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An Evaluation of Ecological Solutions Based on Energy Efficiency in the Vernacular Architecture of Ardabil

Mahsa Javadi nodeh[1], Azadeh shahcheraghi[*2], Alireza Andalib [3]
1. Ph.D. Candidate, Department of Architecture, Science and Research Branch, Islamic Azad University, Tehran, Iran
2. Associate Professor, Department of Architecture, Faculty of Civil, Architecture and Art, Science and Research Branch, Islamic Azad University, Tehran, Iran, *Correspondence author: Shahcheraghi@Srbiau.ac.ir
3. Associate Professor, Department of Urban Development, Faculty of Civil, Architecture and Art, Science and Research Branch, Islamic Azad University, Tehran, Iran

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Abstract: Vernacular architecture is the product of environmental, social, and economic innovations. In fact, this type of architecture seeks to make buildings compatible with the environment via the use of local knowledge and experiences. Bearing in mind the issue of energy efficiency, attending to the sustainable elements of local housing and its ecological aspects is of paramount importance since buildings are one of the structures that cause the highest level of damage to the environment. Therefore, the purpose of this study was to first recognize the ecological components derived from vernacular architecture and then propose indigenous solutions to encounter climatic and environmental problems. In this descriptive analytical study, all these factors were analyzed in three traditional houses built in three different eras in Ardabil. To collect the needed data, documentary studies were checked and various interviews, observations, and field investigations were conducted. In these houses, the architectural features that were derived from ecological components were recognized and investigated via the analysis of various aspects including design and construction techniques, type of plan, orientation, and innovative solutions used to make the spatial layout more appropriate for the comfort and welfare of the residents. The results revealed that in the construction of walls and roofs of these buildings, insulating materials and techniques have been used based on the traditional technology of that time. In addition, paying attention to the size of window openings, use of triple-pane windows, use of greenhouse effect in main spaces, separation of winter and summer living spaces, existence of connection joints, etc. are other ecological solutions that have been derived from the vernacular architecture of this region.
Keywords: Vernacular Architecture; Ecological Solutions; Energy Efficiency; Traditional Houses; Ardabil City.

1. Introduction

The upsurge of environmental problems such as global warming, increase in the concentration of greenhouse gases, and decrease in fossil fuel reserves has led to a shift of attention among human beings to natural resources so as to take the needed measures to deal with climatic variations. Bearing in mind that buildings have become one of the factors that highly damage the environment (Wong & Yuen, ۲۰۱۳), sustainability is of paramount importance since it can reduce the negative effects of buildings on the environment. Accordingly, sustainable designing methods have been propounded as a solution to deal with the current problems in the world. However, sustainability is not a new concept in architecture (Parlak,2019). Vernacular architecture, that has become popular since the middle of the 20th century, has been formed with the aim of coordinating structural environment with nature (Naghavi & Kiani,2019).

Vernacular or local architecture is defined as the unconscious culture and the local needs of the people living in a specific area. In patterns of local housing, all buildings are compatible with environmental, climatic, geographic, economic, cultural, and historical conditions (Khoshandam et al,2019). That is why vernacular architecture is influenced by the variations that arise in these conditions (Vellinga,2015). In fact, the compatibility between vernacular architecture and the surrounding conditions leads to the coordination and integrity of buildings with the environment. In other words, vernacular architecture has already found the ecological solutions required for improving welfare status of the residents as well as the quality of the environment. These solutions can be recognized via investigating different types of traditional houses and determining the role of the ecological components in them. Then, through ecological designing and merging

its components with the environment, the negative effects of buildings on the environment can be controlled to some extent (Bitraf, 2018). Although most of the traditional houses of Iran have many features in common, they are distinct from one another in terms of climatic and geographic conditions. These distinctions have resulted in various differences in their shapes, scales, materials, and types of plan. The traditional houses of Ardabil are instances of vernacular architecture that are compatible with the culture, customs, and traditions of the local people as well as the environmental conditions of the region. The climatic conditions of the region and the relationship between architecture and the surrounding environment in cold regions have made the traditional houses of Ardabil distinctive.

Therefore, in the current study, the ecological elements of three traditional houses in Ardabil (Ebrahimi House, Sadeghi House, & Rezazadeh House) which have been built in three different eras are investigated using descriptive methods and field observations. The aim is to recognize the ecological features derived from vernacular architecture in various aspects such as type of plan, orientation, spatial layout, structural elements, and architectural elements so as to figure out the local designing methods used to encounter the climatic and environmental problems. After analyzing the type of plan, orientation, and spatial layout of the houses in terms of local features, the construction and architectural elements of the houses will also be analyzed and evaluated in terms of the ecological conditions. In fact, the present study investigates the ecological solutions taken from vernacular architecture and examines their usability in new constructions.

2. Materials and Methods

2.1. Vernacular architecture and its ecological solutions

The important characteristic of vernacular architecture is that it is free of unnecessary extensions since its solutions are the product of centuries-long experience and environmental optimization. In fact, this architecture belongs to a specific region and responds to the needs of people in relation to natural factors as well as their material and spiritual desires (Naghavi & Kiani, 2019). Today, besides vernacular architecture, attending to climatic, environmental, and ecological problems is one of the most important issues all over the world (Molanaei & Soleimani, 2016). Vernacular architecture pays more attention to natural materials, local facilities, passive methods of regulating environmental conditions, and ecological forms; that is, why it does the least damage to the environment. Thus, it is an ideal model for sustainable architecture and ecological design (Akrami & Damyar, 2017).

In fact, it can be said that the definition of ecology is under the influence of vernacular architecture. In ecology, environmental factors as well as the compatibility of physical environment with the structural environment are explored (Ardakani, 2009) while vernacular architecture investigates the mutual interrelations among humane-related, natural, and structural dimensions (Naghavi & Kiani, 2019). Therefore, it can be understood that the physical environment that is related to the structural environment, which is itself an outstanding cultural branch and the main consumer of energy and other resources, actually refers to both vernacular architecture and ecology (Armaghan & Gorji-Mahlabani,2009). Accordingly, the cultural and climatic characteristics of vernacular architecture can also be used in ecological design. In fact, the trace of the cultural, geographic, and other features belonging to a specific group of people can be found in spatial-structural layouts, configurations, design patterns, constructions, and materials (Lang, 2009). These features can also be observed in various aspects of structural environments such as the elements of construction and design, type of plan, orientation, form, spatial layout, and their compatibility with the physical environment (Halicioglu, 2012).

2.2. Ardabil and its traditional houses

Ardabil is a city in the northwest of Iran which is situated at the northern latitude of 35^{o} 5ó and the eastern longitude of 45^{o} 10ó to 48^{o} 41ó (Samadzadeh et al., 2012). Based on the data obtained from the meteorological station of Ardabil, which shows the average climatic values during the last 42 years (since 1978), the average maximum and minimum temperatures in each month (Figure 1) indicate that in 53.77% of the time of year, the city's weather is quite cold. The average maximum temperature from Khordad to Shahrivar is 24.31 °C and the average minimum temperature from Azar to Esfand is -4.52 °C. The average yearly temperature of the city is 9.89 °C. Furthermore, the air condition is appropriately sunny in 34% of the time of year and only in 11.9% of the time of year is there an appropriate shadowy condition. Despite its cold weather, the city receives a good level of sunshine (Zohuri, 2016). Moreover, as Figure 2 shows, a desirable wind blows from the east which is accompanied by cool weather and humidity in summer. The undesirable wind, on the other hand, blows from the south-west which is accompanied by cold weather in winter and by hot weather in summer.

Therefore, in terms of climatic conditions, Ardabil is considered a cold and semi-arid region and falls into the group of regions having "very cold winter – warm/cool summer" in the climate classification system (Zohuri, 2016). As a result, it is a region with a high heating requirement and zero cooling requirement. This requirement is met via avoiding the undesirable wind flow and making maximum use of sunshine by creating thermal cages and reducing heat exchanges.

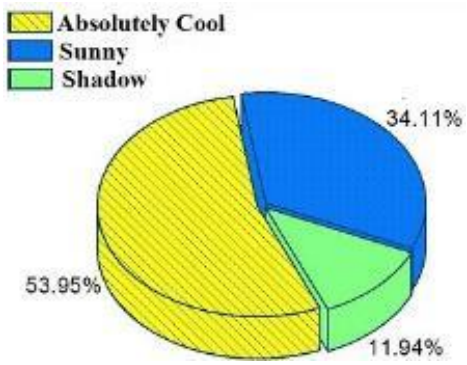


Fig 1. Climatic situation of Ardabil city

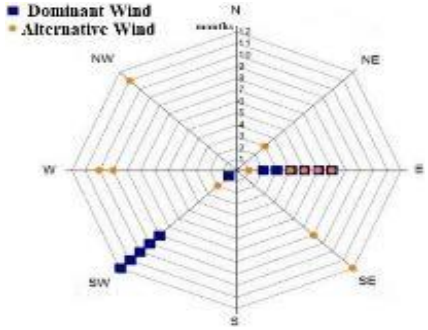


Fig 2. Dominant wind and alternative wind in Ardabil
(Javadi nodeh et al.,2021)

The oldest descriptions about the traditional houses of Ardabil are provided by the international tourists who have visited the city. For instance, in the 11th century Pietro Della Valle describes the houses of the city as situated among trees, gardens, and streams. Tavernier describes the city as a green lush crevice between mountains while the houses of the city, like other houses of Iran, are described as being constructed with mud, soil, and local materials (Safari,1971). However, due to the unstable fortifications of the buildings, military attacks in different eras, earthquakes, etc., the oldest house in the city belongs to the late 18th century (the era of Zand Dynasty) and most of the single- or double-storey traditional houses belong to the mid-19th to mid-20th century. In the following sections, these houses are analyzed in terms of the aforementioned aspects.

2.3. Elements of plan

Focusing on spatial layout based on lifestyle provides the most optimal responses as regards natural, structural, and human-related elements (Javadi nodeh et al.,2021). That is why the analysis of the elements of plan is of great importance for the sustainable formation of spaces.

In the traditional houses of Ardabil, corridors and vestibules are the connection joints of the buildings and influence the spatial layout of the structure. In addition to creating and protecting privacy, these spaces act as an air passage space and filter the straight flow of cold air into the building (Javadi nodeh et al.,2021). Furthermore, in these houses, kitchen is not just a place for cooking, but also a place for spending family time. It consists of various elements such as tandir, oven (similar to modern stoves which was also used for heating), shelves, gholche (a space for storing dishes), teahouse (a small space for tea preparation – gooshvare room), and storehouse. Oftentimes, kitchens are situated behind shahneshin and are connected to tandir room, winter living room, and cellar. They use roof skylights for ventilation and are also connected to all spaces in the building as well as the courtyard through a special hall (Figure 3). The aim of placing the kitchen in the second layer as a thermal insulator has often been to heat the hall space and the main room (Mohamadhoseini,2019). The most important space in the house and the center for collective activities has been the hall. That is why it has a higher ceiling and a larger area. The existence of a big, double- or triple-pane Orosi window in the southern wall of the hall has made it possible for sunshine to enter the inner space and form a thermal cage. Furthermore, although water was publicly available, the bathrooms located in the center of neighborhoods were mainly used, the reason for which was the lack of the required infrastructure inside the houses. Although the city enjoyed one of the first water piping systems (Rezazadeh and Peiyghami,2009), people often dug a water well or built a water reservoir near the pool in the center of the courtyard to meet their water needs. Toilets were mainly situated out of the houses with a special well for wastewater disposal.

Fig 3. An example of a winter living Room and kitchen adjacent to the main hall in Sadeghi Traditional house. (1. Winter Living Room; 2. Kitchen Storage; 3. Roof skylights; 4. Shelves and Tandir room; 5. Gholche and Teahouse; 6. Hall)

Other features of the traditional houses of Ardabil include having a condensed form, not being stretched and spread on the ground, and being situated at one or two sides of the central courtyard. Basement has also been an important part of the buildings for various reasons. First, it made it possible for the building to go down into the thermal mass of the soil and thereby reduce the thermal variations and control heat exchanges. Also, the placement of spaces such as cereal storehouse in the basement made it possible to transfer the heat to the upper floors. Finally, the existence of a basement increased the resistance of the whole building against earthquakes.

2.4. Construction materials and building elements

Ardabil is situated in an area with a high risk of earthquake due to being close to the fault lines of Bozghoosh, Moghan Plain, Masooleh, and Roodbar (Esfandiari, 2014). Although earthquakes have had a big impact on the formation of the city's architecture, other factors such as local customs, culture, and climatic conditions have also influenced the form and shape of the traditional houses in the city. A conscious focus on these factors can be easily observed in the selection of construction materials and systems.

Stone, wood, soil, brick, and metals are often the main construction materials which have been used in the construction of the traditional houses of Ardabil. Stones have been used the most due to having higher thermal capacity and being resistant to water. Local stone types such as black basalt, granite, and rubble have usually been used. Black basalt has often been used in the skirting of the building up until the height of 1.5 meters together with lime mortar and rubble has been used in the foundation of the walls as well as the basement together with a laying of concrete. Also, granite has been used in making pools, paving courtyards, and building high stairs to prevent moisture penetration. The type of the soil around Ardabil is mainly slit and clay (Gafaria et al, 2017). Hence, the ingredients needed for producing clays and bricks to be used in the buildings were quite abundant. In order to prevent heat dissipation, the walls with the thickness of 0.6 to 1 meter have been built by lime mortar, clay, and thatch covered by gypsum coating

In the hinges of doors and windows as well as in knockers, Orosi windows, and locks, metal materials such as iron and bronze have been used. Iron has mostly been used in the hinges of windows and doors while bronze has mainly been used in door handles. Furthermore, except for south-facing windows, all other windows are smaller and narrower. All of the windows are double-glazed and have wooden caps.

Three types of roofs can be observed in the traditional houses of Ardabil: flat, arched, and gable. The main advantage of flat roof is that the snow accumulated on top of it can act as a good insulator and prevent heat loss through the roof (Zohuri, 2016). Gable roof is also a common roof type which came into vogue in late Qajar Era. If the building has a basement, its roof is arched so that it can bear the load of the upper floors. The main entrance doors in the traditional houses of Ardabil are built from thick pine and the Orosi windows are built from beech. Oftentimes, the entrance door that opens from the courtyard to the house has some small windows on top of it which helps the penetration of daylight into the inner spaces.

2.5. Analysis of some instances of traditional houses in Ardabil

These houses are analyzed and evaluated so as to recognize the basic ecological elements which are derived from the vernacular architecture of the region. To this end, the selected houses are investigated in a chronological order from the old one to the new one in terms of the five aforementioned factors, namely the type of plan, orientation, spatial layout, construction elements, and architectural elements (Table 2).

2.5.1. Ebrahimi House (late 18th century)

- *Type of plan:* The house is an L-shaped, single-storey building with a basement and has a Shekam Darideh-shaped courtyard.
- *Orientation:* The building faces south and has an eastern-western stretch.
- *Spatial layout:*

Courtyard: The courtyard, that is the organizing space in the building, has become a closed volume due to climatic conditions. Its level is lower than that of the alley. The building is situated in the northern and eastern parts of the yard.

Kitchen: The kitchen is situated in the northern part of the building and has a roof skylight. There is a separate door in one side of the kitchen which connects it to the cellar at the basement. Moreover, the wall of the kitchen in the southern part is the brick wall of the hall. This adjacency plays a quite effective role in transferring the heat from the kitchen to the hall.

Rooms - Hall: In the northern part of the central courtyard, there is a big winter room situated at the center of the ground floor which consists of two porches and one shahneshin with a height of 4 meters. This room is situated at a level higher than that of any other space in the building. Another relatively bigger three-door room is situated at the eastern part of the courtyard and distant from the private spaces which was used as a winter room for public meetings.

Connection joint and filter space: A small, filter-like space situated at the entrance to the right side of the hall has connected the room, hall, and kitchen to one another. Also, the filter space situated at the entrance to the left side of the hall has connected the room, hall, and the roof of the house.

Wet spaces: The toilet and the wastewater disposal well have been situated at the courtyard in order to have healthier environment.

Other spaces: The storehouse is situated in the basement and is connected to the kitchen (Table 2, Instance 1).

- *Construction elements:*

Walls: The thickness of the outer walls is 80-100 cm and that of the inner walls is 40-60 cm. The inner walls have been built using bricks made of lime and clay mortar covered by thatch and gypsum.

Roof: The roof of the ground floor in the part related to hall is double-layered. In the first layer, the ropes hanging from the round woods have kept the decorated ceiling arches. After a layer of air, the four-lathed woods together with Lambeh Koobi, straw, soil, and mortar have formed the outer roof of the building.

- *Architectural elements:*

Windows: The windows in the eastern side are smaller than those in the northern side. Furthermore, the inner frames of the windows are smaller than the outer ones.

Doors: There are three doors from the central courtyard to the house. The doors of the filter space that connect it to the three-door room and the hall are symmetrical. There is another door in the western side of the house which directly leads to the kitchen and the storehouse. The doors are all made of wood.

2.5.2. Sadeghi House (1862 A.C – mid-19th century):

- *Type of plan:* The house is a double-storey building with a basement consisting of multiple parts. The complex is situated in three courtyards: An L-shaped courtyard, a one-sided courtyard, and a two-sided courtyard.
- *Orientation:* The complex is generally facing the north-west to the south-east.
- *Spatial layout:*

Courtyard: The complex has three courtyards. The first entrance connects the middle and inner courtyard with the alley crossing via a porch and a Hashti. The middle courtyard is a place where formal meetings and commercial relationships are organized. The inner courtyard, on the other hand, is a place in the north of the complex where family meetings and relationships are organized. The second entrance connects the outer courtyard with the alley crossing. The outer courtyard, which is situated at the southern part of the complex, is a place where social meetings and relationships are organized.

Kitchen: Kitchen, which is situated behind the inner hall, transfers heat to the hall. It also connects the winter room and the tandir room. The kitchen has shelves to keep different items, a storehouse, and a small stone pond with a 50-cm-high platform to wash the dishes. The water of this pond was supplied by the adjacent platform. The tandir room is situated in the west side of the kitchen. There is a 2.20-meter-high tandir together with a stove in this room. A roof skylight provides the ventilation and lighting for this space.

Rooms – Hall: In the inner part of the complex, there is a hall with a double-layer roof and a height equaling that of two floors which faces the south. It has a Gooshvare which has been used as both a teahouse and a gholche. The winter room is situated at the east side of the inner hall. This south-facing room is limited in size and has a limited number of openings. It is directly connected to the kitchen and the tandir room. In the southern wing of the inner courtyard, there is a summer room with large and two-sided openings. In the middle part of the complex, there exists a ceremonial hall which faces western daylight. It has a double-layer roof, a height that equals that of two floors, and Gooshvares that are connected to the filter space. Also, in the outer part of the complex, a three-door winter and summer room has been situated.

Connection joints and filter space: In both sides of the three halls, there exists a small space, called filter space, which connects the floors to one another.

Wet spaces: In the northern part of the outer courtyard, there are small spaces wherein toilet wells, water sources, and water wells are situated.

Other spaces: The storehouses and the stable in the basement of the complex have entrances both from the courtyard and from the inner space of the building (Table 2 – Instance 2).

- *Construction elements:*

Walls: In building the walls of the facade of this complex, plinth stone and facade bricks have been used. Also, the inner walls that bear the load of the upper floors are built with bricks, lime mortar, and soil and are covered by a coating of thatch and gypsum.

Roof: In the flat roof of the house, wooden beams have been used. Underneath the beams, slabs, thatch coating, and gypsum coating have been used. On the top of the beams, on the other hand, slabs, sacks of linen, and thatch mortar have been used.

- *Architectural elements:*

Windows: Northern, southern, and eastern views of the complex have skylights. Kitchen and tandir room are also lit up by roof skylights.

Doors: In the alley view, the house has two doors in the south-west with each of them having a porch and a Hashti. Both of them are made of wood.

2.5.3. Rezazadeh House (1909 A.C – early 20th century):

- *Type of plan:* The house is a double-storey building constructed on a platform. It is one-sided and has a columned porch.
- *Orientation:* The house is situated in the north-west to south-east and has a western-eastern stretch.
- *Spatial layout:*

Courtyard: The complex has a courtyard at a level lower than that of the alley. In the south-east of the courtyard, a single-storey summer room with a basement is situated. In the north-west of the courtyard, a double-storey winter room is situated. The winter room does not have a basement. In front of this room, there is a receded porch with a height that equals that of the two floors together.

Kitchen: Considering the existing information, the kitchen had been situated behind the winter room to the left side of the complex. Over time, as the result of manipulations on the building, the kitchen has been removed and its area has been added to the hall so that the hall can take a rectangular shape.

Rooms – hall: The main hall is situated in the second floor. It overlooks the courtyard through a five-door Orosi window. The existence of a porch with the width of 2.70 meters in front of this hall prevents the direct reflection of sunlight into it during summer. Similar to the ground floor, there are two three-door rooms in each side of the hall.

Connecting joints and filter space: At the north-western part of the complex in the first floor, a division space is situated after the entrance door and right in the middle of the area. At the end of this vestibule, there exists a filter space which is connected to the first floor of the complex via two wooden stairs. In the south-eastern part of the complex, there is a division space after porch. In the two sides of this space, summer rooms are situated and in front of it, there is an entrance door to the central courtyard of the complex.

Wet spaces: The services sector is situated in the south-east of the complex and consists of a carriage house and a toilet.

Other spaces: The basement that is situated at the south-east of the complex was used as a cellar and a storehouse (Table 2 – Instance 2).

- *Construction elements:*

Walls: Walls are made of raw clays covered by bricks. Their thickness ranges between 70-100 cm. The façade walls with 12 brick pillars are carved on stone bases and are placed on brick columns. The porch of the complex also has 4 wooden pillars.

Roof: The roof is made of wooden beams, wooden slabs, and thatch mortar.

- *Architectural elements:*

Windows: The windows are situated in the north-western and south-eastern views. There is a big Orosi window in the middle which provides the needed heat for the building during winter. Other windows are also appropriate for winter due to their limited width and the lengthiness of the rooms. The windows of the summer room are also small and receive little direct sunshine.

Doors: The complex has two separate entrance doors: one from the north-west and another from the south-east. The main door is the one in the south-east of the courtyard which has a turn toward the small square in the south-western part of the courtyard. The other door is connected to the alley through the winter room and kitchen.

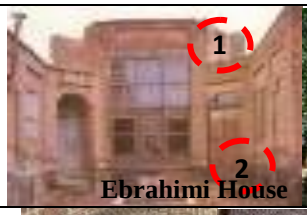
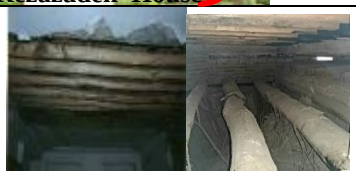
3. Results

3.1. Construction and architectural elements

Regarding construction elements, the use of stone bases and frames, brick walls, wooden beams, lime mortar, thatch mortar, and coatings of gunny has reduced thermal variations and has also increased the flexibility of the building against earthquake. Similar to construction elements, structural elements like the load-bearing brick walls have also been affected by the cold climate of the region. Furthermore, to reduce the load of the building, the foundations are thick; but, as we go to upper floors, the thickness of the walls decreases. Wood has been used both in the construction of the buildings and in decorating the inner and outer spaces of the houses. The wood of trees such as poplar, beech and spruce has been used to cover the roofs and structures as well as to decorate the houses. Windows are placed and arranged in a way that boosts the thermal comfort of the houses. The glasses and frames of the windows have usually been installed close to the outer surface so that the narrow valve of this surface can prevent the

penetration of cold air into the house. In the kitchens, the existence of the roof skylights serves to ventilate the inner space and also lights the environment up. Use of double-layer roofs filled with air or soil also functions as a thermal insulator for the houses (Table 1).

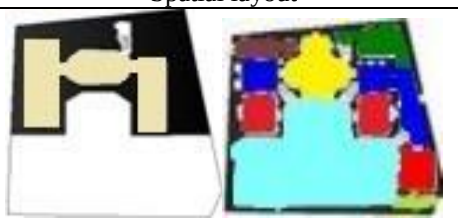
Table 1. Construction and architectural elements in Ardabil Traditional house

Construction elements	samples
Walls: Local stone (black basalt, granite, and rubble) Wooden columns 80 to 100 outer wall thickness of brick With lime mortar or clay	  1. Brick 2. Rock 3. Wood
Roof: Wooden beams and lambeh koobi coatings of gunny, thatch and straw Gypsum mortar and soil and Flooring	 Basement vaulted ceiling  Double roof with wooden beams and execution details
Architectural elements: *Doors:* Bronze and iron metals Poplar and spruce wood	
Windows: Bronze and iron metals Beech and walnut wood	

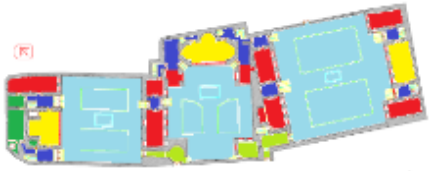
3.2. Plan, orientation, and spatial layout

In Table 2, the results of the analysis of the three traditional houses in Ardabil in terms of factors such as type of plan, orientation, and spatial layout are presented. The houses in the table are ordered based on their age with the oldest one appearing first.

Table 2. Sample analysis; Type of plan, Organization and Spatial layout
(Red; Rooms- Dark Blue; Connecting joints and filter space- Pale Blue; Courtyard- Bold yellow; main hall- light yellow; cellar and storehouse- dark green; kitchen- Pale green; Hashti and Corridors)

Building name	Type of plan/ Organization	Spatial layout
 1. Ebrahimi House (1794)	 The house is an L-shaped, single-storey building/ The building faces south and has an eastern-western stretch.	

2. Sadeghi House (1863)



The house is a double-storey building consisting of multiple parts. an L-shaped / The complex is generally facing the north-west to the south-east.

3. Rezazadeh House (1909)

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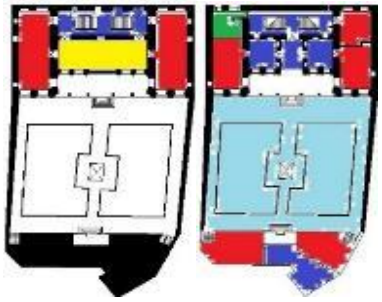

The house is a double-storey building constructed on a platform. It is one-sided and has a columned porch/ The house is situated in the north-west to south-east and has a western-eastern stretch.

4. Discussion

Based on the analytical studies conducted on the traditional houses of Ardabil, the following recommendations can be made for designing buildings that are compatible with ecological elements (Table 3).

Table 3. Criteria for evaluating ecological architecture in traditional houses

Evaluation criteria		Findings and ecological approaches
Orientation		The orientation of the houses is usually towards north-west to south-east or south, with eastern-western stretch. Oftentimes, the eastern and western facades of the houses either do not have any windows or have some small windows in the eastern side.
Spatial layout	Courtyard	Courtyards are places where activities are organized. They provide access to different parts of the house. Additionally, to protect the privacy of the family, they are considered as public spaces for all family members.
	Kitchen	In the climate of this region, kitchen is the most important part of the house. It is usually situated in the second layer of the house behind the hall so that its heat can warm the house. Many of the daily activities are also performed there.
	Hall	Hall is the center of collective activities and is used for multiple purposes. It is usually situated at the center of symmetry of the north side of the central courtyard and functions as the winter room and sometimes summer room.
	Connection joints	Corridors and their hierarchical arrangement prevent the penetration of the cold air into the houses in places where the indoor space is connected to the outdoor space. They reflect the ecological characteristics of the houses. By being placed in the main axis or in a symmetrical order in both sides of the space, they also serve to protect the privacy of the residents.
	Wet spaces	These spaces are usually situated at the central courtyard or spaces inside the house which are related to kitchen.
t i o n	Walls	The use of stone plinths up to the height below the window prevents moisture penetration.

		Also, due to lower thermal conductivity coefficient, the thick inner and outer walls as well as the wooden beams used in roofs provide thermal comfort for the residents.
	Roofs	The roofs are usually constructed using round wooden beams with a diameter of 20-25 cm, bricks, thatch, and gunny. The snow accumulated on them is also used a thermal insulator. Furthermore, double-layer roofs with air-filled gaps are also used as thermal insulators in constructing the roofs of the halls.
Architectural elements	Windows	The windows of the houses are usually double-glazed and have wooden caps. The openings of the windows in the inner side are larger than that of the outer side so as to make the most use of daylight and reduce the effect of cold air. Lighting and heat are provided for the houses through the creation of greenhouse effect in the Orosi windows.
	Doors	Considering the shape of the crossings, the entrance doors to the buildings are usually situated at the south-west of the houses so that entering of the outside air into the porch and taking its orientation can reduce the effects of the undesirable wind.

Over the past, vernacular architecture has focused on using natural sources, conscious selection of materials, and techniques of construction in the environment. Hence, use of local materials, existence of distinctive spatial layouts, and use of innovative construction systems in the traditional houses of Ardabil provide effective ecological solutions for the climatic and geographic problems of the city (Tables 1,2, 3).

Nowadays, the number of traditional houses in Ardabil is decreasing day by day, many traditional houses can be observed in the older parts of the city while, there are only 25 traditional houses in the same old parts. As the result of unplanned urbanization, most of them have been destroyed and replaced by modern apartments. The remaining

instances of vernacular architecture indicate the types of construction, behaviors, and customs that belong to the people of that time. However, there are still some sustainable clues, advantages, and other features in these structures that can be used in modern constructions with an eye on the needs and requirements of the present.

New constructions with materials such as lightweight concrete blocks are not compatible with the climate of the region, the culture of the local people, and their social lifestyle. New construction methods focus just on the financial benefits and ignore other aspects. Hence, they do not keep up the ecological solutions and identity aspects that could successfully meet the needs of the people in vernacular architecture. In other words, passive and more economic systems used in the past have now been replaced by active and energy-consuming systems in heating and cooling the houses. This problem can be observed in many regions of Iran. Cities are losing their identity due to the construction of similar blocks all around the country and new apartments continue to be built without taking into account the climate of the region. That is why we investigated the traditional houses in this study to recognize and make known the advantages of vernacular architecture and encourage its application in modern constructions.

5. Conclusion

Based on the findings of this study, those features of vernacular architecture that have been formed in response to the climatic and geographic conditions can be used in the construction of new buildings. In this region, having eastern-western stretch is of paramount importance in receiving sunshine through the southern and south-eastern walls of the buildings. In fact, there are many factors that have been of great importance in vernacular architecture and can be used in new constructions. They include having windows with larger openings in the inner space compared to the outer space so as to receive more sunlight and less cold air, use of materials with lower thermal conductivity coefficient, attending to the thermal capacity of walls, use of southern canopies in summer, analysis of spatial relations to reduce heat dissipation, creation of thermal comfort, use of appropriate ventilation techniques, etc. In addition, there are usually no windows in the eastern and western sides of the buildings so as to reduce the undesirable effects of the south-western wind. Therefore, most of the windows, especially the largest ones have usually been placed in southern and south-eastern sides of the buildings. Winter rooms and main halls have also been placed in the southern and south-eastern sides of the buildings. The existence of filter spaces and connecting joints before entering the main spaces serves to prevent the penetration of wind and cold air into the house. They also function as a pre-entrance space and serve to protect the privacy of the residents. Kitchen is situated at the second layer of the space. It is directly connected with the winter room or main hall of the house and functions as the heating source for those spaces. Moreover, the skylights of the kitchens were of great importance for the residents regarding ventilation purposes. The space of the kitchen could be used as a dining room, too. Storehouses and cellars are situated in north-western side of the houses and are connected with kitchens. Furthermore, the use of flat, double-layer roofs and double- or triple-pane Orosi windows with innovative local technologies prevented heat dissipation in houses. Therefore, attending to architectural criteria in traditional houses and investigating their compatibility with modern technologies can be helpful for future architectural designs. In the case of Ardabil, ignoring the local construction systems, materials, spatial layouts, etc. has resulted in poor standards of living. Therefore, maintaining the existing traditional structures and using their ecological solutions in the construction of new

buildings are of great importance. Inattention to these criteria results in the reduction of environmental quality and loss of local identity. Put another way, attending to the criteria and strategies employed in vernacular architecture complements the modern architecture and pushes it forward. And this, in the long run, will improve our quality of life.

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Author Contributions

Mahsa Javadi nodeh: Analyzed the data, prepared figures and tables, authored or revised drafts of the paper

Azadeh Shahcheraghi: Proposed the plan, and approved the final draft.

Alireza Andalib: Analyzed the data, and approved the final draft.

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