterion, raising it from 0.122 to 0.294, which seems to be a fundamental and somewhat unexpected leap. Considering the low likelihood of a change in the economic criterion and the minimal impact of the political criterion on the preferred priorities, decision-making can be viewed as having low sensitivity and being somewhat substantial. However, due to the sensitivity of the economic criterion and with the motivation of improving the certainty and robustness of the decision, it is suggested that the planning process for the reuse of the mentioned building as a House- Museum, its economic aspect, especially in the sub-criterion related to "Financial Sustainability of Adaptive reuse", be strengthened. As a solution, it can be helpful to consider income-generating activities in the functional planning of the building. In addition, an integrated urban context can be envisioned that links the building to a cultural cluster.

The advantageous position of the House-Museum alternative is evident in the process of synthesizing priorities. This is supported by the results presented in Table 2, which demonstrate the

Table 2- The Relative Importance of the Alternatives with Respect to the Criteria and Sub-Criteria

Criteria and Sub-criteria	Alternatives					
	House Museum	Art Gallery	Mixed Use	Boutique Hotel	Traditional Restaurant	Grand Total
Architectural (L: .351)	**0.158**	**0.069**	**0.061**	**0.034**	**0.029**	**0.351**
Adaptation to the spatial-physical characteristics of the building (L: .828)	0.136	0.054	0.047	0.029	0.024	0.290
Adaptation to the indoor Environmental quality of the building (L: .172)	0.022	0.015	0.014	0.005	0.005	0.061
Cultural (L: .277)	**0.121**	**0.067**	**0.043**	**0.024**	**0.022**	**0.277**
Continuance of the Cultural Significance of the Building (L: .429)	0.050	0.030	0.020	0.009	0.009	0.118
Adaptation to the Cultural Significance of the Building (L: .341)	0.047	0.017	0.014	0.009	0.008	0.095
Adaptation to the values of local culture and Continuance of them (L: .230)	0.024	0.020	0.009	0.006	0.005	0.064
Economic (L: .150)	**0.035**	**0.019**	**0.018**	**0.056**	**0.022**	**0.150**
Financial Sustainability of Adaptive reuse (L: .608)	0.006	0.003	0.011	0.051	0.020	0.091
Improving the local economy (L: .392)	0.029	0.016	0.007	0.005	0.002	0.059
Social (L: .107)	**0.044**	**0.033**	**0.017**	**0.007**	**0.006**	**0.107**
Having the support of the local community (L: .488)	0.021	0.018	0.007	0.003	0.003	0.052
Improving local community (L: .315)	0.011	0.010	0.007	0.003	0.002	0.033
Adaptation to the local community (L: .197)	0.012	0.005	0.003	0.001	0.001	0.022
Political (L: .081)	**0.024**	**0.021**	**0.019**	**0.008**	**0.009**	**0.081**
Adaptation to building codes, legislation and regulations (blank)	0.024	0.021	0.019	0.008	0.009	0.081
Environmental (L: .034)	**0.012**	**0.011**	**0.005**	**0.005**	**0.001**	**0.034**
Improving the Environmental Quality of the Building (L: .697)	0.009	0.007	0.003	0.004	0.001	0.024
Reducing the Environmental Load of the Building (L: .303)	0.003	0.004	0.002	0.001	0.000	0.010
Grand Total	**0.394**	**0.220**	**0.163**	**0.134**	**0.089**	**1**

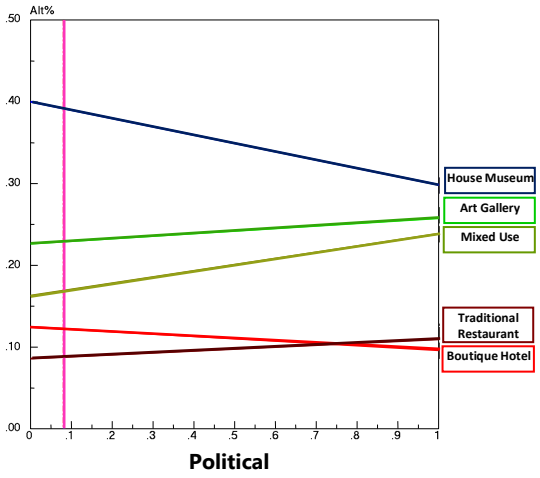

Figure 9. Sensitivity Analysis of Political Criterion

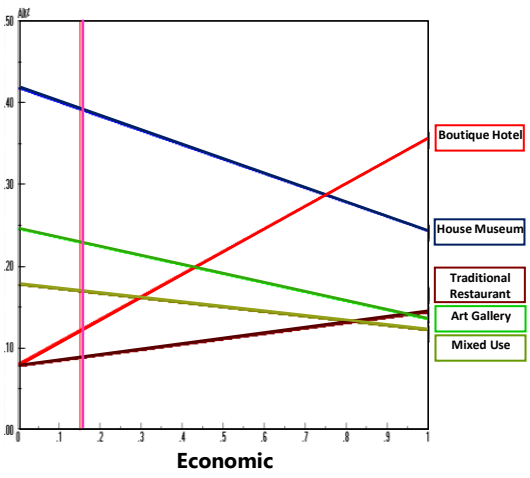

Figure 8. Sensitivity Analysis of Economic Criterion

achievement of ideal priorities in eleven sub-criteria, and consequently in five criteria.. The importance of this finding is that it highlights the role of the two architectural and cultural criteria with the highest weight values, as well as the two sub-criteria of "Adaptation to the spatial-physical characteristics of the building" and then "Continuance of the Cultural Significance of the Building" in obtaining the preferred rank. Based on this analysis, the two sub-criteria mentioned, along with the architectural and cultural criteria, and according to the sensitivity analysis, the economic criterion can be regarded as critical success factors for the adaptive reuse of the Khadivi Historic House. These findings propose a research idea to examine the role of the aforementioned criteria and sub-criteria in the success of adaptive reuse projects of historic buildings.

The above finding, in addition to aligning with the supporting resources' achievement in architectural, cultural, and economic criteria in Table 1, is significantly consistent with the results of studies by Dyson et al. and Vafai et al., who have examined the success factors of heritage buildings adaptation. With the explanation that Vafai et al., corresponding to the three criteria considered in this study, have introduced the items under the headings of the original building's layouts, the history behind that, the architecture of the old and new parts, the socio-cultural impacts of reuse and the economic justification and financial benefits as vital factors in the success of adaptive reuse projects. Dyson et al. have also proposed four factors of research, matching function, design, and minimal change, in order to reduce risks, understand the heritage significance, maintain a greater level of integrity and preserve significant elements, reduce structural change, and reduce commercial uncertainty and the potential for impact of latent conditions as Critical success factors, which correspond to the architectural, cultural and economic criteria of this study.

9. Conclusion

In line with the research idea of this article, a hierarchical structure was formed based on the main goal in the adaptive reuse of the Khadivi Historic House of Zanjan, six criteria, thirteen sub-criteria, and five alternatives as decision-making elements so that it enables the decomposition and structuring of the main issue into a whole. In this regard, Prioritizing the relative importance of the aforementioned elements above, as well as synthesizing them, were fruitful in determining the optimal alternative, so

that the ability of the Analytic Hierarchy Process in the adaptive reuse of historic buildings was revealed, which was realized by selecting the House Museum in the case study of this research based on the three stages of "decomposition and structuring", "measurement", and "synthesis".

The experience gained in this research is prone to limitations that may arise in the methodological aspect of the Analytic Hierarchy Process. The first lesson focuses on the mindset of experts and the possibility of generalizing their bias in judgments and the impact on the weighing of decision-making elements, which requires careful selection and the provision of a neutral and unbiased space when conducting pairwise comparisons. The second lesson concerns determining the relative importance of decision-making elements based on Saaty's fundamental scale, which is sometimes met with doubts in recognizing an exact numerical value from experts, Which has been solved in the Fuzzy Analytic Hierarchy Process (FAHP).

The insights provided in this article emphasize the generalization of the Analytic Hierarchy Process in other decision-making situations related to the adaptive reuse of historic buildings, which, indicates its high potential in various stages from Pre-project to preparation, implementation, and operation.

10. Acknowledgements

In conclusion, I would like to express my gratitude and appreciation to the experts, stakeholders, and trustee of the Khadivi Historic House for their empathy and support in collecting the research data.

11. Endnotes

1. Refer to: (Zavadskas, Antuchevičienė, & Kapliński, 2015, p. 108) (Morkunaite, Kalibatas, & Kalibatiene, 2019, p. 86) (Nadkarni & Puthuvayi, 2020, pp. 5, 9) (Li, Zhao, Huang, & Law, 2021, p. 11)

2. According to Chen et al., a decision group is usually composed of a smaller number of people (5 to 15) (Chen, Chiu, & Tsai, 2018, p. 15). However, there is no general rule for determining sample size (Chan & Ch'ng, 2023, p. 981) and it can vary depending on the type of research and the factors affecting it.

3. See: (PLEVOETS & CLEEMPOEL, 2019), (DEH, 2004, pp. 2-5), (Heritage Office, 2008, p. 10), (Dyson, Matthews, & Love, 2016, p. 45), (UNESCO n.d.), (ICOMOS, n.d.).

4. See: (Scott, 2008, pp. 11, xvii), (Stone, 2019, p. 2), (Cantacuzino, 1975), (Wong, 2017, p. 246), (ICOMOS Australia, 2013), (ICOMOS New Zealand, 2010), (PLEVOETS & CLEEMPOEL, 2019), (Bullen & Love, 2011a, b, c)

5. See: (ICOMOS Australia, 2013), (ICOMOS New Zealand, 2010), (Douglas, 2006, p. 18), (DEH, 2004)

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