# Climatic Sensitivity and Architecture of Traditional Houses in Iran during the Qajar Dynasty (1795-1925)

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## Abstract

*One of the most basic human needs has been a place to call home. People need a safe environment to protect themselves from heat, cold, and life-threatening hazards. These settings originally arose in the form of caves, and then evolved into dwellings. Houses have been created in many forms and styles in various parts of the world throughout history. One of the most significant causes for these changes is the climate which has influenced the structure's construction style, shape, materials, and schematics, causing them to differ, depending on the region and location.*

*With the advancement of technology, the climatic factors that formerly influenced house construction have disappeared. Regardless of various geographies and climates, the design and construction of contemporary houses, which have been created worldwide since the industrial revolution, continue to be imitated. As a result of this condition, climatic comfort has decreased, and non-renewable energy use has increased. The answer to these challenges can be found in historic structures.*

*As one of the world's oldest and most historically significant countries, Iran is rich in historical structures. This study examined the impact of climate related architectural elements on the plan morphology of six distinct buildings from the Qajar dynasty period, in Iran. They are among the historical houses with the most remarkable historical and architectural values on the Cultural Heritage Protection Agency of Iran's list. The climate of Iran is divided into four distinct facets. The most considerable climatic variation between these four climates is found between Alpine and steppe climates. As a result, the structures investigated were chosen from the cities of Tabriz, with an alpine climate, and Yazd, with a steppe climate. As a result of all of the evaluations, with the design used and technological methods that do not require any complex technology, the historical houses of Tabriz are 50% warmer than the outside temperature in winter, and the historical houses of Yazd are 50% colder than the outside temperature in summer. As a result, the city consumes 50% less energy during peak energy seasons.*

**Keywords:** Historical houses, Climatic comfort, Plan morphology, Qajar Dynasty, Iranian architecture.

## Introduction

Human beings are constantly interacting with their space (Kordhaghi, Zolfaghari & Kandemir, 2022). A house is made up of more than just four walls and a roof. Climate conditions are one of the most significant variables determining human health and comfort. This situation has always had an indirect impact on people's lifestyles (Ramezani, Maghsodi & Shafaghati, 2013). Climatic conditions have influenced people's lifestyles and needs since different climates prevail in different world regions. These diverse necessities and lifestyles have led to the formation of distinct architecture and urban designs.

The living spaces and environments directly influence people's satisfaction and comfort. Buildings should cater to people's physical and psychological needs, making them feel valued, safe, and at ease (Sassi, 2006). In order to offer physical satisfaction, the human body must be in a pleasant state both within the structure and outside (Soleymanpour, Parsaee & Banaei, 2015).

Undeniably, the climate is one of the most critical aspects that has an impact on human comfort. As a result of the climatic variations in different regions of the world, building designs and construction techniques which can produce human comfort in every region are essential (Pourvahidi, 2010). Despite recent technological advancements, most new structures however are designed without any regard to the buildings' climatic comfort (Reuther, 1967). This condition results in the usage of non-renewable energy resources, causing more air pollution and climate change. Houses are the most non-renewable energy users of all urban structures. Different architectural approaches should be employed in different climates to avoid this issue. In this context, the architecture of buildings with gardens, which have evolved through centuries to satisfy different needs, have highly unique and intriguing design methods and historic technology that may be used as an example (Singh, Mahapatra & Atreya, 2009).

Traditional design has provided excellent solutions to climate constraints over the years, resulting in increased living comfort (Rakoto-Joseph, et al., 2009). Traditional houses can harmonize the residents with their surroundings. These structures are built to represent Nature, culture, and the history of the area in which they exist (Coch, 1998).

On the other hand, traditional Iranian architecture incorporates design principles in constructing houses to attain climatic comfort conditions in the interiors. Furthermore, these residences are entirely adapted to the natural and social circumstances of the region where they exist (Kasmai, 1993). Various studies on local Iranian architecture have revealed critical elements for obtaining climatic comfort in architectural design (Ghobadian, 1996; 2013).

Although identical architectural patterns were employed in various parts of Iran, distinct approaches have not been used to create contemporary dwellings in different regions. These similar design patterns utilized in modern house designs present specific issues with people's physical and psychological comfort (Soleymanpour, Parsaee & Banaei, 2015). It is vital to classify climates in order to uncover and study the impact of climate on Iranian architecture.

## Objectives

This research aims to identify the climate-related architectural design aspects of historical Qajar buildings in Tabriz and Yazd, which are located in Iran's alpine and steppe climates, and to analyze the climatic impacts of the design features on various locations of the historical buildings. The research unravels the architectural design principles, suggesting that these principles can be utilized to improve climatic efficiency in modern constructions in steppe and alpine climates.

## Literature Review

Various research on the role of climate in architecture and urban design has been undertaken in Iran and the World. The majority of studies focus on the exploration of climate-friendly architecture in a different locations. For example, Bagasi, Calautit & Karban (2021) this paper evaluated the effect of traditional liquor on the indoor thermal environment in a selected building in hot climates. A case study in the most populous region of Saudi Arabia,

"Historical Jeddah," was selected to evaluate and evaluate the performance of drinkers indoors and in comfort. This study showed that open mattresses enable airflow during the day and thus increase air movement and circulation in the room. Ajmat et al. (2017) examine the relationship between the morphology of the plan and the extent to which the building benefits from solar energy. They present a systematic simulation process for analyzing the potential for clean energy production. Martínez Molina et al. (2016) the main purpose of the investigation was to reduce energy consumption and improve indoor thermal comfort while maintaining the buildings' historical value. Ramezani, Maghsodi & Shafaghati (2013) describe the relevance of climate as follows: Climate conditions are one of the most critical variables in human existence, health, and comfort. This factor has had a direct and indirect impact on humanity. Shakoor (2011) shows that climatic designs aim to provide climatic comfort for people in structures. Ghobadian and Mahdavi (2013) has presented various methods for analyzing thermal comfort and climate control and in order to enhance thermal conditions and boost comfort indices. This study concurs that the built environment is highly correlated with climate. There are also several architectural categories based on climatic characteristics, such as cold, temperate, hot-humid, and hot-dry regions. This categorization may be used to determine the level of climatic comfort in structures that are in different climates. Kasmaei (2008) has investigated climatic conditions, climatic parameters, and their application in construction. Salehe (2004) has presented climate design models tailored to the climate of the study area. Razjouyan (1988), in his book, talks about the compatibility of climate comfort with architecture. In this book, he examines the architectural elements that affect the climatic comfort and believes that the environment built based on the climatic elements mentioned in the book can be highly correlated with the climate.

## Climate and Housing

Home, an environment in which human lives, is tied up to all aspects of his life (Eslampour, MirRiahi & Habib, 2022). Climate comfort is an essential factor in human-centered home design (Soleymanpour & Parsaee, 2017). The climate affects the construction, type, form, and renovations of structures (Özata, 2018). Because of the climate, houses with various architectural elements have been constructed worldwide throughout history. Houses constructed in various areas differ in terms of internal spaces, materials, and building style, all of which are impacted by climate. A house is a form of a space in which a person spends most of his/ her time and has always been a special place to architects and has been addressed from different views. Considering the philosophical, sociological, psychological, cultural, aesthetics, functional, and other related issues are among these views (Basouli & Omidvari, 2022). The meaning of the term "home," as stated by the researchers, is briefly given in Table 1.

**Table 1:** Meanings of home
Source: Authors, 2022

| Pundits | Viewpoint | Reference |
|---|---|---|
| Heidegger | "Home and dwelling are single phenomena, the creation by the individual consciousness out of its rootedness in culture, time, and place." | Heidegger, 1971 |
| Castells | Home is where we belong. It is embedded in our experiences, memories, and thoughts. It creates the physical and social platform of life experience for us. | Castells, 1977 |
| Rapoport | Home as a place, the most basic human need after food, has long been more than a shelter for humans. | Rapoport, 1982 |
| Norberg-Schulz | The home is a place where the residents do not feel uncomfortable. | Norberg-Schulz, 1985 |
| Saegert | Home is a method to locate life in a particular geographic region, as well as an experience of life and a part of what we do. | Saegert, 1985 |
| Le Corbusier | The home is a living mechanism that is essential to society's equilibrium. | Le Corbusier, 1986 |
| Bachelard | The home we once lived in is not an empty box. Residential space enhances geometric space. | Bachelard, 1994 |
| Izgi | "The factors which effect on the home architecture are Geography-topography, Content, Climate, and Culture-beliefs." | Izgi, 1999 |

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|---|---|---|
| Moore | For its residents, the home is the center of the universe, as well as a locative structure in the neighborhood. | Moore, 2000 |
| Douglas | "Home is thus an early form of social organization." | Douglas, 2000, Cited in Shabani, 2011 |

## The Impact of Climate on Traditional House Architecture

Iran, the article's case study, is a four-season nation with climatic characteristics that are shared by countries with different climates. Table 2 examines traditional architecture's climatic characteristics in five nations adjacent to Iran's climatic zone.

**Table 2:** Climatic features on the traditional architecture of 5 countries close to Iran's climatic zone
Source: Authors, 2022

| Country | House features and characteristics | Image |
|---|---|---|
| Rome | People lived in multi-story apartments in ancient Rome, with wealthy families living in two-story Atriums and Peri-style houses. The roofs of the Peri-style mansions were designed in the shape of an inverted roof to collect rainwater. The gathered rainwater was dumped into the garden pool via a hole in the middle of the roof. This aperture would also enable light to enter the property, brightening the atmosphere. |  Source: URL-1, 2021 |
| Greece | Because of the rainy and humid climate, classic Greek buildings featured sloping roofs to keep rainwater out. Furthermore, the exteriors of the houses were fully coated with white materials to reduce the amount of temperature outside that penetrated into the building. |  Source: URL-2, 2021 |
| Egypt | Due to the climate, brick and plaster were commonly used as building materials in Egypt. The high heat capacity of the bricks is the explanation behind this. The bricks function as a complete insulation system by keeping hot air from entering and cool air from leaving the house. |  Source: URL-3, 2021 |
| China | Traditional Chinese buildings are often built of adobe and include huge gardens. There is no difference in Chinese houses between the inside and outside of the house. Because China has three distinct climates, the atriums in the hot and rainy parts of the South are shaded to protect against the sun. The tops of the atriums were frequently left open in the northern area, which had a drier climate. |  Source: URL-4, 2021 |
| South Africa | Houses in tiny settlements in South Africa have been built in the shape of huts using the same techniques since ancient times. These huts are constructed as a community in one place, on the edges of each other, with minimal space between them for the tribesmen to reside. Tree branches are the essential material utilized in building these huts. |  Source: URL-5, 2021 |

## Research Methodology

The descriptive literature research, observation, and analytical method were employed in this research. Library and identification techniques were used to collect information on theoretical research on climatic conditions. In contrast, field studies are based on observations. Observations and field research (confirm the locations in the plan, take photos, temperature measurements) were employed to record the layouts of the houses and the volumes of heat (temperature) in the buildings.

Temperature measurements of the areas were collected with the use of digital thermometers in order to evaluate the climatic performance of architectural areas with high climatic efficiency. Measuring the temperatures of the case study houses on 20$^{th}$ February 2021 and 20$^{th}$ July 2021, at 12:00 pm, simultaneously using twenty-five digital thermometers (five thermometers for houses in Yazd and three thermometers for houses in Tabriz) has been accurately measured and recorded. Measurements were performed by six people (one for each

house), two of whom were article authors, and four were volunteers. Temperature measurements were taken with the help of a digital thermometer in the summer room, Winter room, Pool house, balconies, and Sunken Garden (Balcony and the Sunken Garden, which are only in steppe climate), in order to determine whether the climatic architectural features analyzed in each of the six houses provide a sufficient effect for energy saving in today's architecture.

The relationship and correlation between the climatic comfort existing in traditional buildings of these locations and architectural styles are discussed in the second part of the research, which takes into account the climatic qualities of Iran's alpine and steppe climates. Iran has a total of four distinct climatic zones. Tabriz (38° 4' 48.9976" N, 46° 17' 31.9964" E), the capital of the East Azerbaijan province in the Northwest of Iran (Ghofrani, et al., 2020), and Yazd (31.8974°N, 54.3569°E), the capital of the "Yazd province, located in the central plateau of Iran a large section in the central country" (Sahebzadeh et al., 2013) (Fig.1). They are used as case study areas in this research to analyze the structural situations in the alpine and steppe climates, which have the most climatic contrasts among the four climatic zones of Iran.

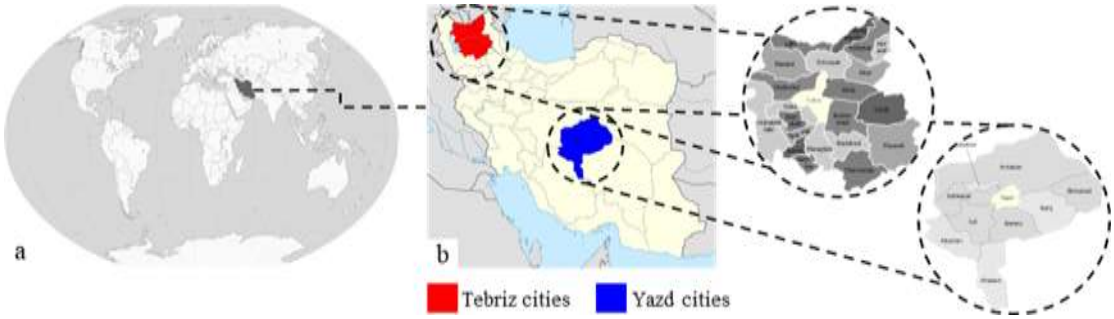



**Fig. 1: (a).** The location of Iran on the world map, **(b).** The location of the cities of Tabriz and Yazd on the map of Iran
Source: Revised by the Authors, 2022**;** using URL-6, 2021

For this research, six ancient mansions from the Qajar period have been chosen from Iran's steppe and alpine regions. The study looked at the plan morphologies, climatic design aspects, and effects of the selected structures, and the peculiarities of the Iranian climates.

In Fig.2, the study methodology and purpose are illustrated schematically.

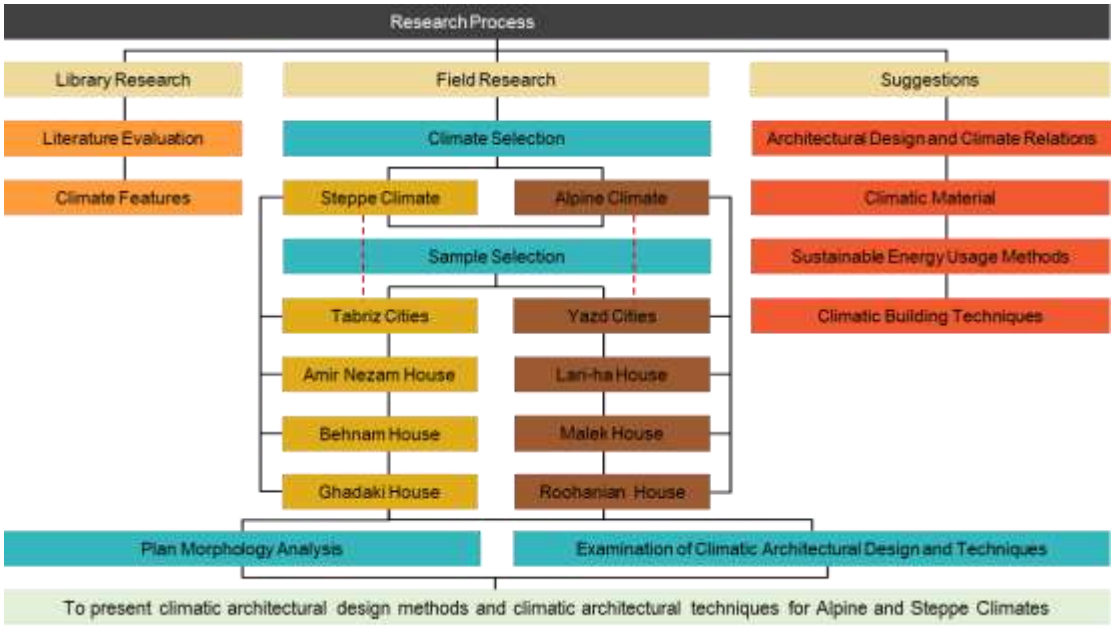



**Fig. 2:** Research method and purpose
Source: Authors, 2022

## Research Findings

### Climate of Iran and Housing

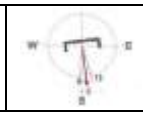
One of the most evident elements in the architecture of traditional Iranian houses is the attention to climatic conditions. This trait has resulted in structures that are in tune with Nature and provide a high level of living comfort (Sev, 2009). It has been discovered that Iran's traditional architecture, climatic design, and construction techniques deliver a high level of climatic comfort in the residences between the years 1800 and 1900. Apart from Iran, this element may be seen in the traditional architecture of many other nations (Salehipour, Etessam & Mofidi, 2021).

In different parts, Iran experiences four various climatic conditions: mild and humid, cold, hot-dry, and hot humid (Mehdizadeh Dalir & Mokhtari, 2018) (Fig.3). The steppe climate dominates the country's largest region. The Lut and Kavir deserts in this region cover around three-quarters of the steppe climate (Ganji, 1995).


**Fig. 3:** Climate map of Iran
Source: Revised by the Authors, 2022; using Nasrollahi, 2015

The largest climatic variance between the four climates outlined above is between alpine and steppe climates. Due to the physical-geographical qualities that are the focus of the research, the climatic data of these two climates are examined in Table 3:

**Table 3:** Climate characteristics in Iran
Source: Edited by the Authors, 2022**;** using Kasmai, 1993; Ghobadian, 2010

| Climate | Characteristics of the climate | Urban textures |
|---|---|---|
| Alpine Climate | • This climate prevails in areas with the most significant number of mountains. | • In a terrestrial environment, urban textures are uniform and created in accordance with building orientations, sun angle, and topography. |
| | • Summers are mild, while winters are very cold. | |
| | • In the winter, precipitation is usually in the form of snow. | |
| | • There is a significant temperature difference between day and night. | • In order to be insulated from the cold, urban areas are designed in a narrow and limited form. |
| | • A low humidity rate prevails throughout the year. | |
| | • Snowfall takes place at a high rate. | |
| | • Long-lasting cold and dry months. | • Building direction:  |
| Steppe Climate | • Located in the most central region of Iran, where the Kavir and Lut deserts exist. | • The density of urban and rural communities is relatively high. |
| | • The days are hot and dry while the nights are cold. | • High barriers and walls encircle urban centers. |
| | • There is a significant difference in temperature between day and night. | • The sun angle and wind influence the direction of communities. |
| | • Summers are dry and hot, and winters are dry and frosty. | • Buildings have adjacent forms. |

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|---|---|---|---|
| | • Low humidity throughout the year. | • The streets are labyrinthine, small, and asymmetrical, with arches occasionally enclosing them to create shade. | |
| | • Snowfall exists at a low rate. | | |
| | • Low annual precipitation. | | |
| | • The region has dusty and sandy air due to the winds that blow over the desert. | • Building direction: |  |

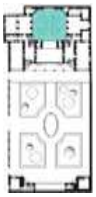
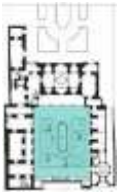
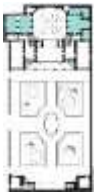
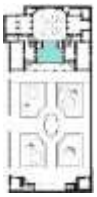
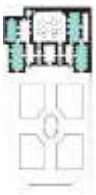
In this article, one historical city from the alpine and steppe climates each and three historical residences from the Qajar period were chosen from each city to perform a plan morphological analysis on the historical houses of Iran. Table 4 outlines the cities and houses chosen:

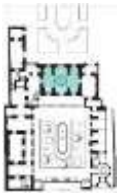
**Table 4:** Details of the sample list of the research
Source: Authors, 2022

| Climate | City | Name of the residence | Year the house was built | Current Use | Image | |
|---|---|---|---|---|---|---|
| Alpine | Tabriz | Amir Nezam House | 1809 | Museum |  Source: Authors, 2022 |  Source: Authors, 2022 |
| | | Behnam House | 1849 | Faculty of Architecture |  Source: Authors, 2022 |  Source: Authors, 2022 |
| | | Ghadaki House | 1850 | Faculty of Architecture |  Source: Authors, 2022 |  Source: Authors, 2022 |
| Steppe | Yazd | Lari-ha House | 1873 | Museum |  Source: Authors, 2022 |  Source: Authors, 2022 |
| | | Malek House | 1869 | Art House |  Source: Authors, 2022 |  Source: Authors, 2022 |
| | | Roohanian House | 1883 | City Hall |  Source: Haji-Ghassemi, 2004 |  Source: Haji-Ghassemi, 2004 |

A few unique features distinguish Iran's Qajar period houses from those of other periods. The distinctive locations relating to the Qajar era houses are described in Table 5. Most of the buildings presented are seen in houses in both regions, although some are unique to the steppe climate and some to the alpine climate.

**Table 5:** Special structures dating back to Qajar period
Source: Authors, 2022, Plans: Revised by using Haji-Ghassemi's works

| Climate, Structure Name | Description | Plan | Image |
|---|---|---|---|
| Alpine and Steppe, Inner Garden | The inner garden at the back of the house is enclosed on all four sides by buildings and was designed specifically for the private use. A small door in this garden leads to the back alleys that existed in the past and are used to enter and exit the building. The winter and summer rooms, the kitchen, and other private areas are accessible from the inner garden. |  |  Behnam House, Inner Garden Source: Authors, 2022 |
| Alpine and Steppe, Outer Garden | The outer garden is the only entrance to the house for visitors and non-private individuals. The outer gardens have a larger and more elegant design than the inner gardens. The Shahneshin (Kings') room, the pool chamber, and the balcony in the outer garden are all accessible from this garden. |  |  Ghadaki House, Outer Garden Source: Authors, 2022 |
| Alpine and Steppe, Summer Rooms | Summer rooms are cold and are used only during the summer. These are frequently designed to protect the seclusion of the residence and to surround the inner garden. They can be found as independent parts in both the outer and inner gardens, depending on the size of the buildings, especially in the steppe climate. |  |  Behnam House, Summer Rooms Source: Authors, 2022 |
| Alpine and Steppe, Winter Rooms | Winter rooms are heated rooms that are exclusively used in the winter. These rooms are often built around the inner garden and are only for the benefit of the occupants. The winter rooms can be found as distinct parts in both the outer and inner gardens, depending on the size of the buildings, especially in the alpine climate. |  |  Ghadaki House, Winter Rooms Source: Authors, 2022 |
| Alpine and Steppe, Shahneshin Room | Shahneshin is the Qajar house's most prominent guest room, situated in the center of the facade overlooking the outer garden. This room is the most ornate section of the residence in terms of architectural ornamentation. The Orosi window, which overlooks the outer garden, is the most prominent symbol of Shahneshin's room. In all climates, the ceiling height of this chamber is double that of Qajar houses. |  |  Behnam House, Shahneshin Room Source: Authors, 2022 |
| Alpine and Steppe, Sardabe | Sardabe was used to store food. These are dark, cold rooms with no natural light, built one or two floors below the ground level. Sardabe has an excellent coldness due to the thick walls, lack of sunshine, and construction beneath the ground floor. Sardabe's were constructed on the summer rooms' facades. |  |  Behnam House, Sardabe Source: Authors, 2022 |

| | | | |
|---|---|---|---|
| Alpine and Steppe, Earring Chambers | The earring chambers are two rooms on the right and left sides of the Shahneshin room. When male and female visitors arrive at the same time during the Qajar period, the males were accommodated in the Shahneshin room, while the ladies were accommodated in the earring chambers, separated from the Shahneshin by a door. Some houses have these rooms on two floors, while others have them on the Shahneshin floor. |  |  Ghadaki House, The Earring Chambers Source: Authors, 2022 |
| Alpine, Pool Chamber | The little stone pool in the midst gave the pool house its name. The brick walls of the pool chambers in the basement reach a thickness of 5-15 meters. The pool chambers were erected to provide inhabitants with a cool spot to sit in the summer and a tranquil atmosphere. |  |  Ghadaki House, Pool Chamber Source: Authors, 2022 |
| Alpine and Steppe, Balcony (Eywan) | Depending on the weather, balconies are a semi-open or entirely open spaces in the garden. In hot areas, balconies were utilized for cooling, and in alpine temps, they were used for decoration. As a result, the building styles of balconies in steppe and alpine climates differ from one another. |  |  Lari-ha House, Balcony Source: Haji-Ghassemi, 2004 |
| Steppe, Sunken Garden | Only a portion of the houses in the steppe climate have this sort of garden, which is for the homeowners' exclusive use. The sunken garden's floor was raised one level above the ground. This garden differs from the inner and outer gardens of the house in that it is smaller, deeper, and the walls that encircle it on all four sides are naturally higher. Because of these elements, the garden is shaded for many hours. |  |  Malek House, Sunken Garden Source: Haji-Ghassemi, 2004 |
| Steppe, The Windcatchers (Badgir) | In hot regions, the ventilation system is a critical architectural component. On the roofs of all ancient dwellings in the steppe climate, this system is accessible in various dimensions. Wind blowing from different districts enters through openings on all four sides of the ventilation, travels along a channel to the pool area in the basement, and cools the atmosphere by touching the water in the pool. This element is still utilized as a sign of Yazd in residences located in the city's old district. |  |  Lari-ha House, Windcatchers (Badgir) Source: Haji-Ghassemi, 2004 |

## Alpine Climate

### Houses in Tabriz

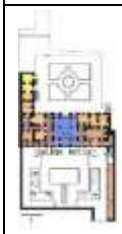
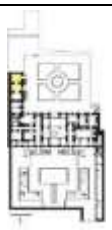
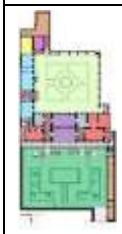
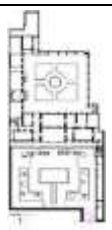
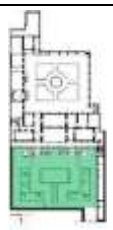
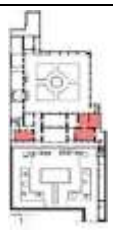
Tabriz, often known as the "city of historic houses," is one of Iran's oldest and most historically significant cities, located in the Northwest of the country (Fig. 4a). Tabriz, located in the coldest section of the alpine climate, has served as Iran's capital and central city several times throughout its history. As a result, the city possesses a large number of ancient buildings. Buildings of the Amir Nezam, Behnam, and Ghadaki houses, examined in Fig.4 and the plan morphology analysis in Tables 6, 7, and 8, were chosen for this study among the ancient structures of Tabriz.

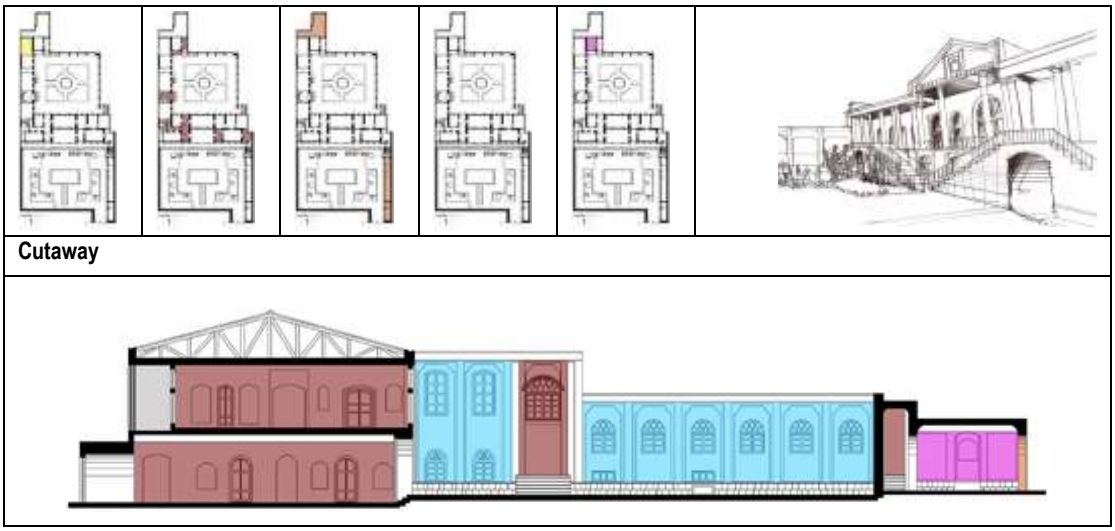

**Fig. 4: (a).** Location of Tabriz city on the map of Iran, **(b).** Location of Tabriz city, **(c).** Location of selected houses
Source: Revised by the Authors, 2022; using Google Earth

## Amir Nezam House

Amir Nezam's House is 1500 $m^2$ in size and is located in Tabriz's Sheshghelan district. This property features both an inside and outdoor garden. The inner garden is in the northern part of the residence and has a door on the East side that leads to the back streets. This garden features two-story chambers on the western facade and brick embellishments on the eastern facade. Two levels make up the building's core section. A large balcony encircles the whole South facade of the house with sixteen columns. Stairs in the garden allow access to the upper story of the residence. The Orosi windows of the Shahneshin room, positioned in the top floor's center, stand out. Two doors under the stairwell in the garden offer access to the basement. The basement may also be accessed from the staircase of the house. The Qajar Museum was established when the mansion was renovated. Table 6 shows the morphology of Amir Nezam's dwelling layout.

**Table 6:** Plan description of Amir Nezam House
Source: Authors, 2022

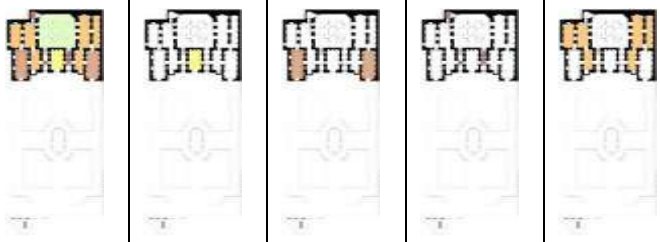
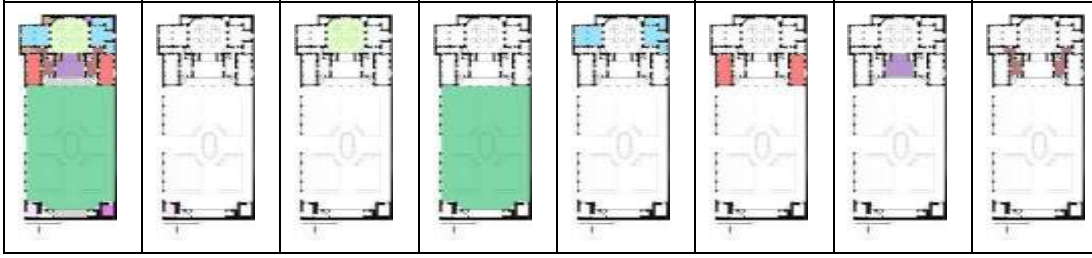
| **Floors Location** | | **Entrance Floor** | | | | | |
|---|---|---|---|---|---|---|---|
| Plan | Kitchen | Storage Room | Corridor | Sardabe | Pool Chamber | | |
|  |  |  |  |  |  | | |
| **Floors Location** | | **Elevated Entrance Floor** | | | | | |
| Plan | Entrance | Inner Garden | Outer Garden | Summer Room | Winter Room | Earring Chambers | Shahneshin |
|  |  |  |  |  |  |  |  |
| Kitchen | Corridor | Storage Room | Balcony (Eywan) | Housemaid Room | **Perspective** | | |

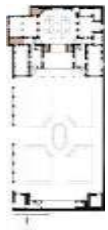
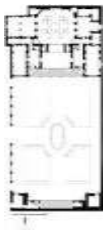
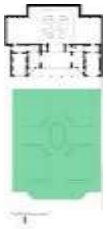
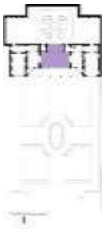
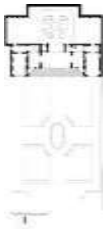



## Behnam House

With a total size of 900 $m^2$, Behnam house is located in the Magsudiyye district in Tabriz's city center. This house is divided into two sections: interior and exterior. Outside, there are Shahneshin and earring chambers. The Orosi window in the Shahneshin room differs from the Orosi windows in all of Tabriz's historical mansions. Double Hung Windows is featured in this Orosi. Each pair of windows has a different design on them. In front of the Shahneshin's room, there is a half-open balcony with four columns. On the other hand, earring chambers are on the upper story of the house where Shahneshin resides and have little windows that open to Shahneshin. Perforated domes are used to cover the roofs of the rooms on the East and West sides of the inner garden. After being renovated, the Behnam house's is now home to the Tabriz Islamic Art University's Faculty of Architecture and Art. Table 7 illustrates the plan morphology of the Behnam house.

**Table 7:** Plan description of Behnam House
Source: Authors, 2022

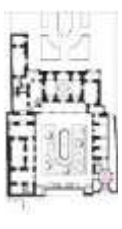
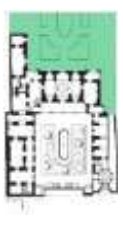
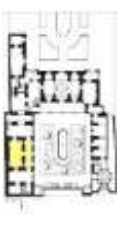
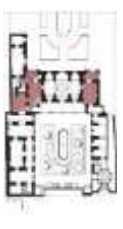
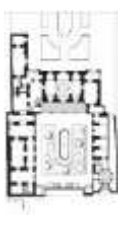
| **Floors Location** | | **Basement Floor** | | | | | |
|---|---|---|---|---|---|---|---|
| Plan | Kitchen | Storage Room | Corridor | Sardabe | | | |
|  | | | | | | | |
| **Floors Location** | | **Entrance Floor** | | | | | |
| Plan | Entrance | Inner Garden | Outer Garden | Summer Room | Winter Room | Shahneshin | Corridor |
|  | | | | | | | |

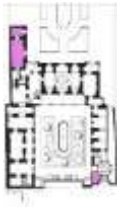
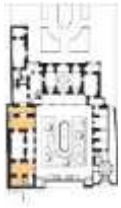
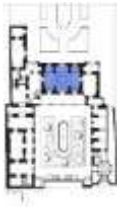
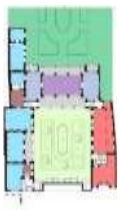
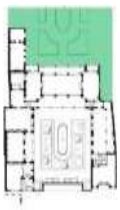
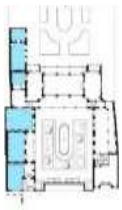
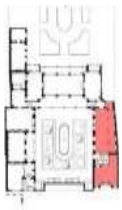
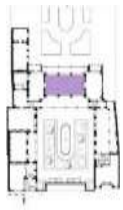
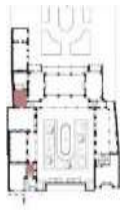
| Storage Room | Balcony (Eywan) | Housemaid Room | **Perspective** | |
|---|---|---|---|---|
|  |  |  |  |  |
| **Floors Location** | | **Elevated Entrance Floor** | | |
| Plan | Inner Garden | Outer Garden | Winter Room | Earring Chambers | Shahneshin | Corridor | Balcony (Eywan) |
|  |  |  |  |  |  |  |  |
| **Cutaway** | | | | | | | |
|  | | | | | | | |

## Ghadaki House

Ghadaki house, constructed 160 years ago close to Behnam house, is located in the Magsudiyye area. With an area of 863 $m^2$, this house was built in the middle of the Qajar period. The inner garden of the Ghadaki house is larger than the inner gardens of the other two Tabriz mansions assessed in this research. There are two-story chambers on the East and West sides of the inner garden. On the upper floor of the East facade, there are summer rooms, and on the upper floor of the West facade, there are winter rooms. The kitchen, Sardabe, and storage rooms are located on the bottom floor of both facades. Ghadaki House serves as the Faculty of Architecture and Art, and it is part of a historical complex that includes Behnam and three other historic houses (two of the houses are under restoration). The walls and entrance parts of the outer gardens of these buildings were removed in order for them to form an adjacent complex within the site. The plan morphology of the Ghadaki house is presented in Table 8.

**Table 8:** Plan description of Ghadaki House
Source: Authors, 2022

| **Floors Location** | | **Basement Floor** | | | | | |
|---|---|---|---|---|---|---|---|
| Plan | Entrance | Inner Garden | Outer Garden | Kitchen | Corridor | Storage Room | Balcony (Eywan) |
|  |  |  |  |  |  |  |  |

| Housemaid Room | Sardabe | Pool Room | **Perspective** | |
|---|---|---|---|---|
|  |  |  |  |  |
| **Floors Location** | | **Elevated Entrance Floor** | | |
| Plan | Inner Garden | Outer Garden | Summer Room | Winter Room | Earring Chambers | Shahneshin | Corridor |
|  |  |  |  |  |  |  |  |
| **Cutaway** | | | | | | | |
|  | | | | | | | |

## Steppe Climate

### Houses in Yazd

Yazd is a historical city in Iran's central region (Fig.5a). Yazd is one of Iran's warmest cities, with a completely distinct architectural texture as a result of the hot temperature. Yazd's buildings are built entirely of adobe, and the city has a unique appearance. The studied houses are Lari-ha (Table 9), Malek (Table 10), and Roohanian (Table 11) buildings (Fig.5c) from Yazd city (Fig.5b), which were built during the Qajar period. These residences are at the heart of Yazd's historical district.

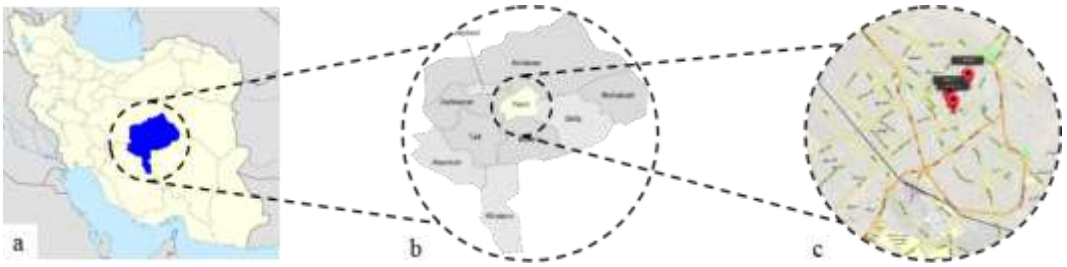


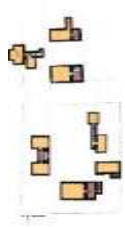
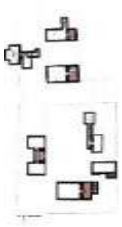
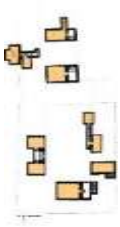
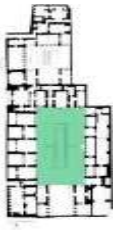
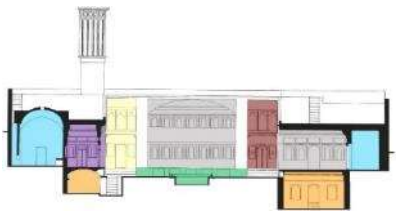

**Fig. 5: (a).** Location of the city of Yazd on the map of Iran, **(b).** Location of the city of Yazd, **(c).** Location of Yazd houses
Source: Revised by the Authors, 2022; using Google Earth

### Lari-ha House

Lari-ha house, which was built 130 years ago and has a total size of 1700 $m^2$, is located in the Fahadan neighborhood, which is located in the historical area of Yazd city. In total, this property features three gardens and three balconies. Its most notable feature is its outer garden,

which has the largest balcony (Eywan) on its southwest facade. The size, architectural ornaments, and windows on all three sides of this balcony make it remarkable. The inner and outer gardens of the Lari-ha house have only one entrance. This entry lies in the midst of the inner and outer gardens, allowing access to both sides of the house. Apart from the main entrance, there are other small doors in the outside body of the house. These doors were explicitly designed for the house areas that were used as service rooms (kitchen, storage, etc.). For many years, the Lari-ha family had resided in this house, which was constructed for them. During the Pahlavi period, this house was abandoned, and it was severely damaged and deteriorated into ruin over time. Later, in 1985, the Iran Cultural Heritage Preservation Institution purchased the house and began using it as a branch of the organization in Yazd. Table 9 illustrates the Lari-ha house's plan morphology.

**Table 9:** Plan description of Lari-ha House
Source: Authors, 2022

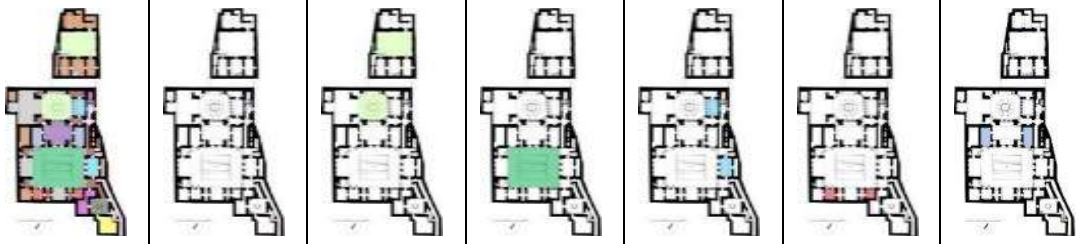
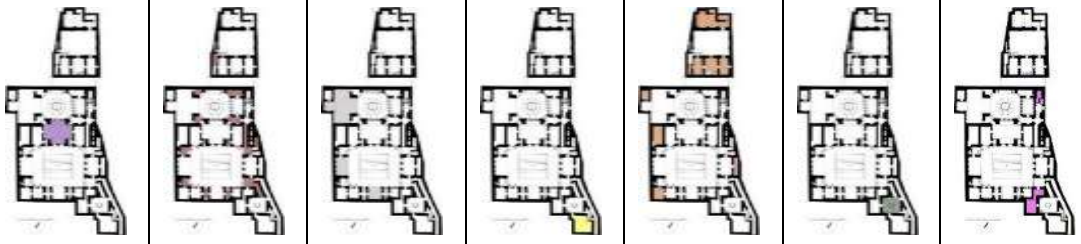
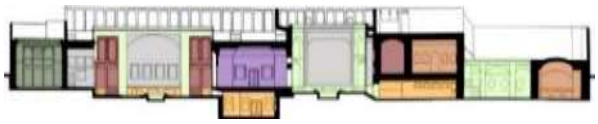
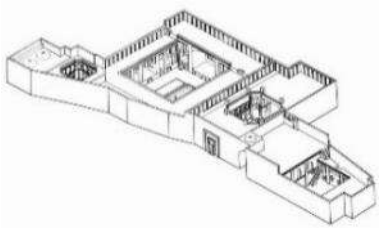
| **Floors Location** | | **Basement Floor** | | | | | |
|---|---|---|---|---|---|---|---|
| Plan | Corridor | Sardabe | Perspective | | | | |
|  |  |  |  | | | | |
| **Floors Location** | | **Elevated Entrance Floor** | | | | | |
| Plan | Entrance | Inner Garden | Outer Garden | Summer Room | Winter Room | Earring Chambers | Shahneshin |
|  |  |  |  |  |  |  |  |
| Corridor | Balcony (Eywan) | Kitchen | Storage Room | Sunken Garden | **Cutaway** | | |
|  |  |  |  |  |  | | |

## Malek House

Malek House is a 150-year-old structure in Yazd's Fahadan district. A covered passage divides the Malek house into two sections. The section of the passage on the North side is smaller than the section on the South. There are a garden and service rooms in the more minor part of the house on both sides. The most critical elements of the house are on the North side of the bigger and colossal section. The Malek house has four gardens and four balconies. Another notable component of the house is the Shahneshin room, which is situated in the midst of the inner and outer gardens and has twin facades. The plan morphology of the Malek house is explained in Table 10.

**Table 10:** Plan description of Malek House

Source: Authors, 2022

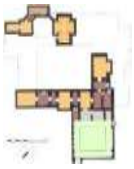
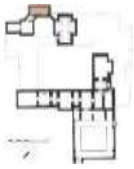
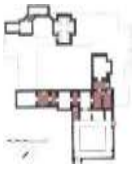
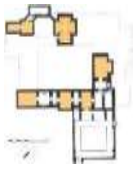
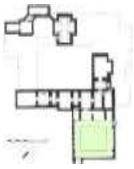
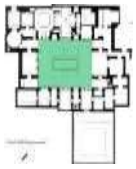
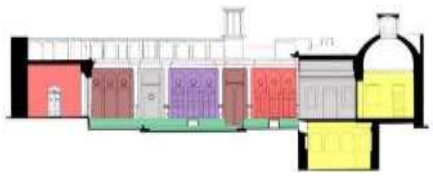
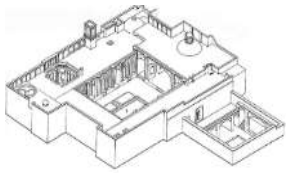
| **Floors Location** | | **Basement Floor** | | | | |
|---|---|---|---|---|---|---|
| Plan | Storage Room | Corridor | Sardabe | Inner Garden | | |
|  | | | | | | |
| **Floors Location** | | **Elevated Entrance Floor** | | | | |
| Plan | Entrance | Inner Garden | Outer Garden | Summer Room | Winter Room | Earring Chambers |
|  | | | | | | |
| Shahneshin | Corridor | Balcony | Kitchen | Storage Room | Sunken Garden | Housemaid Room |
|  | | | | | | |
| **Cutaway** | | | | **Perspective** | | |
|  | | | |  | | |

## Roohanian House

Roohanian house, with its 120-year history and 303 $m^2$ of area, is located in Yazd's Golchinan district. There are two pathways after passing through an open and closed filtration area in the entrance section. One corridor leads to the sunken garden, while the other leads to the outer garden. Shahneshin's room, like Malek's, is open on two sides and overlooks the Sunken and outer garden. As the most essential components of the house, the single-story rooms encircling the outside garden are lined up close. The service rooms of the Roohanian house are primarily in the basement. After being renovated, this mansion serves as the Historical District Municipality of Yazd. The plan morphology of the Roohanian house is explained in Table 11.

**Table 11:** Plan description of Roohanian House
Source: Authors, 2022

| **Floors Location** | | **Basement Floor** | | | | |
|---|---|---|---|---|---|---|
| Plan | Storage Room | Corridor | Sardabe | Inner Garden | | |

| | | | | | | |
|---|---|---|---|---|---|---|
|  |  |  |  |  | | |
| **Floors Location** | | **Elevated Entrance Floor** | | | | |
| Plan | Entrance | Inner Garden | Outer Garden | Summer Room | Winter Room | Earring Chambers |
|  |  |  |  |  |  |  |
| Shahneshin | Corridor | Balcony | Kitchen | Storage Room | Sunken Garden | Sardabe |
|  |  |  |  |  |  |  |
| **Cutaway** | | | | **Perspective** | | |
|  | | | |  | | |

## Evaluation of Qajar Houses Climate Plan Analysis

Some climatic design strategies and elements were identified as a consequence of the plan morphology examination of historical Qajar period houses in the cities of Tabriz and Yazd in Iran's steppe and alpine climates. Table 12 summarizes the climatic design information gained as a result of the analyses:

**Table 12:** Climatic analysis of house plan morphology made between climates
Source: Authors, 2022

| Features and Traits of Climate Design | Design Feature's Climate Impact | Climate/Location of the Feature |
|---|---|---|
| • The houses are designed adjacent to one other. | • Interior areas may be kept compact and warmer. | • Alpine/ Tabriz |
| • The houses are constructed in two directions: North and South. | • Houses benefit from the highest temperature in the winter and the lowest temperature in the summer. | • Alpine/ Tabriz |
| • The walls are composed of brick and clay and are pretty thick. | • Bricks function as a thermal barrier, preventing cold air from entering. | • Alpine/ Tabriz |
| • The houses are constructed above the ground level. | • Building's living areas are protected from the snow, moisture, and coldness of the earth. | • Alpine/ Tabriz |
| • The pool room area is constructed in the basement. | • The basement is kept cold by the dirt beneath the walls. | • Alpine/ Tabriz |
| • In the gardens, there are definitely vast water fountains. | • It keeps the garden cooler in the summertime. | • Alpine/ Tabriz<br>• Steppe/ Yazd |
| • The winter rooms are built in the sun's direction and have a small room | • Room temperature does not shift upwards and can remain warmer in the winter. | • Alpine/ Tabriz<br>• Steppe/ Yazd |

| | | |
|---|---|---|
| height. | | |
| • Summer rooms are built in the shadow direction and have a higher room height than usual. | • The hot air shifts upwards, keeping the rooms cooler in the summertime. | • Alpine/ Tabriz<br>• Steppe/ Yazd |
| • The winter rooms have wide and short windows, whilst the summer rooms have narrow and long windows. | • This guarantees that maximum sunlight penetrates winter rooms while little sunlight penetrates summer rooms. | • Alpine/ Tabriz<br>• Steppe/ Yazd |
| • The houses are built at a lower level than the passageway (street, avenue, etc.) and are buried in the ground. | • When houses are built in a pit, the external walls are raised to provide optimum shade to the internal rooms. | • Steppe/ Yazd |
| • On the roofs, domes are constructed. | • The domes cast a shadow on the roof, which helps to keep it cool. | • Steppe/ Yazd |
| • On the rooftops, one or more Badgir (Windcatcher) are constructed. | • It causes interior ventilation and cool breezes. | • Steppe/ Yazd |
| • The walls are made of mud-brick and clay and are relatively thick. | • Most of the heat from the sun is reflected to the outside by these materials. | • Steppe/ Yazd |
| • The balconies are designed to be used in the summer in steppe climate and are created as deep and lofty space, closed on three sides. | • The high walls, closed ceilings, and profound depth create a semi-open, cold, and shaded environment. | • Steppe/ Yazd |
| • A sunken garden is constructed in a hole that is approximately one floor higher than the rest of the house. | • The sunken gardens provide an open yet cool place due to the shade cast by the surrounding high walls. | • Steppe/ Yazd |
| • The houses are built in the direction of the wind. | • The blowing wind enters the Badgir (Windcatchers) and cools the interiors. | • Steppe/ Yazd |

Table 12 shows that there are some similarities and differences in terms of climatic architectural design features of historical Qajar houses in the steppe and alpine climates of Iran arising from the analysis of architectural design features and climatic effects of historical Qajar houses in these two climates. The interior heights of the summer rooms are high, while of the winter rooms are low; the summer rooms have many thin and long windows, while the winter rooms have few wide and short windows; the winter rooms are built in the direction of the sun, while the summer rooms are built in the shade, and this applies in both climates. There is also a water fountain to cool the garden environment in the summertime.

Some of the differences are the construction directions of the houses towards the wind and the sun, their construction on different ground levels, the building materials utilized, and the structure of the balconies. Although the balconies were found in both steppe and alpine climates, they were utilized only for ornamental purposes in alpine climates and were used only for relaxing in hot weather with climatic design.

Temperature measurements were taken with the help of a digital thermometer in the summer room, Winter room, Pool house, balconies, and Sunken Garden (Balcony and the Sunken Garden, which are only in steppe climate), in order to determine whether the climatic architectural features analyzed in each of the six houses provide a sufficient effect for energy saving in today's architecture. Table 13 shows the average of the temperature measurements of the houses (the average space temperature of three houses in an alpine climate and the average space temperature of three houses in a steppe climate):

**Table 13:** Thermal comfort analysis in historical houses
Source: Authors, 2022

| **Climate** | **Alpine Climate (Tabriz)** | | **Steppe Climate (Yazd)** | |
|---|---|---|---|---|
| Season | Summer | Winter | Summer | Winter |
| City temperature | +36° | -8° | +47° | +3° |
| The average heat rate in the winter room | +34° | +19° | +40° | +22° |

| | | | | |
|---|---|---|---|---|
| The average heat rate in the summer room | +25° | 0° | +26° | +16° |
| The average heat rate in the Pool chamber | +20° | -1° | +23° | +11° |
| The average heat rate in the Sunken Garden | - | - | +34° | 0° |
| The average heat rate in the Balcony | - | - | +29° | +5° |

Table 13 shows that all five areas perform admirably well in terms of climatic comfort depending on the temperature and season. The average temperature of the summer rooms in the three houses is +26°, despite the fact that the summer weather temperature in Yazd is +47°.

## Conclusions

In the contemporary century, with new design methods, new building materials, and many technological devices, many buildings are costly to live in and incompatible with climatic conditions. Given the energy resources we use today to cool and heat homes, we will face problems such as a lack of natural resources in the near future. So, looking at the design and climate construction systems of historic homes that our ancestors used can be a helpful way. Indeed, it is not easy to go back to the ancestral way of life, but certainly, studying and learning from the methods they employed and the climate methods they created and implemented can be vital and beneficial in the current situation.

The plan morphologies of six historic structures in Iran's alpine and steppe climates revealed that the winter and summer rooms, the pool chamber, the balcony, and the sunken garden are the architectural areas with the main climatic architectural traits. Apart from these architectural elements, some climatic building features with excellent climatic efficiency were also identified. The textural form, the geographical orientation of the houses, materials, the levels of houses compared to the ground, window sizes, roof form, and the Badgir (Windcatcher) are among the most important building techniques that impact climatic efficiency, according to these findings.

As a result of all of the evaluations, it was discovered that these five locations performed very well in terms of climatic conditions. Winter rooms are quite significant in Tabriz since the winter season is so lengthy. Summer rooms are quite essential in Yazd due to the city's extended summer season. With the design used and technological methods that do not require any complex technology, the historical houses of Tabriz are 50% warmer than the outside temperature in winter, and the historical houses of Yazd are 50% colder than the outside temperature in summer. As a result, the city consumes 50% less energy during peak energy seasons.

Housing design standards are derived from lifestyle. When the main goal is to make profound changes in the design and construction of housing, it is necessary to consider the spatial arrangement and lifestyle carefully. According to the information obtained in Table 12, following the climatic style of historic houses has disadvantages according to the conditions of the present century. According to research in cold weather, thick brick walls act as thermal insulation, but given that the price of land is much more expensive in the present century, the implementation of wide walls requires much larger land that can be economically Not affordable.

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