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RESILIENT FUTURES: REASSESSING TRADITIONAL HOUSING MODELS FOR LONG-TERM SUSTAINABILITY

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Abstract. Sustainability has emerged as a central challenge in contemporary architecture and urban planning, driven by climate change, rapid urbanization, and the depletion of natural resources. However, many of the solutions sought today were already embedded in the construction logic of traditional dwellings, particularly in rural and vernacular contexts. Traditional architecture embodies the key principles of sustainability - the use of local and renewable materials, climate-adaptive spatial planning, passive ventilation, and thermal regulation - long before these concepts were formally theorized. This study re-evaluates traditional Azerbaijani architecture through the lens of sustainability, analyzing dwellings and monumental structures across various regions of the country. Comparative references are drawn from vernacular architectures in Iran to contextualize regional similarities in climate-responsive design. The analysis focuses on material typology, wall thickness, structural systems, and passive environmental strategies, framed within broader socio-cultural and ecological dimensions. The paper argues that traditional architecture should be recognized not merely as cultural heritage but as a resilient and contextually adaptive model for contemporary sustainable design. Finally, the study proposes an integrative framework for embedding vernacular knowledge into modern architectural education, conservation policy, and sustainable building practices.

Keywords: vernacular architecture, climate-adaptive design, local building materials, passive thermal performance, architectural heritage, sustainable rural development

1.Introduction. In the twenty-first century, sustainability has become one of the most pressing challenges facing architecture and urban planning. Accelerating climate change, rapid urbanization, the depletion of natural resources, and rising energy demands have created a need for new architectural and design strategies. Today, the construction sector faces significant pressure in terms of its ecological footprint, carbon emissions, and energy consumption. Within this context, sustainable architecture can no longer rely solely on technological innovation; it must also draw upon the historical knowledge and traditional construction cultures that once ensured environmental harmony and resilience.

Many of the principles that modern architects now rediscover under the banner of “sustainability” — the use of local materials, climate-responsive design, passive energy strategies, and social adaptability — were already embedded in traditional building practices across diverse regions centuries ago. Vernacular dwellings, particularly those in rural contexts, were designed in harmony with their environment: minimizing energy use, recycling materials, and reflecting social and cultural patterns of life [1]. Traditional Azerbaijani architecture, much like that of Anatolia and the South Caucasus, exemplifies how adaptation to nature and respect for the environment shaped the very foundation of architectural form.

Similar architectural patterns can be observed beyond Azerbaijan’s borders, particularly in Tabriz, Iran — a city sharing both the climatic conditions and the cultural continuum of the region. The

caravanserais, the mosques and the semi-subterranean adobe dwellings of Tabriz demonstrate how architectural aesthetics and environmental functionality coexisted. Thick masonry walls, low ceilings, and narrow window openings contributed to thermal stability by retaining warmth in winter and maintaining coolness in summer. Moreover, the compact urban fabric, where residential and public buildings were physically interconnected, helped reduce heat loss and energy demands. These features embody what is now recognized as the early practice of “passive design.”

Scholarly literature emphasizes that sustainable architecture extends beyond energy efficiency; it also encompasses social, cultural, and economic adaptability [2]. Traditional buildings, in this sense, form the nucleus of sustainability — they minimize environmental impact, optimize material and energy resources, and reflect community-based patterns of living. The architectural heritage of Tabriz and Absheron therefore represents a significant case for both theoretical and practical investigation.

The objective of this study is to comparatively analyze traditional residential structures in the Absheron and mountainous regions of Azerbaijan alongside those in the city of Tabriz, Iran, through the lens of sustainability. The research aims to identify how these traditional architectural models address contemporary ecological challenges and to determine which of their design principles can be effectively transferred to modern architectural practice. The analysis focuses on spatial organization, material selection, structural systems, stylistic features, and climate adaptability. The central hypothesis is that these traditional architectural forms are not merely historical artifacts but offer practical frameworks for future sustainable design — embodying principles that remain both relevant and applicable in the era of global environmental change.

Table 1. Transfer from Vernacular to Sustainable Architecture

Traditional principle	Modern equivalent	Sustainability benefit
Use of local natural materials (clay, brick, stone)	Biodegradable, low-carbon materials	Reduction of carbon footprint
Courtyard-based spatial layout	Passive cooling strategies	Decreased energy consumption
Thick walls and small windows	Thermal mass strategy	Improved temperature stability
Harmony with natural site	Bioclimatic design	Climate-responsive structure
Social-spatial cohesion	Community-based planning	Enhanced social sustainability

2. Research methodology and approach. This study employs a comparative and analytical methodological framework to examine the sustainability features of traditional dwellings located in the Baku, Absheron and mountainous regions of Azerbaijan, as well as in the city of Tabriz, Iran. The principal aim is to identify how vernacular architecture aligns with modern principles of sustainable design in terms of climate adaptability, material selection and energy efficiency.

The research process consisted of three main stages:

1. a systematic review of scientific literature on vernacular sustainability;
2. a typological and structural analysis of selected case studies;
3. a comparative interpretation of results against contemporary sustainable architectural frameworks.

The case studies were selected using a purposive sampling approach, focusing on representative examples of courtyard houses, thick masonry walls and locally sourced construction materials such as stone, brick, clay and timber. Azerbaijani examples were drawn primarily from Absheron villages and mountain settlements in the other regions, while Iranian examples were taken from the historical neighborhoods of Tabriz.

This regional pairing ensured climatic comparability, as both study areas exhibit a semi-arid continental climate characterized by hot summers and cold winters [3, p. 109]. The sustainability potential of traditional architecture was assessed through four key parameters:

1. Microclimate and courtyard design-The courtyard height-to-width (H/W) ratio, spatial form (rectangular, U-, or L-shaped), orientation, and vegetation cover were examined. Previous studies

indicate that courtyard geometry and orientation can reduce indoor air temperatures by 0.5–5 °C in hot and arid regions [4, p. 146; 5, p. 92].

2. Building materials and structural systems-Wall thickness, material composition (stone, adobe, brick), roof type (flat or gabled) and window geometry were evaluated. The use of local natural materials significantly reduces carbon footprint while ensuring thermal stability and ecological compatibility [6, p. 74; 7, p. 118].

3. Passive ventilation and thermal regulation-The configuration of semi-open spaces (sofa, veranda), air circulation paths, and the interaction between thermal mass and natural ventilation were analyzed. Studies demonstrate that ventilated courtyards and semi-enclosed layouts generate passive cooling effects driven by pressure and temperature differentials [8, p. 225; 9, p. 243].

4. Socio-spatial adaptation and resource sustainability-Indicators such as community-based spatial organization, local sourcing, and material reuse were included to address the social and cultural dimensions of sustainability [10, p. 53; 2, p. 67].

Three principal data sources informed the study:

-Literature review: Key works examining the environmental performance of courtyard architecture were reviewed, including *Passive Cooling Effects of Courtyards* [3], *Courtyard Design Variants and Microclimate Performance* [4], and *A Ventilated Courtyard as a Passive Cooling Strategy in the Warm Humid Tropics* [8].

-Typological and morphometric analysis: For each selected dwelling, plan depth, courtyard ratio, wall thickness, window dimensions, and orientation were recorded based on architectural surveys, measured drawings and archival documentation [11, p. 24].

-Material and Assembly Profiling: The thermal and moisture-regulating properties of stone, earth and timber were analyzed using the technical parameters outlined by Carole Ryan in *Traditional Construction for a Sustainable Future* [11, p. 112].

The analytical framework comprised three stages:

A. Courtyard performance assessment-The passive cooling potential of courtyard layouts was assessed according to orientation, wall height, vegetation and shading. Recorded parameters were compared against established empirical benchmarks reporting temperature reductions of 0.5–5 °C [3, p. 110; 5, p. 95].

B. Structural and material evaluation-Wall materials, thickness and window proportions were analyzed in relation to “thermal mass strategy.” Ventilation potential was further interpreted based on the spatial relationship between courtyards and transition zones (sofa/veranda) [8, p. 229].

C. Three-pillar sustainability model-Each case was evaluated using a three-pillar framework encompassing environmental, social, and cultural indicators.

- *Environmental*: energy efficiency and material renewability;
- *Social*: adaptability to community and lifestyle patterns;
- *Cultural*: preservation of vernacular knowledge and building craft.

The scoring matrix situates each dwelling along a continuum from “heritage prototype” to “transferable sustainability model” [7, p. 122].

As no environmental measurements were performed, findings rely on comparative inference using temperature and orientation data reported in prior studies. Seasonal heating penalties associated with deep courtyards were acknowledged but not numerically simulated. Nevertheless, results were triangulated across hot-arid and warm-humid climate studies to ensure contextual reliability [4, p. 148].

3.Results and discussion. The renewed interest in the sustainability of medieval and vernacular architecture arises from its holistic adaptation to both natural conditions and human needs. Traditional Azerbaijani and Tabriz dwellings demonstrate how the synthesis of material, climate, and social structure historically produced environmentally attuned architectural systems. These buildings formed from locally available resources such as limestone, baked brick, timber and clay, anticipated many principles of modern ecological design: low embodied energy, thermal inertia and passive climate control [12, p. 176]. In Azerbaijan, vernacular dwellings evolved through diverse typologies—*qaradam*, *pəyə* and *eyvanlı ev*—corresponding to settlement type (permanent or nomadic), terrain, and

resource availability [13]. Mountain dwellings in Ganja and Nakhchivan used thick masonry or semi-subterranean construction for insulation; plains settlements favored lightweight reed or cane walls allowing air permeability.

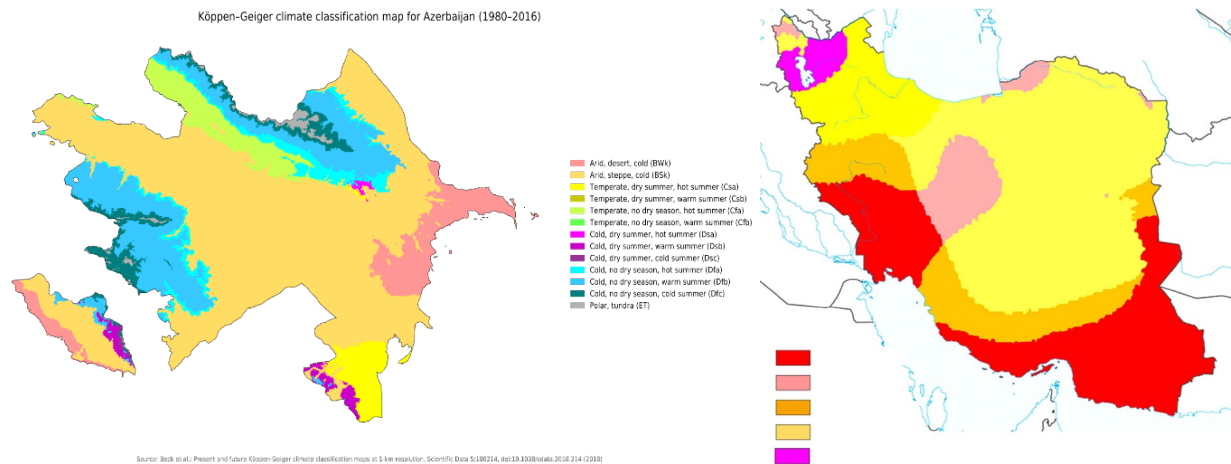


Fig. 1. A.Climate map of Azeerbaijan based on Köppen-Geiger classification method for 1980–2016
b.Climate map of Iran based on Köppen-Geiger classification method,
https://en.wikipedia.org/wiki/Climate_of_Azerbaijan

The *qaradam* houses of the Small Caucasus, composed of clay, stone and timber, balanced thermal mass and humidity buffering, preserving warmth in winter and coolness in summer. In contrast, Absheron architecture shaped by aridity, salt exposure and prevailing northern winds, relied heavily on limestone masonry. The use of lime-clay plaster prevented material expansion under thermal stress, anticipating what contemporary material science terms *adaptive fabric performance*. The Absheron Peninsula, as described by Fətullayev-Fiqarov [14] and Mehtiyev [15], represents a microclimatic laboratory of sustainability. Here, houses were oriented south or southeast to capture limited winter sun while shielding against the *gilavar* wind. Flat earthen roofs with stone gutters enabled rainwater management and provided shaded outdoor sleeping areas—an example of multifunctional envelope design. Kitchen domes (*dubla*) above the *təndir* served simultaneously as ventilation and as thermal chimneys.

Such domed exhausts, according to Akan et al. [16, p. 184], are parallel to Anatolian “*hayat-ocak*” systems, where semi-enclosed courtyards regulate indoor air quality through buoyancy-driven flow. In Tabriz, the material palette shifted toward baked brick and plaster composites, allowing seismic resilience in a tectonically active environment. As highlighted by Cao et al. [7], brick masonry with lime mortar achieves both compressive strength and energy retention, reducing annual heating demand by up to 20%.

Table 2. Comparative material logic in Azerbaijani and Iranian traditional dwellings.

Material	Typical regions	Performance characteristics	Sustainability advantage
Baked brick	Tabriz, Nakhchivan	Seismic stability, thermal retention	Longevity, energy efficiency
Limestone	Absheron, Buzovna	Breathable, adaptive to temperature change	Climate responsiveness
Timber (oak, plane)	Shaki, Qax, Tabriz	Structural–decorative synergy	Renewable, low embodied carbon
Clay/plaster	Ganja, Tabriz	Thermal mass, moisture regulation	Passive insulation, recyclability

Vernacular builders optimized wall thickness (60–80 cm) to stabilize diurnal temperature variation, mirroring the performance thresholds later verified in empirical studies of Anatolian courtyard houses [4].

Table 1 summarizes the comparative material logic of Azerbaijani and Iranian traditional dwellings. Baked brick in Tabriz and Nakhchivan displayed *anti-seismic elasticity* through interlocked joints; limestone on Absheron provided permeability and reflectivity; timber in Shaki–Qax added flexibility and aesthetic continuity; and clay layers acted as renewable insulation. These findings coincide with Örmecioğlu et al. [17] who observed that mixed timber–adobe (*hımış*) systems in Bozova (Turkey) offered high durability with minimal maintenance, emphasizing repairability as a core sustainability trait.

The courtyard-centered plan, common to both Azerbaijani and Anatolian vernacular housing, constitutes a passive climatic device. Courtyards function as thermal buffers: shading in summer, allowing solar gain in winter, and channeling airflow through openings [9]. In Absheron and Shaki, inner yards enclosed by high walls produced microclimates 3–5 °C cooler than external ambient temperature—consistent with empirical observations from Korkuteli houses [16, p. 183]. Orientation towards prevailing winds and the inclusion of semi-covered spaces (*eyvan* or *sofa*) facilitated continuous cross-ventilation, an approach parallel to the bioclimatic zoning of Mediterranean courtyard houses [8].

The hybrid masonry-timber technique found in Azerbaijani shrines such as the *Qarapaltar Piri* (Buzovna, 14th century) and Anatolian *Bozova Houses* shows how compressive and tensile materials were balanced to resist seismic stress. These techniques prefigure today's composite structural strategies aimed at ductility and load distribution. The domed and arched typologies—rooted in Persian-Caucasian masonry logic—ensured the diffusion of vertical loads and enhanced wind resistance. Similar structural wisdom was observed by Akan et al. [16, pp. 185–186], where timber frames integrated with adobe infill extended building life beyond 80 years with minimal repair.

Vernacular sustainability extends beyond physical endurance; it encapsulates cultural continuity and self-maintenance capacity. As noted in the Korkuteli–Bozova study, user participation in construction fosters long-term maintenance literacy among residents [16, p. 187]. In Azerbaijani contexts, families routinely repaired roofs and facades using community labor and locally mixed lime plaster, a practice that sustained both craftsmanship and social cohesion. However, contemporary threats—including unregulated restoration, salt efflorescence and wind erosion on the Absheron Peninsula—undermine this inherited sustainability. Similar degradation patterns are documented for Anatolian earthen structures in *Renewable and Sustainable Energy Reviews* [18], underscoring the need for climate-adaptive conservation protocols.

Traditional Azerbaijani and Tabriz architecture embodies a pre-industrial model of circular economy: local sourcing, low-waste construction and climatic synergy. To re-embed these logics within contemporary practice, several strategic implications arise:

- Design translation: Develop architectural guidelines that reinterpret courtyard and wall-mass systems as modern passive design tools.
- Material substitution: Promote local equivalents of lime, clay and renewable timber over synthetic composites.
- Adaptive restoration: Encourage conservation methods aligned with regional humidity, wind and salt exposure profiles.

Thus, vernacular architecture in the South Caucasus and Northwest Iran offers a tested empirical framework for sustainable building—combining environmental intelligence, structural resilience and cultural identity. Reintegrating this heritage into present design education, urban planning and restoration policy is therefore both a scientific necessity and a cultural imperative.

In contemporary architectural discourse, sustainability has become a strategically significant and globally pressing issue. Under the combined impact of climate change, rising carbon emissions, resource depletion and rapid urbanization, architecture today is assessed not only by its technological innovation or aesthetic quality but also by its ecological responsiveness and social adaptability [7, p. 132,19]. Within this context, vernacular and monumental architectures are increasingly recognized as

early and empirically tested models of sustainable design.

Vernacular architecture represents a harmonious synthesis of material, form and function, shaped by the intelligent use of local climate, topography, social structure and available resources [13, pp. 51–52; 20]. Across Azerbaijan particularly in Nakhchivan, Absheron, Ganja, Shamakhi, and Shaki–Zaqatala and in the culturally and climatically related city of Tabriz, construction materials were meticulously adapted to local environmental conditions. Materials such as baked brick, limestone, river stone, clay, plaster and timber not only minimized environmental impact but also enhanced energy efficiency, thermal stability and structural resilience [11, p. 112].

In seismic regions such as Nakhchivan, the *Momine Khatun* and *Yusuf Kuseir oglu* mausoleums exemplify the mastery of baked brick for both anti-seismic performance and visual aesthetics. A similar approach is evident in the *Ghazan Khan Mausoleum* in Tabriz, where standardized brick dimensions and high-quality mortar contributed to structural longevity [3, p. 93]. On the Absheron Peninsula — notably in the 14th-century *Qarapaltar Piri* shrine in Buzovna — a combination of limestone and clay was employed to counteract temperature fluctuations and humidity, embodying what modern material science refers to as *adaptive material behavior* [7, p. 136].

Traditional spatial configurations also demonstrate sophisticated sustainability logic. The courtyard-centered typology, prevalent across both rural and urban settings, provided microclimatic moderation and social cohesion. Courtyards facilitated shading in summer and wind protection in winter, while the orientation of buildings responded to local climatic forces. In Absheron, houses typically faced south and southeast to maximize passive solar gain, whereas in Tabriz, underground *qanat* cooling systems and thick masonry walls ensured natural temperature regulation [4, p. 174].

Constructive systems formed the technological foundation of durability. The integration of stone and brick masonry, timber seismic bands, and *dry-stone* construction ensured both structural stability and aesthetic rhythm. Domes and arches distributed loads spherically, contributing to exceptional longevity [15, p. 214; 22]. In Shaki architecture, stalactite arches, wooden ceilings, and cornices combined decorative and load-bearing functions. Timber — particularly oak, plane, and elm — acted as a “breathing material,” facilitating natural ventilation and maintaining interior humidity balance [11, p. 114; 23].

These design elements collectively represent not only cultural heritage but also a functional sustainability framework. However, the preservation of this potential requires a systematic, research-based conservation policy. Azerbaijan’s post-independence restoration and conservation initiatives demonstrate a significant shift toward sustainable heritage management. Since the early 2000s, projects conducted under the “Cultural Heritage Preservation Program”, supported by the World Bank, have involved major sites such as the *Palace of the Shirvanshahs* (Baku), *Momine Khatun Mausoleum* (Nakhchivan), *Sheki Khan Palace*, *Ateshgah Temple*, and *Sheikh Babi Complex* [13, p. 120].

The main objective of these projects was not only the restoration of the physical structure, but also the preservation of the monument’s functional and social value. For example, in the Shakikhans’ House, the reconstruction of the 18th-century lifestyle was carried out based on the principle of adaptive reuse. The transformation of the caravanserais in Ganja into hotels and tourism facilities represents a successful example of integrating architectural heritage into social and economic circulation [14, p. 92].

During the conservation works at the Sheikh Babi Complex in the Fuzuli district, measures were taken to improve the chemical and physical durability of materials and to prepare the structure for long-term operation — serving as an example of the technological applications of sustainable architecture [11, p. 128].

The restoration works carried out in regions such as Quba, Qakh, Barda, Salyan, and Balakan demonstrate that the principle of “integral conservation” has taken shape in Azerbaijan. This approach ensures the simultaneous restoration of the constructive, functional and visual layers of architectural heritage.

Thus, the sustainability principles of traditional architecture can be regarded as a methodological basis applicable both in modern restoration practice and in architectural education. Azerbaijan’s experience in this field can be studied and applied as a regional model of sustainable conservation at

the international level.

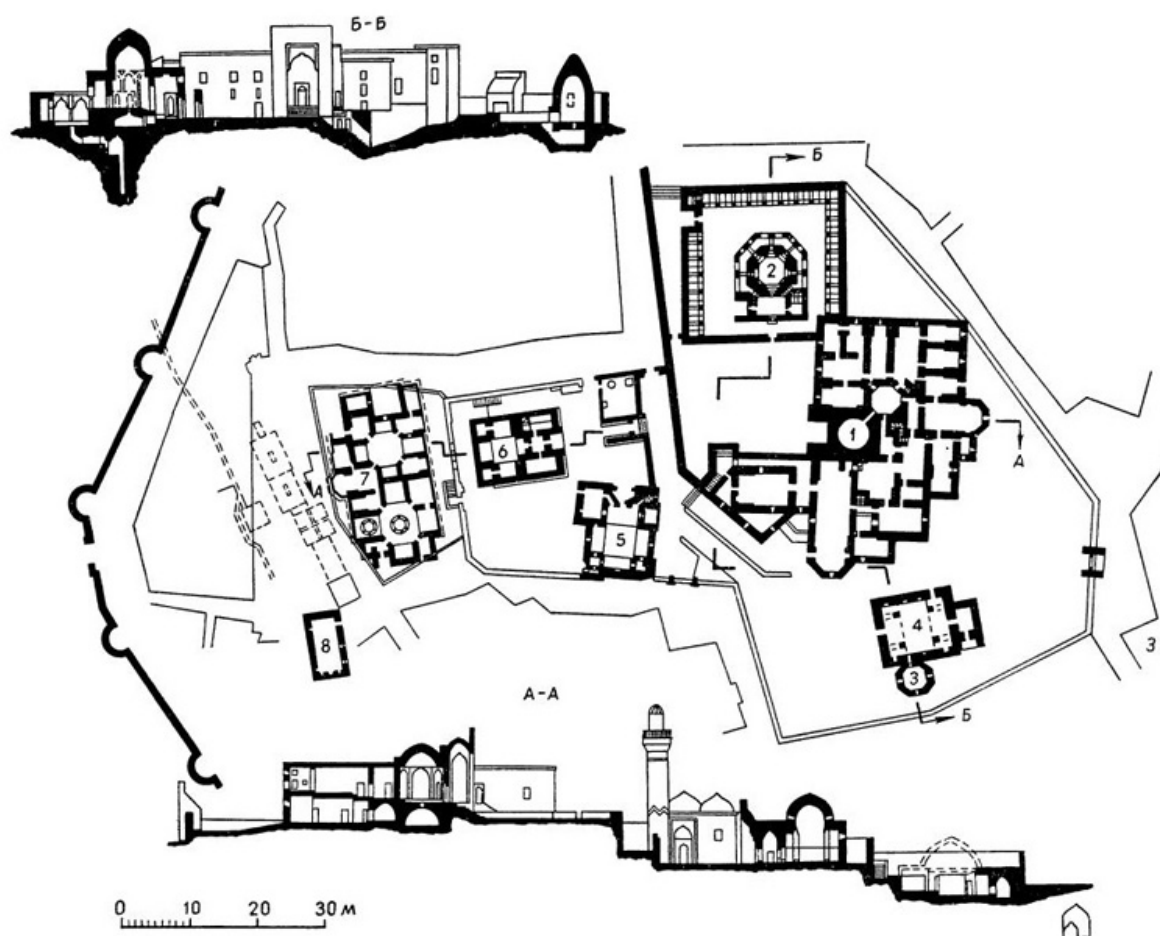


Fig. 2. Baku. Ensemble of the Shirvanshah Palace. General view, axonometry, plan, and sections:
1 — Palace; 2 — Divan-khane; 3 — Mausoleum of Seyid Yahya Bakuvi; 4 — Key-Qubad Mosque; 5 — Palace Mosque; 6 — Mausoleum; 7 — Palace Bathhouse; 8 — Chin Mosque [15]

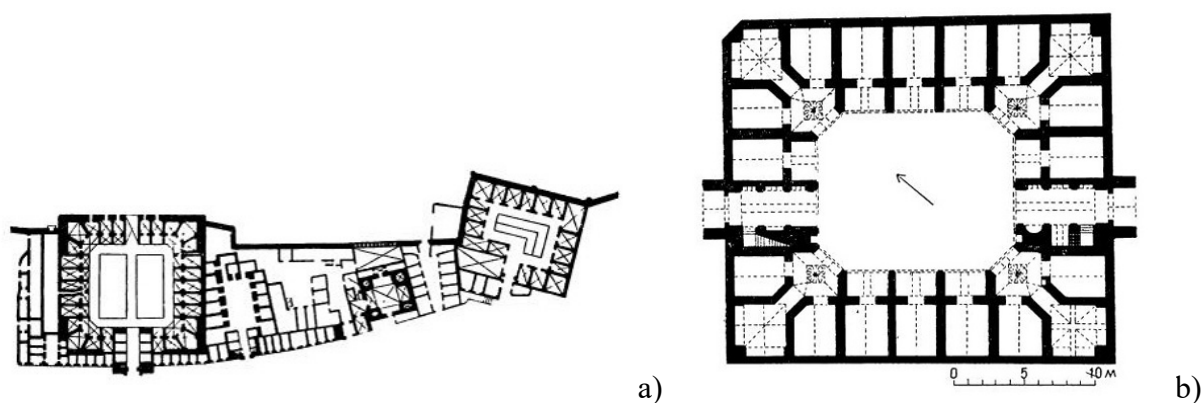


Fig. 3. a — Baku. Commercial complex. Plan of the 19th century.
b — Baku. Icherisheher (Old City). Two-story caravanserai. Plan of the first floor [14]

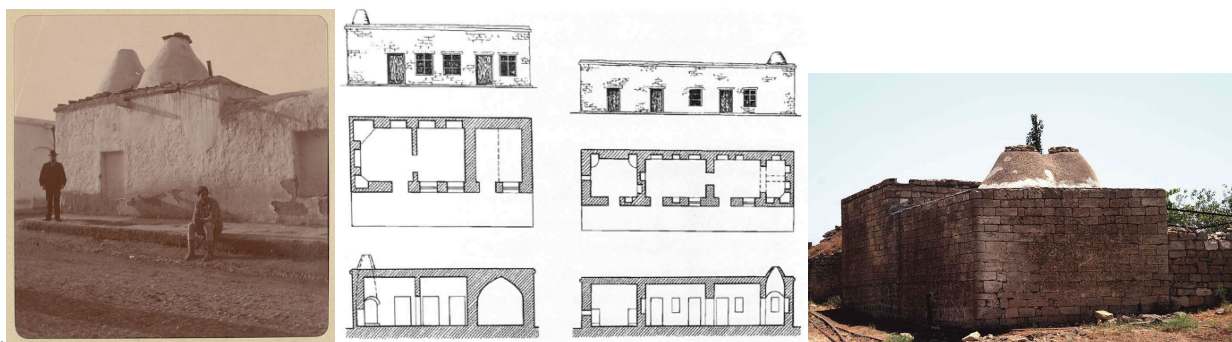


Fig. 4. Residential houses in Absheron (according to A. Mekhtiyev)[15]:

a) Absheron house types, 19th century. Facade, plan, section;

b) Structural scheme of a traditional house wall — thick stone wall (50–70 cm), interior clay plaster layer, wooden ceiling beams, and earthen roof covering. (The diagram illustrates the constructive composition of the wall — the thermal mass of the stone and the insulating function of the earthen layer)

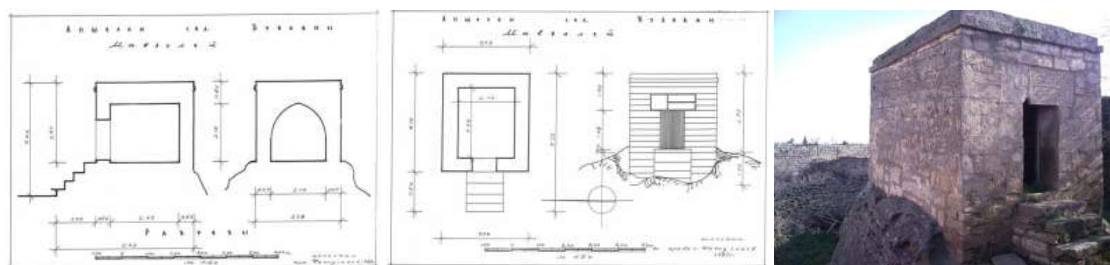


Fig. 5. The domed plan of the Qarapaltar Piri sanctuary in Buzovna (Absheron). 14th century (by Sh. Fatullayev) [13]



Fig. 6. Khinalig residential houses. Courtyard-based house plans adapted to the mountain climate. (The diagram may show the placement of rooms around the courtyard, air circulation directions, solar angles, and shading zones) [13]

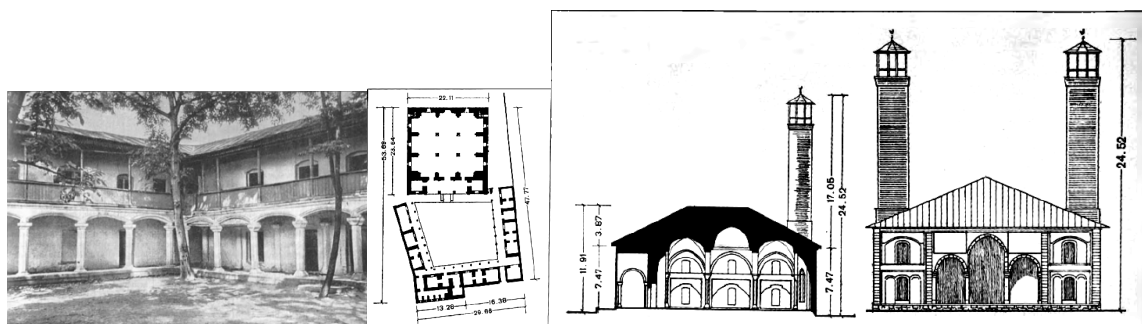


Fig. 7. Shusha. Lower Mosque of Govhar Agha. Facade, section, and plan. Architect K.S. Garabagi, 1874–1875.[13]

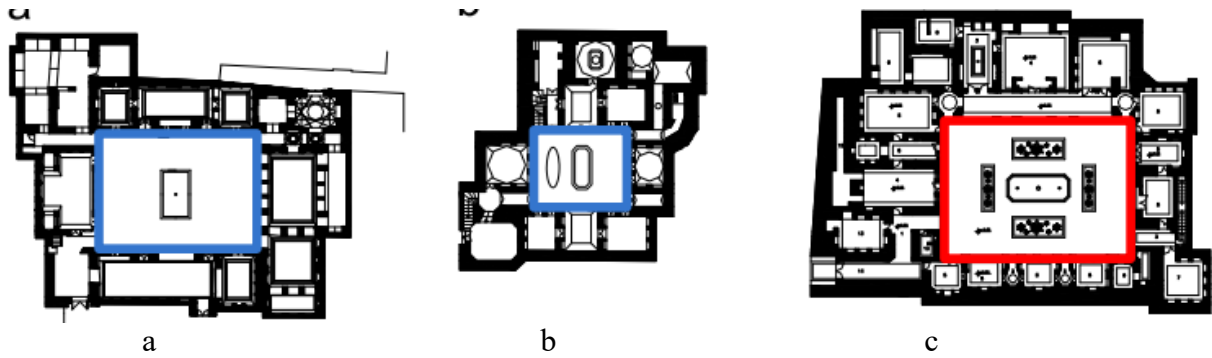


Fig. 8. Traditional Iranian courtyard houses: (a) Lotfali Khan House, Kerman; (b) Azimi House, Kerman; (c) Movahedi House, Kerman; [26]

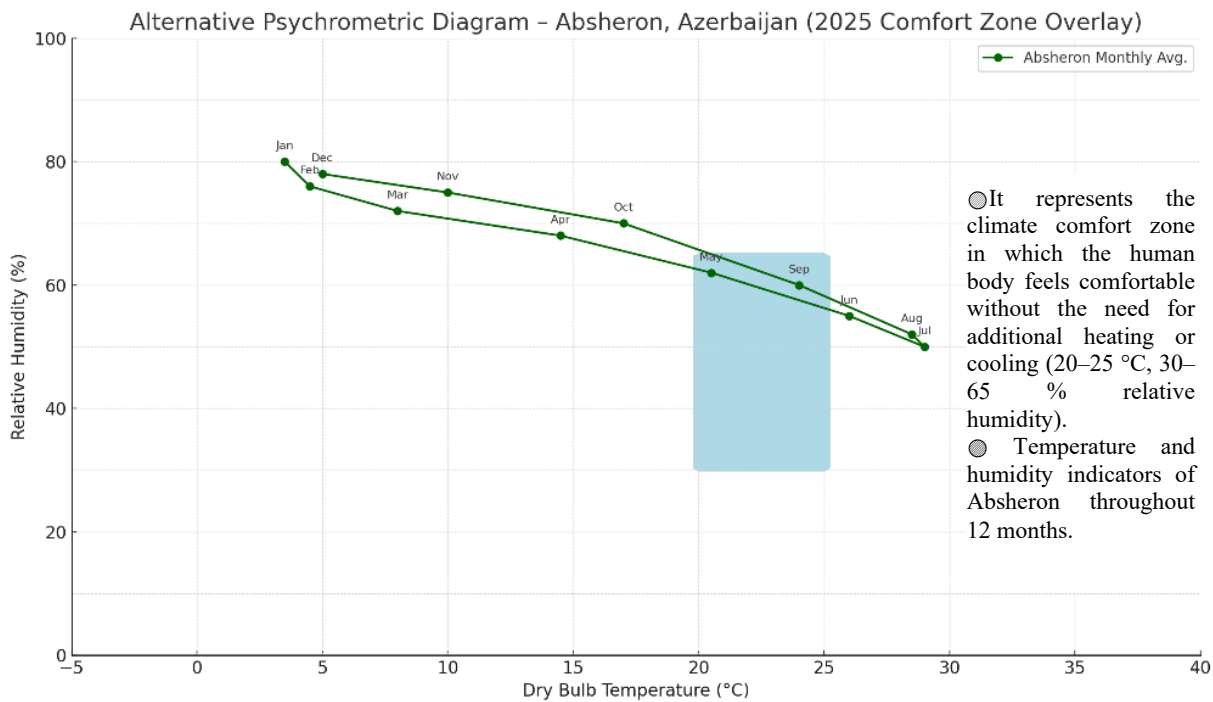


Fig. 9. Alternative psychrometric chart for the Absheron (Azerbaijan) region showing the 2025 California Comfort Model comfort zone (blue area)

The climatic analysis demonstrates that the characteristic weather conditions of the Absheron Peninsula directly affect architectural planning throughout the year. From January to March and November to December, the climate is cold and humid, corresponding to conditions located below and to the left of the comfort zone. From June to August, the weather becomes very hot and relatively dry, i.e., the temperature is above the comfort zone. The most optimal conditions are observed in April, May and September, which are the closest months to the comfort zone.

Based on this analysis, the climate diagram serves as a decision-making tool for architectural design and energy-efficient construction. It enables the planning of key architectural measures such as:

- Defining passive heat-gain zones;
- Designing solar shading systems;
- Planning open spaces for natural ventilation.

The diagram also visually reflects the climate-adaptive planning principles of traditional Absheron houses, which were designed for cold-dry climatic conditions and demonstrate energy-efficient structural solutions.

A similar approach is also emphasized in contemporary scientific research: Starzyk et al. [24] examined the impact of climate adaptation and material selection on the energy performance of zero-carbon timber structures, while Wang and Chiou [25] demonstrated the relationship between the

spatial configuration of traditional residential forms and the principles of sustainable development. In this context, a thermal loss analysis of a traditional Absheron house reveals the following patterns:

Table 2. Analysis and effect of the zones

Zone	Analysis and effect
North Wall	Directly exposed to strong “Khazri” winds — highest heat loss
East Wall	Receives morning sun but remains cold — moderate to high loss
South Wall	Gains solar heat during the day but loses it at night — moderate loss
West Wall	Relatively shielded from sunlight — minimal heat loss
Windows	North-facing windows — very high loss; south-facing windows — potential for solar gain

Architectural implications:

- North walls should be thickened and insulated, with fewer openings.
- South-facing facades can include larger windows integrated with shading systems to capture passive solar energy.

- Material selection and moisture protection remain priorities for maximizing energy efficiency.

This approach bridges the climate-adaptive principles of traditional architecture with modern energy-efficient design, offering a practical foundation for sustainable architecture [23; 24].

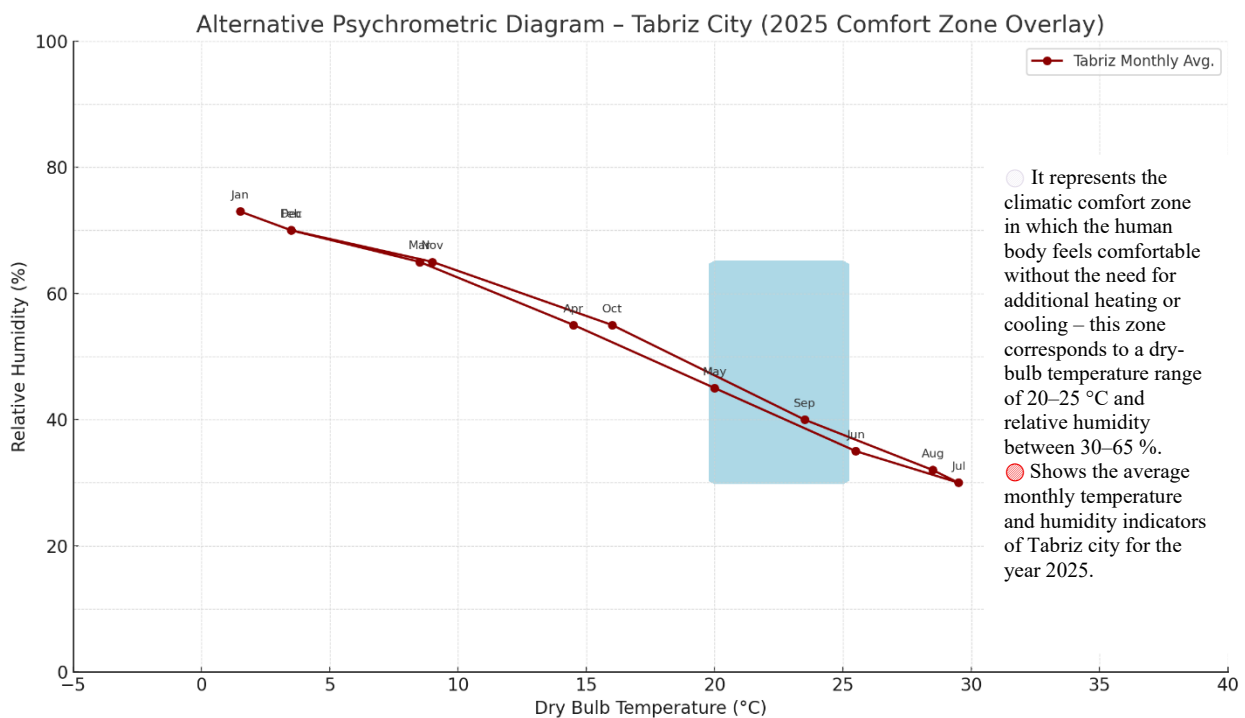


Fig. 10. Alternative psychrometric chart for Tabriz — the transparent background indicates the comfort zone, while the monthly climatic points (temperature + humidity) are marked by dots with corresponding labels

The cold-dry climate type (BSk) of Tabriz city is characterized by significant seasonal temperature differences and low humidity levels. Analyses based on the 2025 California Comfort Model show that the annual climate trajectory of Tabriz partially overlaps with the comfort zone: comfortable conditions are observed in May and September, while during the winter (January–March) and summer (July–August) months, the indicators deviate from this zone.

The main advantage of this diagram is that the annual climate trajectory can be visually tracked, where the blue background represents the *thermal comfort zone*, the area in which the human body

maintains an optimal heat balance. Thus, this model provides a scientific foundation for decision-making in architectural planning and energy-efficient passive design.

In Tabriz, summers are hot and dry, while winters are cold. Traditional Tabriz houses respond to these climatic variations through passive adaptation techniques. Northern rooms are mainly used in summer because they offer cool and shaded conditions, while southern rooms are designed for winter habitation, maximizing solar gain. The courtyard structure—the central yard— helps maintain the building's climatic balance, providing cooling during summer and storing radiant heat in winter.

Such architectural solutions, formed on the basis of local wisdom, confirm the importance of the “*green construction and local wisdom integration*” approach highlighted in modern research [27]. In terms of layout, Tabriz houses are characterized by a compact structure, which reduces heat loss. Their thick walls moderate day–night temperature fluctuations, while the courtyard promotes airflow and creates a microclimate. The building orientation and high courtyard walls act as barriers against cold northern winds.

Traditional materials exhibit energy behavior compatible with the local climate. Mudbrick and stone walls have high thermal mass, retaining heat at night and providing coolness during the day. Unbaked brick and stone floors maintain thermal contact with the ground, ensuring temperature stability. Wooden beams and plaster coatings help regulate humidity and allow surfaces to breathe. Small wooden lattice windows transmit light while reducing heat loss. Pools and fountains in the courtyard increase humidity through evaporation, contributing to cooling during summer.

As noted by Ayoobi et al. [29], these characteristics form an essential foundation for integrating vernacular and sustainable architectural principles within a modern holistic building design framework. Thick double walls enhance thermal insulation, and upper windows enable the release of warm air. The separation of summer and winter rooms contributes to seasonal energy efficiency and extends the period of thermal comfort.

In traditional Tabriz houses, solar gain, shading elements, natural airflow, evaporative cooling, and high thermal-mass materials play a central role. Southern rooms provide passive solar heating in winter, while porches and overhangs block solar radiation in summer. Courtyards and vaulted passages ensure natural ventilation, and water features and plants increase humidity. These methods provide energy savings without reliance on technology, creating living environments in harmony with the climate. Such characteristics serve as indicators of both ecological and social sustainability [28].

Courtyard-based housing plans in various Iranian cities such as Kerman, Isfahan and Tabriz, are based on similar principles. In these designs, the central courtyard functions as a primary microclimatic regulator. Pools and vegetation provide cooling through evaporation, while the orientation of rooms toward the south maximizes solar gain in winter. The northern “taxtabaz” rooms are used as cool spaces during summer.

Natural ventilation is achieved through rooms opening into the courtyard, while corridors and semi-open balconies enhance air circulation. A modular harmony is maintained between the courtyard's size and the surrounding rooms, preserving both energy balance and social functionality. In contemporary research, these traditional architectural models are regarded as valuable examples for maintaining aesthetic, functional and durability values [30].

In conclusion, traditional architecture of Tabriz developed passive climate strategies that align with modern comfort zone criteria centuries ago, providing energy efficiency without technology. This system establishes a living environment in harmony with the climate, while reflecting a sustainable architectural model consistent with social and cultural values.

A comparative analysis of traditional architectural systems reveals that although the architectural practices of both Tabriz and Absheron regions have developed in response to similar climatic conditions, cold–dry and semi-arid climates, the applied architectural solutions and passive design techniques have evolved in different directions. These differences are closely related to each region's geographical location, wind regime, humidity level and socio-cultural context.

The architecture of Tabriz is primarily adapted to a dry continental climate, while Absheron reflects the characteristics of a semi-arid climate influenced by the sea. Both regions share common design principles such as courtyard-centered planning, thick wall structures, passive solar gain, and

orientation in harmony with nature. However, the methods of implementation and construction details differ significantly.

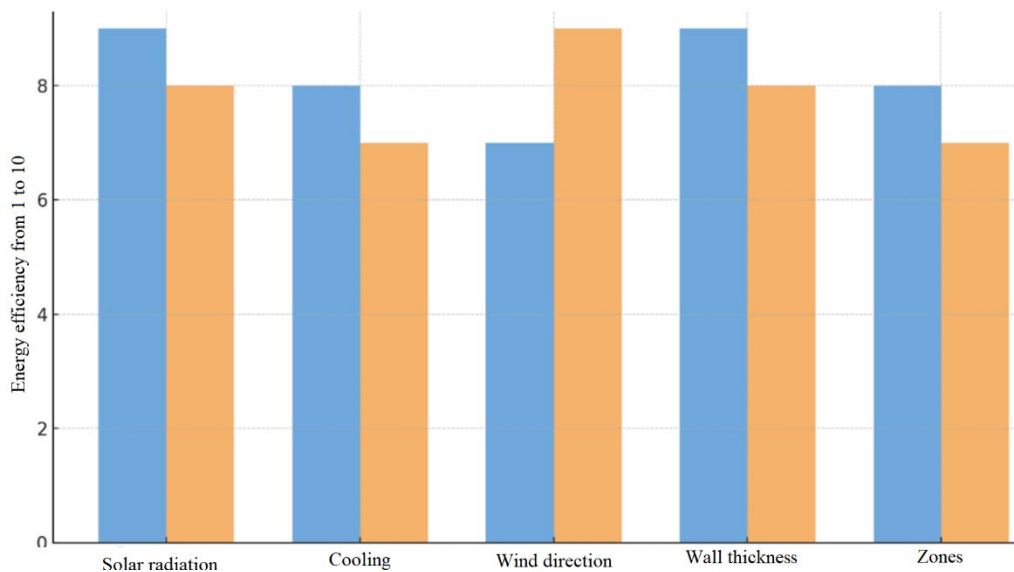


Fig. 11. Comparative Analysis of Tabriz and Absheron Architecture
■ - Tabriz, ■ - Absheron

The comparative analysis indicates that solar gain and thermal mass are more effectively preserved in Tabriz architecture, whereas wind direction utilization and ventilation systems operate more efficiently in Absheron. Although both regions show similar results in terms of wall thickness and spatial zoning, their climatic response strategies are based on distinct priorities.

The Passive Strategy Efficiency Diagram visually demonstrates these differences across five main principles: solar gain, cooling, wind direction, wall thickness and zoning. Tabriz dwellings emphasize heat retention and solar energy gain, while Absheron houses focus on air circulation and wind optimization. This indicates that the two regional models complement each other in terms of achieving climatic balance.

The following comparative assessment describes the effectiveness of the five key passive strategies: solar gain, cooling, wind orientation, wall thickness, and spatial zoning in relation to their climatic adaptability in the traditional architecture of Tabriz and Absheron (Table 4).

Table 4. Passive strategies in the traditional architecture of Tabriz and Absheron

Strategy	Tabriz	Absheron
Solar Gain	South-oriented rooms and thick walls ensure high levels of solar energy collection, maintaining indoor warmth in winter.	South-facing layouts are present but less effective due to humidity and wind exposure.
Cooling	Central courtyards, pools, and shaded areas provide evaporative cooling and passive ventilation.	Cooling relies on cross-ventilation and open yards; however, high humidity slightly limits efficiency.
Wind Orientation	Buildings are arranged to block cold northern winds.	Wind patterns (Khazri and Gilavar) are central to building orientation and ventilation design.
Wall Thickness	Thick adobe and stone walls maintain stable indoor temperatures and minimize diurnal variation.	Thick brick and limestone walls serve a similar purpose but are adapted to milder maritime conditions.
Spatial Zoning	Seasonal room use: south rooms in winter, north rooms in summer ensures flexible	Zoning is present but less pronounced due to smaller climatic fluctuations.

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This comparison demonstrates that both regions preserve local knowledge and material technologies within climate-adapted and energy-efficient systems. As emphasized by Dişli and Arslan [32], this represents a typical example of how traditional knowledge systems contribute to sustainable urban development.

Based on these findings, a Transfer Model for Contemporary Architecture can be developed. This model proposes the integration of principles tested in traditional architecture with modern architectural technologies. Traditional functions can be reinterpreted and revitalized through the use of modern materials, energy systems, and smart technologies, ensuring the continuity of vernacular wisdom within sustainable design practices.

Traditional Function	Modern Adaptation
Central courtyard	Light atrium, green courtyard and natural ventilation core
Thick earthen walls	Insulated “sandwich” walls (brick + EPS + gypsum)
Passive shading (arches, iwans)	Brise-soleil systems, solar-panel shading devices
South–north spatial zoning	Smart seasonal zones for energy-efficient use
Water-based evaporative cooling	Green facades and water-curtain bioclimatic cooling systems

This approach holds strategic importance both for the preservation of cultural heritage and the advancement of sustainable urban development. As noted by Velibeyoğlu and Sedes [31], *symbiotic architecture*: that is, the integration of historical structures with modern technologies, transforms cultural heritage while shaping a sustainable future. In this context, the architectural traditions of Tabriz and Absheron establish a symbiotic relationship between the architectural legacy of the past and the ecological approaches of the future.

Thus, the traditional architecture of Tabriz and Absheron embodies not only historical and aesthetic value, but also serves as a scientific foundation for modern energy-efficient and climate-responsive design. Through the reapplication of these principles, it is possible to create sustainable, ecologically conscious, and socially balanced contemporary living environments. In this sense, traditional architecture represents not merely the experience of the past, but also a localized model for the sustainable design concepts of the future.

4.Conclusion and recommendations. Traditional architecture is not merely a historical heritage of aesthetic value, but a knowledge system that constitutes both the scientific and practical foundations of contemporary sustainable design. A comparative analysis of architectural examples from different regions of Azerbaijan, alongside similar structures in Anatolia and Tabriz—reveals that these architectural forms represent naturally adaptive systems, fully integrated with climate, topography, and social structure. This approach ensured a synthesis of local material use, passive energy strategies, anti-seismic construction techniques and socio-cultural coherence [10, 4]. The architecture of Absheron with its limestone masonry, thick walls, and domed coverings; Nakhchivan structures featuring fired brick and seismically flexible frameworks; and the Shaki–Zaqatala school distinguished by timber, stone, and stalactite arch systems each present distinct models of resilience. Tabriz architecture complements these examples by demonstrating the thermal mass and climatic endurance of fired brick, while Anatolian architecture emphasizes courtyard-centered planning and passive ventilation systems [16, 8]. The comparative study of these regions shows that, despite climatic differences, their traditional forms share a common foundational logic—construction based on local resources, natural ventilation and social adaptability. In the post-independence period, Azerbaijan’s restoration and conservation initiatives such as the Palace of the Shirvanshahs, Shaki Khan’s Palace, Momine Khatun Mausoleum and the Ateshgah Complex illustrate how these traditions have been integrated into modern architectural policy and economic systems. The projects implemented by *Azərbaypa* Scientific-Research Institute and supported by the World Bank’s “Cultural Heritage Preservation” program have demonstrated that architectural heritage conservation is not merely a technical process, but also involves social and functional revitalization [11].

Key Findings

1. The constructive and planning principles of traditional architecture can be directly transferred into modern bioclimatic design and green architecture strategies.
2. The architectural schools of Azerbaijan and Tabriz present regional models of sustainability, maintaining the relationship between local materials and diverse energy balances across climatic zones.
3. Restoration policies should focus not only on technical stability, but also on the integration of heritage sites into cultural, social, and economic circulation (e.g., tourism, education, and public functions).
4. The adaptation of traditional building materials as brick, limestone and wood to modern production systems can promote energy efficiency and reduce carbon emissions [7, 6].
5. The teaching and application of these knowledge systems within architectural education and design practice are essential for fostering interdisciplinary ecological approaches.

Recommendations

- Passive energy systems and climate-responsive material choices derived from traditional architecture should be integrated into modern design standards.
- A “Sustainable Design Atlas” based on regional characteristics should be developed as a practical guide for architects and engineers.
- Policies promoting the reuse and adaptive use of protected buildings with new functions should be institutionalized at the state level.
- The eco-friendly reproduction of traditional materials and their linkage to local economies should be defined as a priority direction.
- Conservation and urban planning policies must be reinforced with new climate-responsive durability standards to ensure the longevity of architectural heritage.

In conclusion, the traditional architectures of Azerbaijan, Tabriz and Anatolia demonstrate that the architecture of a sustainable future is achievable through the reinterpretation of the codes of the past. This architectural legacy represents not only a cultural value, but also a scientific model of ecological stability, social harmony, and material circulation, defining the future trajectory of contemporary sustainable architecture.

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