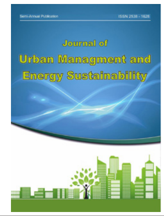
Int. J. Urban Manage. Energy Sustainability, 6(2): 281-300, 2025

International Journal of Urban Management and Energy Sustainability (IJUMES)

Homepage: http://www.ijumes.com



CASAE STUDY RESEARCH PAPER

Comparative Evaluation of Physical Resilience, Connection with Nature, and Climatic Adaptability Indicators in the Architecture of First Pahlavi-Era Residential Houses (Case Studies: Ghaffari and Hakkak Houses, Kerman City, Iran)

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ARTICLE INFO

Article History:
Received 2025-07-25
Revised 2025-08-17
Accepted 2025-10-30

Keywords:
Climatic adaptability, connection to nature, first Pahlavi era, Kerman city, physical resilience, residential architecture

DOI: 10.22034/IJUMES.2025.733079

ABSTRACT

This study investigates residential architecture of the First Pahlavi era in the city of Kerman, examining the degree of climatic adaptability and built-form resilience within the city's cold semi-arid climate context. Given the growing importance of reinterpreting indigenous knowledge in addressing contemporary climate challenges, the primary objective of this research is a comparative evaluation of three indicators, physical resilience, connection to nature, and climatic adaptability in two representative case studies: the Ghaffari and Hakkak Houses located within the historic urban fabric of Kerman. In terms of purpose, the research is applied, and methodologically it adopts a descriptive–analytical and comparative approach conducted through multiple case studies. Data were collected through documentary sources, field surveys, and a researcher-developed questionnaire. Indicator evaluation was carried out based on expert judgment from specialists in architecture and climate-responsive architecture. Data analysis employed descriptive statistics and structural equation modeling using the Partial Least Squares approach to examine the relationships among indicators and their level of realization in each case. The findings show that both houses follow an introverted central courtyard typology and utilize indigenous materials with high thermal mass. However, the Ghaffari House demonstrates a higher level of climatic adaptability and stronger coherence between spatial organization and climatic design strategies. The results indicate that the effectiveness of First Pahlavi-era residential architecture in climate response depended on maintaining a balance between continuity of indigenous spatial logic and modern built-form transformations. Reinterpreting these architectural experiences can inform and inspire contemporary sustainable design practices.

Running Title: : The Architecture of First Pahlavi-Era Residential Houses

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
23	05	20

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INTRODUCTION

Historically, The relationship between humans and their environment has always been one of the fundamental issues of human civilization. Settlements, ranging from early villages to today's megacities, were initially formed as responses to human needs for protection against climatic conditions, access to natural resources, and security (Rapoport, 1969). To address diverse needs in different climates, architecture requires distinct adaptive responses (Soleymanpour, 2015). In fact, building ecology emphasizes a structure's capacity to integrate environmental and atmospheric factors and transform them into spatial qualities and comfort (Joudat, 2001). Consequently, climatic differences lead to variation in architectural responses in vernacular buildings. Vernacular architecture constitutes a significant part of Iran's traditional architecture, with a history extending back approximately 8,000 years (Memarian, 2006). Studies of vernacular buildings across different climates clearly demonstrate that all vernacular structures were designed according to climatic principles to maximize the use of natural energies and mitigate extreme heat and cold; these designs were fully aligned with the local culture, defining the concepts of vernacular and climate-adapted architecture (Cyrus, 2014). Since ancient times, human societies, relying on indigenous knowledge, have constructed structures that achieve maximum harmony with the natural environment. Examples include mudbrick houses in the hot and arid regions of Iran, nomadic yurts in Central Asia, wooden cottages in Scandinavia, and timber-based houses in Southeast Asia— all demonstrating climate-responsive architectural adaptation (Hyde, 2000). Traditional climate-aware structures, known as vernacular architecture (the principal construction method for generations across various countries), have been able to consume significantly less energy and produce considerably lower pollution compared to modern buildings, while simultaneously providing comfortable and sustainable living environments adapted to diverse climates (Abro, 1994; Fathy, 1986). Houses create a set of internal conditions—interior spaces distinguished from the outdoors—which have the potential to protect inhabitants from many aspects of the external world, particularly adverse weather conditions (Dunn et al., 2024). Rapoport, in Culture, Architecture, and Design, emphasizes that social, cultural, and physical aspects must be considered together. Factors influencing the final built form in each region are affected by climate, culture, and geography, and are not uniform; however, these factors can be integrated according to the classifications proposed by Dr. Gholamhossein Memarian and other variables based on Rapoport's theory of house form formation. Analyzing this set of factors demonstrates that the final form of residential architecture is a multidimensional phenomenon shaped by numerous and diverse influences (Bamrinejad et al., 2023). Different morphological patterns of houses in regions with similar economic, climatic, and construction-technological conditions are also the result of cultural differences in those areas (Kokurina, 2006). Given Iran's climatic, cultural, and historical diversity, residential architectural styles and patterns in each period reflect the social and cultural transformations of their time. In recent decades, attention to vernacular and historic architecture in formulating contemporary architectural models has increased; this trend, responding to environmental, cultural, and societal identity needs, plays a significant role in preserving Iran's architectural heritage (Razmara et al., 2016). Historically, the evolution of architecture during the Pahlavi era focused primarily on the influence of modernity and new structural systems; this period functioned as a bridge between indigenous culture and modern culture and is considered a symbol of temporal and cultural transformation (Shah-Timouri & Mazaherian, 2008). These buildings were primarily constructed according to Western modernist architectural principles, though in some cases, they were redesigned in alignment with Iranian vernacular and climatic needs (Aslipour, 2015). Despite extensive studies on Iranian vernacular and climate-responsive architecture, systematic and quantitative analyses of climate-adaptive design patterns in Pahlavi-era residential buildings are limited. Most existing research has been qualitative and descriptive or focused primarily on aesthetic and stylistic aspects. During the First Pahlavi era, Iranian residential architecture was in a transitional state between tradition and modernity. Although European modernist patterns were introduced in façade organization, materials, and structural systems, fundamental principles of climatic adaptation were still maintained in many cities with hot and arid climates, such as Kerman. Proper solar orientation, continuation of central courtyard use, control of openings, utilization of thick walls for thermal storage, and creation of deep shading devices were among the enduring features (Kasmai, 2003; Fathy, 1986). However, a significant difference from the Qajar period was the reduction of absolute introversion and a gradual increase in controlled extroversion. The use of larger windows, balconies, and changes in courtyard proportions indicate that the climatic approach was no longer solely based on traditional patterns but was adapting to new social and functional requirements (Memarian, 2006; Soleymanpour et al., 2015). Overall, First Pahlavi-era residential architecture represents neither a complete rupture from Iranian climatic tradition nor its total continuity; rather, it presents a hybrid model that preserves effective climatic elements (courtyard, shading, natural ventilation) while incorporating new technologies (industrial materials, larger glazing), with the success of each building dependent on the integration of these two approaches.

MATERIALS AND METHODS

Climate-Responsive Design

Climate is one of the most influential factors shaping spatial organization in traditional architecture. Each climatic region generates unique architectural responses and spatial qualities. Traditional Iranian architecture has been heavily influenced by climatic factors (Chavoshizadeh, 2015). Due to its vast territory and diverse topography, Iran is divided into four main climatic regions: temperate-humid (north), cold-dry (mountainous areas), hot-dry (central plateau and desert regions), and hot-humid (southern coasts). Each of these regions has produced distinct architectural responses shaped by local environmental conditions, available materials, and cultural practices (Kasmai, 2003). Climatic design is a method for comprehensively reducing a building's energy consumption. The building itself acts as the first line of defense against external climatic forces. In all climates, buildings designed according to climate-responsive principles minimize the need for mechanical heating and cooling, instead utilizing the natural energy available around the building. This approach leads to energy savings and optimizes environmental conditions to provide comfort for occupants. Climate-responsive architecture has two primary objectives: during winter, to resist heat loss and maximize solar heat gain (e.g., sunlight through south-facing windows); during summer, when cooling is required, the goals are reversed resisting solar heat gain through shading and promoting heat dissipation from the interior (Watson & Labs, 1983).

Residential Architecture and Design Patterns of *the First Pahlavi Era*

During the First Pahlavi era, Iranian architecture was heavily influenced by global modernist trends. At the superficial level, contemporary European elements and forms, such as clean lines, geometric structures, the use of modern materials, and glass façades, were incorporated into Iranian architecture. This trend, alongside the preservation of traditional elements, created a synthesis and alignment between the old and new worlds. A prominent example of this influence is the Tehran Municipality building, constructed in the 1940s, where modern architectural elements coexist with traditional Iranian forms such as small domes alongside large windows and simplified façades (Farahbakhsh et al., 2009). This demonstrates that architects sought to combine traditional elements with modern methods to meet contemporary needs while preserving Iranian identity. Furthermore, governmental, cultural, and administrative buildings, such as the Ministry of Education, exemplify the adoption of international modern architecture. These structures were mainly based on Western modernist architectural principles, though in some cases, they were redesigned in alignment with local and climatic needs (Aslipour, 2015).

A fundamental feature of the First Pahlavi period was the attempt to revive Iranian architectural elements within modern forms. This trend was especially observed in public, residential, cultural, and religious buildings, which aimed to emphasize the country's historical and cultural heritage while employing contemporary approaches suitable to the era. Many buildings feature large domes, windcatchers, arches, and artistic reliefs. These elements, within modern architecture, were used symbolically within contemporary structures. For example, cultural buildings in various major cities combine Iranian architectural elements with European styles (Haeri Mazandaran, 2004). In residential house design, attention to central courtyards, use of Iranian decorative elements, tilework, and arabesque motifs demonstrates a return to historical heritage. In First Pahlavi architectural designs, Iranian symbols such as reliefs, plasterwork, and arabesque motifs were incorporated symbolically within modern forms. This approach not only preserved national identity but also reflected architects' desire to integrate cultural heritage with global modern elements. Representative examples include houses such as the Akhavi House in Tehran and cultural buildings in Isfahan and Shiraz, which expanded these elements into new spatial compositions (Arianpour, 2010). During the First Pahlavi era, significant advances occurred in the use of modern materials and construction technologies. These changes were primarily driven by the introduction of Western construction materials and technologies and the interest of governmental institutions and architects in modernizing buildings. Materials such as reinforced concrete, steel frames, large glazing, and machine-made bricks replaced traditional materials like adobe and handmade bricks, enabling the construction of taller buildings, transparent spaces, and modern façades. Notable examples include office towers, governmental buildings, and cultural centers constructed with these new technologies (Hyde, 2000). One of the key focuses in architectural design during the First Pahlavi era was a particular attention to aesthetics and modern forms. Architects, alongside the use of traditional elements, aimed to implement linear, simple, and geometric forms in buildings to ensure visually pleasing and harmonious designs. Principles such as proportion, the use of straight lines and geometric curves, and the interplay of open and enclosed spaces were central to design. Building façades were executed using modern materials with minimal ornamentation, though some decorative elements were included to maintain harmony between form and content (Architecture Studies Center, 2005). In shaping the spatial organization of traditional Iranian houses, various factors are influential, categorized into nature-related and human-related factors. Natural factors include climate, geographical characteristics, site location within the urban fabric, and vernacular materials, while human-related factors comprise cultural, social, and economic aspects, all affecting the spatial structure of traditional houses (Heydarnataj & Ahmadi, 2019). Consequently, architectural patterns in most historical residential fabrics are influenced by both natural and human systems (Farahbakhsh et al., 2017), resulting in three types of spaces within traditional houses: open, semi-open (covered), and enclosed (Haeri Mazandarani, 2009). Culturally, these three spatial types create a diverse spectrum of spaces ranging from fully private to public (Valizadeh Oghani, 2017); environmentally, the arrangement of these spaces within the house creates two adjacency patterns between the courtyard as an open space and the building as an enclosed space. In the first pattern, termed extroverted, the courtyard surrounds the building, with courtyard walls playing a key role in defining the open space. In the second pattern, termed introverted, the building encloses the courtyard, with walls positioned on the sides where the building is absent (Taheri Sarmad et al., 2019). In the spatial structure of introverted Iranian houses, the courtyard is the most important element in organizing different parts of the house (Yazdi et al., 2019). Depending on the arrangement of enclosed and covered spaces around the courtyard, spatial structures are categorized into four patterns: two-side configuration (two perpendicular façades), two-side configuration (two opposing façades), three-side configuration, and four-side configuration (central courtyard) (Meir et al., 1995).

Methodology

This study is applied in terms of objective and descriptive–analytical with a comparative approach in terms of nature. It aims to evaluate and compare the realization of three indicators—physical resilience, connection to nature, and climatic adaptability—in First Pahlavi-era residential houses in the city of Kerman. The research design is based on a multiple case study framework, with two historic houses, Ghaffari and Hakkak, selected as representative samples from Kerman's historic urban fabric. Sample selection was purposive, based on criteria including affiliation with the First Pahlavi period, location within the historic core, preservation of physical authenticity, and availability of architectural documentation. The conceptual framework of the study is structured around three main indicators—physical resilience, connection to nature, and climatic adaptability—each of which is assessed using specific evaluation metrics. Data collection was conducted in two phases. In the first phase, through documentary research and field surveys, information regarding physical characteristics, materials, spatial organization, openings, natural ventilation strategies, degree of extroversion, and structural details of both houses was extracted. In the second phase, a researcher-developed questionnaire was designed to assess the extent to which the indicators were realized. The questionnaire was formulated based on the metrics defined in the indicator table, and experts in architecture, climate-responsive architecture, and historical building conservation were asked to evaluate each indicator in both case studies using a specified assessment scale. The evaluation for all three indicators relied on expert judgment, with the resulting data possessing a perceptual–analytical nature. The statistical population comprised 60 experts, selected using the snowball sampling method. To ensure the validity of the measurement tool, content validity of the questionnaire was confirmed through expert reviews as specified in the research table, and reliability was assessed using Cronbach's alpha (Tab.1). Following data collection, information was entered into statistical software, and descriptive analysis of the indicators, including mean and standard deviation, was performed. Subsequently, to examine the relationships among indicators and evaluate the conceptual model structure, structural equation modeling (SEM) based on the Partial Least Squares approach (PLS-SEM) was employed. SmartPLS software was used to estimate path coefficients, factor loadings, and construct reliability. Furthermore, to rank and compare the final performance of the two case studies in the targeted indicators, a multi-criteria decision-making (MCDM) technique was applied, using the questionnaire scores as input for the ranking model. Preliminary statistical analyses were also conducted using SPSS software. Finally, the results of the quantitative analysis of the questionnaire data were integrated with the qualitative assessment of the physical and spatial characteristics of both houses. This comparative evaluation approach enabled simultaneous examination of perceptual–expert dimensions and objective physical features, providing a comprehensive understanding of the realization of climatic adaptability and other studied indicators in First Pahlavi-era residential architecture in Kerman.

Table 1: Research framework for evaluating the three architectural indices of residential buildings during the Pahlavi period (Source: Author)

Index	Description	Metric	Type of Evaluation	Evaluation Method
Physical Resilience	Assessment of the quality of materials, details, and structural elements for resistance and stability against climatic changes and varied uses	Quality of materials, details, and structure	Survey	Questionnaire
Connection with Nature	Degree of spatial interaction with natural elements (light, view, landscape, natural ventilation) and the level of extroversion or introversion in architecture	Level of extroversion	Survey	Questionnaire
Climate Adaptability	Building's compatibility with regional climatic requirements (ventilation, shading, number of openings, and use of local materials)	Degree of adaptability	Survey	Questionnaire

Case stady

The city of Kerman is located in a temperate-cold or cold and foothill climate. Overall, the region is characterized by two interconnected elevated axes that extend from northwest Kerman to the central areas of the province, as well as scattered lands at altitudes above 2,000 meters (Kasmai, 2003). The formation of Kerman is rooted in the ancient settlement system of Iran's central plateau, and its urban structure has been directly shaped by the semi-arid climate, limited water resources, and historical communication networks. The initial core of the city was organized around groundwater sources and qanats, in connection with the governmental citadel, a linear bazaar, and religious complexes. The city's growth pattern developed gradually and organically, with the urban fabric composed of independent neighborhoods, each with distinct socio-economic identities. These neighborhoods generally formed around a local center, including a mosque, water reservoir, bathhouse, and main street, while the street network was designed to be narrow, winding, and shaded to reduce excessive solar radiation and unfavorable winds. The historical bazaar of Kerman, as the city's spatial backbone, played an organizing role in the urban fabric, linking the citadel, residential neighborhoods, and public spaces. Throughout different historical periods, particularly from the Safavid to the Qajar era, the city's development largely followed this introverted structure based on central courtyards, forming a dense fabric with continuous walls and compact massing, which responded to both climatic and security requirements. During the First Pahlavi period, with the introduction of urban modernization policies, parts of the city's organic structure were altered. New street layouts, the creation of direct axes, and the widening of passageways were gradually implemented in some areas; however, historical cores and old neighborhoods largely retained their traditional structure. The historic Ghaffari and Hakkak houses are located within these historic, introverted urban fabrics—characterized by relatively deep parcels, courtyard-centered layouts, and interconnected building masses along narrow streets. This dense and interlinked fabric not only creates mutual shading among buildings but also moderates thermal conditions and reduces undesired environmental exchanges. Consequently, the climatic performance of these houses is influenced not only by their internal spatial features but also by the broader physical organization of the neighborhood (Fig.1)

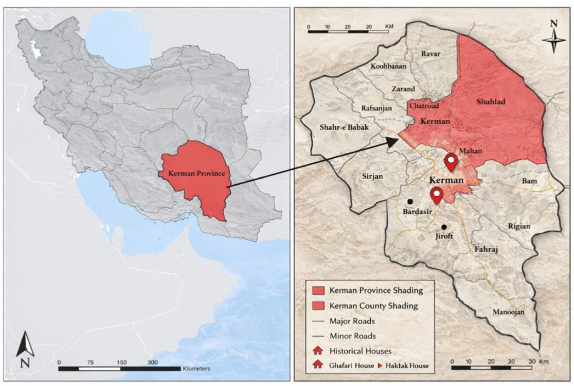

Figure 1: Location of Kerman city, its historical fabric, and the position of the case study houses

These buildings also reflect the architectural style of their period and can be studied in either their preserved or restored state. Spatial elements of the houses, in terms of their impact on the transparency of the residence, are categorized into two groups: "rooms" and "corridors." Rooms serve diverse functional purposes, while corridors act as connective elements. In this approach, similar to form-based studies, spatial elements are analyzed independently of their functional use. For the "mass" indicator, the organization and composition of the house's elements in the plan are examined. To gain a clear understanding of the spatial order and arrangement of spaces around the courtyard, the plan is analyzed based on four components. Spatial layering reveals that in courtyard-centered houses, with the expansion of the building and increase in the number of rooms, in addition to the layer adjacent to the courtyard, a secondary spatial layer is formed, whose position and formation are evaluated. The rhythm component examines the sequence of room placement relative to corridors along different courtyard façades and the potential patterns among them. Symmetry assesses the presence or absence of symmetry in the façades as a reflection of the plan composition, and the harmony of opposite façades measures the spatial correspondence of opposing fronts in terms of the number and dimensions of elements. For the "courtyard structure" indicator, the house is analyzed as an integrated whole, and the central role of the courtyard is assessed through two components: courtyard elongation, serving as an indirect indicator of geographic orientation, and courtyard proportions, i.e., the ratio of its length to width (Fig. 2).

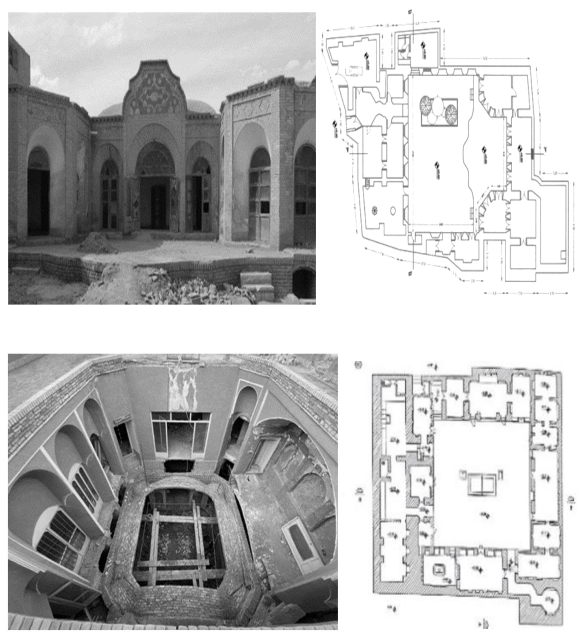

Figure 2: Sample images of the case study houses. Top: exterior view and plan of the Ghaffari House; bottom: interior view and plan of the Hakkak House

Climatic Analysis of Kerman and Comparative Evaluation of the Bioclimatic Performance of Ghaffari and Hakkak Houses

The bioclimatic analysis of Kerman, as the study's contextual backdrop, serves as the starting point for the comparative assessment of the climatic performance of the Ghaffari and Hakkak houses. Kerman is located within Iran's cold semi-arid foothill climate, characterized by hot, dry summers, cold winters, high diurnal temperature variations, low relative humidity, and significant solar radiation. The annual average precipitation ranges from 130 to 150 mm, and the mean annual temperature is approximately 16–17°C, while summer daytime-nighttime temperature differences can exceed 20°C. Plotting Kerman's climatic data on the Givoni bioclimatic chart indicates that a substantial portion of the year falls outside thermal comfort zones, making the achievement of indoor comfort largely dependent on passive design strategies. During the hot months, it is essential to reduce direct solar gain, provide effective shading, enhance natural ventilation—particularly at night—and utilize high thermal mass to moderate temperature fluctuations. Conversely, in cold months, maximizing solar gain, controlling cold wind infiltration, and retaining indoor warmth become priorities. Mahoney indices for this climate also recommend relatively compact plans, central courtyards with shading walls, controlled openings mainly on the southern façades, walls with high thermal storage capacity, and semi-open spaces such as verandas. This theoretical climatic framework formed the basis for evaluating the two First Pahlavi-era case studies. Spatial analysis of the Ghaffari and Hakkak houses shows that both employ a central courtyard pattern, yet significant differences exist in courtyard orientation, elongation, and the arrangement of spaces, resulting in different thermal responses. In the Ghaffari House, the courtyard's main axis is oriented approximately northwest–southeast, with primary winter-use spaces located on the southern side of the courtyard. Major openings face south and southeast, facilitating absorption of low-angle winter sunlight, while during summer, the higher sun angle is effectively blocked by deeper shaded verandas. The height-to-width ratio of the courtyard walls ensures that a substantial portion of the courtyard remains shaded during peak summer hours, and the high thermal mass of the walls moderates nighttime temperatures. In contrast, the Hakkak House has a courtyard axis closer to east–west orientation, with some openings exposed to direct western sunlight—a direction considered thermally unfavorable in Kerman's climate. The depth of shading devices in this house is shallower than in the Ghaffari House, and the courtyard's greater elongation results in more direct solar exposure of the courtyard floor at midday during summer. From a bioclimatic perspective, these differences indicate that the Ghaffari House aligns more closely with the strategies recommended by the Givoni chart and Mahoney indices, while the Hakkak House tends toward a more open massing and higher solar exposure, possibly reflecting a desire for a more modern architectural expression during the First Pahlavi period. A comparative assessment of spatial organization at macro, meso, and micro levels reveals that, at the macro level, the Ghaffari House has a more compact plan with a lower surface-to-volume ratio, reducing unwanted heat exchange with the environment. In contrast, the elongated plan of the Hakkak House and the increased exposed surface area raise its potential for unwanted heat gain. At the meso level, the seasonal zoning in the Ghaffari House, winter-use spaces facing south and summer-use spaces oriented toward shaded façades, demonstrates continuity of traditional climatic logic, whereas the Hakkak House shows a weaker spatial separation, with some spaces exposed to western sunlight. At the micro level, both houses use high thermal-mass materials, but the Ghaffari House exhibits better-controlled window-to-wall ratios, while the Hakkak House shows relatively larger openings, especially on certain façades, indicating a trend toward greater transparency and a modern architectural expression, which could increase summer heat load. The findings of this morphological analysis align with the quantitative research results. The Ghaffari House's higher score in climatic adaptability can be attributed to more favorable orientation, more effective shading, greater compactness, and precise control of openings. Conversely, while the Hakkak House also employs a central courtyard, it diverges from traditional climatic logic in some aspects. This demonstrates that First Pahlavi-era residential architecture in Kerman represents neither a complete break from Iran's climatic traditions nor their unaltered continuity. Instead, it constitutes an interaction between indigenous spatial logic and modernist tendencies, with climatic performance dependent on the balance achieved between these two approaches. Where traditional spatial organization and new technologies or architectural expression coexist in equilibrium, bioclimatic performance remains more effective.

FINDINGS AND DISCUSSION

TheEvaluation of the Physical Resilience Indicator

Physical resilience refers to the capacity of residential spaces to withstand physical, biological, and economic disturbances, minimizing vulnerability and enabling a rapid return to their original or improved functionality. In the context of Iranian architecture, physical resilience can be analyzed at three levels: architectural-structural, functional-spatial, and organizational-governance, and is closely associated with concepts such as sustainability, flexibility, and responsiveness to environmental pressures. From a structuralist perspective, each space and wall acquires meaning through its function and symbolic hierarchy, and resilience develops within the continuity and coherence of the spatial network. This approach emphasizes the functional adaptability and potential for redefining spaces, rather than merely focusing on structural resistance. In this framework, the interconnectedness of physical elements and spatial relationships plays a pivotal role. Physical resilience also encompasses the capacity to adapt to climatic changes, limited functional transformations, and demographic shifts. Considering the history of Iranian architecture, this highlights how residential spaces can respond to floods, earthquakes, extreme heat, and cold through surface-level or deep modifications without losing their spatial identity or fundamental structure. This concept also addresses temporal dynamics and evolving use of spaces over historical periods; for instance, traditional houses whose functions were redefined according to socio-economic changes demonstrate adaptive capacity. From a philosophical and theoretical standpoint, physical resilience relates to the relationship between spatial sustainability and human meanings how a residential space, when confronted with crises, embodies stability and security for occupants, and how this security translates into lived experience. In practical terms, this indicator can be measured through an examination of materials, construction techniques, structural integrity, and the coherence and continuity of spatial dimensions. In other words, material strength, design flexibility, and maintenance of core functions serve as operational indicators of resilience. Physical resilience is not limited to mere protection; it also encompasses the ability to restore and reactivate spaces after a crisis, ensuring minimal disruption to daily life. Finally, the analysis of physical resilience requires consideration of spatial and historical variations: the Qajar period with traditional structures and local materials, the Pahlavi period with modern ruptures and new functional programs, and the contemporary period with technological complexities and local identity, all present distinct opportunities and challenges for resilience. Thus, the analysis of physical resilience should focus on the interrelationships among components and spatial representations, rather than solely on physical resistance, to achieve a comprehensive understanding of how spaces perform under stress and during post-crisis recovery. Ultimately, the evaluation of this indicator should provide a clear depiction of how residential spaces can develop capacities for rapid responsiveness, functional flexibility, and structural identity preservation, offering a well-defined understanding of physical resilience within Iranian architectural studies. (Tab. 1-2, Fig. 3)

Table2: Factors Influencing the Assessment of Physical Resilience (Source: Author)

No.	Factor	Description
1	Durability of materials and construction methods	Longevity and capacity for restoration after damaging events
2	Spatial continuity and hierarchy of functions	Continuity of essential functions across different residential spaces
3	Flexibility of space usage	Possibility to change function without heavy costs
4	Ability to withstand environmental shocks	Resistance against heat, humidity, floods, and earthquakes
5	Connection of spaces to urban utility systems	Access to water, electricity, sewage, and emergency networks
6	Reproducibility and rapid return to function	Speed of resuming daily activities after a crisis
7	Semantic and symbolic coherence of space	Continuity of architectural identity under pressure
8	Adaptation to demographic changes	Capacity to adjust to changes in household composition
9	Integration with urban fabric and landscape	Response to surrounding context and urban landscape during crises
10	Repair and reconstruction costs	Economically feasible level for restoration and strengthening

Table 3: Questionnaire evaluation results of the physical resilience attribute (Source: Author)

Physical Resilience Index	Case Study Building	Question	Number of Responses by Frequency					Weighted Score (Sum × Importance)
			Very High (5)	High (4)	Medium (3)	Low (2)	Very Low (1)	
	Ghaffari	60	3	6	21	15	15	147
	Hakkak	60	0	0	24	24	12	132

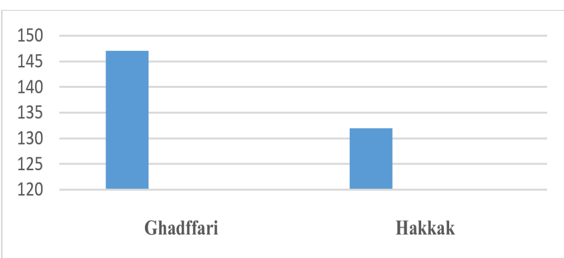

Figure 3: Questionnaire evaluation results of the physical resilience attribute (Source: Author)

Evaluation of the Nature-Integration Indicator

Integration with nature in Iranian residential architecture refers to the intertwining of interior spaces with natural elements, including sunlight, natural ventilation, views of greenery, and the use of functional natural materials such as wood and stone. This integration not only serves biological and health-related functions for residents but also reflects the cultural identity of local climates and communities. From a structuralist perspective, each space acquires meaning through symbols and space–nature relationships, and integration with nature emerges through semiotic networks and visual corridors. In this view, nature is not merely an external element but is perceived as an intrinsic part of the spatial structures, interacting with light, heat, and ventilation, while also symbolically representing environmental context. Each space thus gains significance in relation to its natural surroundings. Sunlight penetration through windows and inner courtyards acts as a natural source of energy while enhancing spatial perception, and seasonal variations in light help reconfigure spatial functions dynamically. This flexibility aligns with the historical practices of Iranian architecture, where light and ventilation were guided in native ways with minimal reliance on external energy sources. From a philosophical and theoretical standpoint, integration with nature provides a safer and more secure experience of human presence in space. Spaces connected to open views and natural environments enhance both physiological and psychological well-being and strengthen the sense of belonging to the environment. Using a structuralist approach, the combination of interior and exterior spaces, windows, courtyards, and small gardens forms a semantic network that acquires distinct meanings in each historical period and contributes to spatial identity representation. Integration with nature is also associated with adaptive resilience to climatic and seasonal changes. Houses, through central courtyards, light wells, and reflective open plans, dynamically adjust to temperature and humidity variations without compromising core functionality. Ultimately, analyzing nature-integration should provide a clear picture of how open spaces, light, and ventilation are meaningfully incorporated into residential layouts, enabling a period-based explanation of differences and continuities in the integration of natural elements across historical architectural phases. (Tab. 4-5, Fig. 4)

Table 4: Factors affecting the evaluation of the nature-connection attribute (Source: Author)

No.	Factor	Description
1	Access to open spaces and internal courtyards	Presence of central courtyards, patios, or internal gardens
2	Daylighting and visual connection to the outside	Windows, skylights, reduction of obstructive shadows
3	Natural ventilation and indoor air circulation	Ventilation through open design and airflow axes
4	Use of natural elements in materials and surfaces	Materials with natural texture and natural colors
5	Visual landscape relationship with urban context	Internal–external views and visual hierarchy
6	Open-space-based spatial functions	Outdoor sitting areas, terraces, balconies with daily functions
7	Flexibility of natural/open spaces	Ability to convert outdoor spaces to different uses
8	Use of natural light at different times of day	Distribution of daylight across day and seasons
9	Relationship with water elements	Presence of water features indoors or nearby
10	Ecological sustainability in vegetation selection	Native and climate-resistant plants

Table 5: Questionnaire evaluation results of the nature-connection attribute

Nature-Connection Attribute	Case Study Building	Question	Number of Responses by Frequency					Weighted Score (Sum × Importance)
			Very High (5)	High (4)	Medium (3)	Low (2)	Very Low (1)	
	Ghaffari	60	3	6	18	18	15	144
	Hakkak	60	0	3	24	24	9	141

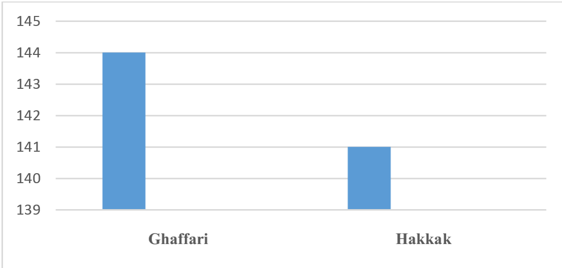

Figure 4: Frequency distribution chart of participants' responses to the nature-connection index questions

Evaluation of the Climate-Adaptability Indicator

Climate adaptability refers to the capacity of residential spaces to adjust to climatic variations and local weather conditions in a way that maintains biological functions, comfort, and energy sustainability, while preserving the architectural identity. Within a structuralist framework, this adaptability emerges through spatial networks and symbolic interactions among architectural elements, meaning that the understanding and interpretation of the climate is reproduced through signs and spatial connections. Solar exposure, building orientation, natural ventilation, shading strategies, and the use of local materials collectively create a sense of spatial flexibility, enabling the redefinition of functional uses across different historical periods. During the Qajar era, given urban fabrics and the use of inner courtyards, spatial flexibility against summer heat and winter cold relied on natural ventilation and traditional shading methods. In the Pahlavi period, urban expansion and modernization provided opportunities to enhance climatic performance through light-guiding channels and mechanical ventilation, while still preserving some local and sustainable elements. In the contemporary period, despite advanced technologies, indigenous strategies—such as open-plan layouts and dynamic integration of interior and exterior spaces—are applied to respond to temperature and humidity fluctuations. From a philosophical perspective, climate adaptability embodies the interaction between human spaces and the natural environment, in which inhabitants achieve a lived experience of security, comfort, and spatial identity in response to environmental changes. Practically, this indicator can be measured through evaluation of spatial orientation relative to solar exposure, integration of natural ventilation, appropriate use of skylights, and spatial functions that allow flexible adaptation to climatic changes. Furthermore, the analysis of climate adaptability must consider spatial-historical differences: various periods in Iran applied distinct strategies for managing light, ventilation, and heating/cooling, each reflecting the capacity of residential spaces to respond to climatic pressures. From a structuralist standpoint, spatial meanings emerge in response to climate through the interactions of walls, windows, courtyards, and the network of spatial relationships. Each historical period redefines these semantic relations, contributing to a distinct local identity. Ultimately, the analysis of climate adaptability should provide a comprehensive understanding of how residential spaces adjust to future climatic variations, enabling the explanation of period-based differences and continuities in spatial response strategies. (Tab. 6-7, Fig. 5)

Table 6: Factors affecting the evaluation of the climatic adaptability attribute (Source: Author)

No.	Factor	Description
1	Building orientation and solar exposure	Proper orientation to benefit from sunlight in different seasons
2	Natural and internal ventilation	Degree of use of natural ventilation and airflow channels between spaces
3	Window layout and skylights	Size, position, and performance of natural lighting openings

4	Spatial shading and shadow-casting elements	Courtyards, iwans, and climate-based shading devices
5	Thermal transfer channels between spaces	Links between cool and warm spaces for temperature balance
6	Energy recovery and thermal regulation systems	Presence of low-energy systems
7	Functional flexibility of climate-responsive spaces	Ability to change spatial use across seasons
8	Visual connection to open space	Visual linkage to exterior space for psycho-thermal comfort
9	Vegetation and natural shading elements	Use of trees and green cover for temperature control
10	Access to natural resources for evaporation/condensation control	Presence of water sources or pools for microclimate regulation
12	Ecological sustainability of materials	Use of native materials resistant to climate variation
13	Reuse and redefinition of outdoor spaces	Ability to reuse outdoor spaces in different seasons
14	Seasonal daylight management	Light control strategies for winter and summer comfort
15	Climate-related acoustic insulation	Protection from noise pollution and preservation of indoor calm
16	Reduction of solar heat gain through façades	Use of open façades or shaded envelope systems

Table 7: Questionnaire evaluation results of the climatic adaptability index (Source: Author)

Climatic Adaptability Index	Case Study Building	Question	Number of Responses by Frequency					Number of Responses by Frequency Weighted Score (Sum × Importance)
			Very High (5)	High (4)	Medium (3)	Low (2)	Very Low (1)	
	Ghaffari	60	3	12	18	18	9	162
	Hakkak	60	0	6	21	18	15	138

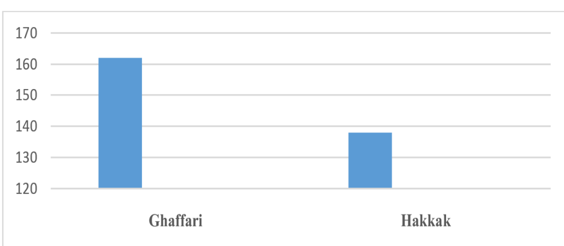

Figure 5: Frequency distribution chart of participants' responses to the climatic adaptability index questions

Reliability and Validity Tests of the Model

Cronbach's Alpha Test

Cronbach's alpha is considered the oldest and most widely used test for measuring the internal consistency of indicators. This test evaluates the internal correlation of the items within a construct, independent of the model structure. According to Tenenhaus (2005), the correlation among items for each construct should be at least 0.7. (Tab. 8)

Table 8: Cronbach's alpha coefficients (Source: Author)

Index	Cronbach's Alpha
Physical Resilience	0.974
Connection with Nature	0.973
Climatic Adaptability	0.867

In this study, all Cronbach's alpha coefficients exceed 0.7, confirming the reliability of the constructs.

Composite Reliability (Dillon-Goldstein Test)

Composite reliability is regarded as the most significant reliability measure in structural equation modeling (SEM) software. While its definition is similar to Cronbach's alpha, composite reliability assesses item correlations within the context of the full model, taking into account factor loadings, path coefficients, measurement errors, and other parameters. Hence, it provides a more realistic measure of the generalizability of results. According to Henseler (2009), composite reliability values should also exceed 0.7 for each construct. (Tab. 9)

Table 9: Composite Reliability Coefficients (Source: Author)

Index	Composite Reliability
Physical Resilience	0.981
Connection with Nature	0.976
Climatic Adaptability	0.937

All composite reliability values in this study are above the 0.7 threshold, confirming model reliability.

Spearman's Rho-A Test

Many researchers argue that Likert scales are inherently ordinal, making Pearson-based tests (like Cronbach's alpha or composite reliability) theoretically inappropriate. To address this concern, Ringle (2017) introduced Rho-A in PLS software, which is a non-parametric Spearman correlation among the items. The cutoff for acceptable reliability is 0.7 for each construct. (Tab. 10)

Table 10: Spearman Correlation of the Indices (RHO-A) (Source: Author)

Index	rho_A
Physical Resilience	0.975
Connection with Nature	0.976
Climatic Adaptability	0.874

Table 11: Communality Reliability Test (Source: Author)

Index	Communality
Physical Resilience	0.927
Connection with Nature	0.716
Climatic Adaptability	0.882

Summary of Reliability Tests

Since Cronbach's alpha, composite reliability, Rho-A, and shared reliability (AVE) all yield satisfactory results, the construct reliability is confirmed.

Model Validity Tests

Validity or model credibility means that before data collection, it is first examined in the form of face validity and content validity. Then, to ensure that the researcher's standard instrument measures exactly the variables intended, the construct validity must be assessed (unfortunately, according to studies conducted in Iran, only a very small percentage of research possesses construct validity). According to Gefen (2016), construct validity consists of two parts: convergent validity and discriminant validity. Convergent validity means that the reflective indicators of a variable, without considering errors, should have correlation or convergence with each other. On the other hand, discriminant validity, also called diagnostic, distinct, or divergent validity, means that the indicators of one variable or component do not correlate with the indicators of another variable or component. In the global scientific and academic context, for quantitative research, the most important aspect of research acceptability is having discriminant validity. Based on this classification, their tests are now performed.

Convergent Validity Tests

To establish this type of model validity, two essential conditions exist. The first condition concerns the Average Variance Extracted (AVE), and the second involves comparing it with composite reliability. (Tab. 12)

a) AVE > 0.5

Table 12: Average Variance Extracted (AVE) Values (Source: Author)

Index	Average Variance Extracted (AVE)
Physical Resilience	0.927
Connection with Nature	0.716
Climatic Adaptability	0.882

All the values in the table of Average Variance Extracted exceed the threshold of 0.5, and therefore the first condition for convergent validity is satisfied. (Tab. 13)

b) CR > AVE

Table 13: Comparison of Average Variance Extracted and Composite Reliability (Source: Author)

Index	Composite Reliability	Average Variance Extracted (AVE)
Physical Resilience	0.981	0.927
Connection with Nature	0.976	0.716
Climatic Adaptability	0.937	0.882

All variables satisfy the second condition of convergent validity, and now, based on Table 1, it can be stated that the modified outer model of the research possesses convergent validity. In other words, the indicators of each latent variable of the study converge and are collinear.

Reflective Outer Model Quality

Variance-based methods, unlike covariance-based methods, do not have high validity in terms of the fit of results or the alignment of observations with reality in the population. In other words, the meaning of "fit" in variance-based methods is not the same as in covariance-based methods. Instead, there are indices that assess the quality of the model (Gifen, 2012). Currently, the quality of the outer model is evaluated using the index called Cross-Validated Communality (CV Com). According to Henseler (2009), this index is calculated with three thresholds: 0.02, 0.15, and 0.35, representing weak, moderate, and strong quality, respectively. (Tab. 14)

Table 14: Cross-Validated Communality Index (CV-COM) Assessment (Source: Author)

Q^2 (=1-SSE/SSO)	
Physical Resilience	0.778
Connection with Nature	0.614
Climatic Adaptability	0.524

All values are much higher than 0.15; therefore, the quality of the measurement model is at a moderate level. This means that the questions or indicators selected by the researcher measure their respective variables with acceptable quality. At this point, the tests of the measurement model, or the reflective outer model, are complete, and the researcher can proceed to the tests of the structural model. In interpreting the "connection with nature" index, it can also be stated that examining Qajar-era samples compared to other samples shows that buildings from this period have higher scores. This could be due to better access to green spaces or more open views, greater use of natural light, and appropriate integration of interior–exterior spaces using materials compatible with the environment. However, the presence of lower-scoring samples from earlier periods or those with limited access to green spaces or natural views indicates that the connection with nature is not entirely dependent on the historical period. Instead, it depends on local characteristics, spatial layout, placement of openings, and landscape management. In other words, the connection with nature is a combined outcome of building orientation, the arrangement of interior and exterior spaces, access to light and views, use of local and environmentally compatible materials, and ventilation design. These factors interact with one another and are specifically shaped or adjusted in each individual building. It can be concluded that the period-related differences in connection with nature may reflect variations in access to green spaces, external views, and daylighting of interior spaces, emphasizing that rather than relying on a single factor, the architectural and physical characteristics of each building should be examined individually.

Ranking Case Study Samples

Table 15: Initial Decision Matrix (Source: Author)

Initial Decision Matrix			
	Physical Resilience	Connection with Nature	Climatic Adaptability
Ghaffari	0.0734	0.0821	0.0874
Hakkak	0.0659	0.0803	0.0744

Table 16: Linear Normalized Matrix (Source: Authors)

Linear Normalization			
	Physical Resilience	Connection with Nature	Climatic Adaptability
Ghaffari	0.0734	0.0821	0.0874
Hakkak	0.0659	0.0803	0.0744

Table 17: Weighted Matrix (Source: Authors)

Weighting			
	Physical Resilience	Connection with Nature	Climatic Adaptability
Ghaffari	0.0090	0.0100	0.0109
Hakkak	0.0081	0.0098	0.0093

Table 18: Positive and Negative Ideal Solutions (Source: Author)

Ideal	Positive and Negative Ideal Solutions							
Possitive	0.0136	0.0130	0.0145	0.0153	0.0180	0.0200	0.0120	0.0237
Negative	0.0077	0.0065	0.0065	0.0058	0.0047	0.0075	0.0061	0.0015

Table 19: Positive and Negative Separation Measures and Ranking of Selected Houses (Source: Author)

	di+	di-	cl	rank
Ghaffari	0.020544757	0.014092398	0.406858	1
Hakkak	0.022458172	0.012432888	0.356334	2

Therefore, based on the obtained results, the ranking of the examined buildings can be explained as follows:

Table 20: Ranking of the Examined Buildings (Source: Author)

Case Study Building	Rank	
Hakkak	1	0.35
Ghaffari	2	0.40

RESULTS AND CONCLUSION

The present study aimed to comparatively assess the characteristics of physical resilience, connection with nature, and climatic adaptability in residential houses of the Pahlavi I period in Kerman. It sought to provide a comprehensive understanding of how architecture of this era responded to the cold semi-arid climate of the region by combining morphological analysis with expert-based evaluations. Selecting the Ghafari and Hakkak houses as representative examples from the historical fabric of the city allowed for an in-depth examination of the interaction between traditional spatial logic and the modernist tendencies emerging in the early 20th century. The findings indicate that both houses were still organized around the central courtyard pattern and introverted structure, a model that had been established over centuries as an effective response to the climatic conditions of central Iran. However, adherence to traditional climatic logic was not identical in the two houses; differences were observed in orientation, spatial organization, window ratios, and the arrangement of seasonal spaces, all of which influenced their thermal performance. Regarding physical resilience, both houses performed well due to the use of local materials with high thermal mass, appropriate wall thickness, and structural details consistent with traditional construction knowledge. This suggests that despite the gradual introduction of modern technologies during the Pahlavi I period, foundational structural principles and indigenous building logic were maintained, serving as a stabilizing factor against thermal fluctuations and climate variations. Comparative analysis showed that the Ghafari house exhibited greater coherence between materials, structure, and spatial organization, with its thermal mass aligned with proper orientation and effective shading. In contrast, in the Hakkak house, certain changes in spatial proportions and increased window areas somewhat reduced the thermal performance, reflecting a gradual shift toward a different architectural expression rather than structural weakness. In the connection-with-nature index, both houses established a dynamic relationship between living spaces and natural elements through central courtyards, internal-facing windows, and opportunities for natural ventilation. However, variations in the degree of outward openness and the arrangement of spaces toward the courtyard resulted in differing intensity and quality of this connection. The Hakkak house, in some facades, shows a greater tendency toward openness, which may indicate a shift in spatial and social preferences during the Pahlavi I period. Regarding climatic adaptability, expert evaluations revealed that the Ghafari house was better aligned with Kerman's climatic requirements. Its optimal orientation, deeper verandas, more compact plan, and precise control of openings enabled balanced thermal performance in both summer heat and winter cold. While the Hakkak house still adhered to climatic principles, certain architectural features slightly reduced its thermal efficiency compared to the Ghafari house. Analysis of the questionnaire data and structural modeling demonstrated significant correlations among the three main indices, showing that climatic adaptability largely depends on the quality of physical resilience and the degree of connection with nature. This confirms that building performance is not determined by a single factor but emerges from the interaction of structure, spatial organization, and engagement with the natural environment. Urban context analysis also indicated that the placement of these houses within Kerman's dense, organic historical core enhanced their climatic performance. The continuity of building masses, narrow passageways, and mutual shading among buildings contributed to thermal moderation at the neighborhood scale, not just at the individual building level. These findings suggest that Pahlavi I residential architecture in Kerman should not be seen as a sudden rupture from traditional climatic practices; rather, it represents a transitional phase where indigenous elements still dominate, while signs of spatial evolution and increased openness are visible. The success of each house in responding to climate depended on the balance between these two approaches. Theoretically, this study demonstrates that analyzing historical architecture based solely on stylistic or formal characteristics is insufficient; climatic performance and sustainability indices must also be incorporated as evaluation criteria. The indicator-based approach employed allows for relative, comparable assessments of the samples, moving beyond purely qualitative judgments. Methodologically, combining field data with expert evaluations and structural statistical analysis provides a replicable framework for similar studies in other historical cities of Iran. This model can also be applied to assess other transitional-period buildings between tradition and modernity and offers a basis for comparisons across different climatic regions. Moreover, the findings emphasize that any restoration interventions must consider the original climatic logic of these buildings, as changes in window ratios, removal of verandas, or use of incompatible materials could disrupt the historical thermal balance and reduce performance. These results show that Pahlavi I residential houses in Kerman reflect a smart continuation of traditional climatic practices within the context of new social and physical transformations, with their adaptability dependent on the integration of indigenous spatial logic and modern tendencies. The Ghafari house, maintaining a greater balance between these approaches, exhibits better climatic performance, whereas the Hakkak house represents a gradual transition in the bioclimatic pattern. Ultimately, it can be concluded that the historical architecture of Kerman, particularly during the transitional Pahlavi I period, embodies a repository of indigenous climate-responsive knowledge. Its systematic scientific reevaluation can contribute to improving contemporary architectural quality in similar climates and provide a theoretical framework linking architectural heritage with modern sustainability approaches.

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HOW TO CITE THIS ARTICLE

Eskandari,H. (2025). Evaluation of the architectural model of a residential building based on the structuralist approach in the Pahlavi period in Iran (Case study: Hakkaki and Ghaffari House). International Journal of Urban Management and Energy Sustainability, 6(2), 281-298.

DOI: 10.22034/ijumes.2025.733079