FLEXIBLE CONFIGURATION AND ENVIRONMENTAL ADAPTATION
IN TRADITIONAL HOUSES OF SABZEVAR, IRAN

(FLEXIBLE KONFIGURATION UND ANPASSUNG AN DIE UMWELT AM BEISPIEL DER TRADITIONELLEN WOHNHÄUSER SABZEVARS, IRAN)

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Supervisor:
Univ.-Prof. Dipl.-Ing. Dr.techn. KARIN RAITH

Appraiser:
Ao.Univ.Prof.Dipl.-Ing.Dr.techn. ERICH LEHNER

Presented by
HASSAN ESTAJI

(Vienna) January 2017

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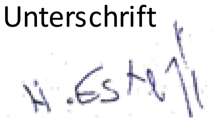
01.18.2017	

Acknowledgements

First and foremost I would like to express my sincere gratitude to my advisor Prof. Karin Raith for her constructive and positive guidance. While doing my research I also had the great fortune to learn a lot from her advice that will certainly be useful in my future career.
Very special thanks go out to the Sabzevar Cultural Heritage Organisation for sharing documents and old photos of traditional houses and Hakim Sabzevari University (Iran) for financial support.

I dedicate this thesis to the love of my life, my wife and friend Sanaz and to my beloved son Aras who was born and grew up while I was writing this thesis.

Table of Contents

1 INTRODUCTION

Most of my childhood memories in Sabzevar can be traced to a small blue pool in a yard with red fish that danced with floating apples in the water. We would gather in the house of my grandparents on weekends and holidays and play with our cousins and nephews, while our parents were chatting in the shade of trees. Now families live in separate apartments; children play digital games in their own rooms, while their parents are watching TV in the cold blast of air conditioners.

In previous generations, social cohesion and exchange of ideas were even more intense, since all members of the extended family lived together in one big house.

Societies as well as living conditions are subject to continuous change. Societies have to adapt to their environment, and consequently the living spaces must be changed in accordance with new demands. An 'ideal hypothetical house' would meet all needs of its residents or future users from birth to death. Living in an ecosystem- with predictable and unpredictable variables- requires a flexible and changeable spatial configuration.

1.1 Motivation

The topic of this study is "flexible configuration and environmental adaptation in traditional houses of Sabzevar, Iran". To explain why I chose this very topic, I break down my general theme into four questions:

- Why does the study focus on flexibility and adaptability?
- Why is flexibility in housing design more important than in other types of building?
- Concerning the flexibility and adaptability, what in traditional Iranian architecture is worth investigating?
- How did "environmental adaptation" happen in the traditional houses?

Sustainable Architecture, Green Architecture, Environmental Design, Energy Efficient Building, Zero and Plus Building, and Low Carbon Building are repetitive phrases that architects and researchers see all the time in journals, conference themes and even hear in the daily news. Literature is full of technical solutions for reducing energy consumption in building industry. Some of the proposed high tech solutions are very expensive especially if low-income housing has to be retrofitted accordingly. On the other hand, in vernacular architecture all over the world sustainable passive strategies have been developed to cope with climatic challenges. Too much attention to elaborate technical solutions sometimes leads to the neglect of intelligent simple solutions. This can be illustrated by a simple example. Sometimes we try to reduce a building's energy consumption by using new thermal insulation or new mechanical systems, while the building's size does not correspond to its function. If we optimize it, we get better results.

A house is not primarily a solid building; it is a system of activities. It has to accommodate a broad range of diurnal and nocturnal activities throughout the entire year and this can best be achieved by means of a flexible spatial configuration. Figure 1-1 compares the different activities in a house and some other types of buildings.

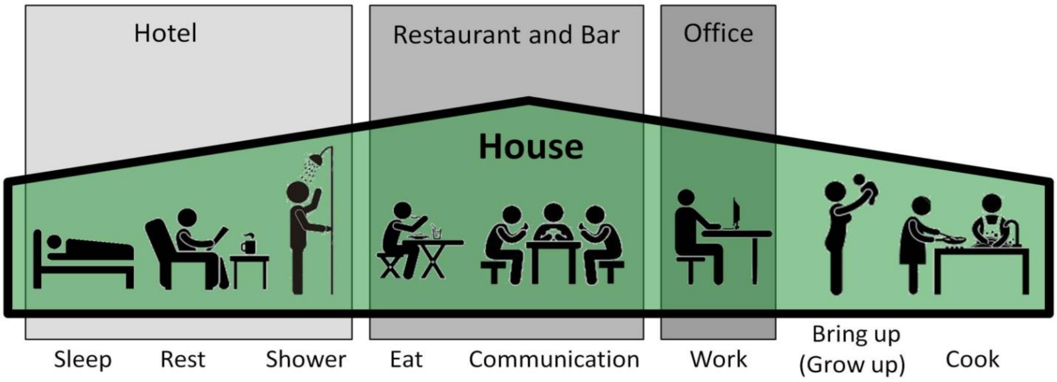


Figure 1-1: Human activities in different types of building (Estaji, 2014)

The house as a place for living must accommodate all human growth phases, whereas other special-purpose dwellings such as children's homes or nursing homes are only meant to be lived in for a certain limited period. There are other types of architecture as, for example, kindergartens and working places that are used merely during three stages of development (Figure 1-2).

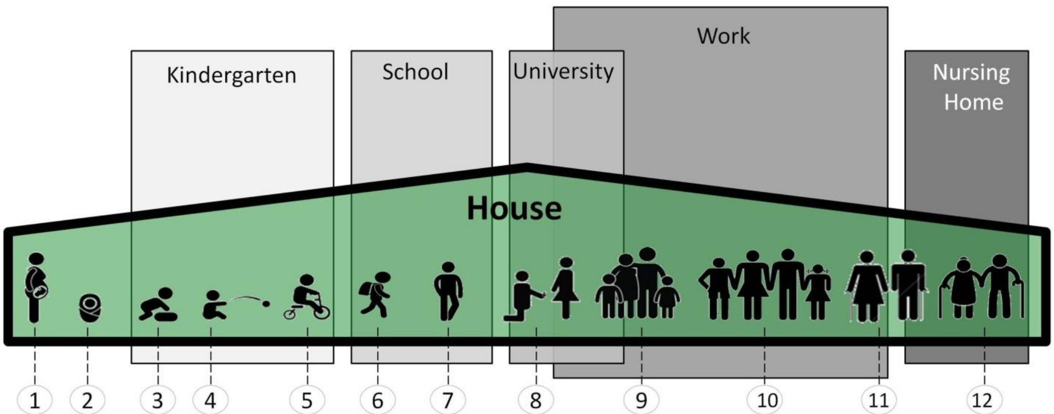


Figure 1-2: Comparing the coverage of human development phases by different buildings (Estaji, 2014)

Any changes in the house users and their needs affect the space requirements, but we cannot predict and control these processes. For example, family size and family structure change over time without any fixed patterns. Even if a house cannot necessarily meet all the users' needs at the same time, it must be flexible enough for any changes. A second concern is the effect of climatic conditions. The central plateau of Iran is characterized by a typical desert climate with hot and dry summers, cold winters and low relative humidity. These harsh climatic conditions, in addition to the lack of water for farming and daily consumption and dust storms, do not provide a desirable environment for living. However, traditional Iranian architecture, based on ages of experience, has been able to provide reasonable passive solutions for comfortable living in this region. The variety of these strategies motivated the author to focus on them.

1.2 Research Questions

This (case) study focuses on fourteen traditional houses in Sabzevar (a city in a hot and arid region of Iran) that are registered on the National Iranian heritage list. They are analyzed and examined in terms of their adaptation to the climatic conditions and their flexibility.

The main research questions of this study are:

1- How were traditional houses in the city of Sabzevar adapted to climatic conditions in hot and arid regions only by using passive strategies?

2- What strategies were applied in traditional houses of Sabzevar to meet the needs of different residents during the lifecycle of the house?

1.3 Limitations of the Study

Due to rapid economic development in Iran during the past decades, changing lifestyles and the inability of the authorities to preserve the historical buildings, most of the valuable traditional houses have been destroyed or have lost their original function. In 1975, when the number of cars in the city increased and new streets were needed, the municipalities of Sabzevar commissioned a master plan with the objective of facilitating traffic. A rectangular grid of new wide streets was cut into the urban fabric of Sabzevar, ignoring the centuries-old structure of the city. These cuts destroyed many houses and changed the coherence of old neighborhoods. There is no scientific documentation of the demolished building stock. The remaining houses are in danger of being destroyed. Since the beginning of my study, four traditional houses have been demolished. The loss of these research resources has proven a huge obstacle in the research process and limits the use of experimental research in this study.

The next problem I faced while doing my research was the lack of information and reliable documents about traditional historical houses in Sabzevar. The documents relating to these buildings are incomplete due to the lack of important documentations in the previous decades in Iran.

Complementing the surveys and correcting documents and maps proved arduous and time-consuming, and especially difficult in the case of destroyed houses. For correcting the mistakes, different documents from the archives of Cultural Heritage Organization, registration report of houses, old photos and plans of houses were compared. Some of the existing houses were surveyed and mapped from scratch in a research project at Hakim Sabzevari University carried out under my supervision in 2010.

2 FLEXIBILITY AND ADAPTABILITY

This chapter draws on the publication '*A Review of Flexibility and Adaptability in Housing Design*' by the author that was published in the Conference Proceedings of the 2nd International Conference S.ARCH 2015 (Environment and Architecture), Budva, Montenegro. In addition to this chapter the following papers have been published based on the research findings of the thesis:

- Estaji, H. & Raith, K. 2016. "*The Role of Qanat and Irrigation Networks in the Process of City Formation and Evolution in the Central Plateau of Iran, the Case of Sabzevar*", In: Arefian, F. F. & Moeini, S. H. I. (eds.) *Urban Change in Iran*, Springer International Publishing.
- Estaji, H. 2014. "*Flexible Spatial Configuration in Traditional Houses, the Case of Sabzevar*". *International Journal of Contemporary Architecture "The New ARCH",* 1**,** 26–35.

A preliminary search for relevant research on flexibility and adaptability in architecture with a special focus on housing design was conducted using Google Scholar with search terms including *'Sustainable', 'Adaptable', 'Flexible', 'Housing'* and their cognates and synonyms. This initial search allowed me to identify the leading researchers and research groups working in this field. I then proceeded to do some detailed searches in archives, looking through architectural books, journals and conference proceedings. Finally, the books and papers cited in the works found were checked for relevance.

This comprehensive review presents a summary of different definitions from various points of view and tries to categorize and classify the findings of previous studies in this field.

2.1 Sustainability, Flexibility, and Adaptability

The words sustainability and flexibility have become increasingly prominent in recent years. Figure 2-1 displays a graph showing how those phrases have appeared in English books over the previous years. It indicates that use of the phrase "Flexible Architecture" became more widespread in the late 1960s, and also the phrase "Sustainable Architecture" was more common from 1987 after the first consensus was reached between countries on sustainable development under the auspices of the World Commission on Environment and Development (WCED), known as Brundtland report (Brundtland, 1987). It is interesting to note that even though flexibility is only one aspect of sustainability, in recent years both terms are used almost to the same extent in literature.

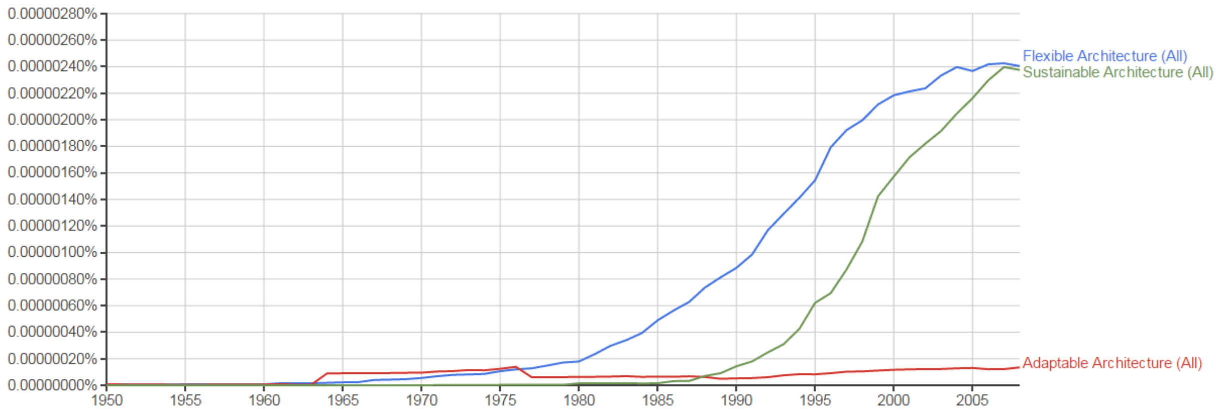


Figure 2-1- Comparing the use of the terms sustainable, flexible And adaptable architecture over time Google Books Ngram Viewer (Google Books, 2015)

There are many definitions of sustainability and sustainable development, but all of them are based on the World Commission on Environment and Development report of 1987:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland, 1987, P. 41)

Building construction and operation consume large amounts of energy and material. Sustainable architecture is designed to reduce this consumption of material and energy. If a building does not only serve the present purposes but is also able to meet future requirements to a certain extent, a lot of energy and material can be saved. Therefore the biggest challenge in architecture is rapidly changing needs and requirements. Buildings need a flexible structure and flexible spatial configuration to be able to meet rapidly changing demands.

> "A sustainable building is not one that must last forever, but one that can easily adapt to change."(Graham, 2005, P. 7)
>
> "If a building doesn't support change and reuse, you have only an illusion of sustainability...." (Croxton, 2003, P. 147)

In general, one of the most important ways to achieve sustainability is to develop the flexibility and adaptability of systems. Sebastian Moffatt and Peter Russell (2001) argue that adaptable designs and materials can improve the environmental performance of buildings in at least three ways:

a- "More efficient use of space - adaptable buildings are likely to use the same amount of space and materials more efficiently, on average, over their entire life."

b- "Increased longevity - adaptability extends the total lifetime of buildings."

c- "Improved operating performance" (Moffatt and Russell, 2001, pp. 4-5)

2.2 Flexibility and Adaptability in Housing Design

In general, the potential of change is described in terms of flexibility and adaptability. These two words are sometimes confused or used synonymously in literature (Schneider and Till, 2007). So what is the difference between them?

Usually, researchers and architects use "flexible" for physical changes and "adaptable" for non-physical changes. Steven Groák (1944–1998) proposed a distinction between these two terms; he defined "adaptability as *capable of different social uses* and flexibility as *capable of different physical arrangements"*(Groák, 1992) cited by (Schneider and Till, 2007, p. 5).

Using a space in a variety of ways without making physical changes refers to the adaptability, and according to the Groák's definition the flexibility is achieved by modifying the physical form of the building; by joining, splitting, extending, and merging spaces (Schneider and Till, 2007). This study tries to use the Groák's definition, but since the functional and physical changes in the houses usually happen at the same time, there is no rigid or clear border between these terms. Tatiana Schneider and Jeremy Till (2007) in their book used the term "flexible housing" to cover issues of both flexibility and adaptability.

Before addressing the flexibility and adaptability, it is better to distinguish between the development of a house type and the evolution of an individual house. House types develop over time and are adapted to relatively stable natural givens (climate, topography, availability of building material, etc.) and more rapidly changing social and cultural conditions and new economic situations. The introduction of technical innovations also changes house types as well as lifestyles. These long-term transformations take place gradually over generations of builders and users.

The adaptability in the individual houses (in this study the traditional houses of Sabzevar) usually involves short-term adaptation. A specific house changes over time to be adapted to the new requirements of residents. The house is evaluated to cope with the new lifestyle, new size of family, new economic situation and so on. This research in chapter seven investigates the evolution of individual cases in detail.

Schneider and Till (2007) argue that flexible housing has developed in two different ways: a) vernacular buildings not designed by architects and b) buildings by promoted by professional architects. Vernacular housing development is a long-term process - one based on collective experiences that have accumulated over generations. The other way is a short-term development based on individual ingenuity and expertise.

Vernacular houses emerged gradually, based on the exigencies of a given time. Vernacular architecture can accommodate a certain range of uses and respond to economic and social developments to a limited extent. For this reason, in certain critical situations (e.g., a sudden increase in population, rapid economic growth and changing lifestyles) vernacular architecture is not able to cope with the rapid changes.

Humans can adapt themselves to climatic conditions by means of three flexible skins. First, there is the skin of the body, which can control temperature changes by altering blood vessel diameter. The second level is clothing: you can add or remove some clothes to cope with heat and cold. The final shield is architecture. All buildings are able to react to changing weather conditions to a certain extent, e.g., the residents can open or close the windows, turn on the heater on cold days, or adjust the thermal comfort by using a smart system.

The residents can change the furniture layout of the living room to host a party or make some significant changes to divide a flat into two for renting. These different degrees of adaptability are addressed in a wide variety of definitions and approaches in the literature.
Robert Schmidt and his colleagues at Adaptable Futures Research Group, Loughborough University (Schmidt III et al., 2010) observed that overarching definitions are mostly limited to four areas: capacity for change which refers to changes in the size, function, organization, or performance of spaces. A second group of definitions are about the “ability for the building to remain ‘fit’ for purpose”(Schmidt III et al., 2010, p.3) to provide spaces required by its residents under changing living conditions. A third group of definitions focuses on the ‘value’ that includes maximizing the productive use and minimizing the cost of changes and maintenance of buildings. A final group is about the ‘time’; frequency and time of changes that happened during the lifecycle of building. (Schmidt III et al., 2010) that refers to the degree of adaptability on the one hand and the pace of change of living conditions on the other.
They proposed a general definition for adaptability [and flexibility] based on these different views:

> ‘the capacity of a building to accommodate effectively the evolving demands of its context, thus maximizing value through life’ (Schmidt III et al., 2010, p. 235).

In 1961, N.Jahn Habraken published ‘*De Dragers en de Mensen: het einde van de massawoningbouw’* in Dutch, which was translated into English as *Supports: An Alternative to Mass Housing* in 1972. The central idea of Open Building approach is the separation of “Support and Infill”. Humans can control the built environment at different levels. “Levels describe the interrelated configurations of physical elements and decision clusters that occur within a larger dependency hierarchy”(Kendall and Teicher, 2010, p. 288). According to Habraken these different levels of decision making are urban street, tissue[1], support (building), infill (tenant work, detachable unit) and finally furniture (Habraken, 1988). The support /infill idea came from the necessity to build large apartment buildings for high-density situations. In this approach, professional urban designers and architects design and operate all levels of building construction except the infill and furniture; the residents are enabled to change the layout and the interior of the housing units. (Figure 2-2)

[1] “the streets and related urban elements on the scale of the neighborhood, most directly related to the building” (Habraken, 1988, p. 8)

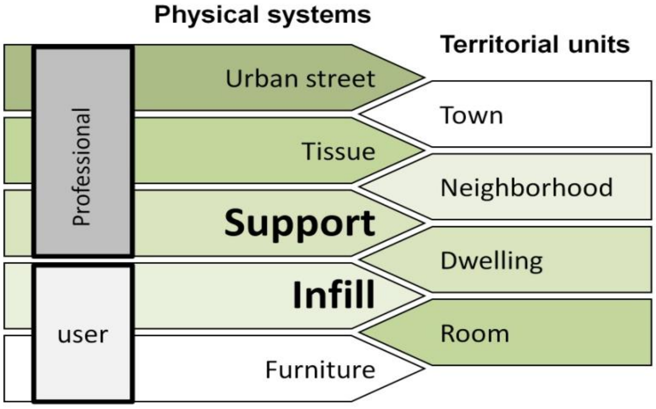


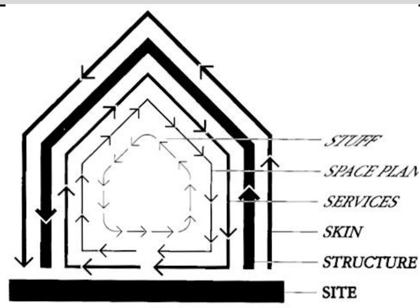
Figure 2-2- Control pattern of Support /Infill idea, data from: (Habraken, 1988)

British architect Frank Duffy (1990) also took into account the temporal dimension linked to the building layers. He proposed the first theory of the rate of change in buildings, "Shearing Layers", in 1990. Stewart Brand (1995, p. 12) quotes Duffy: "Our basic argument is that there isn't such a thing as a building…. A building properly conceived is several layers of longevity of built components." Duffy classified the physical and temporal layers of buildings in four layers: Shell, Service, Scenery, and Set. Shell is the permanent structure and enclosure of the building. The service parts - heating, cooling, ventilation devices, pipes and cable- with shorter lives are attached to the building shell. Scenery refers to the fitting-out components which accommodate the particular use in the solid shell. And finally, the setting is a short-term managing or rearranging of the furniture and stuff to be adapted to the daily activities. (McGregor and Then, 1999)

Brand developed and revised the "Shearing Layers" idea in his book in 1995. He expanded the Duffy's "four S's" into "six S's" (Table 2-1). The time layer idea helps architects to understand how buildings actually behave and how a building relates to the people.(Brand, 1995)

The complete separation of different layers in building construction can help to increase the lifespan of the building. Inner partitions and façade elements which are not load-bearing can easily be changed and rearranged to accommodate new uses while the structural carcass is maintained.

Table 2-1- Building layers and Longevity, image and data: (Brand, 1995)

Shearing Layers (different rate of change)	Layer	Description	Longevity
	Site	Geographic setting, urban location	Eternal
	Structure	Foundations and load bearing elements	30 to 300 years
	Skin	Exterior surfaces (Façades)	20 years
	Services	Wiring, plumbing, HVAC systems and …	7 to 15 years
	Space Plan	The interior layout	3 to 30 years
	Stuff	Furniture, kitchen appliances	Daily to monthly

The other idea in Brand's concept is the differences in the decision level which facilitate or hamper changes. Different levels of stability and flexibility can be defined according to the 'shearing layers' idea; the sequence is as follows: city, neighborhood, load-bearing structure, façades, inner partitions and finishing and furniture. The city structure is the most stable element, followed by the neighborhood. Changes in this "layer" require a high decision level – a political conception of (top down) town planning intervention or a concerted (bottom up) action from the residents' side. A few persons or even an individual can implement the changes in the lower levels – finishing, furniture.
This dissertation uses different scales of built environment – from urban scale to room and façade –to review some key ideas in the history of architecture that have influenced on the flexible and adaptable housing. In this classification, the movability is also examined in different scales.

2.2.1 Flexibility in Urban Scale

> "The morphology and spatial patterns of (...) cities have gradually developed to satisfy the cultural needs of their populations, and at the same time, to respond to the surrounding environment." (Kheirabadi, 2000, p. 1)

Chapter five focuses on phenomena of change on an urban scale; it describes the transformation of agricultural lands into residential units in Sabzevar due to the rapid increase in population and new lifestyles. The basic pattern of streets remained stable over decades while minor urban elements on individual plots (fields, gardens, houses) changed.

2.2.1.1 Movability in Urban Scale

Nomadism as one of the oldest ways of living that still exists in different forms is a good example of adaptation to the environment. The concept of mobility has developed in the course of time in different scales. From the mid-twentieth century on, a new type of modern nomadism, and new transport systems changed this idea dramatically. Faith in technological progress tempted designers to use this idea on urban scales. In 1964 Archigram proposed "a nomadic city infrastructure in which urban utilities would not be tied to a specific location"(Archigram Archive, 2016). Ron Herron's "walking city", 1964, was a vision of large urban structures moving freely on huge robotic legs. Not only specific urban elements would be able change their position, but the entire city. (Figure 2-3)

Figure 2-3: moving cities, 1964, Ron Herron the walking city in New York (Archigram Archive, 2016)

The main idea of the walking city was a movement towards new resources or economic opportunities. This raises the question whether it is necessary to use lots of energy and material to direct a city towards new resources. Is there a consensus of all individuals to travel to the same place? It is rather a horrifying vision of an authoritarian world. Despite huge technological advancements and economic growth in recent years, it is still easier and less costly to bring resources to the cities.

The walking city idea remains an architectural dream, but this idea has been implemented on a smaller scale, - on cruise ships. They are used for pleasure trips, but since they provide some urban facilities they can also be used as residential accommodation and have come to be regarded as a sort of floating city. During the 2016 Rio Olympic Games the men's and women's US basketball teams stayed on a luxury cruise ship (Silver Cloud) instead of the Rio de Janeiro Olympic Village. According to the website of the cruise, the Silver Cloud could accommodate 296 guests and a crew of 222. It features pools, gyms, bar and restaurants, shops, a library and ...(SilverSee, 2016). Figure 2-4 shows the ship docked at Rio de Janeiro and the interiors of the living spaces.

Figure 2-4: tops- the interior of suites (SilverSee, 2016), bottom-the Silver Cloud docked at Rio de Janeiro for the duration of the 2016 Rio Olympics (newsday, 2016)

2.2.2 Flexibility in the Scale of Additions to Buildings

2.2.2.1 Expandability

Each building can be expanded horizontally if there is vacant land next to it or vertically if its structure is strong enough or is improved to bear additional floors and if building codes allow one to do so. In the following examples, the buildings were not designed for extension originally. Only after some time had passed and new spaces were needed did the new architects provide plans for the expansion of the buildings.

A law firm that was located on the first and second floor of a building on the corner of two streets in the inner city of Vienna attempted to expand their office so as to have a large meeting room and some smaller office units. In 1987-88 Coop-Himmelb(l)au (Wolf D. Prix, Helmut Swiczinsky + Partner) designed and built two stories with a surface area of 400 m². They added a large meeting room and three office units to the old building by remodeling the previously unused attic (Coop-Himmelb(l)au, 2016) (Figure 2-5). The old building provided service and access to the new floors; the total useable spaces could be increased thanks to the sufficient load carrying capacity of the old structure.

Figure 2-5: Roof-top Remodeling Falkestrasse, Vienna, 1988, photos:(Coop-Himmelb(l)au, 2016)

The Serpentine Sackler Gallery in the Kensington Gardens Royal Park of London is a contemporary art exhibition space. The building is a classic 19th-century brick structure, a former 1805 gunpowder store, which now is used as an art center. Between 2009 and 2013, Zaha Hadid Architects renovated the old part and expanded it. They added a restaurant to the historic building (Hadid, 2016). Figure 2-6 shows the expansion part attached to the old building.

Figure 2-6: Expansion of Serpentine Sackler Gallery, London, 2013, Photos by author

The Eslami and Mohammadiyani houses in Sabzevar are two examples of long-term expandability in traditional Iranian houses. Both of them were built at the end of the Qajar period. In the first Pahlavi period (1924-41) two new wings were added to them (Figure 2-7). In the Mohammadiyani house, a wall of the old courtyard was demolished replaced by a new wing which provides access to the annexed plot. This kind of connection did not introduce any changes in the old plan. However, it is clear that the spatial configuration and relationship of spaces are entirely changed. In the Eslami house, an opening on the ground floor and two openings on the first floor connect two parts of the building. These modifications changed the plan of the old part completely. The pool room on the ground floor, for example, was turned into a circulation space to facilitate access to both houses. Detailed plans are presented in chapter six.

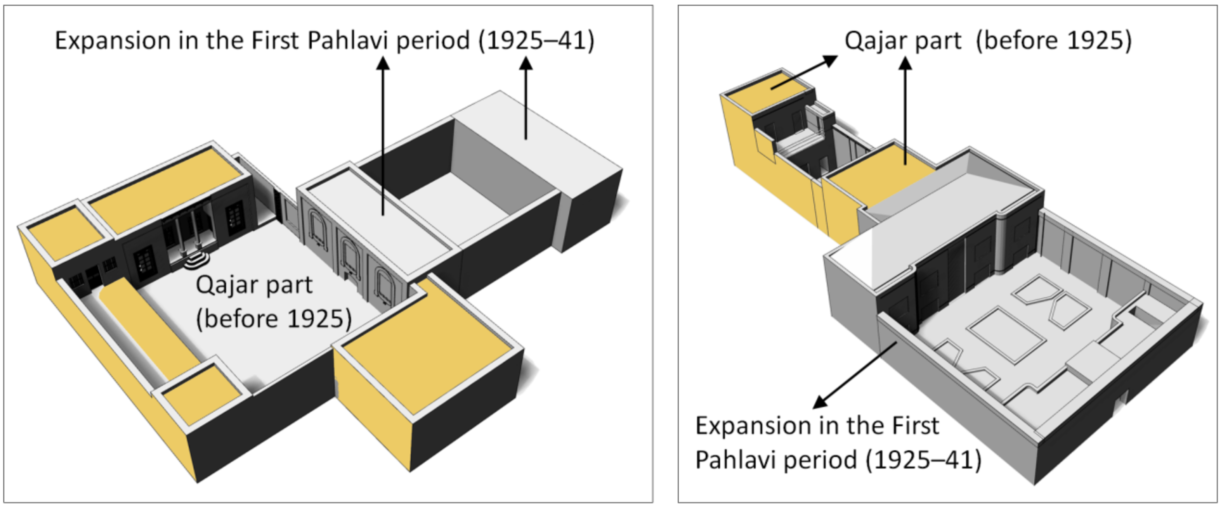


Figure 2-7: horizontal expansion of the Mohammadiyani (left) and Eslami (right) houses

The house extension was facilitated by the specific structures of both the houses and the urban neighborhood. In the traditional building typology daylight and access to the rooms was nearly exclusively provided via the courtyards. Thus the houses could do without windows or doors facing the plot boundaries. The enclosing walls of the house border directly onto the neighboring plots. This introvert structure in turn allowed the houses to be densely built.

Contemporary residential buildings are only built in the form of extrovert multi-story apartment blocks with windows opening to the perimeters of the plots. They can therefore not be enlarged and combined in keeping with the traditional courtyard houses. They require completely different architectural solutions in line with the new zoning regulations. Flexibility within the buildings on the individual plots may be provided by the specific layout of the plans, but since they are not compatible with courtyard houses, flexibility in terms of free combinability between these two basic building types cannot be ensured.

2.2.2.2 Planned Expandability

In this type of expandability, the architect not only designed a building for current use, he also proposed a plan for future expansion. The best example of this idea is the 'half of a good house' project designed by Alejandro Aravena. In the Quinta Monroy project in Chile, the challenge was to accommodate a hundred low-income families with only 7,500 dollars per house so that it was sufficient for a usable area of thirty-six square meters (Elemental, 2016b). On the other hand, these small units were not suitable for large families. Aravena (Elemental

Architects) solved the problem by providing expandable homes. The residents are supposed to complete their homes themselves by converting the voids between the built units into further living space. (Figure 2-8)

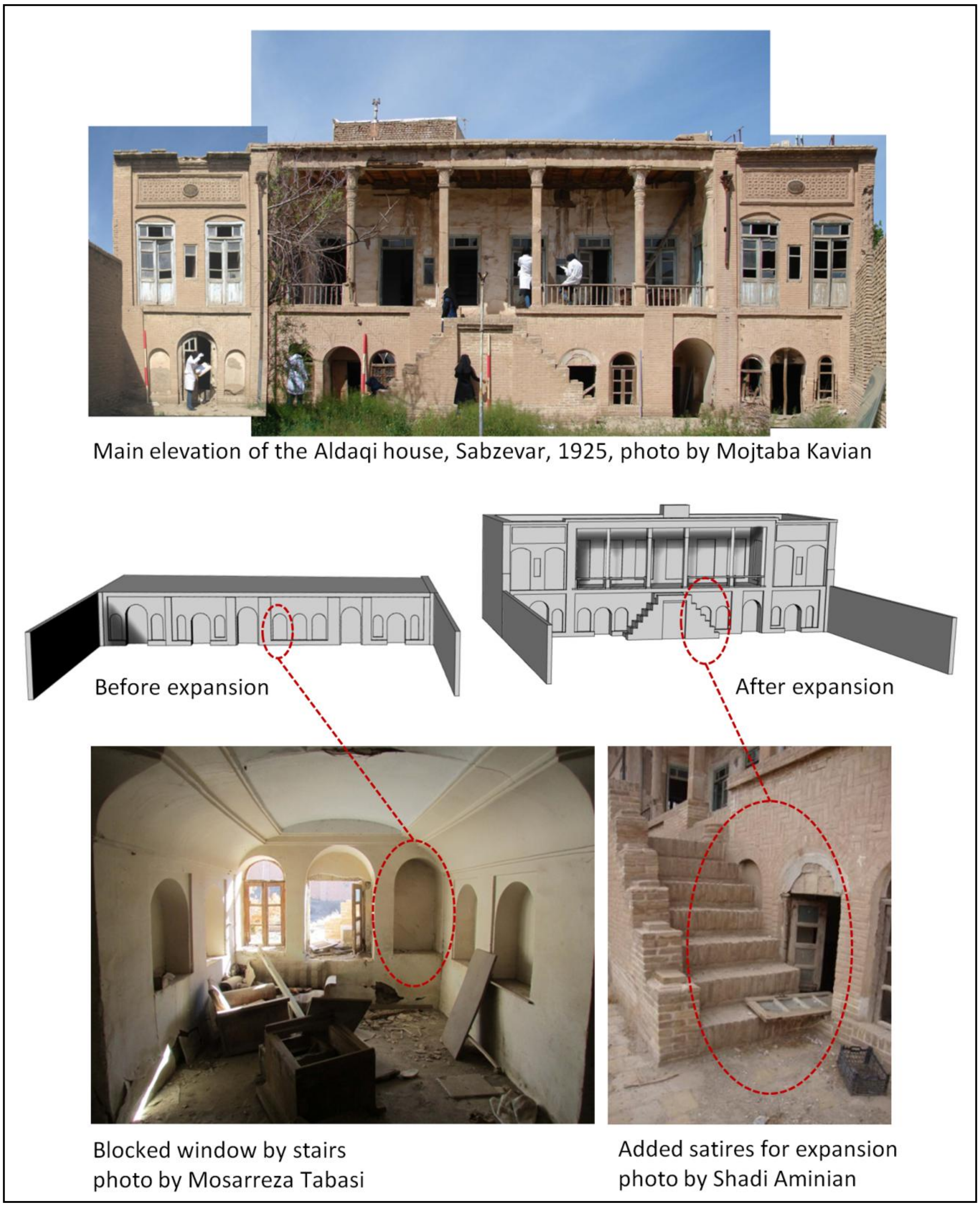
Figure 2-8: Quinta Monroy Housing, 2004, Iquique, Chile, "half of a good house" idea before and after expansion by the residents, Photos by Cristobal Palma (Elemental, 2016b)

Aravena applied the 'planned expandability' idea in designing the Villa Verde housing project in Constitución, Chile in 2010 for employees and contractors of the Arauco Forest Company. Given the greater availability of resources in comparison to the Quinta Monroy project the size of apartments is bigger. The residents can increase the space from 57 m² (original surface area of each unit), up to 85 m² (Elemental, 2016c).The Monterrey housing is another expandable project by Aravena in Mexico. (Figure 2-9)

Figure 2-9: left- Villa Verde, 484 incremental houses, Constitución, Chile, 2013 (Elemental, 2016c)
Right- Monterrey housing project, Monterrey, Mexico, 2010 (Elemental, 2016a)

Alejandro Aravena received the 2016 Pritzker Architecture Prize for his socially engaged projects. The jury stated that "[he] has a holistic understanding of the built environment and has clearly demonstrated the ability to connect social responsibility, economic demands, design of human habitat and the city."(Pritzker, 2016)

Expandability was a key feature in the Iranian traditional houses. The houses evolved step by step according to the new needs and changes in the economic situation of the family. The economy of pre-modern families in the central plateau of Iran was mainly based on agriculture. As this kind of economy is not a predictable economy, it has an effect on the housing construction strategies. Sometimes the house owner must wait for a rainy year to earn more money to be able to complete or expand the house. The changing size of the extended family was also another factor in the expansion of traditional houses. Traditional architects usually designed a master plan for houses, defining the position of different masses in the land plot in different phases. The construction of the building usually started in the best part of land in terms of best orientation according to the sun or the geometry of the land. In the Aldaqi houses in Sabzevar, the first construction phase only included the ground floor. The geometry of the plan, the symmetrical windows in the main room that was located on the ground floor, the fact that one of the windows was blocked by the external stairs and details of the stairs suggest that the first floor was added several years later (Figure 2-10). This assumption was confirmed by an interview with the daughter of Mr. Aldaqi. In this case, the architect designed a ground floor knowing that this part of the building alone did not meet all requirements and thus added stronger walls to allow for future vertical extension. The extension part is not perfectly coordinated with the ground floor; the ground floor and upper floor are not symmetrical. This suggests that the positions of walls and windows on the second floor were not yet planned in detail when the ground floor was built.



Main elevation of the Aldaqi house, Sabzevar, 1925, photo by Mojtaba Kavian

Before expansion

After expansion

Blocked window by stairs
photo by Mosarreza Tabasi

Added satires for expansion
photo by Shadi Aminian

Figure 2-10: expansion process of the Aldaqi house, Sabzevar, 1925

2.2.2.3 Plug-in Architecture

The main idea of Plug-in Architecture is a complete separation between the load-bearing structure and service spaces on the one hand and living spaces on the other. The spaces are inserted into, or attached to, a main rigid structure. For the first time, in 1947, Le Corbusier introduced this concept for designing the Unité d'habitation, an apartment building in Marseille. Le Corbusier illustrated his idea with a model of the building; a prefabricated L-shaped living unit is inserted into a structural grid (Figure 2-11). In practice the housing units were not prefabricated as complete units in a workshop and then mounted to the structure but rather assembled from smaller prefabricated parts.

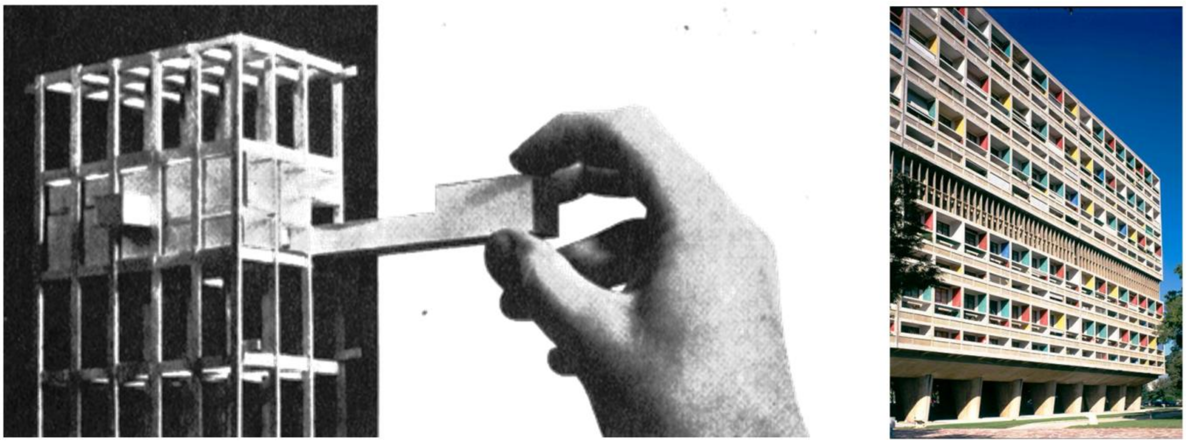


Figure 2-11: left- inserting the apartment units into the structural grid of Unité d'habitation model (1947) source of photo: (von Moos, 2009, p. 157) right- Unité d'Habitation, Marseille, Photo: Paul Kozlowski 1997 © FLC/ADAGP (Fondation Le Corbusier, 2016)

Between 1962 and 1964, the ‘Archigram’ group proposed and developed the plug-in idea on a large scale. In ‘The Plug-in City’ project, metal cabins were to be attached to a ‘mega-structure’ of concrete. The city was designed to operate like a factory that was able to assemble and disassemble itself. A grid of railways and cranes that run through the city facilitates attaching the units to the structure and rearranging the capsules (Cook et al., 1999, pp. 36-41). Figure 2-12 shows a schematic section of the plug-in city proposed by Peter Cook in 1964.

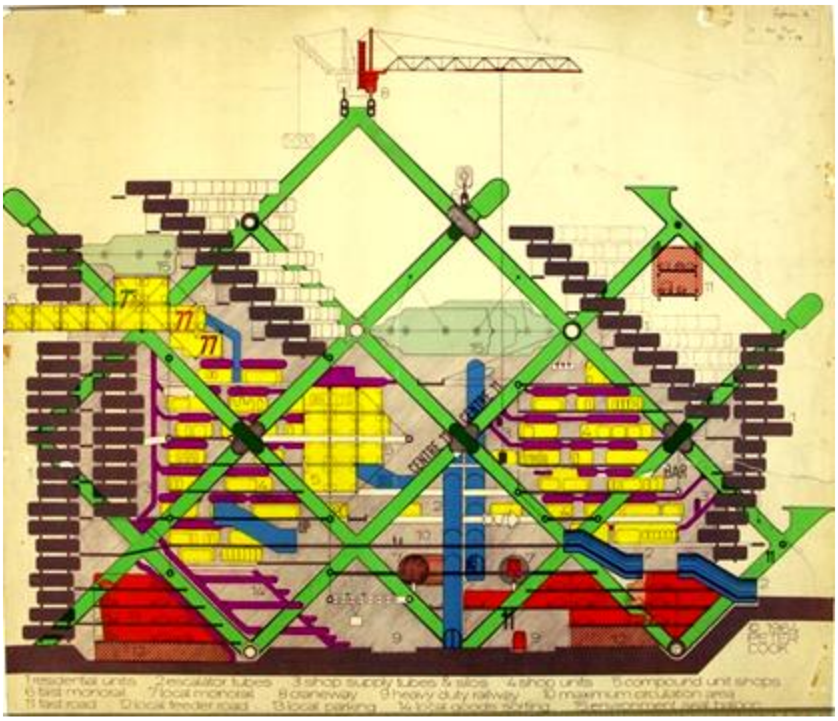


Figure 2-12: Plug-in-City, drawn by Peter Cook, 1964 (Archigram Archive, 2016)

The Archigram group also used the 'Plug-in' idea for the design of 'Capsule Homes.' In this proposal, compact living spaces – prefabricated capsules –were attached to a structural core that provided access and services for them. (Figure 2-13)

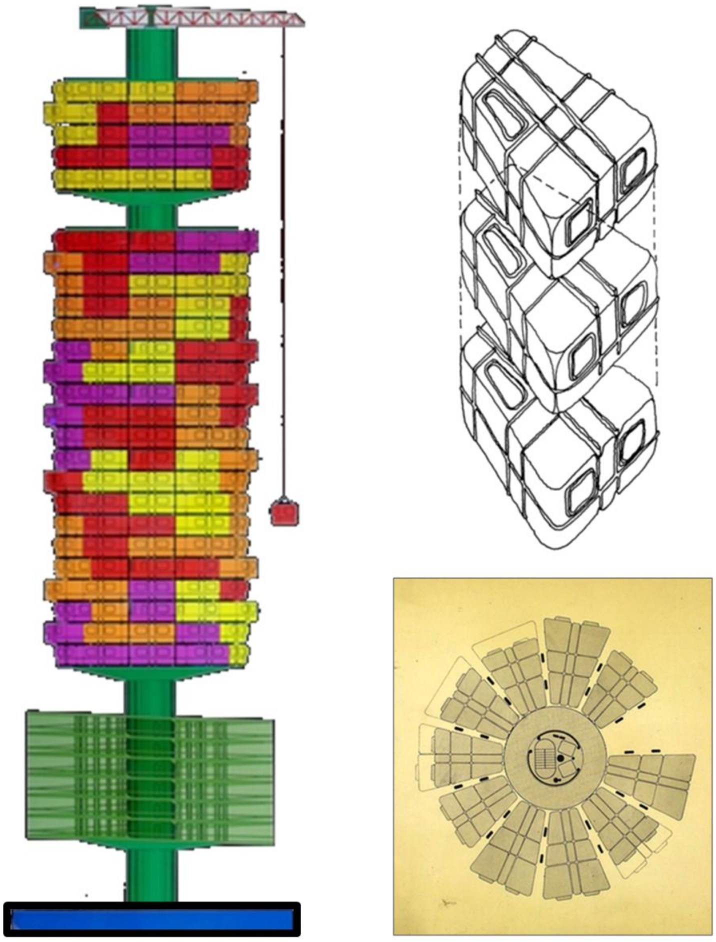


Figure 2-13: capsule homes project, 1964 (Archigram Archive, 2016)

The world's first capsule architecture that was actually built was the "Nakagin Capsule Tower" designed by Kisho Kurokawa in 1970 (Kurokawa, 2015). The Japanese architect was one of the founders of "Metabolism Architecture" with Kiyonori Kikutake, Noboru Kawazoe, Masato Otaka, and Fumihiko Maki. The Metabolist architects believed that urban spaces and buildings are not a fixed issue; they change along with society and must be flexible so that like a living organism they can keep growing. They "sought to apply theories of organic growth to the problem of the expanding metropolitan city." (Braham and Hale, 2013, p. 218)

The Nakagin building is a mixed-use office and residential tower, 144 studio steel capsules were attached to two concrete cores that provide access and service to the individual units. The capsules containing appliances, furniture, audio and telephone system were prefabricated in a factory off-site. Each capsule unit is attached to one of the concrete cores only with four bolts (Kurokawa, 2015). By using a crane, the capsules were mounted in one month's time (Mallgrave and Goodman, 2011, p. 81). (Figure 2-14)

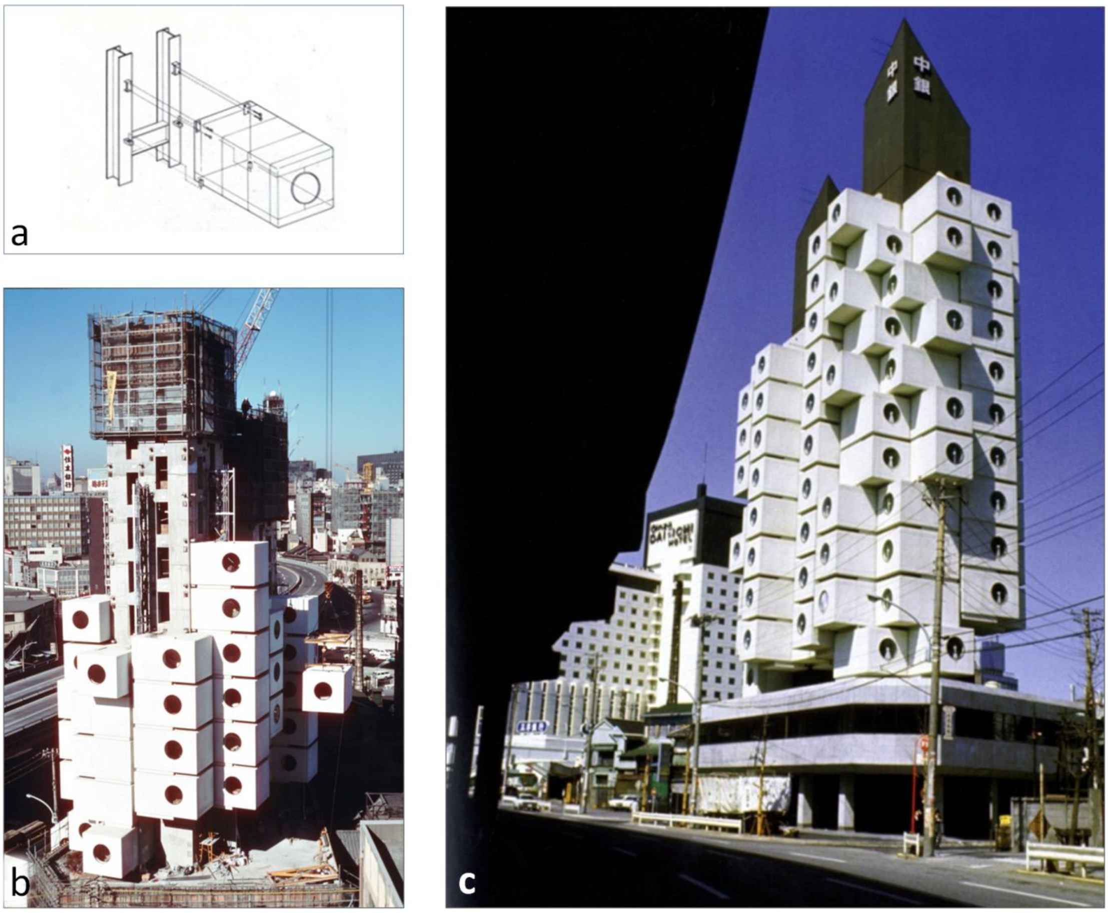


Figure 2-14: a- detail of joining a capsule to the shaft (Kurokawa, 1977, p. 108), b- assembly process (Bergdoll et al., 2008, p. 145) c- street view of Nakagin tower (Kurokawa, 2015)

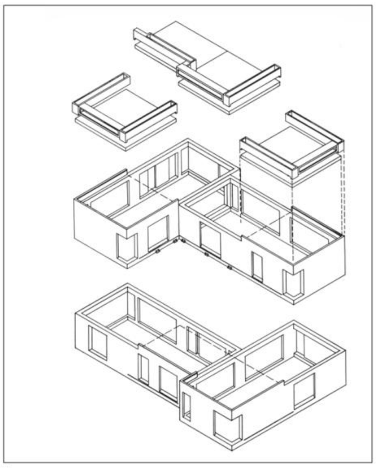
This building is the 'icon of metabolism movement' and Kurokava expressly states that "The Nakagin Capsule Tower realizes the ideas of metabolism, exchangeability, recyclability as the prototype of sustainable architecture"(Kurokawa, 2015). But there is a paradox; the building never was changed during its lifecycle. In the late 1990s, Kurokawa's architectural firm and Taisei Corporation made a proposal for the replacement of the capsules. In this proposal, the capsules were to be removed and after being completely renovated re-attached to the old shafts. But due to the high costs, the owner of the building did not accept it. Another proposal in 2006 was replacing the original capsules with new ones – a proposal that was also rejected (Lin, 2011, Shimbun, 2015). In 2007, the house owners suggested demolishing the building and replacing it with a new fourteen-story tower. For this reason, Kurokawa launched a popular campaign to save it(Lin, 2011). The following pictures (Figure 2-15) show the current situation of the building: some of the capsules were abandoned, while others were turned into storage space (Soares and Magalhães, 2014). According to the metabolism manifesto, a building must continue to grow and change, but in practice, the Nakagin tower remained static like a conventional building!

The future of a building does not always unfold the way the designers thought it might. Designers should not only consider the technical solutions for physical flexibility, but also the spatial arrangements which might become necessary in the future because of social and economic changes. If the designers of the tower had considered this problem in initial studies, along with focusing on a flexible structure, they would have tried to design a flexible management system for coming economic and social changes.

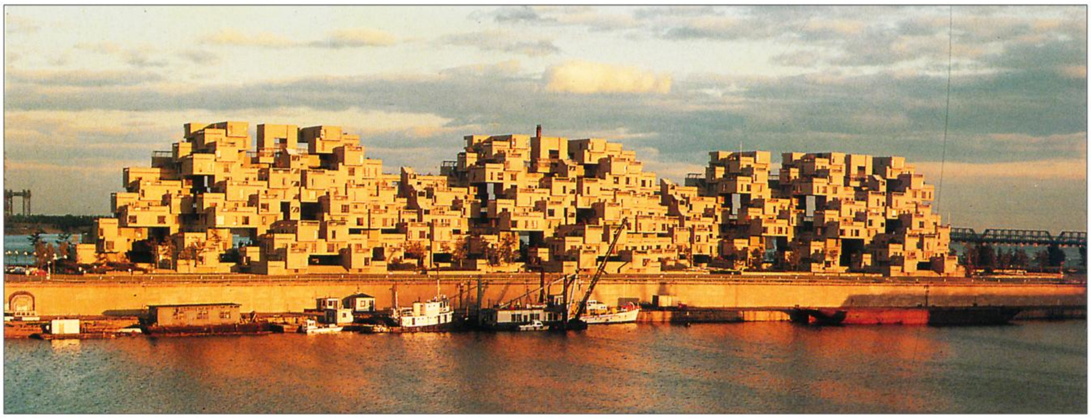
Figure 2-15: the lack of maintenance in the Nakagin tower,
Source of left photo:(O'Connell, 2009), right photo:(Soares and Magalhães, 2014)

Five years before completing the Nakagin building Moshe Safdie designed a building for the EXPO ’67 World Fair in Montreal, one that became well known as Habitat 67. The building is a residential complex, composed of 354 prefabricated concrete units, which provided 158 apartments (Kohn, 1996, p. 41). In this project, unlike the Unité d'habitation and Nakagin project, there is not any separate structural frame; the load-bearing modular concrete boxes act as a structure. The prefabricated elements are connected to each other by means of high-tension rods, cables, and welding. In other words, in this project, the units are attached together instead of being plugged into a solid core or a structural grid (Figure 2-16) .Unlike the appearance of the project the cubes cannot be rearranged.

a



b



c

Figure 2-16: a- the construction process of Habitat '67 (1965) b- module assembly diagram c- view from Montreal's port, sources of the photos: (Kohn, 1996)

All of the above examples of plug-in architecture can be categorized under flexibility in the construction process, whether the final product was a flexible unit or not.

In 2015, the Penda studio designed the Vijayawada high-rise residential building in India based on the plug-in system (Figure 2-17). In this LEGO-like building the apartment owner can determine the size of the unit, the size of a terrace and private garden, and then the prefabricated module will be inserted into the structural framework. The different modules are composed of various arrangements of floors, facade element, railings and pots of plants (Penda, 2016). The architects provided a diagram (Figure 2-18) for their work that obviously refers to the Unité d'habitation model of Le Corbusier. The difference to the projects discussed before is that the modules of this project are flexible in themselves. This idea enables the house-buyers to design their own home in a flexible system. The products of this process cannot guarantee the flexibility of units after the planning phase.

Figure 2-17: Vijayawada high-rise residential building (Penda, 2016)

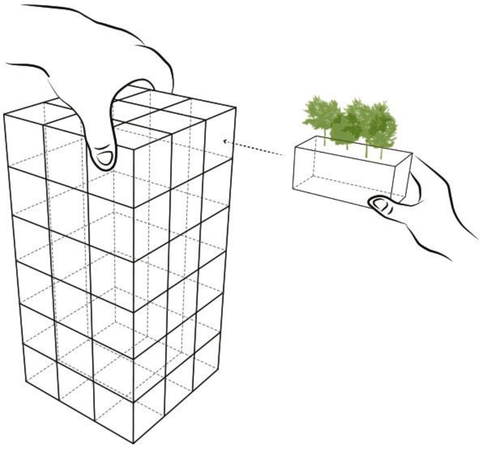


Figure 2-18: the concept of the Vijayawada Garden Estate Penda, "A modular system of a structural framework and functional plug-ins offers the residents a great amount of flexibility to design their own home." (Penda, 2016)

2.2.3 Flexibility in Building Scale

2.2.3.1 Le Corbusier's plan libre (Domino system)

The Domino system was a concrete frame structure that consisted of columns and slabs (Figure 2-19). This structural system allowed the facade and interior partitions to be separated from the load-bearing structure. Le Corbusier used the term 'plan libre' for this spatial flexibility (Risselada, 1988). He presented his ideas about modern architecture in his manifesto - Five Points of a New Architecture- in 1927 (Le Corbusier, 1975). Two of the five points are free-floor plan and free façade design. Using columns instead of load-bearing walls enables the architect to design whatever shape of space he desired without being obstructed by load-bearing walls. In fact, this idea refers to the flexibility in design and building process.

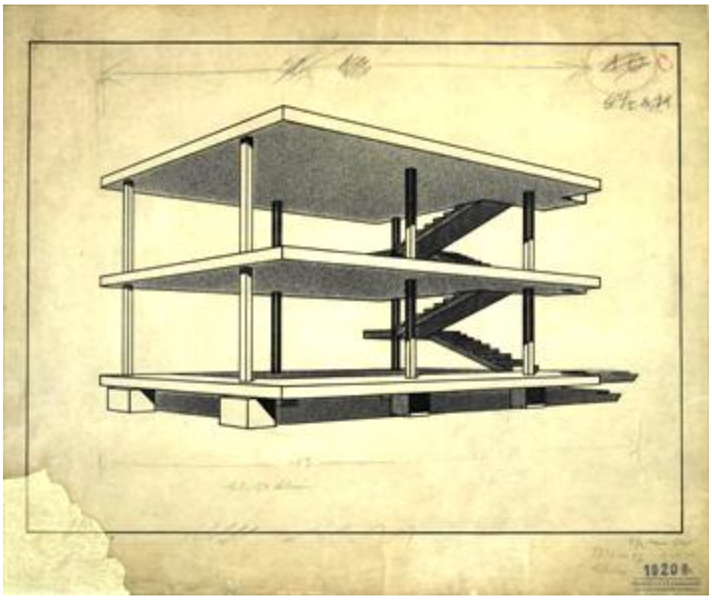


Figure 2-19- Le Corbusier's Domino House 1914 (Fondation Le Corbusier, 2015)

2.2.3.2 Mies van der Rohe's neutral space

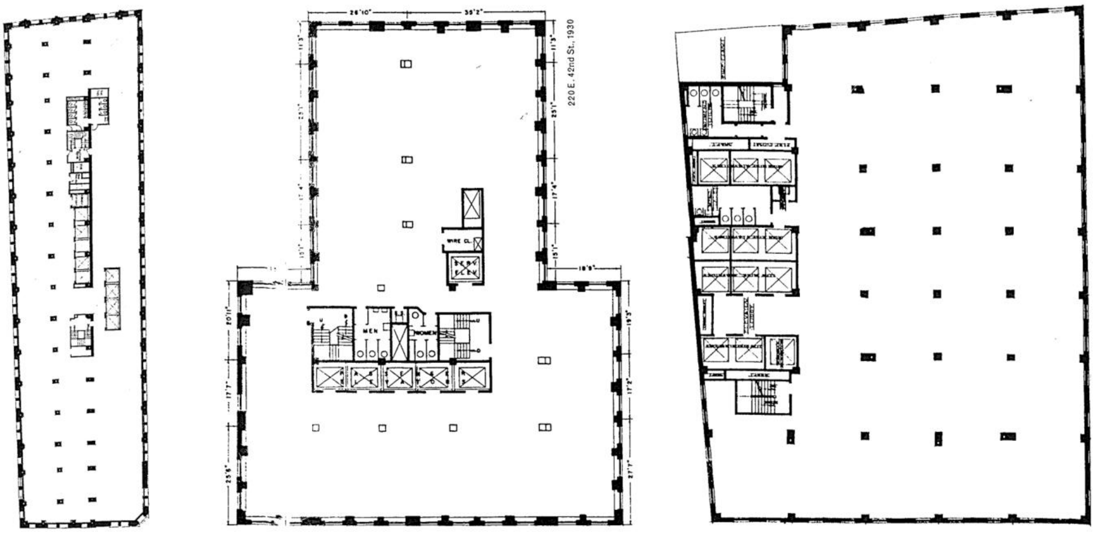
Another idea regarding the open plan was the 'skin and bone structure,' proposed by Mies van der Rohe (1923) that he defined as: "Supporting girder construction with a non-supporting wall"(Mies van der Rohe, 1923, p. 241). This idea is similar to Le Corbusier's structural separation of primary and secondary elements allowing a free plan and free facade as communicated in his five points of architecture.

In order to ensure maximum freedom of use within a building, Mies van der Rohe advocated the idea of a neutral space (clear concept). The 'clear concept' provides a large, unobstructed and empty space that offers an enormous variety of options. For example, in the new National Gallery in Berlin designed by Mies van der Rohe (built from 1965 to 1968), the wide steel roof structure of the upper gallery is only supported by eight columns and thus offers a vast space for all sorts of exhibitions. Figure 2-20 shows the empty space of the gallery. This neutral space could be easily divided and assigned to different exhibitions in various sizes.

Figure 2-20: top- The steel roof structure of the new National Gallery Berlin, taken in 1967©SMB, Zentralarchiv (Preussischer Kulturbesitz, 2016), bottom: the interior space of the gallery (Neue Nationalgalerie, 2016)

2.2.3.3 Typical Plan

Rem Koolhaas, in his 1993 essay, Typical Plan, which was published in 1995 in the book 'S,M,L,XL' called these neutral, unspecific and empty spaces "Typical Plan." He argues that the "Typical Plan is an American innovation. It is a zero-degree architecture, architecture stripped of all traces of uniqueness and specificity" (Koolhaas et al., 1995, p. 335). It "is as empty as possible: a floor, a core, a perimeter, and a minimum of columns" (Koolhaas et al., 1995, p. 344). The load-bearing structure is reduced to a central core and columns at the perimeter. The core is composed of staircases, elevators, mechanical and electrical ducts, and service spaces, that are fixed. The space between the external façade and the core is completely undefined; this neutral space can easily be subdivided into smaller units using light partitions to accommodate different office scenarios. (Figure 2-21)



111 Broadway, 1905 220 E. 42nd St., 1930 80 Broad St., 1931

Figure 2-21: three examples of the Typical Plan, source of plans: (Koolhaas et al., 1995)

The main idea of the Typical Plan is to create neutral spaces for unknown future users. The development of manufacturing technology and the use of mega-structures enable architects and land developers to build wide open spaces easily. Figure 2-22 shows one of these types of building in London. This concept was invented for office buildings, but was adapted for residential architecture in recent years for two reasons. It provides the absolutely necessary minimum of built structure and allows the residents to complement the basic architecture with “infill” according to the amount of money they are able to invest in order to improve the comfort for living.

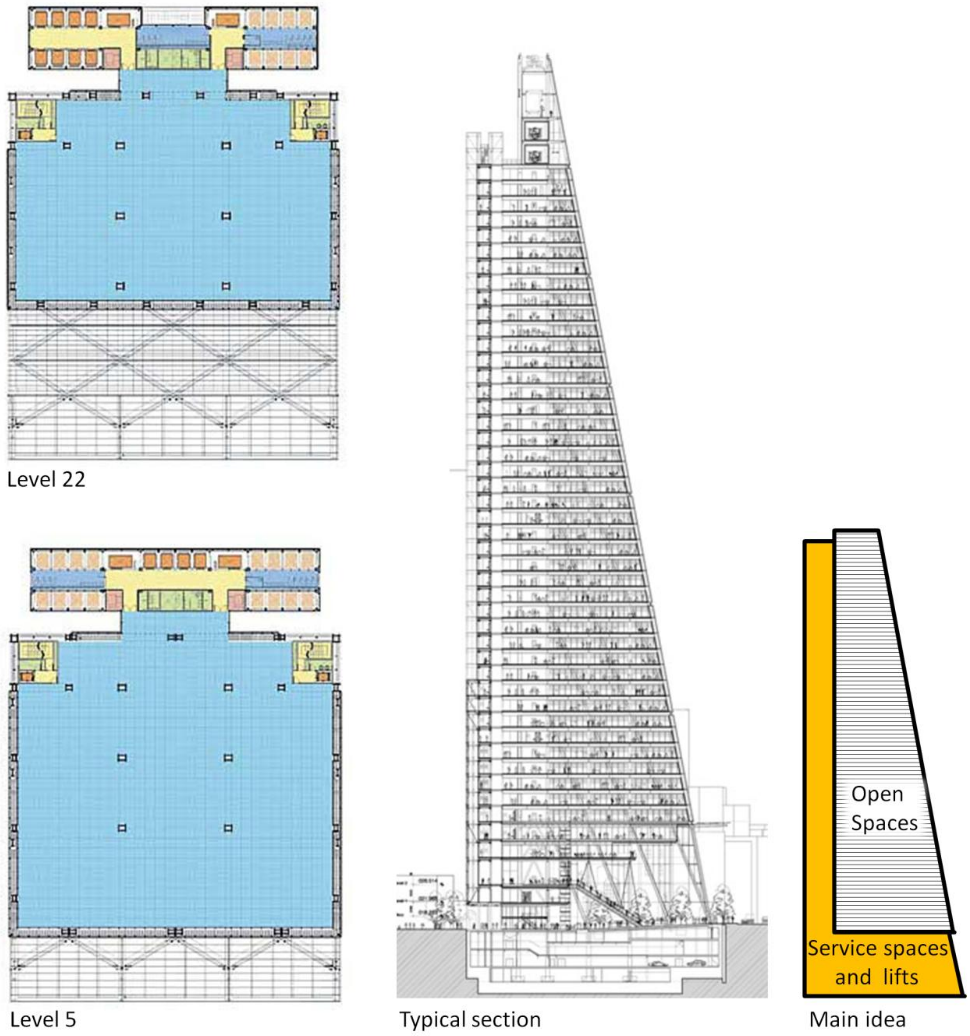


Figure 2-22: The Leadenhall Building (opened 2014), London, design by Rogers Stirk Harbour + Partners, source of plans and section: (Young et al., 2013)

Rem Koolhaas explicitly states that the “Typical Plan” is Western. There is no any equivalent in any other culture”(Koolhaas et al., 1995, p. 339). The use of load-bearing walls instead of columns and the lack of appropriate materials for wide-span floors such as long wooden beams in traditional Iranian architecture limited the creation of wide empty spaces, but nevertheless the idea of ‘neutrality’ was one of the strategies of flexibility applied in a traditional building. It means the rooms were completely free of a particular function and could be used in various ways. A room could be equally used as a sleeping room, living room, guest room, kitchen, and even as a storeroom in different situations.

2.2.3.4 Movability in Building Scale

Using the car instead of an animal for transportation in the twentieth century has created a new type of nomadism and mobile building; temporary homes on wheels. This mobile space can range from a simple tent on the wheels to a luxury home equipped with the latest technologies. Figure 2-23 shows different type of mobile homes during this period.

1- 1932 Gilkie Tent Trailer, RV Collection

2-1954 Yellowstone travel trailer, RV Collection

3- 1958 Platt home, MH Collection

4- 1978 T2 Westfalia Camper, Volkswagen museum

5-1985 "De Markies" (The Awning), mobile and extendable home for "Temporary Living" competition, designed by Böhtlingk

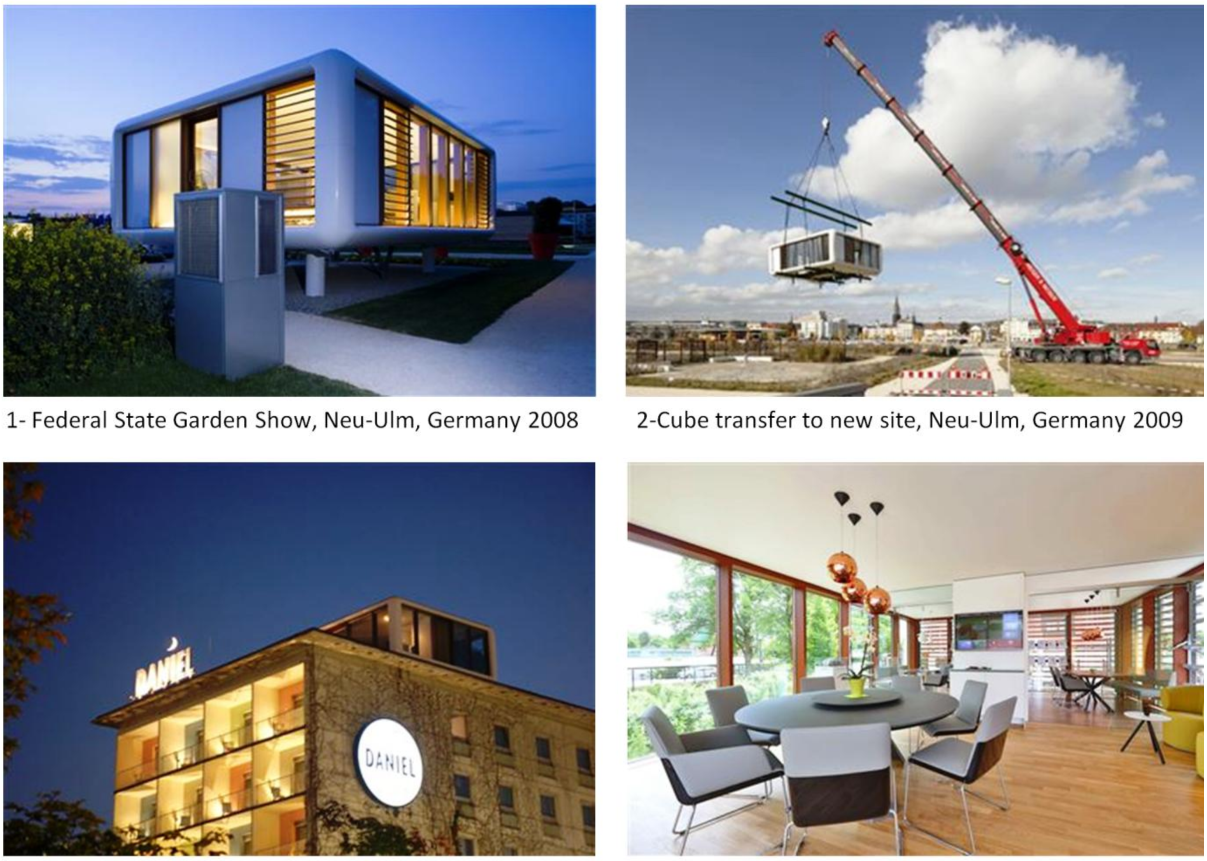
6- 2008 luxury motor coach with movable balcony, Country Coach Company

Figure 2-23: different mobile homes over time, source of photos: 1, 2 and 3-(Fame Museum, 2016), 4-(Volkswagen Museum, 2016), 5-(Böhtlingk, 2016), 6- (New Atlas, 2016)

Mobile homes are not bound to a particular location. Usually their space is rather compact; only some of them (e.g., De Markies and Country Coach) can be extended by adding a light canopy. In this sense they are rather inflexible. They are used only at certain times of the year and at other times they are parked in garages, making them a less sustainable option.

Prefabricated module buildings are yet another type of movable architecture. In this type of construction the modules are assembled on site. In 2003, Werner Aisslinger Studio designed a small prefab living space for the tops of buildings and called their project 'LoftCube'. This module manufactured completely in the factory and can be moved to any site in one or more pieces. For the first time, In 2009, after the federal state show in Neu-Ulm, Germany, the entire building was lifted by crane to another site to be used as a showroom(LoftCube, 2016).

Figure 2-24 shows a LoftCube module that can be easily moved from one site to another site. This case unlike the mobile homes is a multi-purpose building that can be easily adapted to different functions (in this case living space and office).



1- Federal State Garden Show, Neu-Ulm, Germany 2008

2-Cube transfer to new site, Neu-Ulm, Germany 2009

3- Expansion of Hotel Daniel Graz, 2014

4- Isaria Wohnabu AG, luxury sales office, Munich, 2015

Figure 2-24: different functions of LoftCube; exhibition space, hotel, and office, source of photos: (LoftCube, 2016)

2.2.4 Flexibility in Room Scale

2.2.4.1 Flexible Spatial Configuration

Neutral functionality is the base of spatial flexibility. Simple spaces without specific labels can change into the different uses according to the residents' requirements (Schneider and Till, 2007, p. 186). The neutral and open spaces also can be divided into smaller spaces for specific uses. Partitionability (divisibility) “is the possibility of splitting up, rearranging or combining different spatial units in a simple way.” (Geraedts, 2008, p. 14)

In traditional Japanese architecture, the sliding doors (Shōji) and walls that made from light wooden panel or paper in a wooden frame enable the rooms to be rearranged.

Japanese architecture had a great influence on the early modern architecture. Many leaders of the modern movement such as Hermann Muthesius, Walter Gropius, Bruno Taut and Frank Lloyd Wright greatly admired Japanese architecture and their own work was certainly inspired by it. (Melendo et al., 2014)

The Kings Road house/studio in West Hollywood, USA, designed by Rudolph M. Schindler in 1922 is a unique project inspired by Japanese architecture. In 1926, Schindler described the future relationship between body and nature: “...The walls will be few, thin, and removable. All rooms will become part of an organic unit, instead of being separate small boxes with peepholes” (Schindler, 1926, pp. 46-47). The following photos show the similarity of the Schindler house with a traditional Japanese house. (Figure 2-25)


1- Kusakabe House, Takayama, Japan, originally early-mid 19th century, rebuilt 1879


2- Modular Structure and sliding panels in Schindler House, West Hollywood, US, 1921-22


3- Schindler House, West Hollywood, US, 1921-22

Figure 2-25: Schindler house; inspiration from Japanese Architecture, source of photos: 1- (AHA, 2016) 2-(MAk, 2016b) 3-(MAK, 2016a)

Due to the building technology of pre-modern Iranian houses – thick load-bearing brick walls - it is impossible to rearrange the position of room partitions to make changes. However, in these houses the use of multiple doors as a connection between rooms allows the relationship between spaces to be changed and a wide variety of spatial configurations to be created. Connectability “refers back to the traditional system of ‘Enfilade’, whereby a series of adjacent rooms can be connected through sliding wall panels or doors." (Schneider and Till, 2007, p. 190)

The following photos (Figure 2-26) show the described use of doors as devices to separate or selectively connect rooms by the example of two houses from two different climates in Iran: Isfahan in the hot and arid region of the central Iranian plateau and Bushehr in the hot and humid climate zone along the Persian Gulf.

1- the Dehdashti House, Isfahan, Iran, early Qajar period

2- the Ruqani (Dehdashti) House, Bushehr, Iran, mid Qajar period

Figure 2-26: selective connectability in traditional Iranian houses, source of photos: 1- (Haji-Qassemi, 1996, pp. 105 & 107), 2-(Makanbin, 2016)

Thanks to technological advancements in recent decades the partitionability idea has developed in housing design. The MIMA House, designed by MIMA Architects in 2011, consists of a modular structure and removable partitions. The lightweight interior panels can be easily assembled and relocated in a grid of rails in the floor and ceiling by two people (MIMA, 2016). An easily assembled solid panel as a shading device or external wall can control the sunshine or provide privacy by blocking the direct view. (Figure 2-27)

Prefabricated modular construction

Solid panel as a shading device

Interior panel installation

Placing modular wall in grids of rails

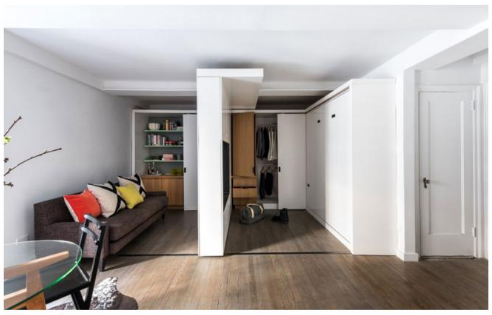
Figure 2-27: MIMA House, movable and customizable walls, Portugal, 2011 (MIMA, 2016)

The Five to One Apartment designed by MKCA in New York City is a compact home that integrates different functional and spatial elements for different uses in a room measuring only in 36 m2. A sliding wall that can be moved by means of a motor from one side of the room to the other creates different living, sleeping, dressing, working, and entertaining spaces (MKCA, 2015). Figure 2-28 shows different spaces at different times based on the needs of residents.

living room/ home office

Sliding wall

Bedroom



Dressing room

Figure 2-28: Five to One apartment, sliding wall, New York, 2015 (MKCA, 2015)

Another example of using technology to create changeable spaces is the Sharifi-ha House in Tehran, which was designed by Alireza Taghaboni (Nextoffice) in 2013 (Figure 2-29). By designing three rotatable boxes, the architecture allows the residents to create different open or closed, private or public spaces based on seasonal or functional changes. The project is inspired by the idea of seasonal movement in the traditional Iranian houses. In the past, residents moved between different zones to adapt themselves to different conditions (Figure 2-30), but now thanks to technology the designer moves the spaces to create the various required spaces (zones). The point, however, that flexibility is only one aspect of sustainability; the use of energy consuming (and expensive) technologies to create a flexible building contradicts the spirit of sustainability. The house is one of the most expensive buildings in Tehran.

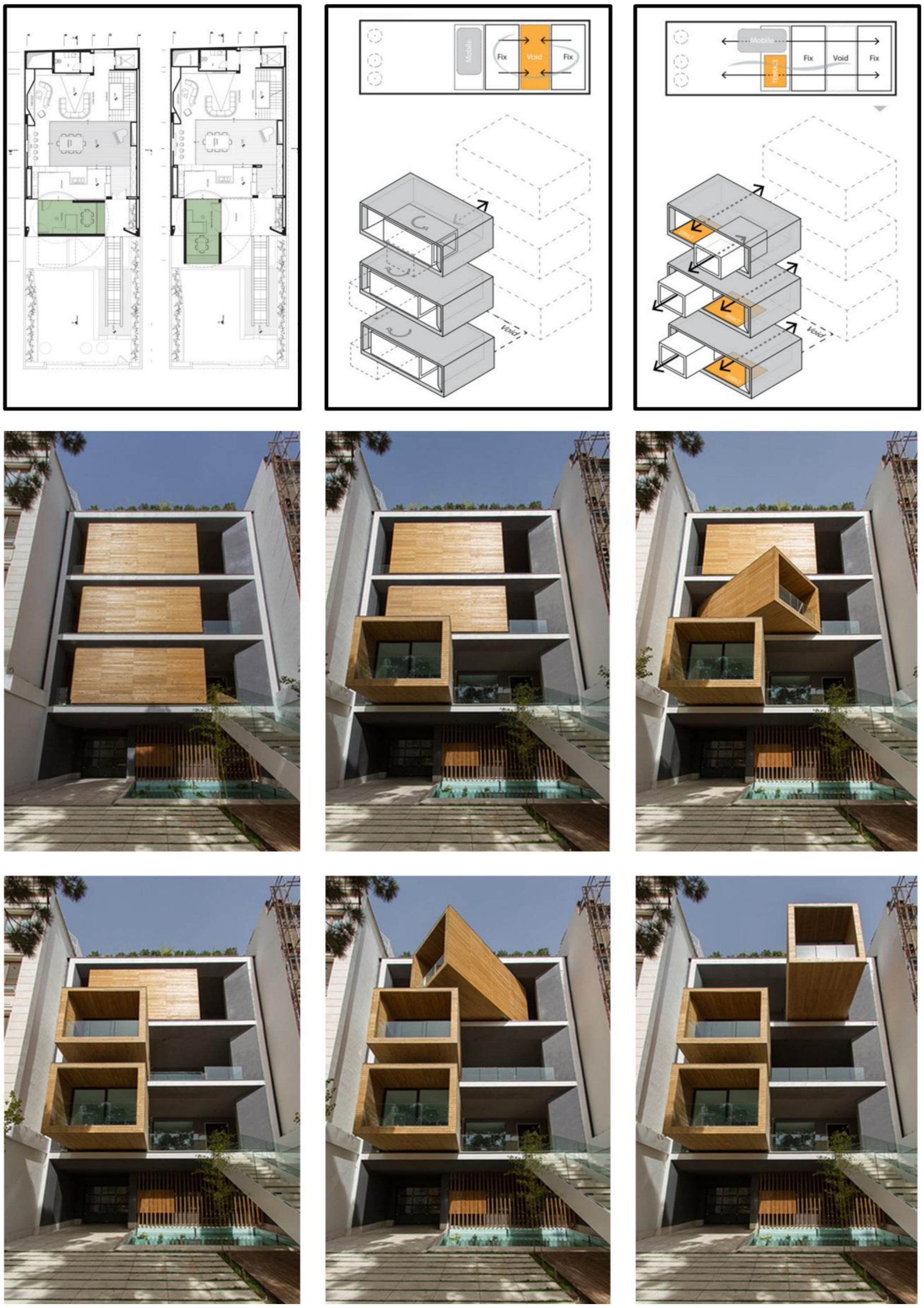


Figure 2-29: different scenarios of the Sharifi-ha House (Taghaboni, 2013)

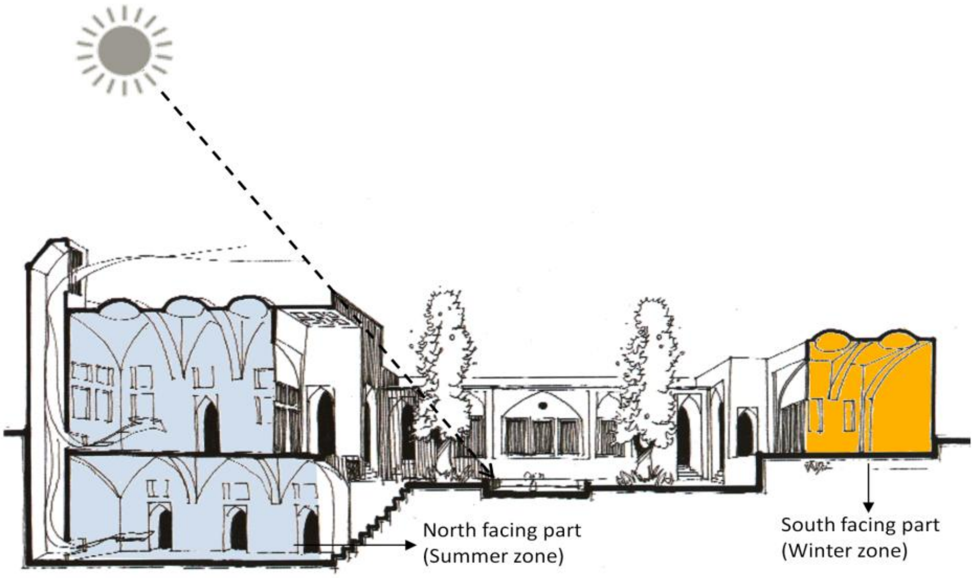


Figure 2-30: seasonal movement between summer and winter zones in traditional Iranian houses, source of sketch: (Ghobadian, 2009, p. 58)

2.2.5 Flexible Façades

The building envelope protects the building and residents against harsh winds, direct sunshine, and rain. The façade provides controlled fresh air and also light and view for interior spaces. The different types of windows and doors in traditional houses were invented to modulate the connection between house and environment in different situations. Using several window/doors in the main walls facing the courtyard was a common strategy in the Qajar houses in Iran. The large amount of openings enables the house to be adapted to the different climatic condition in different season and during the day and night by opening or closing them. These flexible façades also can be changed according to the different functional needs. The following photos (Figure 2-31) show traditional Qajar seh-dari (three-doors) and panj-dari (five-doors) in Isfahan.

Figure 2-31: left- a seh-dari (three-doors) room in the Sheikh-Harandi house, Isfahan, Qajar period (Haji-Qassemi, 1996, p.77) right- two seh-dari (three-doors) and a panj-dari (five-doors) rooms in the Kahkeshan house, Isfahan, Qajar period (Haji-Qassemi, 1996, p. 46)

Another window type in traditional Iranian architecture in the Qajar period is ‘Orosi’, a movable sliding window. Depending on their width the openings are divided into odd numbers of windows; three, five, seven and even nine. Figure 2-32 shows a five-part orosi in the Vasiq Ansari house. By sliding the windows the residents of the house can change the size and arrangements of openings and control the relationship of inside and outside in different situations.

Figure 2-32: the main façade of the Vasiq Ansari house, Isfahan, around 1850 (Haji-Qassemi, 1996, pp. 23,26)

In addition different windows, window shutters and simple shading devises were used on the façades of traditional houses in hot and arid regions. Figure 2-33 (right) shows two double-layered windows on a west-facing façade in a Pahlavi house in Sabzevar. The external layer is a shutter window that can block direct sunlight in hot afternoons. Using an internal textile curtain and external mat curtain was another simple solution to control the direct sunlight. Figure 2-33 (left) shows simple mat curtains on the main façade of the Kian house in Sabzevar.

Figure 2-33: left- simple mat curtain on the main façade of the Kian house in Sabzevar (Qajar) Right-shutter windows on a west facing façade in a Pahlavi house in Sabzevar

The use of sensors, digital controllers, motorized diaphragms and other innovations in building industry enable the architects to design dynamic façades for contemporary buildings. In the following some iconic examples of adaptable dynamic façades are listed.

2.2.5.1 Kinetic (dynamic) Façades

In this type of flexible architecture, the main structure of the building and the spaces are fixed. Only façades are moved or transformed to adapt the building to the internal and external changes.

An unconventional and quite extreme example is the Sliding house designed by dRMM studio in Suffolk, England. It has large mobile walls and a roof that can be moved on rails to cover and uncover the different parts of the building. These parts (main house, glass living room, and the guest annex) are arranged in one line. The garage is located next to the rails (Figure 2-34). The mobile roof/wall enclosure can be moved by means of small electric motor wheels that are hidden in the wall (dRMM, 2016).The different positions of the enclosure create variable open and closed spaces with different qualities and views for different scenarios. The sliding house can also control the sunlight in different seasons.

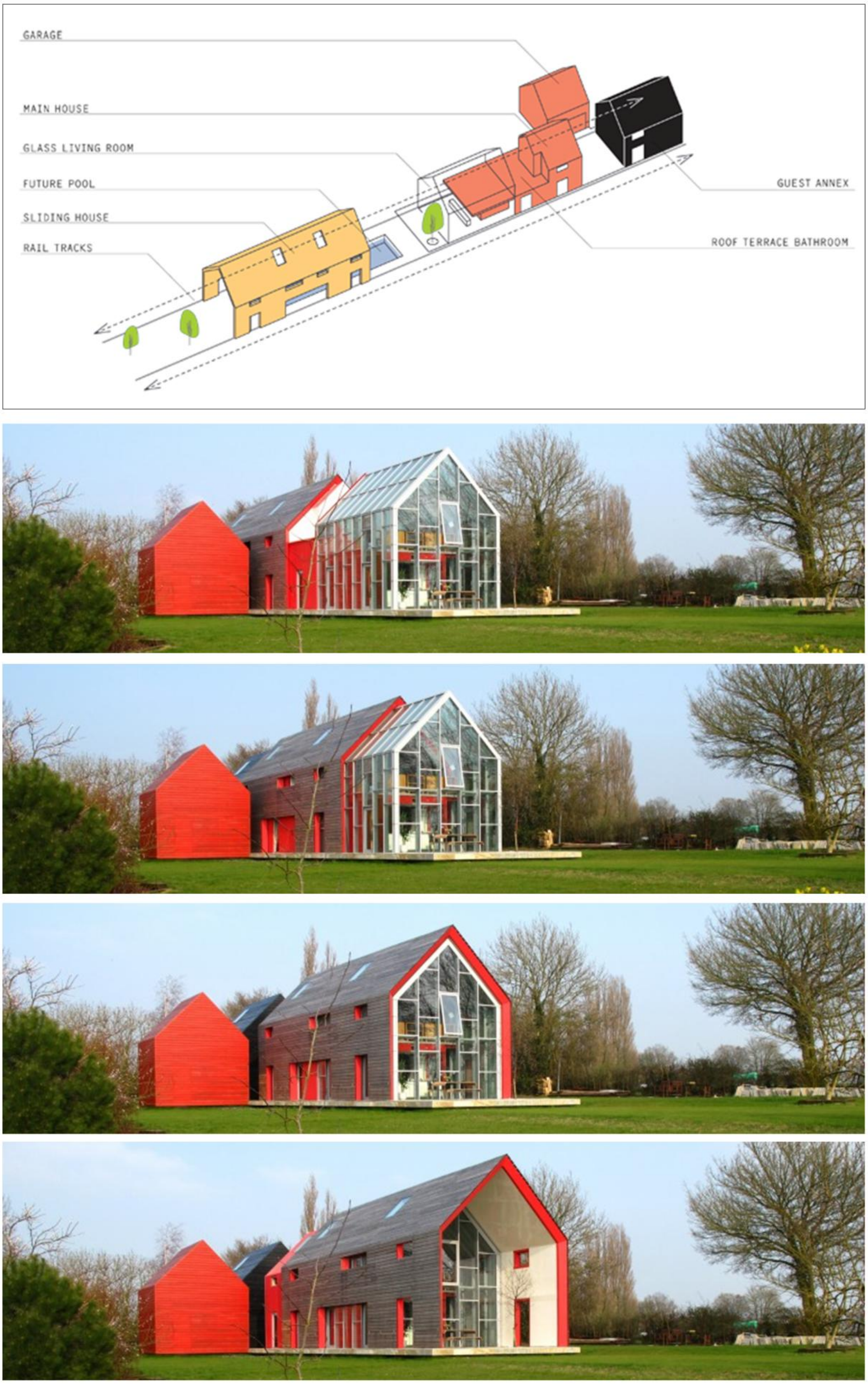
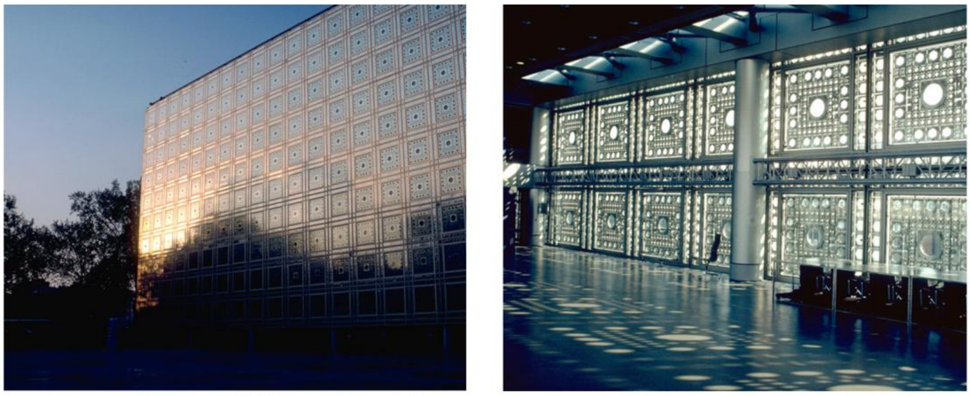


Figure 2-34: top- diagram of the sliding house (dRMM, 2016), bottom- different positions of the enclosure (Architects' Republic, 2014)

The southern façade of the Arab World Institute designed and constructed by Jean Nouvel, P.Soria, G. Lezènes architects and Robain, Galmiche, Tisnado & Bonneise studios was fabricated using two hundred and forty square metal modules (Institut du Monde Arabe, 2016). One hundred and thirteen of these panels are photosensitive, equipped with motorized diaphragms that can control the amount of light in the interior spaces (Aga Khan Foundation, 2016). The project in Paris, France was completed in 1987. (Figure 2-35)

Another example is the Al Bahr Towers in Abu Dhabi. Two large computerised dynamic façades cover the twin towers. In this project, 2098 adaptive 'flower shaped' modules that open and close in response to sunlight provide kinetic shading devices. These adaptive skins reduce solar gain by shading the towers.(Diar Consult, 2016) (Figure 2-35)

In the Kiefer Technic Showroom project designed by 'Giselbrecht + Partner' in 2007, one hundred and twelve folding modules can be controlled electrically. A digital processor controls the motors of the elements. These façades can be changed according to the functional and environmental requirements, such as weather, wind direction, sun position, and different events.(giselbrecht, 2016) (Figure 2-35)



1- Dynamic façade of the Arab World Institute, Paris, 1987

2- computerized dynamic façades of Al Bahr Towers, Abu Dhabi, 2009

3-changeable façade of Kiefer technic showroom, Bad Gleichenberg, Austria , 2007

Figure 2-35: three examples of a kinetic façade, source of photos: 1- (Aga Khan Foundation, 2016), 2- (AHR, 2016), 3- © Paul Ott (giselbrecht, 2016)

2.3 Flexibility and Adaptability in Iranian Traditional Architecture

In the vast majority of studies of traditional and vernacular architecture, popular culture is referred to as one of the main factors in shaping architecture. “The folk tradition is much more closely related to the culture of the majority and life as it is really lived than the grand design tradition, which represents the culture of the elites”(Rapoport, 1969, p. 2).

After the emergence of Islam in Iran, the formation and evolution of Iranian cities were based on the religion and culture along with the climate (and availability of water) (Kheirabadi, 2000). Memarian and Brown (2003) believe that these are the main factors in shaping the courtyard houses In Iran. Over time religion and the other aspects of culture and physical environment became inseparably linked. For example, it is impossible to say with certainty whether the privacy in traditional housing design was more a subject of culture or religion or whether it was rather a reaction to climatic conditions. It might be reasonably assumed that the courtyard house in this region was primarily developed for climatic reasons; the main task of the courtyard was creating a pleasant microclimate in the harsh environment. This space also provided security for residents and animals. This concept is much older than Islam. But the scheme perfectly matches the concept of Muslim privacy, therefore the pattern of the courtyard house consolidated.

The previous section listed different types of flexibility and adaptability, which can be found in architecture. Only a few of these strategies have been applied in traditional Iranian buildings.

Almost all the researchers working on traditional Iranian architecture mentioned the flexibility and adaptability of residential buildings in their studies, but there are not many comprehensive studies that specifically focus on these very aspects. Alireza Eini Far (2003), in a research project examined the aspects of flexibility in pre-modern Iranian houses. He describes three types of flexibility. The first one is multi-functionality. He argues that by using a space for different purposes, reducing the access spaces, and using rooms in a way that facilitates the functional changes traditional houses are able to increase their flexibility. The second factor is versatility (adaptability) that means the use of different spaces at different times, which takes place in two ways, i.e., daily movement between ground floor and first floor and seasonal movement between the summer zone and winter zone. And finally, there is changeability, which refers to the ability of a house to be expanded in response to new needs or be broken down into smaller units (divisibility). (Eini Far, 2003)

In addition to climatic conditions, privacy is another major factor that affects the form and the spatial configuration of traditional Iranian houses. The house manages the social interaction between family members and guests by separating private and reception areas.

If we wanted to design an ideal hypothetical house according to climate and privacy based on Iranian traditional architecture, we needed four spaces – two spaces for responding to climatic conditions and two spaces for separating the family and guest zones. (Figure 2-36)

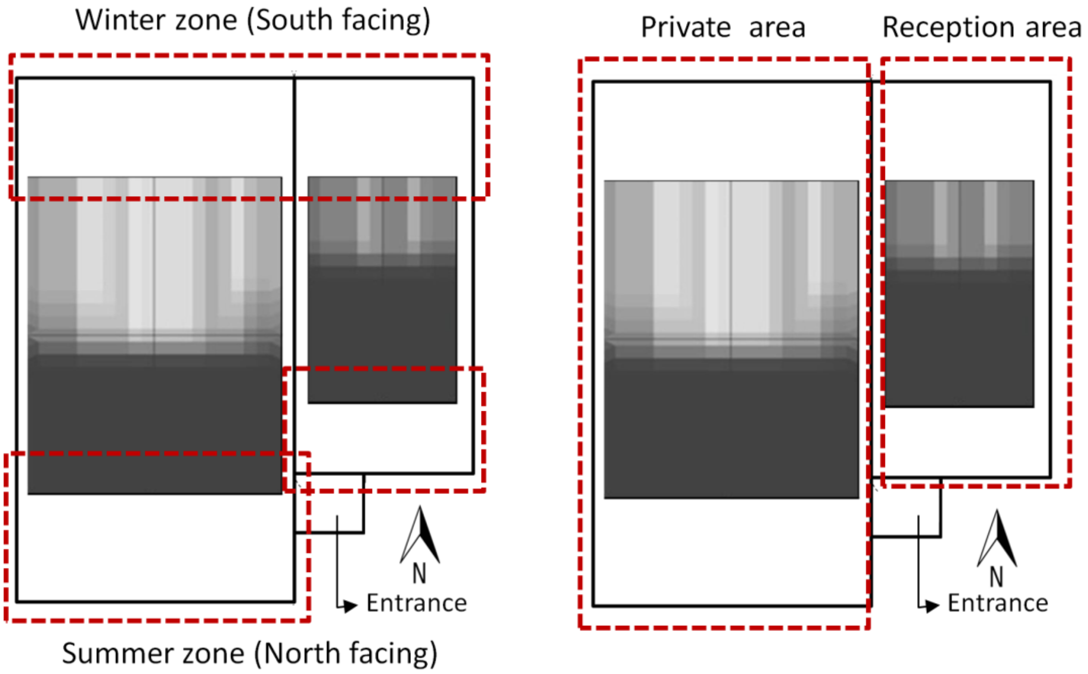


Figure 2-36: ideal hypothetical house based on Iranian traditional architecture (Estaji, 2014)

The *Moslem* house in Sabzevar was designed based on this concept in the last years of the Qajar era (around 1925). Seasonal movement took place in response to climatic changes during the year: people moved vertically in the private zones and horizontally in the reception zones. (Figure 2-37)

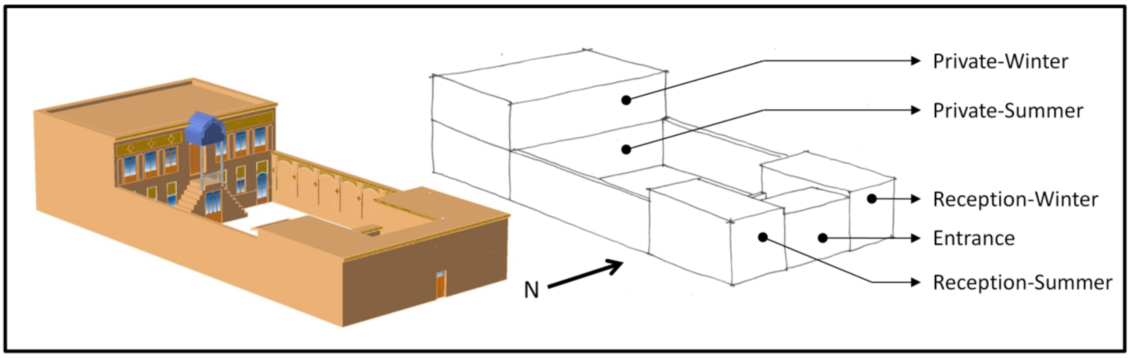


Figure 2-37: the *Moslem* house in Sabzevar (Estaji, 2014)

In order to meet the requirements of privacy and climate control in the best possible way a building of considerable size is necessary. In the past a large family used to reside in such a home; therefore it was acceptable and even necessary to build a large house. Nowadays only smaller families live together. Therefore the question arises: is it possible to apply the traditional concept to contemporary houses? In other words, is it a sustainable solution today?

To answer this question, an ideal (hypothetical) house based on the maximum density of a building is imagined. This model is formed according to the following items of sustainability:

- compact living
- mixed-land uses

- using land efficiently
- multifunctional spaces
- minimum use of material
- minimum need for energy and water
- minimum circulation spaces

In this model, all functional areas would coincide (maximum overlap). (Figure 2-38 Right)

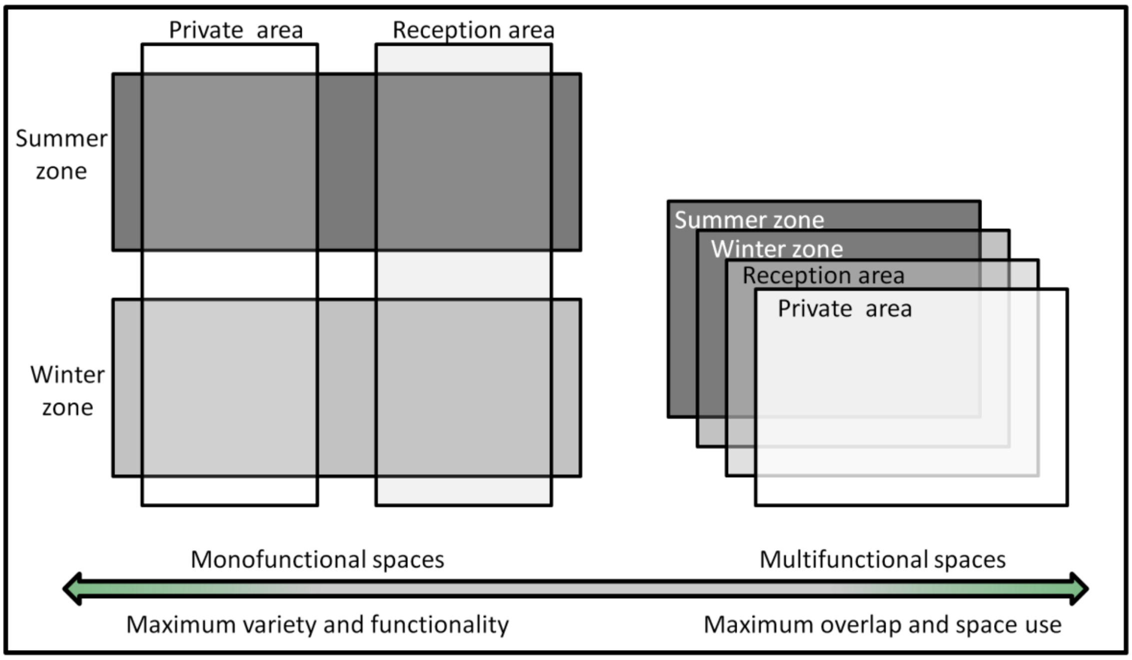


Figure 2-38: comparing two ideal house concepts (Estaji, 2014)

In the hypothetical house on the left-hand side, there are areas within the building, which are dedicated to a specific use (private areas, reception areas, winter zones, summer zones). The rooms within each area can be flexibly used for various functions such as sleeping, living, eating (even as a kitchen or a storeroom).

On the right-hand side, all zones overlap. There is no difference between private areas, reception areas, winter zones and summer zones anymore. In the compact alternative, the rooms could be designed as flexible spaces but the whole system is inflexible compared to the extended model. A house with a large number of rooms can respond better to future changes. The large number of spaces in the left model increases the flexibility of the system with respect to future changes; however, the high material consumption makes it less sustainable.

These traditional differentiations have increasingly disappeared as a result of social changes and technological developments. Most people living in cities have given up the more introverted domestic life and adopted a more extroverted Western lifestyle. Therefore a strictly private zone is no longer necessary. Mechanical air condition has largely replaced the elaborate management of the interior climate and the habit of wandering around in the house depending on the season and daytime.

The high price of energy in recent years has encouraged house owners and architects to reintroduce traditional passive strategies in contemporary houses. Considering the favorable orientation of the building, the use of shadings to control the sunlight, and natural ventilation are some examples of reusing traditional passive strategies in contemporary architecture in this area. 6.4. section (Passive Cooling and Heating Methods in Traditional Iranian Houses) introduces these passive strategies in this region. However, the problem is that some of them are no longer feasible in the current situation. For example, the use of summer and winter zones is cost-efficient regarding yearly energy, but the lacks of land, the sharp rise in the costs of construction and maintenance, and above of all the changes in the lifestyle and family structure limit the use of winter and summer areas in contemporary housing design. In fact, the traditional strategies must be adapted to the new situation. Reducing the cost of construction and maintenance cannot be only the task of architects. Designing a compact house (second idea) reduces the costs, but it is clear that nobody wants to live in one space which is used for all activities.

3 RESEARCH METHODOLOGY

Case study research is essentially a mixed-method strategy because here the researcher investigates the cases from different points of view by using various methods.

Since the house is a place for human activities; it cannot be viewed independently from its context and users. In general, the qualitative approach is appropriate for studying human behavior. This research in parallel with qualitative methods to study the human behavior in the houses uses the Space Syntax theory. The set of Space Syntax tools quantify the spatial patterns of houses and clarify the relationships between spaces and the house users.

3.1 Mixed Methodology

The use of a mixed methodology that integrates qualitative and quantitative techniques has become increasingly popular since the 1980s (Bryman, 2008). The combination of qualitative and quantitative methods (mixed methodology) can provide more nuanced results on the issues being investigated. Looking at a case from multiple points of view (Triangulation) improves the accuracy of research. (Neuman, 2014)
Linda Groat and David Wang (2013) defined six main architectural research strategies by means of pie-shaped wedges. The case studies methods and/or combined strategies are located at the center of the circle. (Figure 3-1)

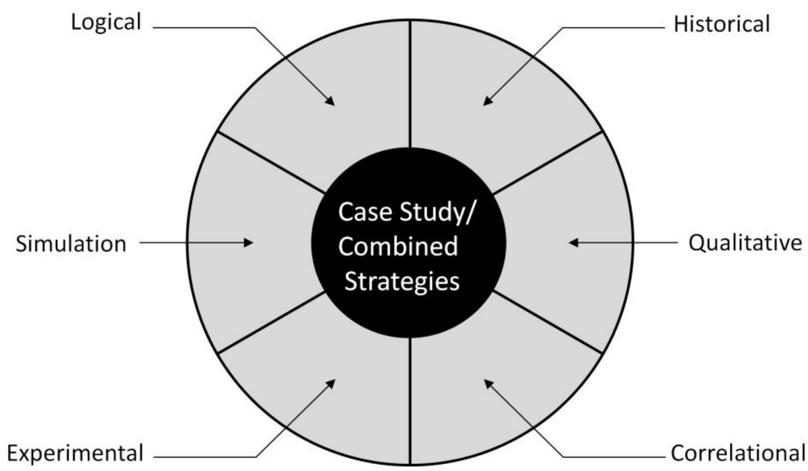


Figure 3-1: A conceptual framework for research methods (Groat and Wang, 2013) Simplified by the author

3.1.1 Historical Research

The historical research is a study on a specific topic that has happened in the past, 'because the "something from the past" is not empirically accessible.'(Groat and Wang, 2013, p. 175) In this kind of research, the researcher tries to obtain the right insights through data collection, evaluation and verifying the information.
This research analyses different historical research material such as old photos, plans, and maps to consider the traditional houses in their real context in the past.

3.1.2 Qualitative Research

> "Qualitative research is empirical research where the data are not in the form of numbers."(Punch, 2013, p. 3)

This is the simplest definition of qualitative research in the literature. Qualitative research tries to explore the objects and phenomena in their real context. "This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them." (Denzin and Lincoln, 2011, p.3).This research uses different empirical research tools - case study, personal experience, introspective, life story, interview, observational, historical, interactional (Denzin and Lincoln, 2011) historical photos and old documents to explore how the life of the residents is reflected in the history of the traditional houses.

3.1.2.1 Grounded Theory

This study started by examining sustainability in traditional houses five years ago. While the literature was being reviewed and data colllected, the study shifted and focused on flexibility and adaptability in housing design. "In qualitative research, we may develop theory during the data collection process."(Neuman, 2014, p.177) This inductive method means that the researcher is forming a theory based on data —grounding the theory in the data. In fact, Grounded theory facilitates the interaction between the data and theory, and increases the flexibility of the research. (Neuman, 2014)

3.1.3 Correlational Research

Correlational research is a method used to explore and clarify patterns of relationships between two or more variables (Groat and Wang, 2013).

3.1.4 Simulation Research

Architects and researchers increasingly use computer modeling and simulation as a methodological approach to architectural design and research. Simulation tools support the design and operation of buildings and allow the designer to model different alternative solutions to a particular problem before construction begins.
Simulation helps researchers to create observations by "moving forward" into the future (Dooley, 2002). This study, however, uses it to "look backward" to assess the thermal performance of traditional houses in Sabzevar while they were still in use before demolition.

This research simulates the path of the sun and the position of shades, the shading masks for the main windows of houses, and the incident solar radiation for spaces by using Ecotect, EnergyPlus, and Geco software.

3.1.5 Logical Research

> "Logical argumentation entails the framing of broad explanatory theories. Of course, theoretical thinking permeates any research design. But when a broad explanatory theory is itself the targeted outcome of a research endeavor, most likely the strategy used to get there is logical argumentation." (Groat and Wang, 2013, p.379)

Logical argumentation is a complementary research method along with other methods, for this reason, in the literature it is known less as a research method. As an example shows categorizing the data obtained by any research methods is often based on logical argumentation. But researchers usually do not call it logical research and would only typically mention the method(s) that helped them to collect data. (Groat and Wang, 2013)
According to the nature of this method, "Flexible Configuration and Envoermental Adaptation" research uses logical research in combination with other methods.

This research makes use of all of the main architectural research strategies with the exception of the experimental method (Figure 3-1).

3.2 Criteria for Selecting Case Studies

For this project, fifteen traditional houses in Sabzevar were singled out for closer examination. The houses were selected from a large number of buildings in Sabzevar based on the following criteria:

3.2.1 Historical and Architectural Value

All of them are registered on the National Iranian heritage list. One of the criteria for listing a building is its historical and architectural value; another one may be that it fills the gap of information on a specific historical period and particular type of building. The majority of the selected houses belong to the Qajar and first Pahlavi periods, one was built in the Timurid era and one in the Safavid era.

3.2.2 Function

The function of all the buildings in the case studies is residential or multifunctional with their primary functions being residential. The function of some of these houses has changed over time, but the basis for choosing them is the function of the buildings in their original context. There is only one - the Mashhadi building - that was erected as a family tomb, but is typologically related to buildings that served other residential functions.
. The general concept of this building was based on the country house type that is called in Persian "khaneh-bagh" (house-garden). In parallel with the sepulchral function (tomb), the building was used as a temporary residence (villa). Since the building was also used as a residential building for around 30 years until 2001, this research investigates this as well.

3.2.3 House-Type Diversity

The traditional houses in this region differ with regard to the layout of open and closed spaces on the land plot. This research tried to select at least one case for each type. The sixth chapter introduces these different types of traditional houses and elaborates on them in detail.

3.2.4 Time Frame

This study focuses on the last decades of the last traditional Iranian architectural style (Isfahani), before the emergence of Modernism in Iran and, more specifically, in Sabzevar. Since Sabzevar is a small historical city, far away from the capital, the transition from traditional to modern architecture did not take place until the first Pahlavi period (1925-41). It means that the Qajar houses in Sabzevar belong to the last period of traditional Iranian architecture in this region. The selected houses were built before modern construction materials such as steel columns, steel beams and large glass panes were introduced into Iranian residential architecture. Nevertheless in these traditional houses signs of the influence of European architecture can be noted. As we approach the end of Qajar, more impact can be seen, e.g. the size and proportion of windows resemble Western window types. The use of new material and new technology such as the skeleton structure instead of load-bearing walls changed the architecture dramatically. Introduction of new materials changed the proportion of spaces and even the spatial configuration of them. These changes were accompanied by the use of active cooling and heating systems in the houses. As a result of the low price of oil and electricity at that time in Iran the use of passive heating and cooling strategies became forgotten in architecture. These factors created a gap between traditional architecture and modern architecture in Iran. (Figure 3-2)
There is only one Timurid house (Azimian) in Sabzevar and there was a Safavid house (Dareini) that was demolished around 2005. These two houses are also examined in this study.

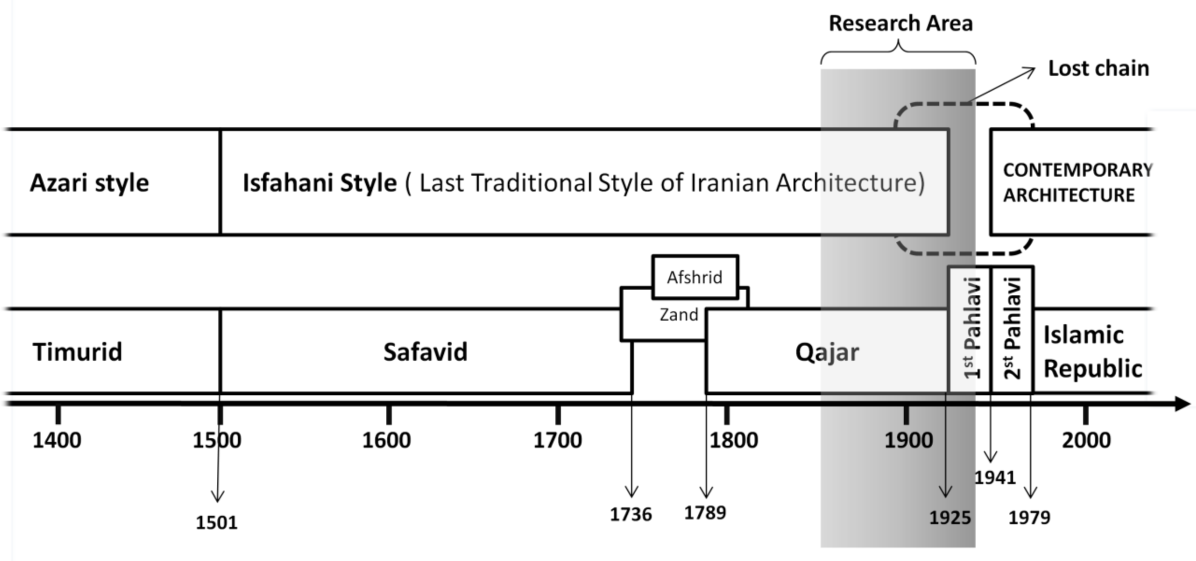


Figure 3-2: Timeline of Iranian Architectural styles from 1400 AD

3.2.5 Location

All of the houses are located in the old city of Sabzevar. Twelve case studies were carried out in the walled old city; one building was attached to the wall, and another one was near the city wall. Figure 3-3 (left) presents the distribution of the houses in the old city on the 1956 aerial map. The old city wall is clearly visible in the map. The right map depicts the urban development of Sabzevar.

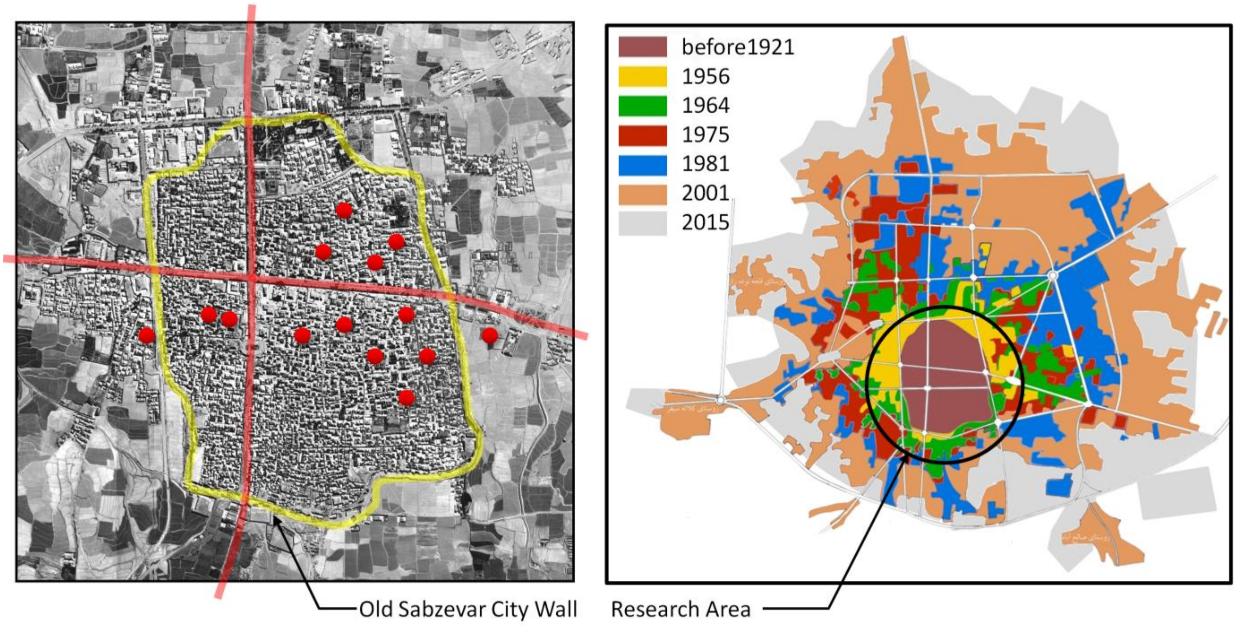


Figure 3-3: left- the situation of houses in the old city 1956, base map (Zanganeh, 2003a) right- urban development of Sabzevar (Zanganeh, 2002) with modification

4 CLIMATE AND CULTURE OF SABZEVAR

The house is a product of a mutual interaction between cultural environment and climatic conditions. Therefore, this chapter studies the context of houses before addressing the traditional houses in Sabzevar.

4.1 Geographical and Climatic Conditions of Sabzevar

Sabzevar (36° 12´ N, 57° 39´ E) is located in the northeast of Iran, to the south of the Sabzevar Mountains (also known as Siah-Kuh or Joghatay Mountains) on the outer rim of the Central Plateau of Iran. These mountains lie 80 km south of the East Alborz. The city and the neighboring villages are situated between the mountain range and the Salt Desert, parallel to the Sabzevar Mountains. (Figure 4-1)

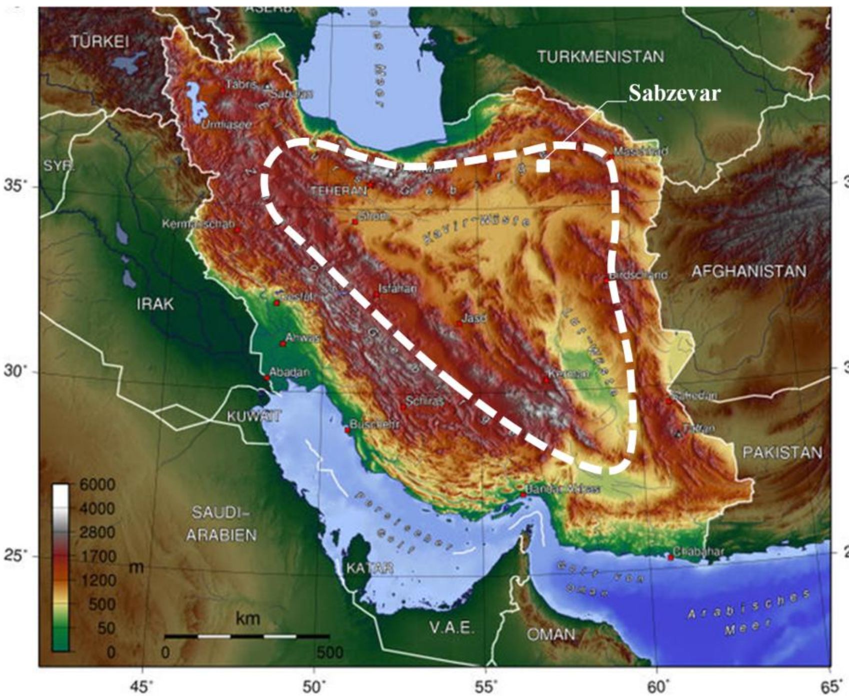


Figure 4-1: Topographic map of Iran (world of maps, 2012)

Iran is a country with different climates; the variety of climatic conditions requires different architectural strategies to adapt to the surrounding environment. [In 1953] Dr. H. Ganjee divided Iran into four different climatic regions according to the Koppen classification with some changes due to the geographical features of Iran:

- Humid temperate climate (Caspian Sea)
- Cold climate (high mountains)
- Hot and dry climate (Central Plateau)
- Hot and humid climate (South Coast) (Kasmaei, 2004, p.83)

This general division became a base for the other scholars in this field, according to this common classification Sabzevar is located in the warm and dry climate (Figure 4-2).

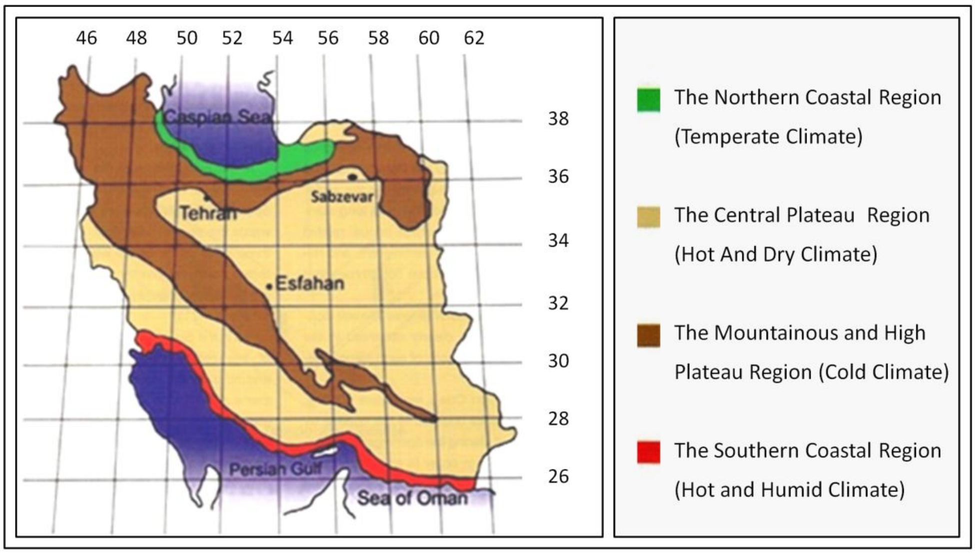


Figure 4-2: Climatic regions of Iran (Ghobadian, 2009)

In 1992 the 'Building and Housing Research Centre' affiliated to the Ministry of Housing and Urban Development of Iran commissioned a comprehensive study on the climatic classification of Iran for housing and urban design. This research project was carried out by Morteza Kasmaei (1992). The study involved 216 meteorological stations in different parts of Iran. These data were used to calculate the thermal comfort period and the heating/cooling needs of the buildings during the year(Kasmaei, 2015). He divided Iran into eight climate zones for Residential Buildings:

- Very cold
- Cold
- Moderate and rainy
- Semi-moderate and rainy
- Semi-arid
- Hot and dry
- Very hot and dry
- Very hot and humid

According to this study, Sabzevar is located in a semi-arid zone, very close to the hot and dry zone (Figure 4-3).

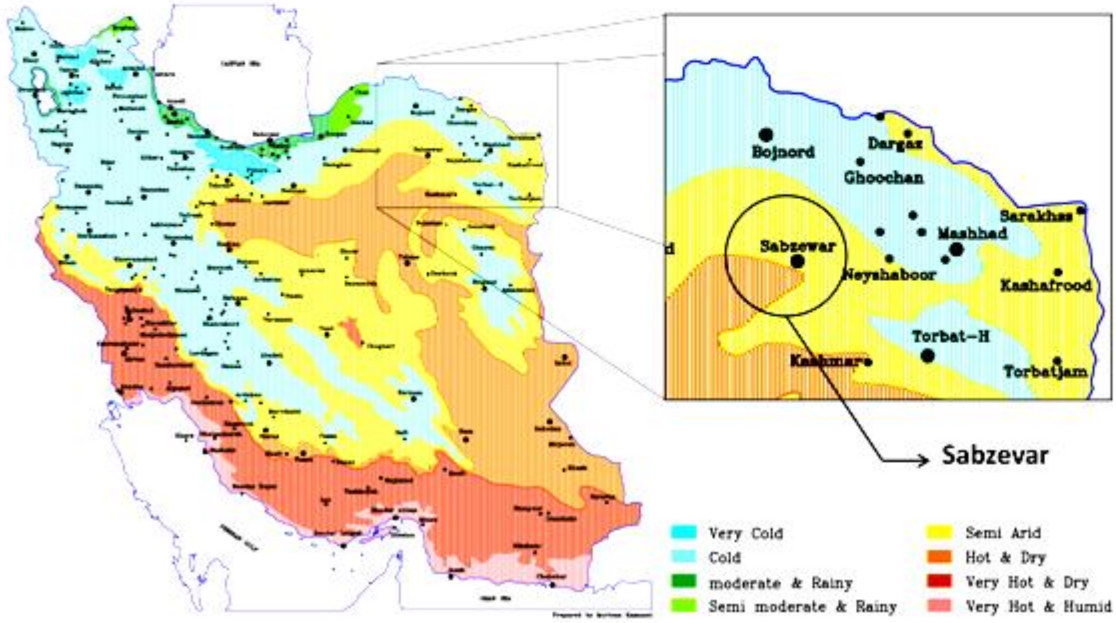


Figure 4-3: Climate zoning of Iran for residential buildings (Kasmaei, 2015)

4.1.1 Climatic Parameters of Sabzevar

One of the biggest challenges researchers face while gathering weather data for their research projects is the distance between local weather stations and the site; ideally, there would be a micro station for each case, but this is impossible in historical research. Fortunately, the Sabzevar weather station is located in the center of Sabzevar city close to the traditional houses. It increases the reliability of data in this research.

Modern records of the Sabzevar climate began in 1954. To use this weather data in modeling and simulating the energy performance of buildings, I generated a weather data file (.wea) for Sabzevar. In 2009, Iran Energy Efficiency Organization (IEEO) generated the Sabzevar eQUEST/DOE-2 (.bin) file to be used in the Persian version of *eQUEST*[2] software. However, this file is not complete and has some missing data. To complete the missing data, I applied the *Meteonorm*[3] software to create another weather file. Then I used the *elements*[4] software for combining and editing these two files. Finally, I normalized the data according to the local weather data recorded fifty years ago. Despite the reliability of the generated file, this study tries to use local weather data as much as possible.

4.1.1.1 Air Temperature

Recorded Air temperatures during 1955 to 2014 show that Sabzevar has cold winters and warm summers. For architects it is a real challenge since they have to apply both heating and

[2] eQUEST is a free building energy use simulation tool.

[3] *Meteonorm* is a program for creating synthetic hourly weather data, based on measured long-term mean values.

[4] *Elements* is a free, open-source, cross-platform software tool that allows a user to create and edit custom weather files for building energy modelling. http://energy-models.com/forum/elements-new-weather-tool

cooling strategies. The average of air temperature of Sabzevar varies between 2°C and 30°C from January to July. According to the ASHRAE Standard-55 in Sabzevar design strategies must provide comfort conditions for house users in the outdoor air temperature range of -9°C to 40°C (Figure 4-4).

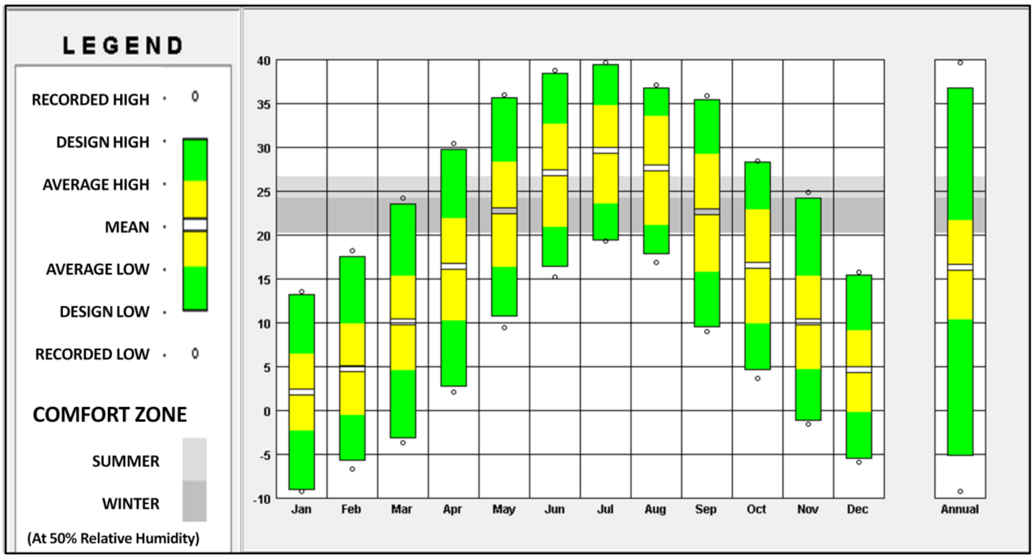
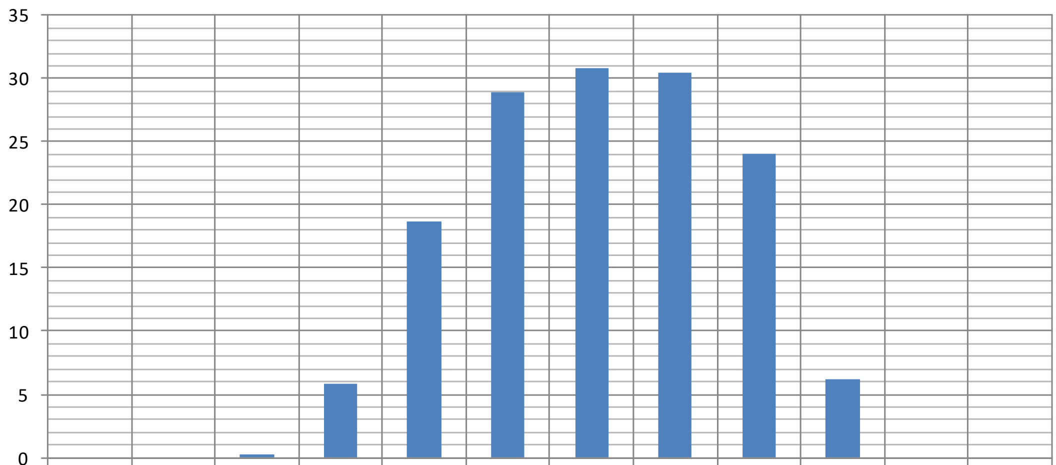


Figure 4-4: Air Temperature range of Sabzevar, Data from the Islamic Republic of IRAN Meteorological Organization (IRIMO, 2015) and generated Sabzevar weather file, Graphic display by using *Climate Consultant 6.0 BETA*[5] software

From 1957 to 2010 the average annual number of days with a maximum temperature of 30°C and above was 145.2 (Figure 4-5). This enormous number of hot days highlights the importance of traditional passive cooling strategies to ensure comfortable living conditions in this region.



JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
0	0	0.3	5.8	18.7	28.9	30.8	30.5	24	6.2	0	0

Figure 4-5: Average number of days with maximum temperature equal 30 and above in Sabzevar during 1957 to 2010, Data: (IRIMO, 2015)

[5] *Climate Consultant* is a design tool for visualizing the energy implications. It uses annual 8,760 hour (.epw) format climate data.

4.1.1.2 Heating and Cooling Degree Days (HDD and CDD)

Since the Heating and Cooling Degree Days parameters are a combination of time and temperature, they offer a better understanding of a building's energy consumption across different weather conditions. Heating and Cooling Degree Days are a measure of how much, and for how long (in days), outside air temperature was lower or higher than the comfort temperature.

An analysis of heating and cooling degree days of Sabzevar from 1957 to 2010 shows that in each year Sabzevar has an average of 987.4 cooling degree days (Base 21° C) and 1669.7 heating degree days (Base 18° C). These data show +0.0073 growth rates in CDD and -0.0054 growth rates in HDD (Figure 4-6), meaning that Sabzevar weather has become warmer in the last half century. This result corroborates the theory of global warming and climate change. Taking into account that Sabzevar's weather has been colder in the last century helps to understand better the thermal concept of traditional houses in this town.

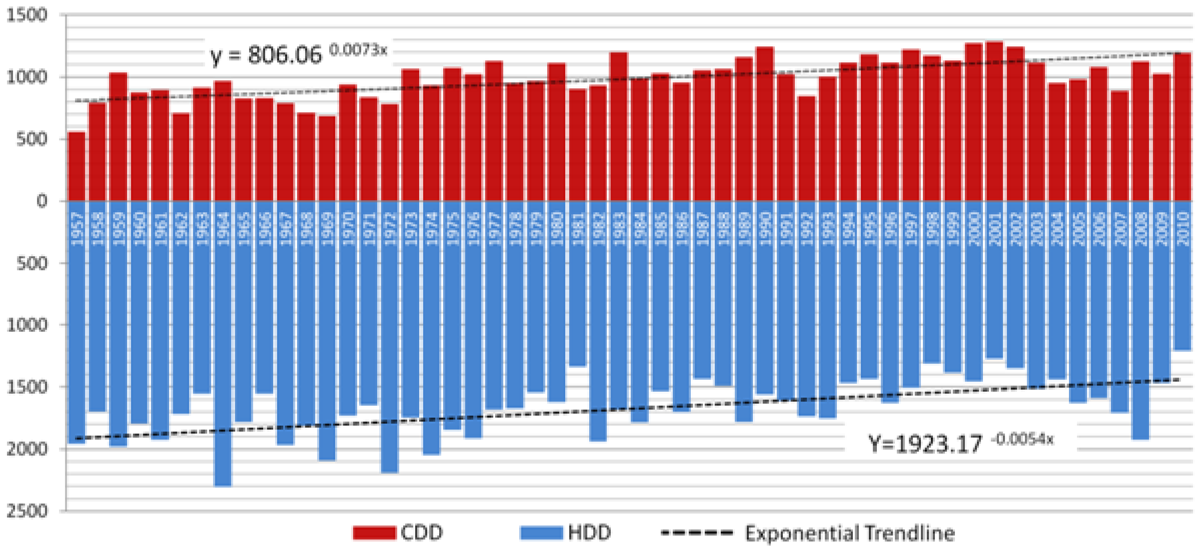
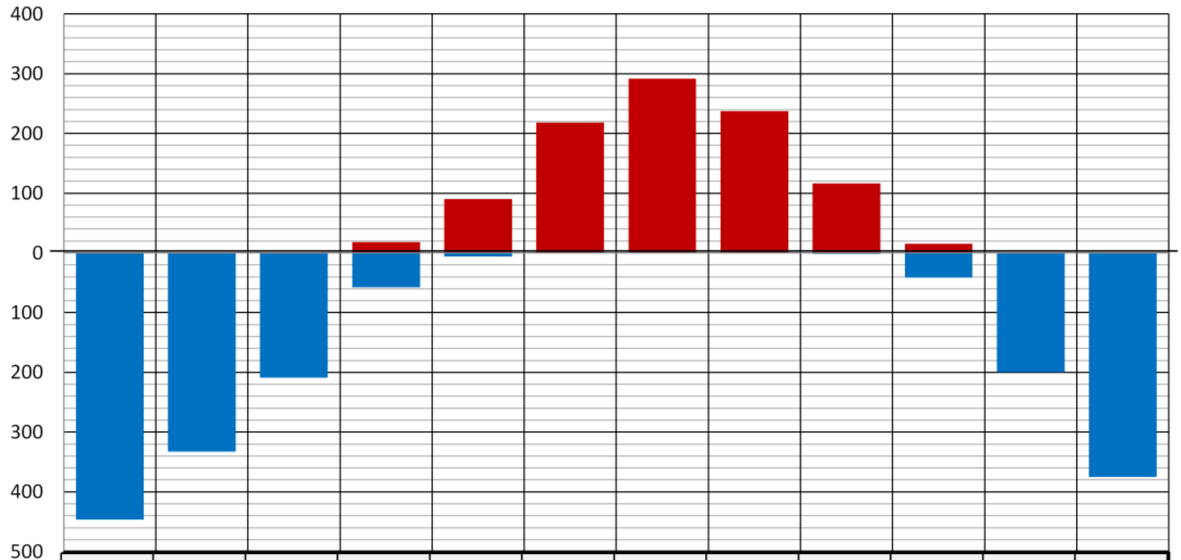


Figure 4-6: Annual Heating and Cooling Degree Days in Sabzevar from 1957 to 2010, Data from (IRIMO, 2015)

The monthly HDD and CDD of Sabzevar (Figure 4-7) gives an estimate of the energy needed to cool indoor air to a comfortable temperature in warm days, from May to September, and energy required to heat indoor air on cold days, from November to March.



	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
CDD	0	0	0.4	18	90.2	218.5	291.6	237.3	116.1	15.2	0.1	0
HDD	446.8	332.3	208.8	57.8	6.2	0.1	0	0	1.7	41.4	199.5	375.1

Figure 4-7: Average monthly heating and cooling degree days (HDD and CDD) in Sabzevar, from 1957 to 2010, Data: (IRIMO, 2015)

CDD and HDD are usually calculated on the basis of 21° C and 18° C. Researchers use these standard temperatures to make it easier to compare the different projects. However, in reality, the comfort temperature is not a fixed parameter in these projects. Thermal comfort as a psychological factor that reflects a general satisfaction with the thermal environment depends on the geographical location, lifestyle, clothing culture and physiological differences between different ethnicities. The people who live in hot and arid regions (in this case Sabzevar) are accustomed to hot weather. 18° C is cold for them; the comfort range temperature in this region is between 23° C and 27° C. In practical terms it means that the houses in this region need more energy for heating and less energy for cooling as opposed to the energy estimated on the basis of standard heating and cooling degree days (21°C and 18°C).

4.1.1.3 Relative Humidity and Precipitation

The annual average relative humidity of Sabzevar is 41 percent, and the monthly relative humidity is limited to 23 percent in August and 66 percent in January. (Figure 4-8)

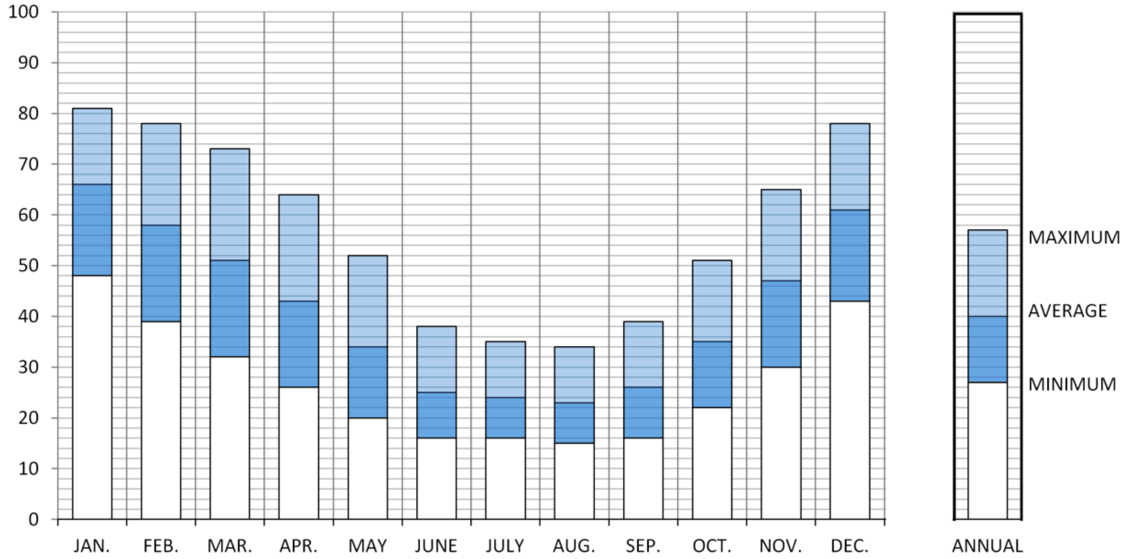


Figure 4-8: minimum, maximum and average Relative Humidity of Sabzevar in percent, Data: (IRIMO, 2015)

A common classification for desert areas is based on average annual precipitation; according to Grove (1977), hyper-arid regions have less than 25 mm, arid regions between 25 and 200 mm and semiarid regions between 200 and 500 mm of annual precipitation (Laity, 2009). Based on the precipitation recorded in Sabzevar from 1955 to 2014, the average of annual precipitation is 186.3. This means that according to the Grove classification Sabzevar is located in the arid zone. Figure 4-9 shows the monthly total of Sabzevar precipitation in millimeters. The lack of rainfall during the hot days exacerbates the effects of hot and dry weather.

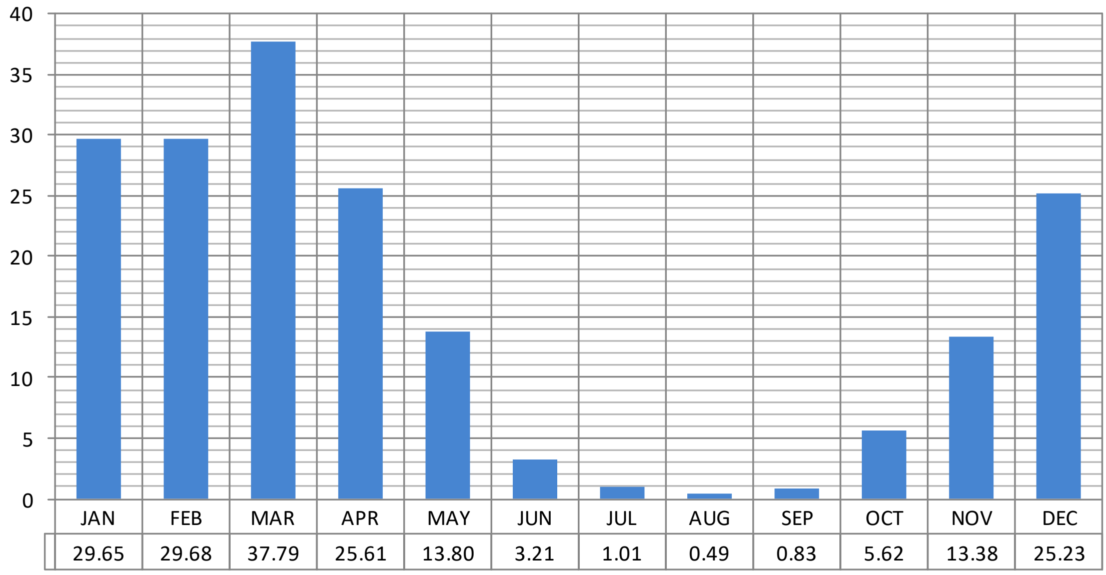


Figure 4-9: monthly total precipitation of Sabzevar from 1955 to 2014 in mm, Data: (IRIMO, 2015)

4.1.1.4 Evapotranspiration

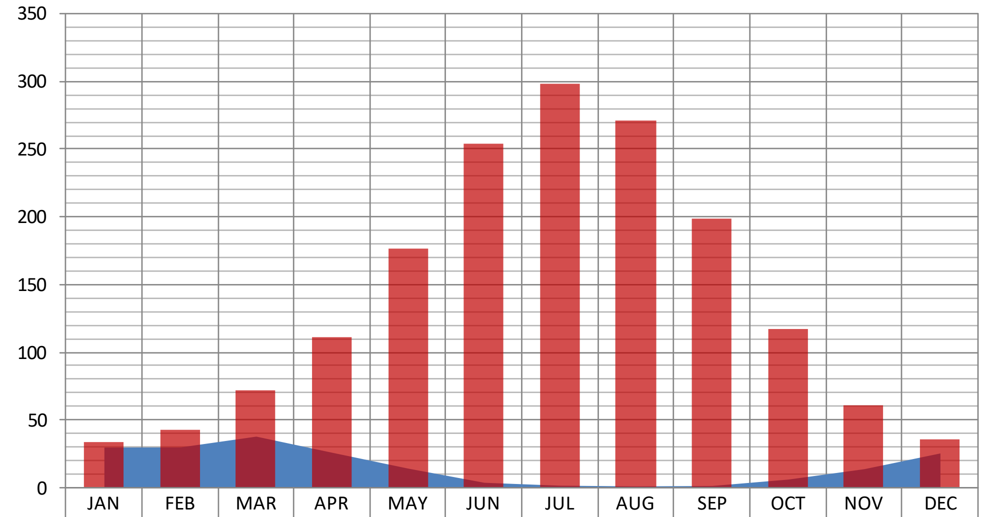
"The Reference Evapotranspiration (ETo) represents the potential evaporation of a well-watered grass crop" (FAO, 2015, p. 3). This climatic parameter is used in agriculture to determine the water needs of other crops. But it is also a useful parameter for architects to examine the possibility of using a passive evaporative cooling system for reducing heat in hot and dry regions. ETo depends on the temperature, humidity, the sunshine and wind speed (Allen, 1998). Although there are several methods for determining ETo, in this study the Penman-Monteith Method (FAO, 2015) based on CROPWAT [6] software (Table 4-1) was used.

Table 4-1: Evapotranspiration (ETo) Penman-Monteith Data of Sabzevar, Data: (IRIMO, 2015) generated by CROPWAT 8 (FAO, 2015)

Country: Iran			Station: Sabzevar					
Altitude: 972 m.			Latitude: 36.20 °N				Longitude: 57.65 °E	
Month	Min Temp °C	Max Temp °C	Humidity %	Wind m/s	Sun hours	Rad MJ/m²/day	ETo mm/day	ETo mm/Month
Jan	-1.6	8.7	66	1.3	5.4	9.2	1.07	33.17
Feb	0.4	12	58	1.1	6.3	12.2	1.51	42.28
Mar	5.1	17.6	51	1	6.3	15.1	2.32	71.92
Apr	10.9	24.6	43	1.1	7.7	19.5	3.7	111
May	16	30.4	34	1.8	9.4	23.5	5.71	177.01
Jun	20.9	35.9	25	3	11	26.3	8.47	254.1
Jul	23.2	37.7	24	3.6	11.3	26.3	9.61	297.91
Aug	21	36.4	23	3.3	11.3	25	8.76	271.56
Sep	16.6	32.7	26	2.7	10	20.6	6.62	198.6
Oct	10.6	26	35	1.7	8.6	15.5	3.78	117.18
Nov	4.7	18.1	47	1.3	7	11.1	2.04	61.2
Dec	0.4	11.4	61	1.1	5.4	8.6	1.16	35.96
Average	10.7	24.3	41	1.9	8.3	17.7	4.56	139.32

To provide a better idea of the amount of Potential Evapotranspiration in Sabzevar, it was compared with precipitation in Sabzevar in Figure 4-10. In July ETo is 9.61 mm/day (297.91 mm/month) while the highest amount of monthly precipitation is 37.8 mm in March. It means that in the summer water evaporates eight times more than the maximum precipitation in spring. This very high level of ETo indicates the hotness and dryness of Sabzevar in summer; on the other hand, it shows the huge potential of this region in using the passive evaporative cooling system on hot days.

[6] CROPWAT is a decision-making support tool developed by the Land and Water Development Division of FAO. For more information: http://www.fao.org/nr/water/infores_databases_cropwat.html and http://www.fao.org/nr/water/docs/CROPWAT8.0Example.pdf



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Precipitation mm	29.6	29.7	37.8	25.7	13.8	3.2	1	0.5	0.8	5.6	13.4	25.2
ETO mm/month	33.17	42.28	71.92	111	177.01	254.1	297.91	271.56	198.6	117.18	61.2	35.96

Figure 4-10: Monthly Precipitation and Potential Evapotranspiration of Sabzevar, Data: (IRIMO, 2015) and CROPWAT 8 software (FAO, 2015)

4.1.1.5 Wind Direction and Speed

The following diagram (Figure 4-11) visualizes wind patterns in Sabzevar. It shows the speed, direction and frequencies of wind in this region. Almost all winds blow from the East and ENE to the West and WSW. This fixed wind direction is an advantage for a site given that wind behavior is predictable and architects can control and apply it in passive design.

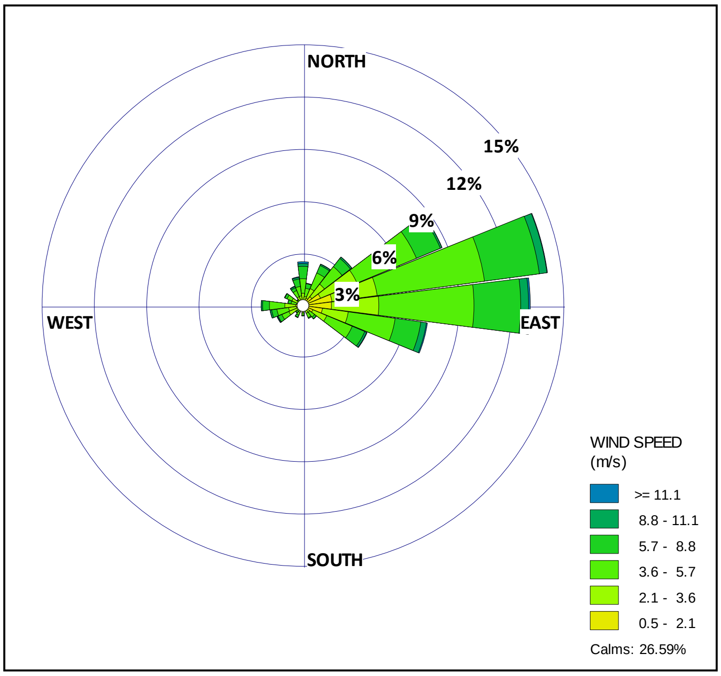
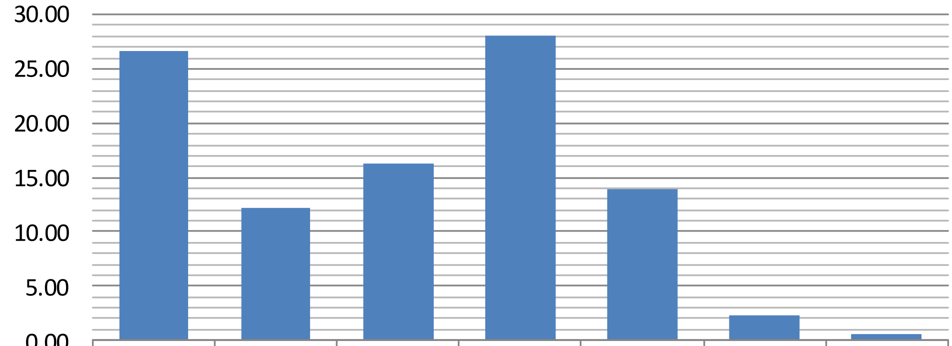


Figure 4-11: Wind Rose of Sabzevar from 2000 to 2006, Data from IRIMO Local office in Sabzevar (2012) Graphic display by using WRPLOT[7] software

[7] *WRPLOT View* is a fully operational wind rose program for meteorological data provided by *Lakes Environmental Software.* It provides visual wind rose plots and frequency analysis based imported data. For more information please visit: http://www.weblakes.com/products/wrplot/

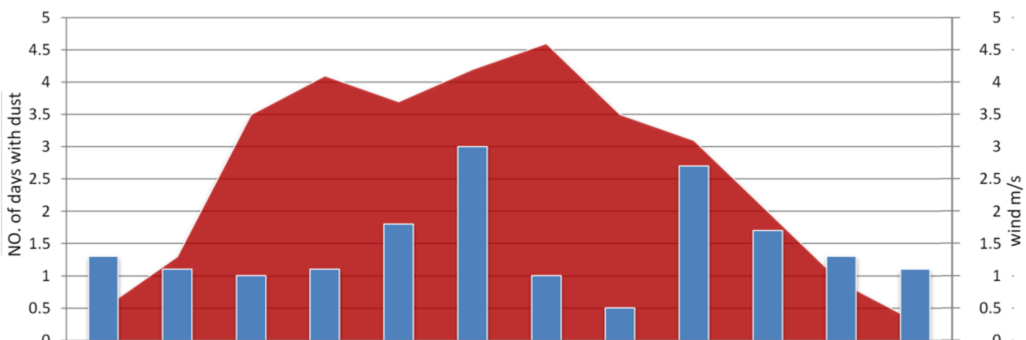
The other important factor of wind to be considered in architectural design is speed. The average wind speed in Sabzevar is 3.23 m/s; 26.59% of winds in this area are less than 0.5 m/s that are called calm winds. Figure 4-12 shows wind class frequency distribution in Sabzevar. Permanent winds with a fixed direction enable architects to easily use them in passive cooling and natural ventilation. (See 6.4.4 Natural Ventilation)



	Calms	0.5 - 2.1	2.1 - 3.6	3.6 - 5.7	5.7 - 8.8	8.8 - 11.1	>= 11.1
Wind Class %	26.59	12.22	16.34	28.03	13.97	2.30	0.55

Figure 4-12: wind class frequency distribution in Sabzevar from 2000 to 2006, Data from IRIMO Local office in Sabzevar (2012)

The biggest challenge in terms of the use of wind in hot and dry regions is dust. The combination of the wind, dust, and hot air makes for harsh weather against which designers try to protect buildings. Figure 4-13 shows the monthly number of days with dust and the average of wind speed. Sabzevar has an average of 31.8 dusty days in a year. Due to the combination of dust and heavy winds in June and September, these are critical months of the year. To prevent the wind and dust from entering the streets they were laid out in a specific direction.



	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
NO. of days with dust	0.5	1.3	3.5	4.1	3.7	4.2	4.6	3.5	3.1	2	0.9	0.3
wind m/s	1.3	1.1	1	1.1	1.8	3	1	0.5	2.7	1.7	1.3	1.1

Figure 4-13: Number of days with dust and monthly average speed of the wind in Sabzevar from 1955 to 2010, Data: (IRIMO, 2015)

4.1.1.6 Solar Radiation

According to the daily movement of the sun from east to west, changing sun altitude during the year and the different sky cloud cover the horizontal and vertical surfaces gain different insolation. The following graph (Figure 4-14) shows the different sun altitude angles in the summer and winter for two solstices (June 21 and December 22). Figure 4-15 shows the monthly averaged solar radiation on a horizontal surface in Sabzevar.

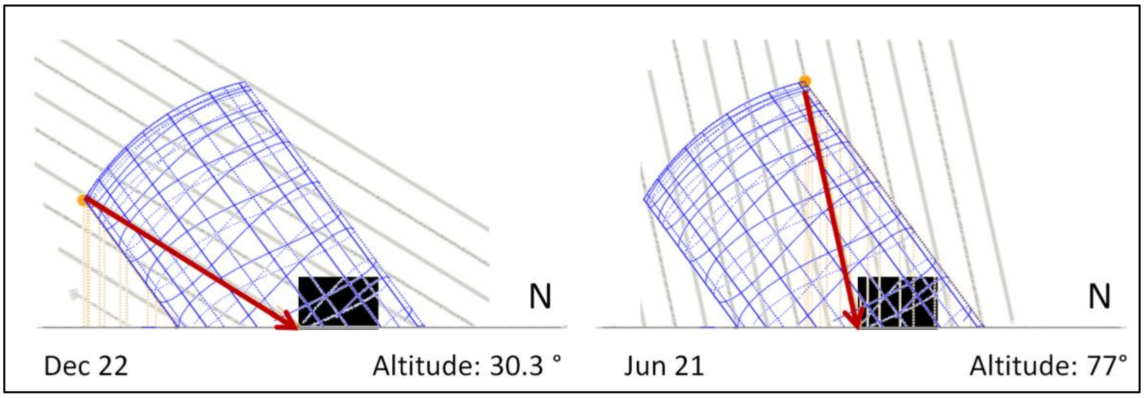


Figure 4-14: the different positions of the sun in Sabzevar (sun altitude angle)

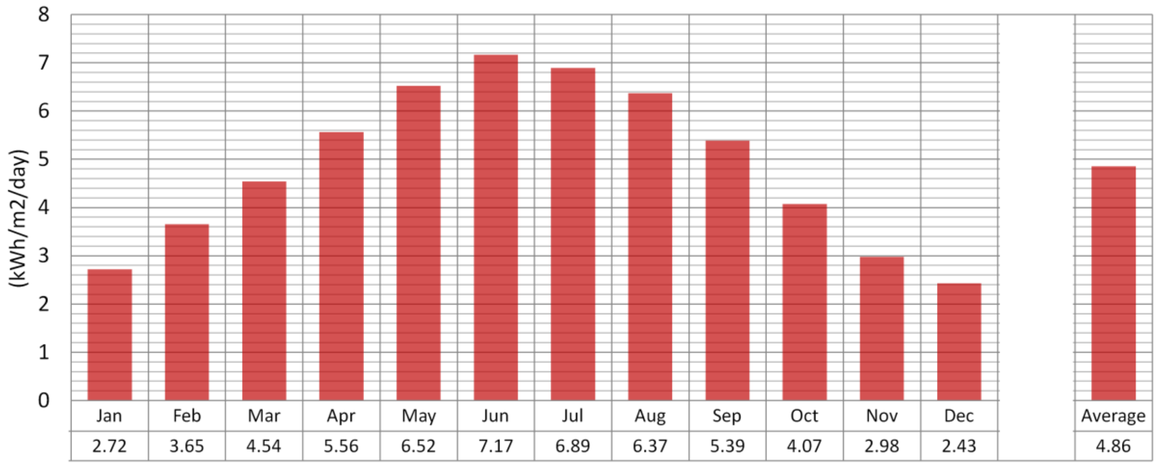


Figure 4-15: Monthly averaged insolation incident on a horizontal surface in Sabzevar (kWh/m2/day), Data: (NASA, 2016)

The radiation incident on the vertical surfaces in addition to the above factors depends on the surface orientation. The following graph (Figure 4-16) shows the radiation incident on a vertical surface in different orientations in Sabzevar, divided into hot and cold days. These calculations help to determine the best and worse orientation of the building façades based on the minimum radiation incident on hot days and maximum on cold days. The graph resulting from the calculation shows that the best orientation during cold days be the façades facing south with a 10- degree rotation to the west and 20 degrees to the east and during the hot days it is the façades facing north and with a little tolerance, the ones facing south between 10 degrees orientation to the west and east. It can thus be concluded that on hot days the best orientation for buildings in Sabzevar is to the south and that throughout the entire year the south-facing façades with an orientation between 10 degrees to the west and 15 degrees to the east (Figure 4-17) fare best. But a building does not only consist of one façade. Thus the ideal orientation also depends on the geometry, proportion and the layout of spaces in a building. The ideal building only according to the sun position would be a building with all rooms facing south, i.e., a narrow linear type, but because of the shape and proportion of the lands and the unfavorable spatial configuration of this pattern, the use of this concept is rare. A compromise is keeping the facades facing west and east without windows or adding Eivans or verandas in front of them in order to minimize solar energy intake.

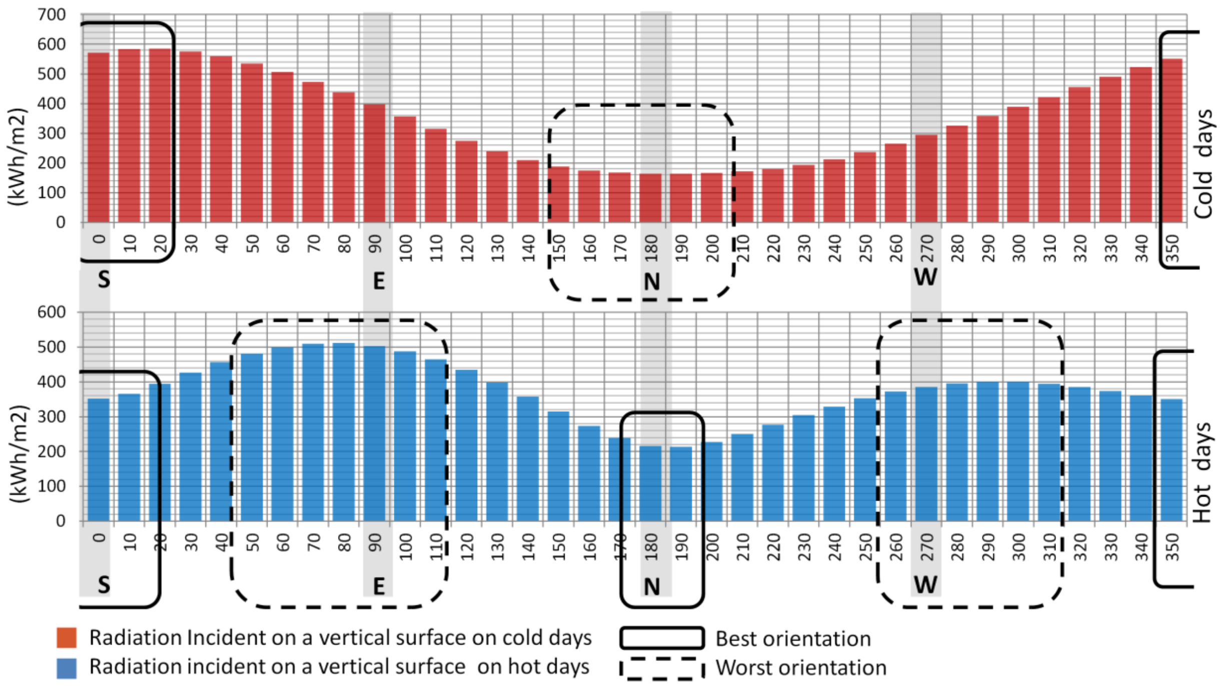


Figure 4-16: Radiation incident on a vertical surface in different orientations in Sabzevar (kWh/m2), Data: Generated Sabzevar weather file, Simulation by using GECO[8]

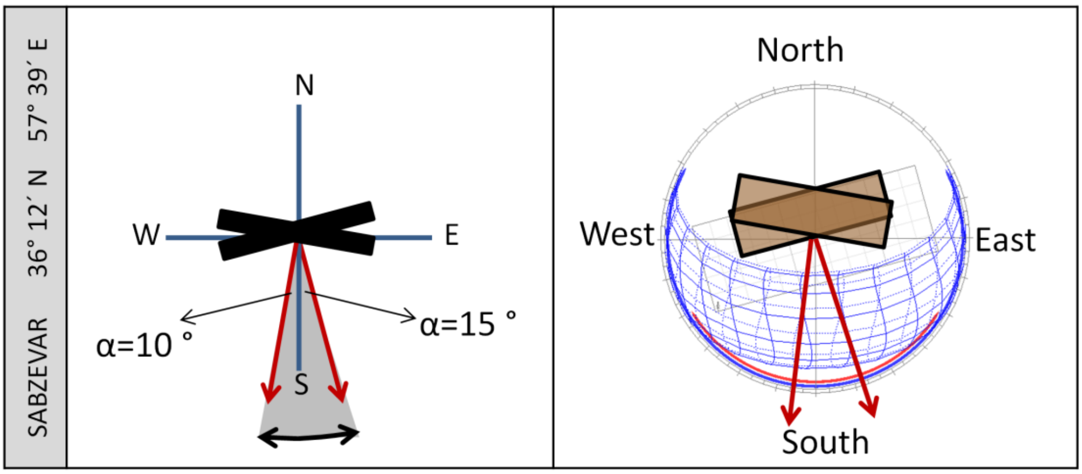


Figure 4-17: Best buildings orientation in Sabzevar only based on the solar radiation

[8] GECO is a plug in for Grasshopper, which offers a direct link between Rhino/Grasshopper models and Autodesk Ecotect.

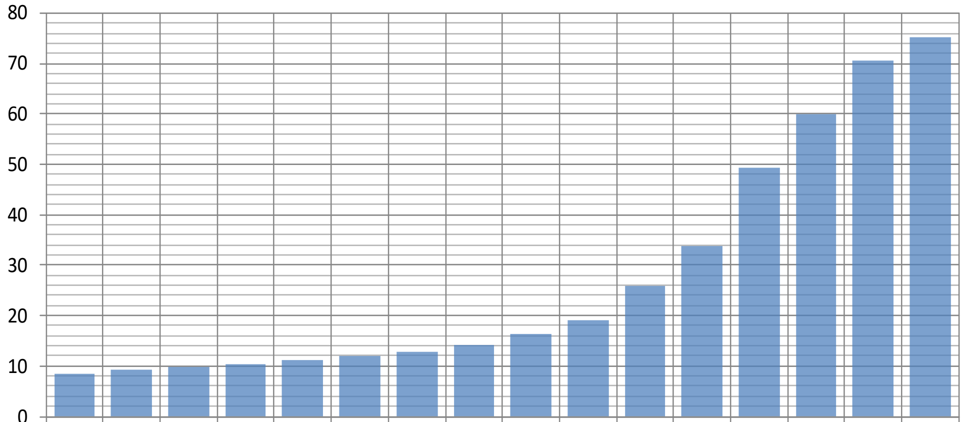
4.2 Cultural Environment

Since the researched buildings mostly date from the late Qajar[9] and early Pahlavi period in Iran, this part of research addresses the culture and lifestyle during that time as the context of traditional houses in Sabzevar. On the other hand, these houses have been used to date and must adapt themselves to a new context. Therefore, the comparison of lifestyle in the past and present is necessary.

4.2.1 Comparison of the Lifestyle in Late Qajar and Present

4.2.1.1 Population and Distribution Pattern

According to the latest census taken, the Iran population was around 75 million in 2011, the graph of the population of Iran during 1900 to 2011 indicates the rapid population growth in Iran during the last decades. (Figure 4-18)



	1900	1911	1921	1926	1931	1936	1941	1946	1951	1956	1966	1976	1986	1996	2006	2011
Population (Million)	8.6	9.1	9.7	10.5	11.2	11.9	12.8	14.2	16.2	19.0	25.9	33.7	49.4	60.0	70.5	75.1

Figure 4-18: population of Iran during 1900 to 2011, data: (Statistical Centre of Iran, 2015)

Rapid population growth in Iran has changed the size of land plots, the type of houses and the lifestyle of urban residents dramatically. Migration from the countryside to cities has exacerbated these changes. In 2011, about 54 million people were living in urban areas and about 21 million people in rural areas. In 1980, the urban and rural population was about equal (each one 25 million). The following graph shows the rapid changes in the pattern of the urban and rural population over the last fifty years. In 1956, around 70 percent of people lived in villages, but now more than 70 percent of people live in cities (Figure 4-19).

9 The Qajar dynasty ended in 1925.

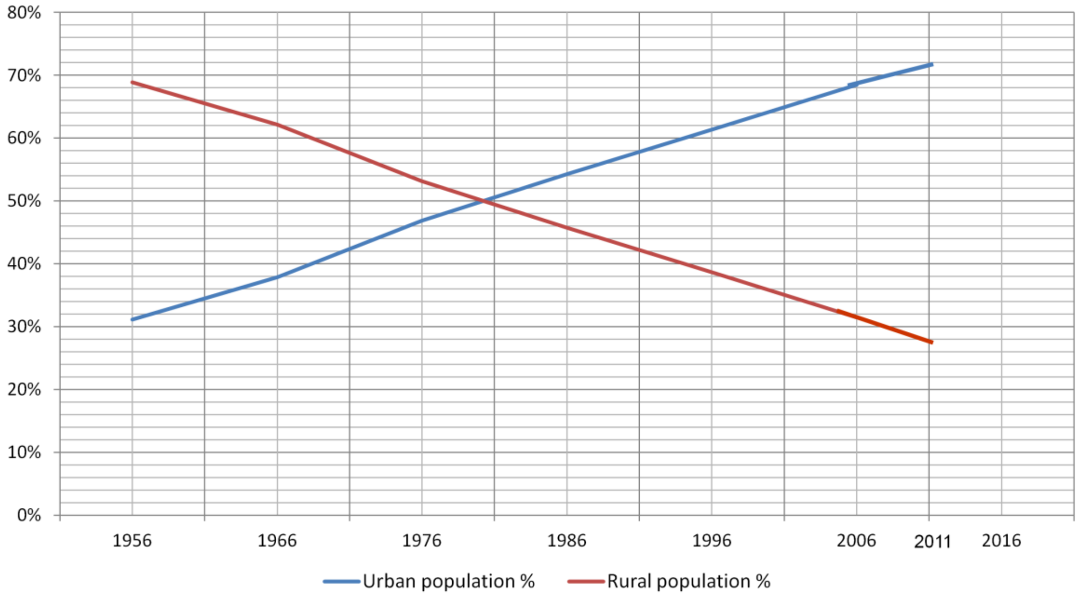


Figure 4-19: percent of urban and rural population of Iran during 1956 to 2011, base data: (Statistical Centre of Iran, 2015)

This rapid increase in urban population has put pressure on cities to provide more and more buildings for residential and other purposes. A comparison of the urban population of Sabzevar in the last half century shows that the recent urban population of Sabzevar is eight times larger than fifty years ago (Figure 4-20). This rapid growth indicates that it is catastrophic if historical cities cannot adapt themselves to new conditions.

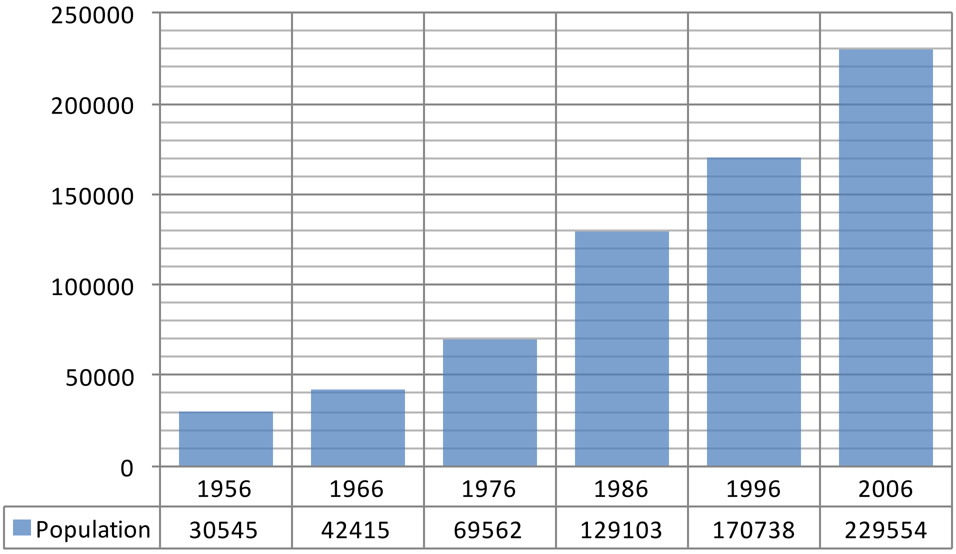


Figure 4-20: Sabzevar city population during 1956 to 2011, data: (Statistical Centre of Iran, 2015)

4.2.1.2 Family Structure and House Size

The household in the Qajar period consisted of the extended family that comprised several generations. The grandparents as the family head, and two more generations lived together in one house. Married sons used to stay in the house with their wives and children. Now the families live in single-family units; this primary social unit is called nuclear family, which only consists of parents and their children. The latest statistical data about family size in Sabzevar shows that four-person households are the most frequent ones, followed by families made up of five and three persons, respectively (Figure 4-21).

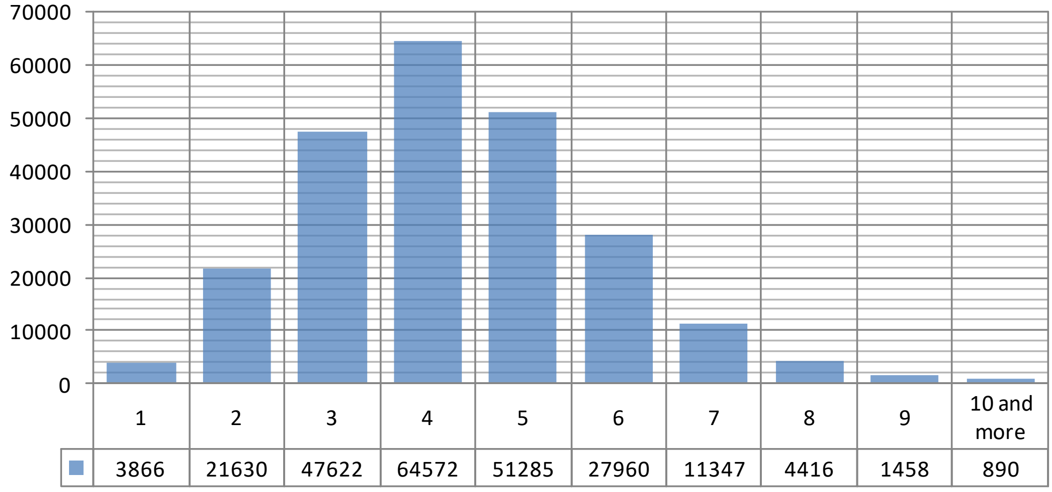


Figure 4-21: Family size, Sabzevar Household population based on the number of people in families in 2006, Data: (Statistical Centre of Iran, 2015)

In addition to the extended family in the Qajar period, in wealthy families the servants and seasonal workers lived in the same house; today this is only rarely the case. Contemporary families hire nurses and workers on an hourly basis. Statistics on the number of rooms in modern Sabzevar houses in 2006 show that most of them today have three, two and four rooms, respectively. (Figure 4-22)

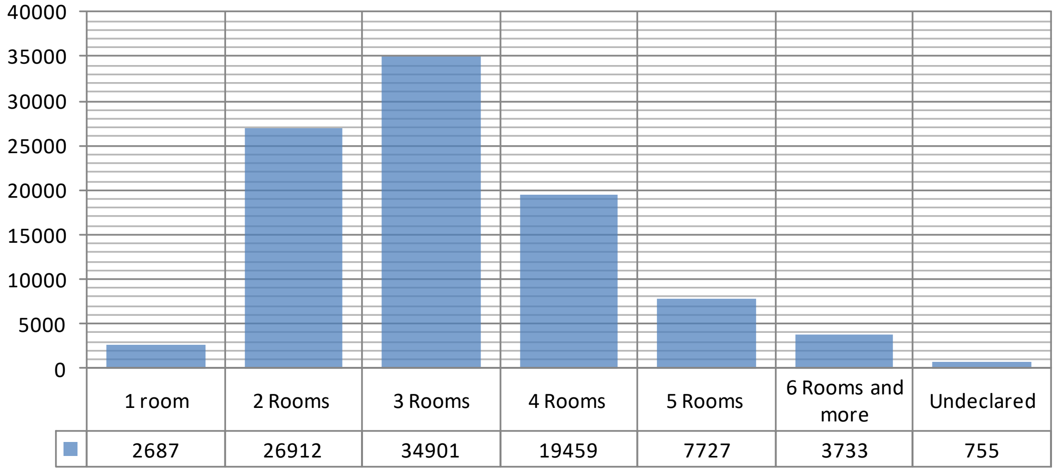


Figure 4-22: The number of households in housing units based on the number of rooms in Sabzevar 2006, Data: (Statistical Centre of Iran, 2015)

The small size of households, the rapid growth of population, rising land prices and changing lifestyles have affected the size of houses in recent years. Smaller units have replaced big households and in recent decades mostly smaller flats have been built in multiple story residential buildings. The 2006 statistic shows that most families in Sabzevar are living in houses measuring between 76 and 100 square meters. (Figure 4-23)

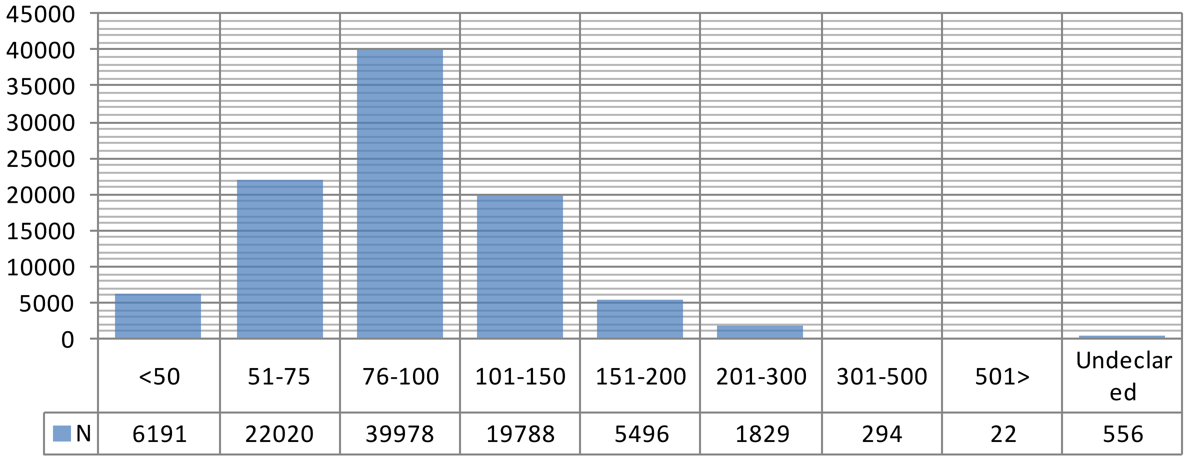


Figure 4-23: the number of Residential units according to the base area in Sabzevar 2006, Data: (Statistical Centre of Iran, 2015)

4.2.1.3 Privacy

Residential architecture in the Qajar period was influenced by the position and role of women in society. In keeping with the Islamic religion and traditional culture in Qajar, a house had to be divided into two parts: an inner area for women and men who by religion were allowed in, and an outer zone for male guests (Mahdavi, 2012) . In popular culture and Islamic law, women were not required to wear a hijab in front of their husbands, fathers, fathers-in-law, brothers, nephews and uncles that were called “Mahram” in Persian and Arabic. These people could easily retreat to the private area of the houses. But given the small size of households and buildings in contemporary houses in this region, changes in lifestyle, less presence of women in the home resulting from working in occupations outside the home; there are not two separate zones.

The main kitchen was located in the inside zone, although there would be a small pantry in the outer area for serving tea and refreshments to visitors. In wealthy families, the area for guests would have kitchens as well (Mahdavi, 2012). In contemporary houses, there is only one kitchen that serves the family and guests at the same time.

4.2.1.4 Spatial Requirements

Bread as an essential daily staple was served with all meals. It was always eaten fresh. Buying bread from the bakery was not common in Sabzevar. The housewife or workers usually prepared bread at home in a room that was especially designed for this purpose.

“Toward the end of the Qajar period, drinking water was provided by[…] water carriers who carried the water in leather containers from door to door [in Tehran]” (Mahdavi, 2012, p. 360). In Sabzevar, children and the workers had to carry drinking water from the exit point of qanats that were scattered across the city, especially in the north of the city, to the houses. Moreover, for daily washing and cleaning they stored water that flowed in the subsidiary channels branching from the main qanat water distribution system in water reservoirs and pools of houses. The water stream was not constant. It would only run for several hours every ten days.

In small cities like Sabzevar, the family economy was based on agriculture. Herbs, fruit and vegetables were grown in the fields that were usually located near the city or in the ancestral villages of the residents. Lots of rooms were required for agricultural equipment and storing of the products. By the end of winter and the beginning of the cultivation season, seeds and agricultural tools were moved to the fields for planting. In some cases, surplus agricultural products and seeds were sold at the market. After emptying the rooms, they could easily be transformed to accommodate other usages. In fact, the compact mode of life in the cold season turned again into a distributed living in summer. This possibility increases the flexibility of traditional houses. The current changes in lifestyle and in the economy of families from agriculture to business and administrative occupations entailed changes in spatial requirements.

With the new lifestyle the kitchen lost its central role; contemporary houses do not need large storages nor a large reception room; guests are now hosted in a restaurant. The new lifestyle calls for separate sleeping rooms for each member of the family, a place for watching television, space to work at home, and a garage for car(s).

Table 4-2 summarizes and compares the properties of houses and lifestyle in the late Qajar period and present.

Table 4-2: Comparison of the lifestyle and characteristics of houses in Late Qajar and contemporary houses or flats

	the late Qajar and early Pahlavi (past)	Contemporary Time (present)
Family household	Extended family	Nuclear family
The number of generations that live together	Three and more	Maximum two
The servants and workers	overnight accommodation	Without accommodation
Family and Guests	Completely separated	Without separated zones
Economy	Based on Agriculture	Based on business and administrative occupations
Family size	Large	Small
House type	Shared houses	Independent units (small flat in an apartment)
House size	Large	Small
Spaces (rooms)	Multifunctional	Mono-functional
	Shared	Independent

5 SABZEVAR FORMATION AND EVOLUTION

We cannot investigate cities without considering their environments. 'The primary physical factors for the development of Central Iranian cities have been the hostile climate and the shortage of water within the bowl-shaped physiography of the Iranian Plateau' (Kheirabadi, 2000, p. 1). This chapter examines the role of a specific type of water supply—the Qanat system—in the formation and morphology of Iranian desert cities.[10]

5.1 Iranian Desert Cities

Dasht-e Kavir and Dasht-e Lut, Iran's two largest deserts, which together amount to one seventh of the total area of the country, are located in the central plateau. The region is characterised by a typical desert climate with cold winters and hot and dry summers, low relative humidity (about 60 % in winters and 20 % in summers) and an average annual precipitation between 150 and 300 mm (Ghobadian, 2009, p. 24). The main cities of the central plateau of Iran are mostly concentrated on the outer edge. This distribution of the cities within the territory is determined by climatic conditions. Due to scarce precipitation and rapid evaporation of water prevailing for more than six months of the year, the region lacks permanent rivers, and therefore it was hard to establish permanent settlements. A society of livestock breeders had to move between mountains and plains seasonally in order to nourish themselves and their animals, but the invention of the 'Qanat' (from a Semitic word meaning 'to dig', in Persian 'Kariz') changed living conditions in this area. By means of these underground aqueducts water was funneled from mountainous areas and aquifers to lower lands. Alluvial fans could be opened up to settlements, and agrarian civilisations evolved.
The Qanat became a crucial element of the habitat. The nomadic herding was largely replaced by settled farming. Nadji (1972, pp. 938-939) states that the sedentary civilization in the central plateau of Iran evolved through the qanat (Kariz) technology and calls it 'Kariz's Civilisation'. In his opinion, over the past centuries the Qanat system has played a key role in various aspects of civilisation in this region.

[10] The sections 5.1. to 5.6. in this chapter are a slightly modified version of a part of the following paper: Estaji, H. and Raith, K. 2016 "The Role of Qanat and Irrigation Networks in the Process of City Formation and Evolution in the Central Plateau of Iran, the Case of Sabzevar", In: Arefian, F. F. & Moeini, S. H. I. (eds.) Urban Change in Iran. Springer International Publishing.

5.2 The Structure of Qanat

A qanat is a water supply system that taps groundwater reserves and channels them to settlements and agricultural areas located at a lower level. It consists of a slightly inclined underground gallery and a row of vertical shafts giving access to the low-lying tunnel. Usually 'the first shaft (mother well) is sunk[en] … into an alluvial fan to a level below the groundwater table' (International Centre on Qanats and Historic Hydraulic Structures, (ICQHS, 2012)).

The length of a qanat depends on various factors: the topography, the location of the aquifer and the material of underground layers. It can range from a few hundred metres to several dozens of kilometres. According to the definition of the ICQHS (2012) each qanat consists of three main sections: *water production* (the section where underground water resources are developed), *water transport* and *water use*. The most important parts of a qanat are described as follows (Figure 5-1):

• Gallery: The gallery serves both water production and transport, and extends over both sections, i.e., from the groundwater recharge zone to the zone where the water is used. It is a tunnel, which taps a water-bearing stratum (aquifer) and channels the water to the surface over a long distance. The extremely low gradient [maximum 1:1000 or 1:1500 according to English (1968, p. 173)] prevents the gallery from being eroded by rapidly flowing water.

• Shaft wells: are the vertical funnels or ducts, which are dug at intervals between 20 and 200 m (depending on the depth of the gallery). While the qanat is being constructed, they are used to remove excavation material and are essential for ventilating and maintaining the qanat.

• Mother well: The mother well is the shaft located closest to the aquifer at the beginning of the qanat. As such, it is also the deepest of all the shafts along the gallery. Mother wells can have a depth of up to 300 m (the qanat of Gonabad).

• Exit point of the qanat: At the exit point of the qanat or 'Mazhar' (literally 'where the water appears') the gallery meets the surface.

• Farm: Agricultural areas located lower than the Mazhar are supplied with water via surface channels. 'The extent of the cultivated area depends on several factors such as the qanat discharge, soil quality, soil permeability, local climatic conditions, etc.' (ICQHS, 2012).

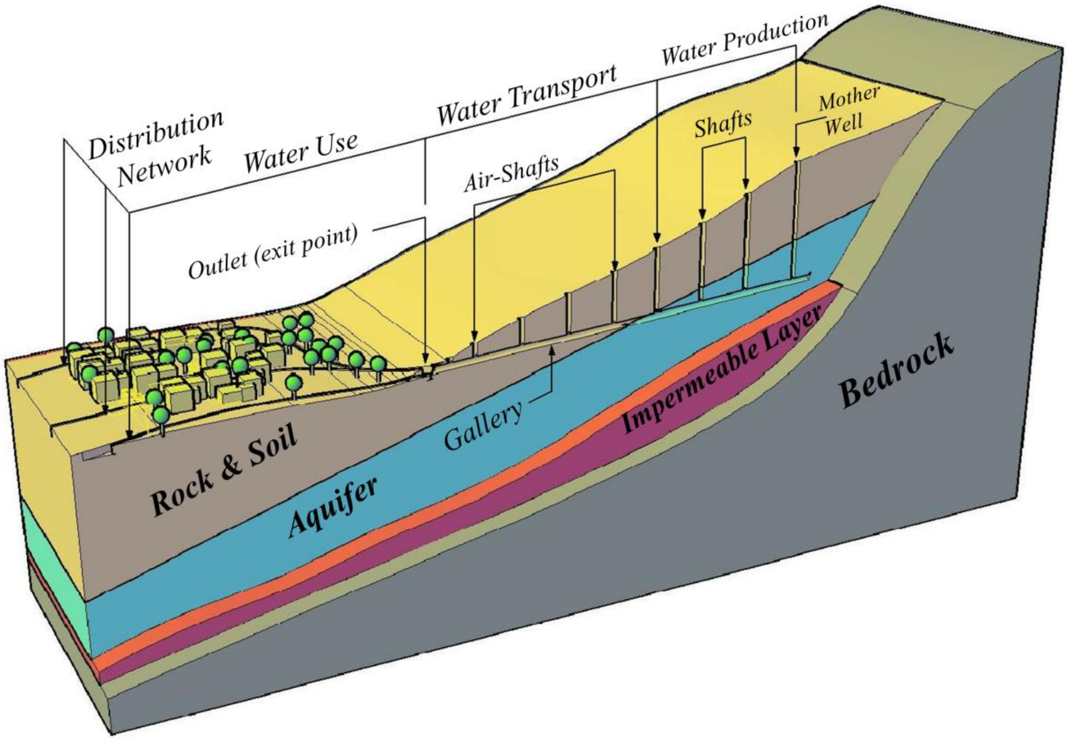


Figure 5-1: 3D cross-section of a typical qanat (Estaji and Raith, 2016), data from (ICQHS, 2012)

5.3 Human Settlements and the Geographical Distribution of Qanats in Iran

‘The qanat technology was known in Iran by the sixth century BC, when Indo-Iranians began to settle as agriculturists’ (English, 1998, p. 196). To meet the challenges of positioning the qanats almost all large towns and early settlements were built on the plains between high mountains and the desert, on the outer rim of the central plateau of Iran. The statistics and the map of the geographical distribution of qanats in Iran clearly show this pattern (Figure 5-2).

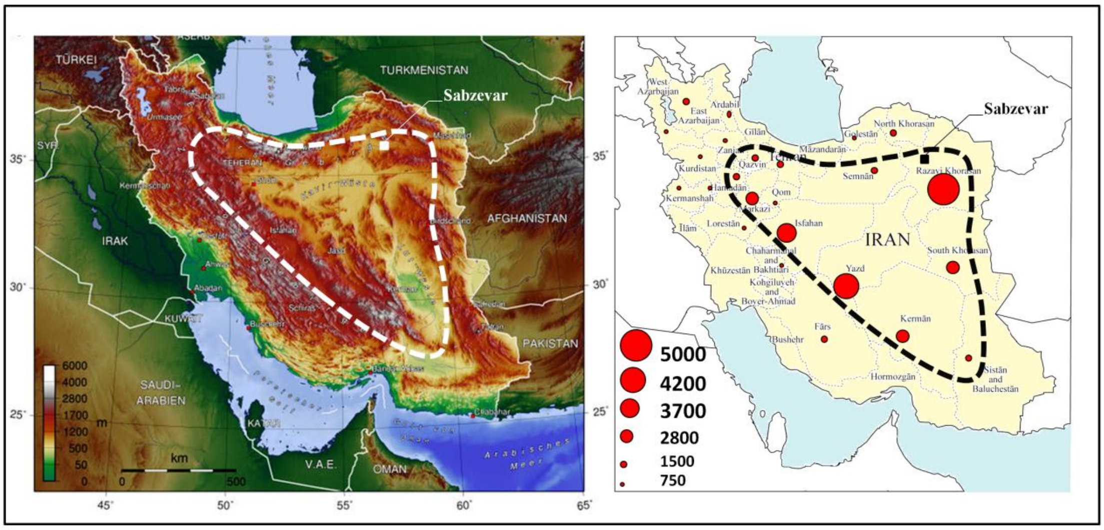


Figure 5-2: Left Topographic map of Iranian central plateau (World of maps, 2011). *Right* The number of qanats in 2005 in each province, data from Iranian qanat database (Iran Hydrology, 2005), blank map:(Sankakukei, 2012), presented by (Estaji and Raith, 2016)

By providing water for the fertile downstream lands qanats facilitated the development of Iranian cities in the plains of desert regions.

5.4 Sabzevar

Sabzevar is located in the northeast of Iran, south of the Sabzevar Mountains (also known as Siah-Kuh or Joghatay Mountains) on the outer edge of the Central Plateau (Figure 5-2). These mountains lie 80 km to the south of the East Alborz. The city and the neighboring villages are situated between the mountain range and the Salt Desert, parallel to the Sabzevar Mountains. According to the last statistics released by the Ministry of Agriculture (Iran Hydrology, 2005), there are 864 qanats in Sabzevar and the surrounding villages. The location of the settlements and the main qanats confirms that Sabzevar and its surrounding rural settlements were established according to the qanat system. The distance between the mountains and the settlements is between 10 and 15 km depending on the length of the main qanats (Figure 5-3).

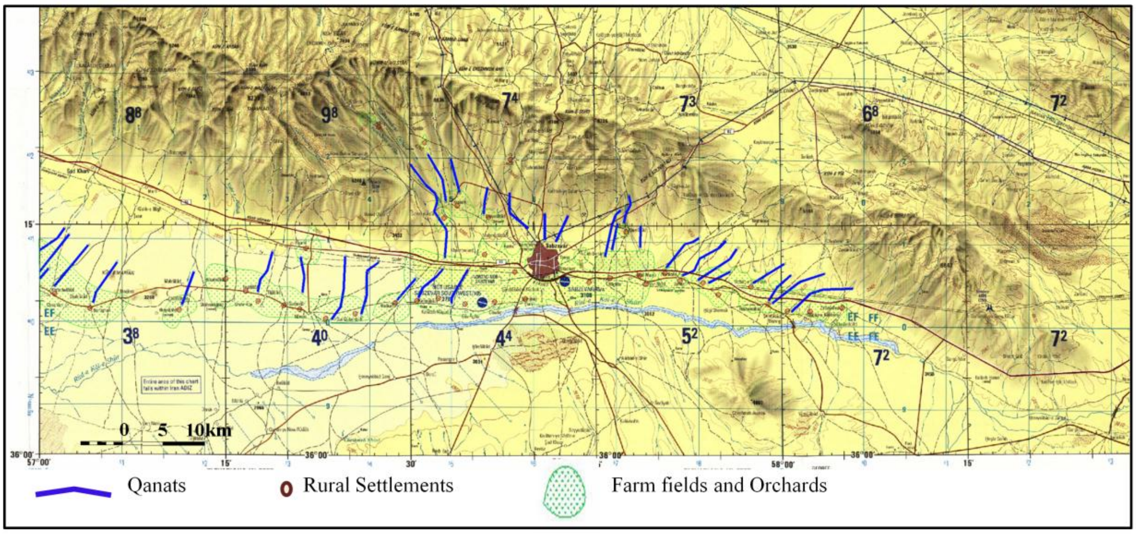


Figure 5-3: Distribution of main qanats in the Sabzevar region (Estaji and Raith, 2016), base map: (National Imagery and Mapping Agency, 1999)

5.5 The Qanat Network

'The built environments of most alluvial fan towns and villages on the Iranian Plateau are aligned along the major watercourses (shahjub) that run from the mouth of the qanat down the slope through the length of the settlement' (English, 1998, p. 198).

The hierarchy of the irrigation network is as follows (Figure 5-4):

1. Main irrigation channels: main water streams usually run parallel to the main slope of the land.

2. Sub-main irrigation channels (link channels): flowing into fields following land topographies.

3. Subsidiary channels: branching from main networks. These smaller streams irrigate the gardens and farms and provide water for ‘water storage’ in houses.

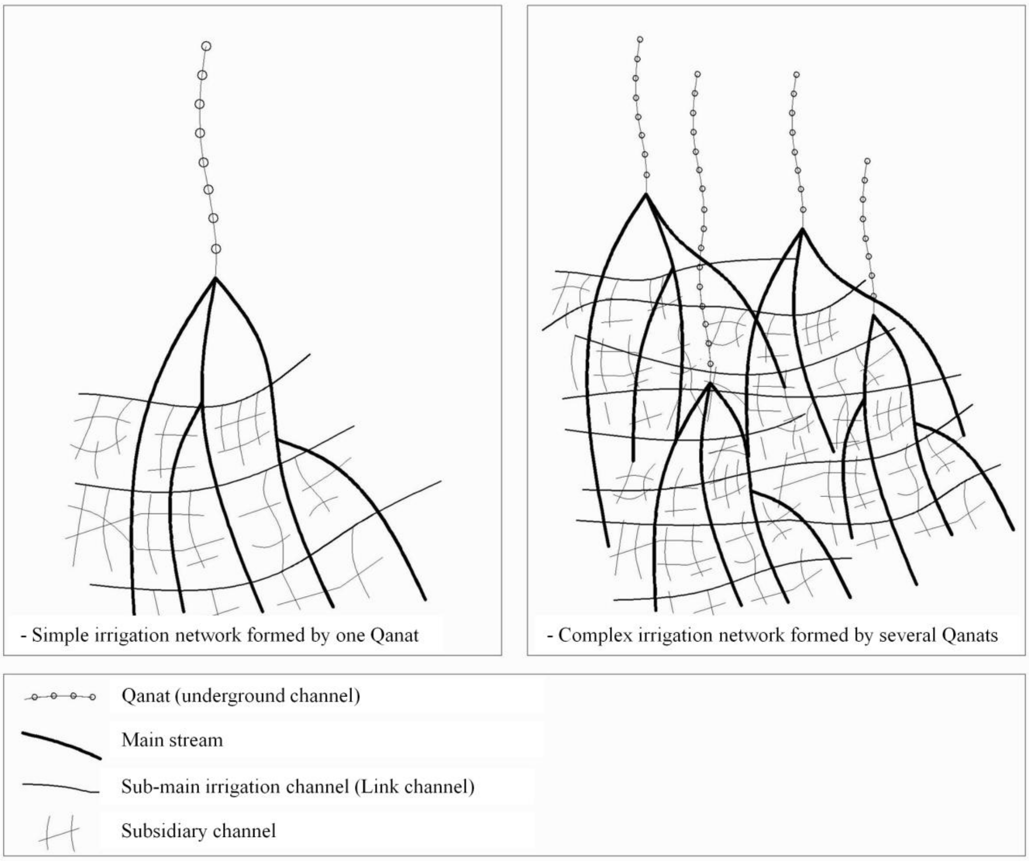


Figure 5-4: irrigation network (Estaji and Raith, 2016)

In a dry climate, water ownership is more important than ownership of the land. The qanat network allows landowners to buy water from several qanats. This flexibility makes the irrigation network a sustainable system. If one of the qanats dries up or needs repair, this organic network enables farmers to bring water from another qanat to their farms and gardens via link channels (sub-main irrigation channels).

5.6 The Role of the Qanat in the City’s Morphology

For repair and maintenance of the qanat and irrigation networks, and to make gardens and farms accessible, ancient Iranians had made narrow paths for humans and animals on one or both sides of the channels. The width of these paths depends on water discharge rate and the hierarchy of the qanat network. The primary function of qanats and irrigation systems was to supply water for household consumption and agriculture but as a side effect a spatial pattern was created which played a formative role in the city layout and urban evolution. The water supply system is thus one of the important influences on the morphology of desert cities. As an Iranian desert city Sabzevar also emerged according to this pattern – a point mentioned by Kheirabadi (2000, p. 33) in his book. For a more detailed study, two maps of the old Sabzevar irrigation network and the historic streets and alleys were drawn up (Figure 5-5). A comparison of these maps revealed that the urban pattern of the old Sabzevar matches the irrigation network. When in the course of urbanization farming lots were built up and turned into houses with gardens, main streets were laid out along the course of main irrigation channels and alleys along subsidiary channels. The resulting street pattern corresponds to the irrigation network and, interestingly enough, the hierarchy of streets follows the hierarchy of the water distribution network. This map shows the final years (around 1950) of the qanat system still fully functioning in Sabzevar. At that time three main and around 15 small qanats were included in the system that provided water for 30,000 people.

In the early twentieth century, a transformation from an agrarian to an urban society took place. Growing wealth, together with the development of fossil energies, led to a sharp increase in motor traffic. As a result of population growth, the demand for drinking water grew. Cities expanded into suburban areas and overran gardens.

Surface channels were replaced by underground water pipes for sanitary reasons.

The vital vessels of running water on the surface lost their life and gardens dried up. These developments happened about sixty years ago. Nevertheless the 'dead network' and the dried gardens and farms kept their formative role for urban development. The network of the irrigation system, which was already accompanied by public spaces, now became streets and alleys and dried farms and gardens were divided into smaller lots for residential buildings (Figure 5-5).

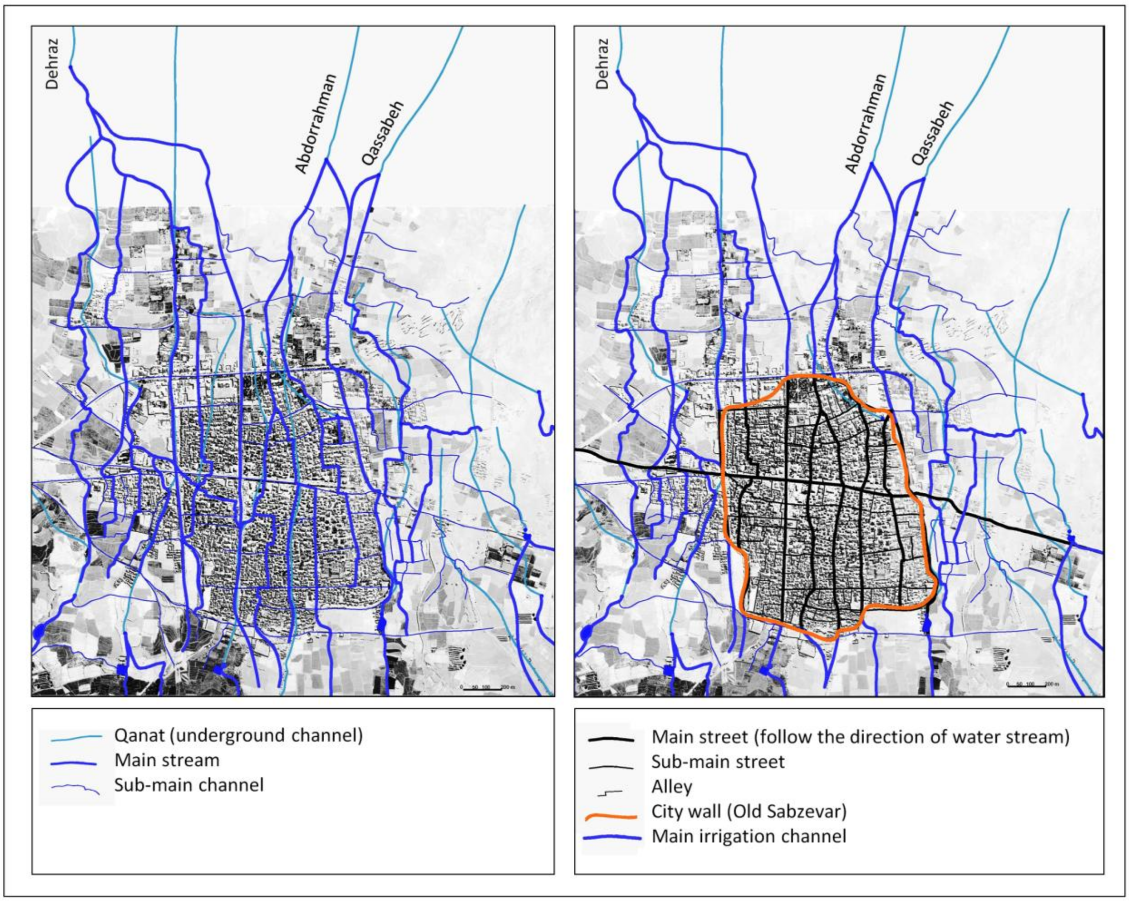


Figure 5-5: old Sabzevar irrigation network and the position of old Sabzevar and the city wall based on the 1956 Sabzevar map (Estaji and Raith, 2016), base map: (Zanganeh, 2003a)

The first law concerning the ‘widening and development of streets’ in Iran, approved by the Iranian parliament in 1933, accelerated these changes. The municipalities made a master plan with the objective of facilitating traffic. In the first years of this urbanization process, traffic density was still relatively low and so problems could be solved by slightly modifying the dried irrigation network.

The following maps (Figure 5-6) show the transformation of farming lots into urban residential spaces in Sabzevar (the southwest of the old city is shown as an example). The last part of the old city wall can be seen clearly in the 1956 aerial photo - it was demolished and replaced with a new street in 1964. Until 1975 the irrigation network determined the street pattern even after losing its original function. After that the organic network could no longer cope with the traffic due to the increasing number of cars. In the last decades the traditional order of the city was abandoned. The authorities and urban designers chose the simplest solution for the traffic problem: starting in 1975, they cut a rectangular grid of new wide streets into the urban fabric of Sabzevar- ignoring the centuries-old structure of the city. These incisions can be seen in the aerial photograph of Sabzevar (Figure 5-6).

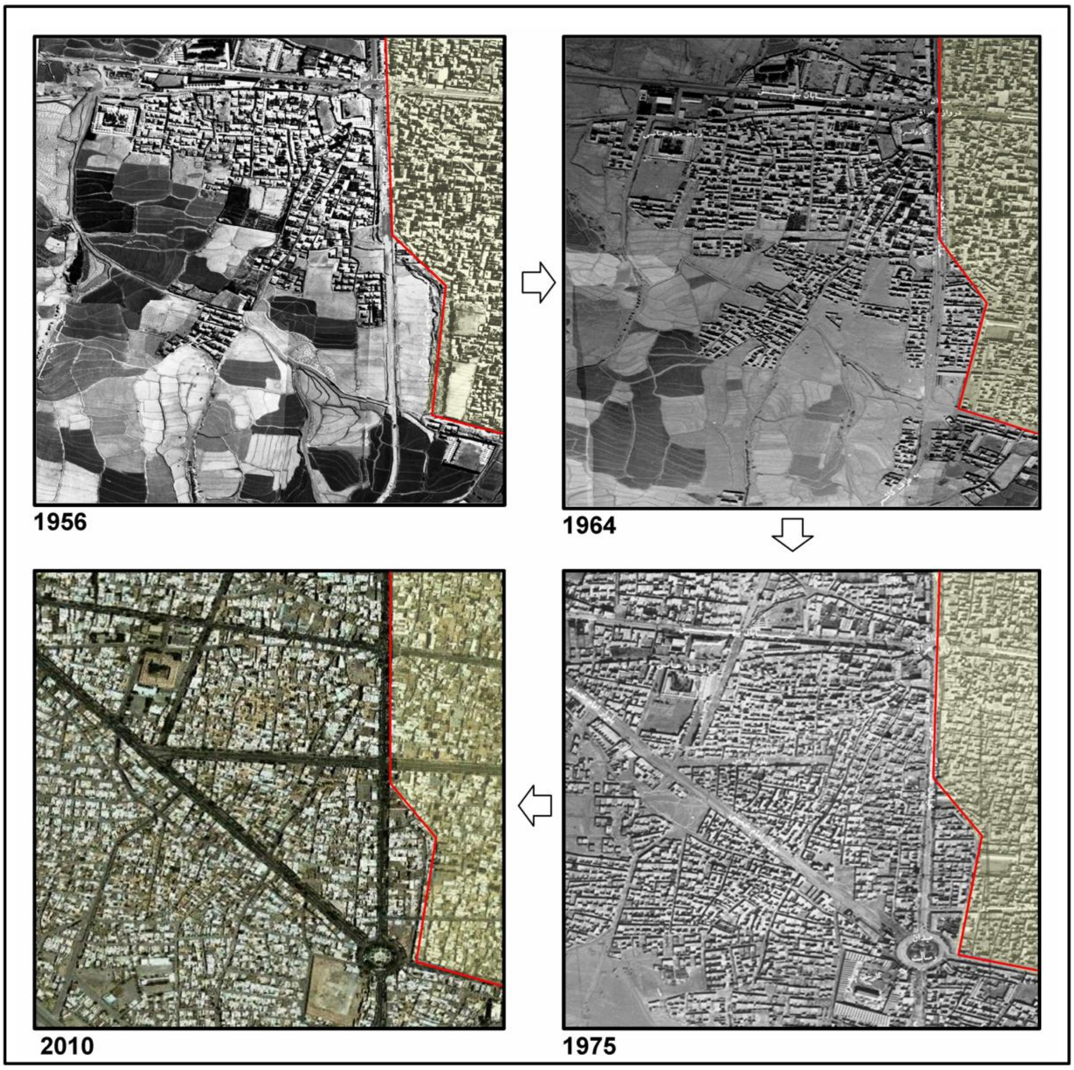


Figure 5-6: the development and transformation process of the south-west part of Sabzevar (Estaji and Raith, 2016), base maps: (Zanganeh, 2003a, b, c) and (Google Earth, 2010)

The qanats as sustainable irrigation systems played a key role in the foundation and development of agricultural settlements on the Iranian plateau. The local water conditions and the possibility of building qanats determined the location of the main Iranian cities in this region, on the plains between the high mountains and the desert on the outer edge of the central plateau of Iran. The ancient Iranians constructed qanats and irrigation networks primarily for household water supply and farming, but at the same time these networks determined the shapes and growth patterns of cities. In fact, they created the foundation platform for city formation and urban evolution.

Thus the water supply system is one of the crucial influences on the morphology of the Iranian desert cities. For example, the urban pattern of old Sabzevar matches the irrigation network and the hierarchy of the old Sabzevar streets, following the hierarchy of the water distribution network. This network kept its role as a formative force in urban development even after losing its original function. The urban development pattern of Sabzevar is based on the transformation of farming lots into urban residential spaces. The no longer used irrigation network and the path system connected to it kept their shape and became streets and alleys; the dried farms were divided into smaller lots of land for residential buildings.

5.7 House Orientation According to the Position of the Sun

Was the building orientation in Sabzevar determined only by the old irrigation network? Or were the houses designed according to seasonal variations in the sun's path and prevailing wind patterns?

The main slope of Sabzevar is north to south, so for this reason the underground channel and main irrigation channels were laid out in this direction. On the other hand, the sub-main irrigation channels (link channels) followed the direction of the topography that in Sabzevar in general is west to east. It means that the old water distribution network formed a north-south grid that had been turned into the street and alleys.

Chapter 4 (4.1.1.6 Solar Radiation) indicated that the best building orientation in Sabzevar only based on the radiation incident for the entire year is south, between 10 degrees orientation to the west and 15 degrees to the east (Figure 4-17). It was noted, on closer scrutiny, that the best orientation for a house in Sabzevar could be calculated on the basis of some additional criteria. The first criterion is ensuring maximum shading on horizontal surfaces of courtyards and passages on hot days. For this purpose a simple vertical surface is assumed as given and the lengths of shade in different orientations are calculated by means of Rhino/Grasshopper, and Geco and Galapagos (it is an Evolutionary Solvers and Genetic Algorithms plug-in for optimization). The best orientation for this surface is north- south with a three-degree rotation to the east.

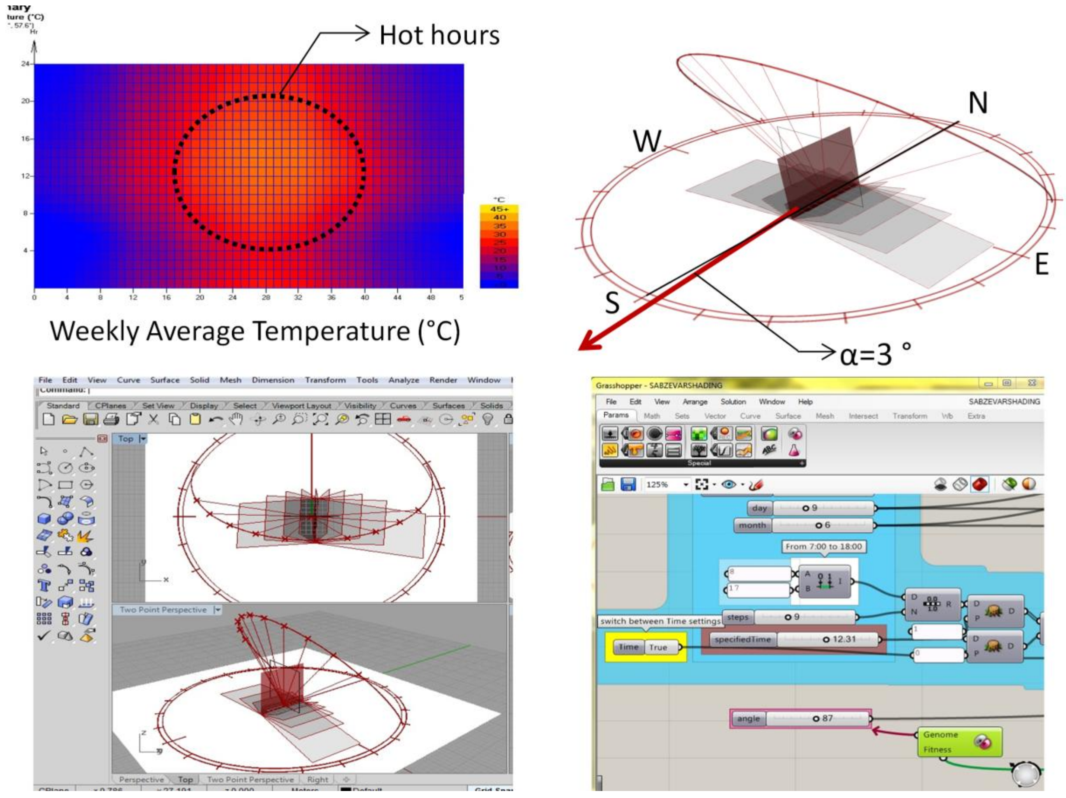


Figure 5-7: best orientation to have the maximum shade in hot days in Sabzevar

The second criterion is obtaining minimum radiation on the horizontal surface of a simple pathway during hot days in Sabzevar. Shading does not only depend on the orientation of the alley, but also depends on the width of the pathway and the height of the walls on each side. A four meters wide pathway, enclosed by four meters high walls was modeled. It showed that the best orientation for the streets and alleys is north/south with a six-degree rotation to the west.

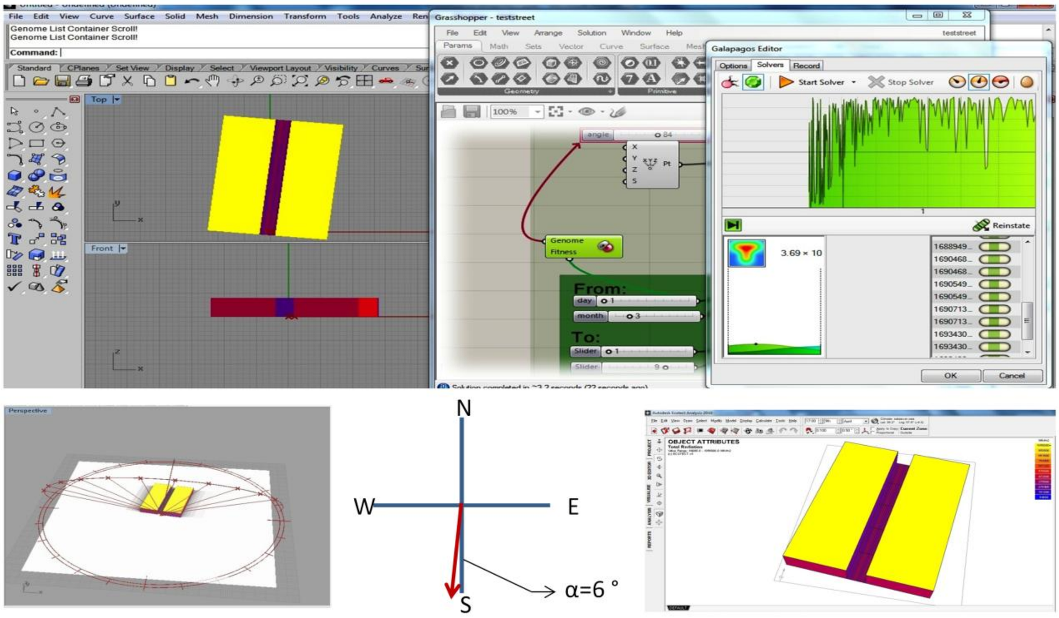


Figure 5-8: best orientation for minimum total radiation on street on hot days in Sabzevar

The optimum orientation in Sabzevar for a façade to receive the maximum total radiation on cold days and minimum on hot days is north to south with a seven-degree rotation to the east.

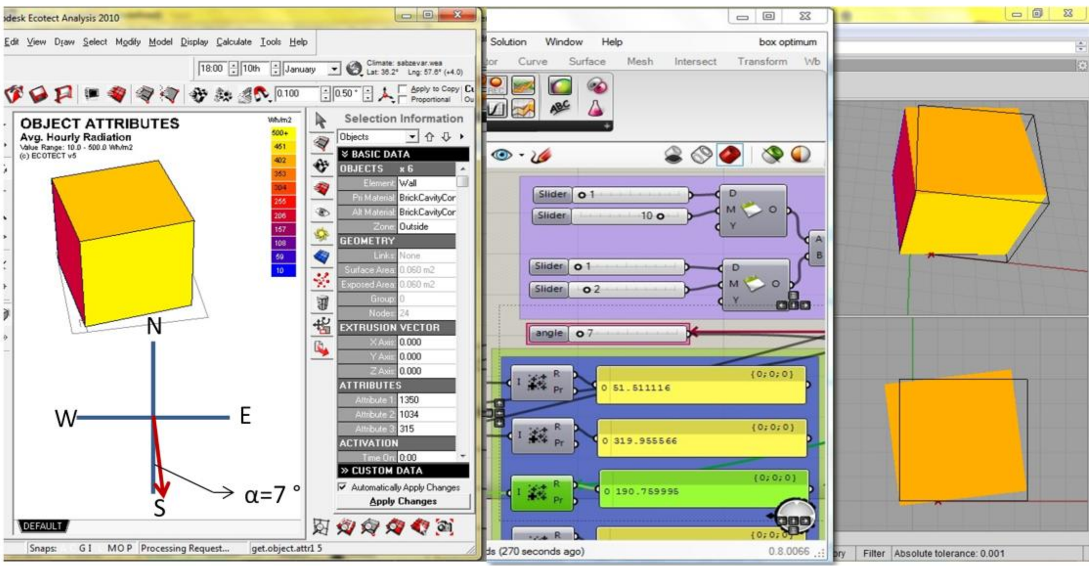


Figure 5-9: optimum façade orientation in Sabzevar

Another tool for optimizing building orientation is Weather Tools of Autodesk Ecotect Analysis. The main criteria are achieving maximum solar radiation in winter and avoiding sun radiation on hot days. This tool uses all environmental factors of a site for this purpose. The best orientation for Sabzevar calculated by Ecotect is north/south with a five degrees rotation to the east.

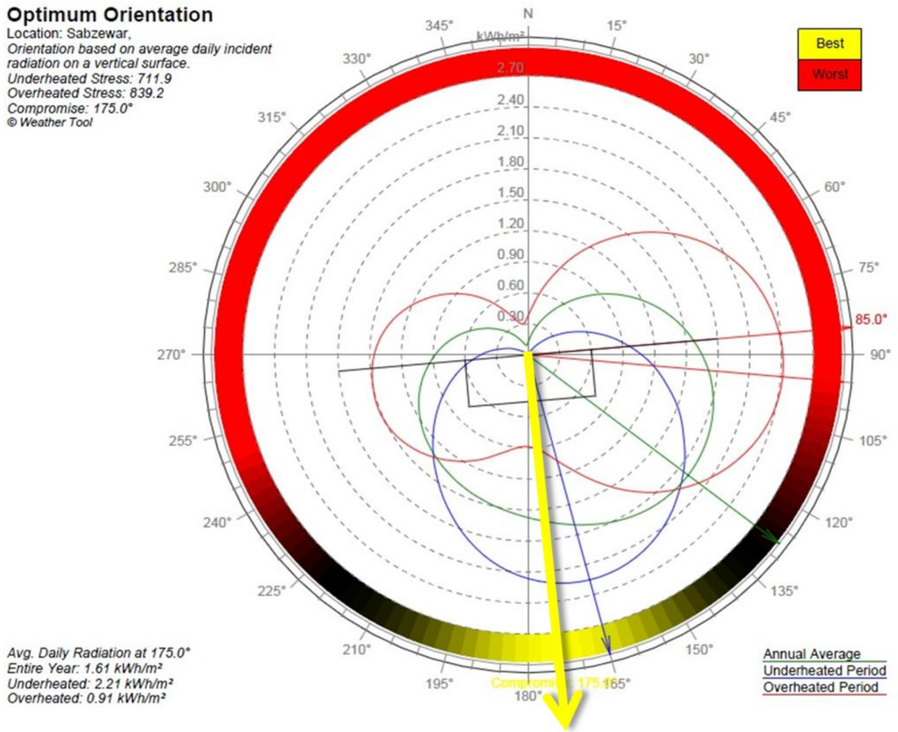


Figure 5-10: optimum orientation in Sabzevar calculated by Weather tools of Autodesk Ecotect Analysis

According to the above calculations for buildings in Sabzevar the best direction for the main façades is south. It is remarkable to see that there is a convergence between the optimum house orientation in Sabzevar and the urban access network resulting from the irrigation network. There is also no courtyard rotation in the land plots of the Sabzevar houses. We can thus conclude that there is a perfect convergence between these two grids.

Whether it is a coincidence that the best façade orientation and the grid orientation determined by the qanat system do not conflict with each other or whether the position and orientation of the city was purposefully chosen right from the beginning in order to meet all of these requirements would be worth a further, historical investigation.

6 TRADITIONAL HOUSES IN SABZEVAR

This chapter introduces and classifies traditional houses in Sabzevar from the late Qajar and early Pahlavi period. In fact, these houses belong to the last decades of the last traditional Iranian architecture style (Isfahani style) that is associated with the old city of Sabzevar. The rapid development of Sabzevar in recent decades, the changing lifestyle, the increasing number of cars in the city, the ignorance of authorities regarding the preservation of historic buildings, and the rapid growth of land prices in Sabzevar has resulted in the destruction of most of the valuable historical buildings or the loss of their original function. In 2008, I started to collect and document the preserved valuable houses in a research project that I conducted with the help of a group of students (Minoo Qasemi, Ahmad Ashkani-rad, Ali Kiani-Pouya, Narges Kheirabadi, Reza Bahadori, Arash Sayyadi) from the Faculty of Architecture and Urbanism. Hakim Sabzevari University (HSU) supported the research project. For this purpose, various documents (old maps and photos) from several sources were collected and compared. The main sources used for this project were the archives of the local office of Iran Cultural Heritage, Handcrafts and Tourism Organization (ICHTO) in Sabzevar, official documents submitted to register houses on Iranian Heritage List and finally field work. The research project *'Heritage of Ancestors: A Documentary of Traditional Houses in Sabzevar'* (in Persian: میراث نیاکان: مستند نگاری خانه های تاریخی سبزوار)(Estaji, 2010) was completed in 2010.
The raw material of this chapter, which includes maps, plans, photos, and sketches, is based on that unpublished research. In order to make the architectural surveys comparable I reproduced them in a consistent style for the present work. In keeping with the new research requirements, I also had to create some new plans, e.g., site plans referring to different time periods, perspectives, and so on.

6.1 Building Materials

One of the main principles of sustainability in traditional architecture – not only in Iran but all over the world – is 'self-sufficiency'. Traditional architects tried to maximize the use of locally available material. By using local materials a building would be more in harmony with its environmental context and materials would always be easily available for expanding, changing and repairing the building, (Qayyoomi Bidhendi and Abdollahzadeh, 2015).
Traditional buildings usually were located in the less fertile part of agricultural lands. The workers that usually were the owner's relatives dug foundation pit and sorted the obtained soil into large stone, gravel, sand and clay. They used stone and gravel for the foundation and produced adobe (sun-burned) bricks from clay and sand for building walls, vaults and domes.

The adobe brick production was easy and the product had very low embodied energy. It is about 2500 BTU[11] per brick, as the following chart (Figure 6-1) shows, in which the embodied energy of adobe is compared with the equal volume of other building materials.

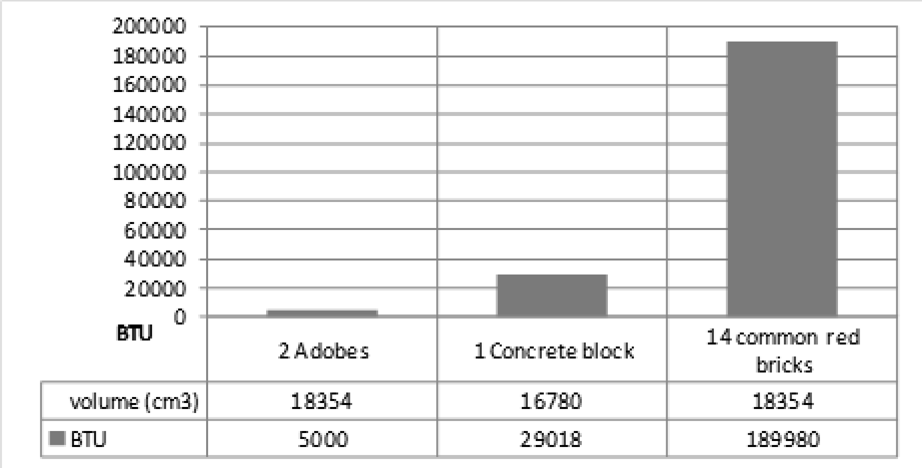


Figure 6-1: Embodied Energy of Adobe in compare with the equal volume of other building materials, data from (Sanchez and Sanchez, 2008)

This mode of brick production, unlike fired brick, does not remove the soil from the natural life cycle. This sustainable strategy minimizes the negative environmental impacts resulting from building demolition. Even in some cases, the farmers use this construction debris for fertilizing their farms. The following diagram (Figure 6-2) illustrates this cycle.

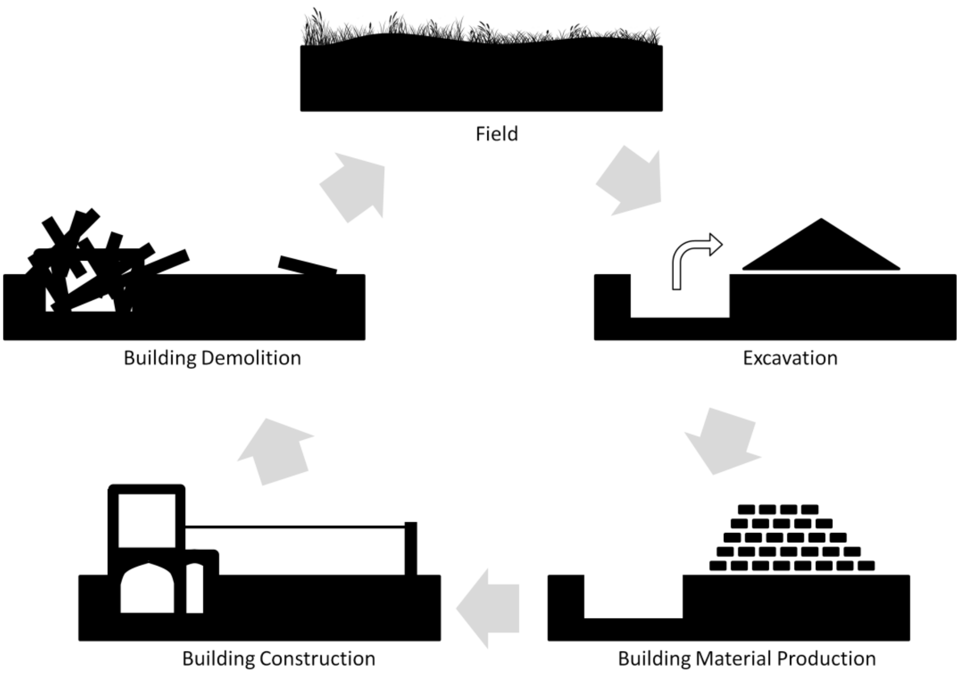


Figure 6-2: the natural life cycle of adobe houses

[11] BTU (British Thermal Unit) is the amount of energy needed to heat one pound of water by one degree Fahrenheit.

The old photograph of Sabzevar shows the close relationship of buildings and agricultural lands in the historical fabric of Sabzevar (Figure 6-3). In the other photo, the homogeneity of used natural materials, taken from the ground, is clearly visible.(Figure 6-4)

Figure 6-3: Sabzevar city from the top of Governmental Castle towards to the Grand Mosque in 1895, photo by Abdullah Qajar, source: the local archives of ICHTO

Figure 6-4: Sabzevar city from the top of Grand Mosque towards the Governmental Castle in 1895, photo by Abdullah Qajar, source: the local archive of ICHTO

The use of earth materials in traditional architecture has many advantages. It balances indoor climate by absorbing and emmiting humidity and storing heat; it works as a thermal mass. Usable soil is often found on the site, as a result of which production and transportation costs are reduced. Construction can usually be executed by non-professionals. The loam preserves timber and other organic materials (Minke, 2012); "Owing to its low equilibrium moisture content of 0.4% to 6% by weight and its high capillarity, loam conserves the timber elements that remain in contact with it by keeping them dry." (Minke, 2012, P. 13)

The earth walls can absorb pollutants dissolved in water (Minke, 2012, P. 13). It is a fire-resistant material; In addition to being non-flammable, it can protect the wooden structures inside the walls and ceilings against fire. Finally, it is easy to recycle and reuse.

Minke (2012) addresses three problems of using earth materials in building construction. First, adobe is not a standardized building material because the amounts and types of clay, silt and sand differ from site to site. Second, due to the evaporation of the water used to prepare the Adobe, the loam mixtures shrink while drying. And third, it is not water-resistant and must be protected from rain and frost. In addition to these disadvantages other problems might also be cited; due to the low tensile strength and considerable weight, the structures with this material are vulnerable to earthquakes. Thick earth walls consume more floor area than slender skeleton structures; this reduces the economic efficiency of land usage.

In traditional Iranian architecture some strategies are applied to reduce the weakness of adobe structures. Straw added to the bricks and mortars served as reinforcement and prevented the material from cracking

Adobe is not water-resistant and must be protected from rain and frost. For this reason, buildings were traditionally covered by a more rain-resistant layer. In the Qajar period commonly baked bricks and 'Kah-gel'-plaster of clay and straw were used. Kah-gel' is a mixture of clay, straw and water. To produce one cubic meter of it, around fifty kilograms of straw, four hundred liters of water and one cubic meter of soil are mixed and after three or four days the mixture is ready for use.

Since fired baked bricks were produced outside the site, the house builders tried to reduce their use in building construction in order to minimize production and transportation costs. In the traditional houses of Sabzevar, baked bricks were used only for the main facades. They simultaneously serve as a rain-resistant material and a decorative element (Figure 6-5).

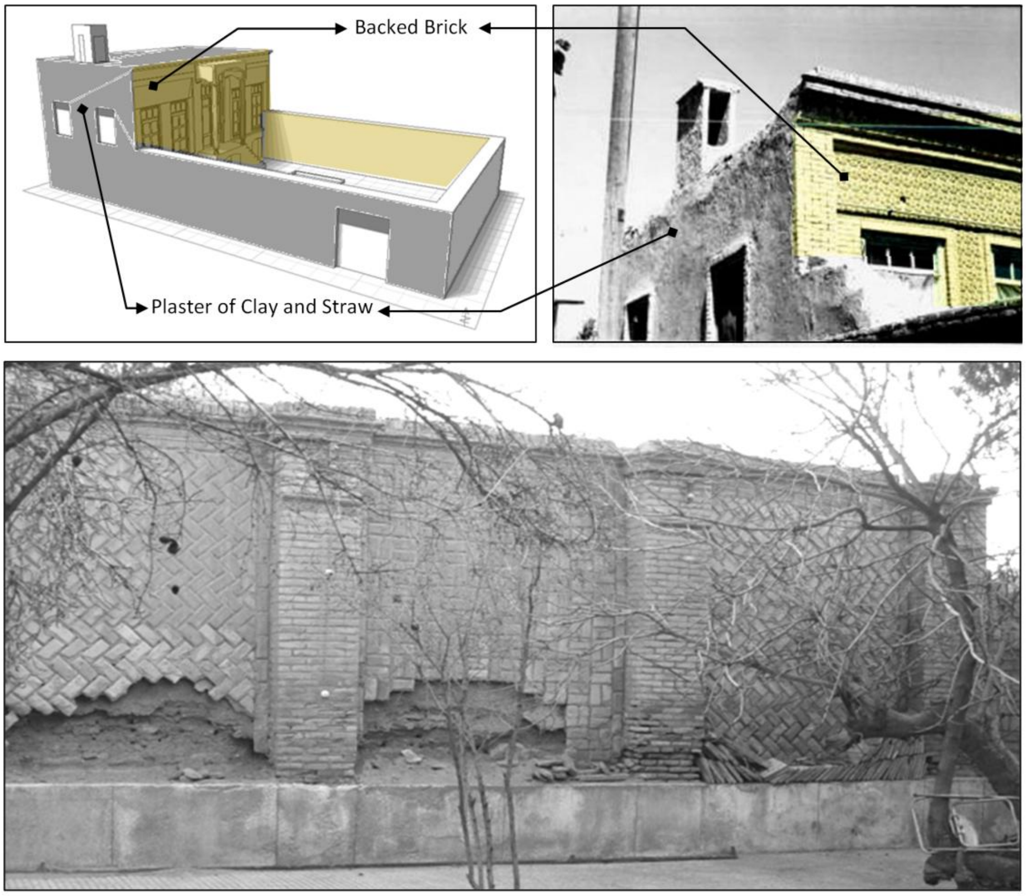


Figure 6-5: top: different façade finishing materials in the Afchangi house (Sabzevar, end of Qajar), right photo by Kermani-Moqaddam (2002a), bottom: baked bricks as a rain-resistant material and a decorative element, Hejazian house

Another strategy for reducing the amount of required materials in the load-bearing wall was to make niches on both sides of the wall. For this purpose, arches were integrated in the wall (usually 3 or 5) which also provided potential openings and could be turned into niches or doors. This strategy improved the usability of space and above all, increased the building's flexibility to be able to accommodate for future changes. This capability enabled residents to change the spatial configuration of the house with minor constructional modifications. Figure 6-6 shows various scenarios for a wall between two rooms. Alternative (A) provides three niches for the left room, while the second alternative (B) connects the rooms, and alternative (C) provides two niches for each room and a door between them. In the last alternative, there are two niches for the left room and one for the other room.

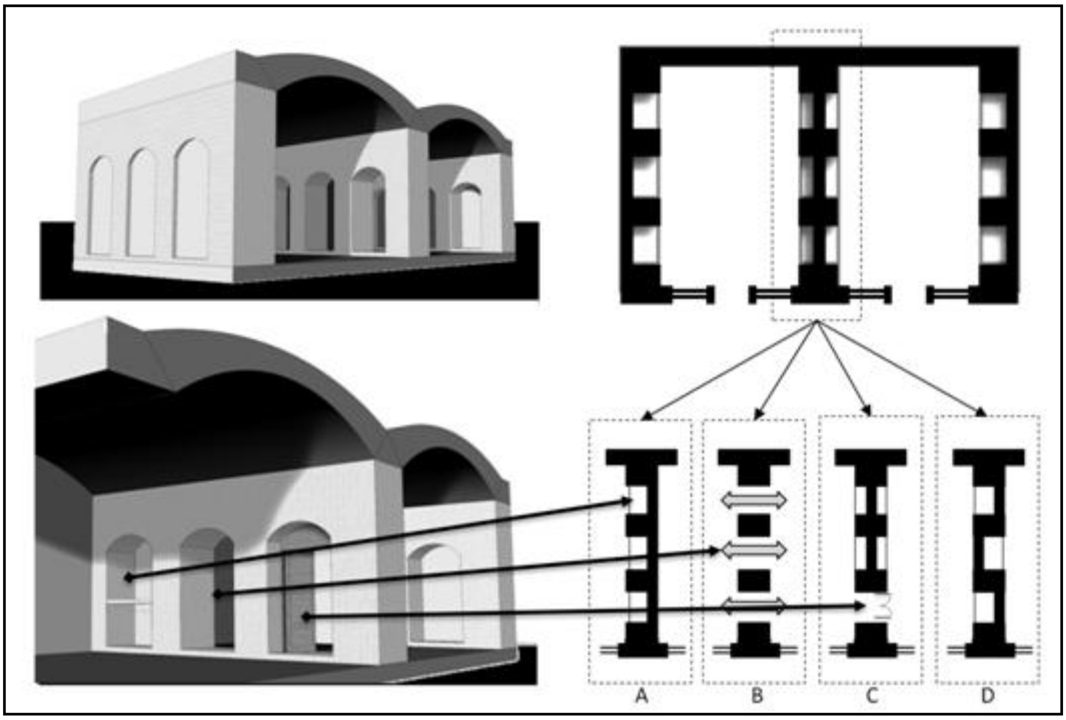


Figure 6-6: different possible scenarios for a load-bearing wall

The use of non-local materials in the house construction was inevitable. Fired bricks were produced in the southern suburb of Sabzevar. Timber came from surrounding villages. Limestone, gypsum, glass, and iron were produced outside the city.
The construction system and the materials required for each individual building were selected depending on various factors. The economic and social conditions of the owner, the size of the building, the availability of wood, the soil quality on the site, and the availability of skilled workers determined the choice of construction methods and materials.

6.2 Building technology in the Traditional Qajar Houses in Sabzevar

The 19th century marked the beginning of intensified communication between Iran and the West. The Qajar era was a transition period from traditional to modern architecture in Iran. As traveling and commercial relations with the West increased and students were sent to Europe to bring modern knowledge and technology to Iran, little by little, the traditional Iranian architecture assimilated influences from western and global modern architecture.
Due to the great distance from the capital, the agriculture-based economy, strong religious beliefs and local culture the small historical city of Sabzevar was affected by these changes much later. For Sabzevar, the transition from traditional to modern architecture only happened in the first Pahlavi period (1925-41). This means that Qajarid traditional houses in Sabzevar can be regarded as the last traditional Iranian architecture in this region. The techniques used in building construction are also local and traditional.
All houses that were built in Sabzevar during the Qajar period have one or two stories. The main structural elements are load-bearing walls, columns, floors and the roof. The main functions of load-bearing walls are transferring the compressive loads to the foundations,

acting as shear walls and providing a stable base for the roof. Columns rarely played a structural role. They only had to carry the wooden roof of a portico or a pillared veranda. They primarily served as decorative elements. There were two methods for roofing: flat wooden roof and domed brick roof. The following picture (Figure 6-7) shows the common roofing for one- or two-story Qajar houses in Sabzevar. In one-story buildings, the use of domes was more common than the flat roof. On top of the dome, there was an opening that allowed for a skylight through the roof into the rooms and provided ventilation in summer. This opening lets the warm air, which accumulated under the ceiling, to go out and be replaced by fresh air that comes in through doors and windows.
The Qajar architects tried to reduce the weight of the structure from the bottom to top. For this reason, the floor construction above the ground floor of two-story buildings usually was made with heavy building materials (brick) and the roof was a flat timber construction. Two vaulted constructions above each other were rarely built because of the significant weight of the structure and the difficulties in controlling the horizontal forces.

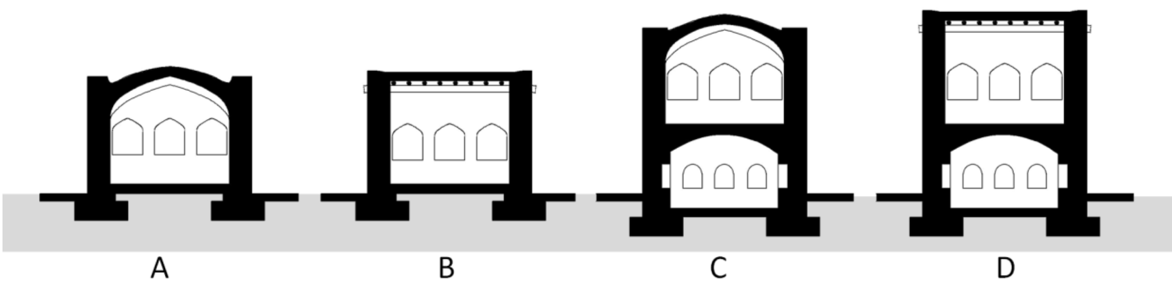


Figure 6-7: schematic structure of one or two-story Qajar houses in Sabzevar

In general, the structural concept of two-storey Qajar houses in Sabzevar includes a basement with a vaulted floor on the load-bearing walls and a flat wooden roof resting on the load-bearing walls of the first floor. A portico or veranda is supported by wooden columns. (Figure 6-8).

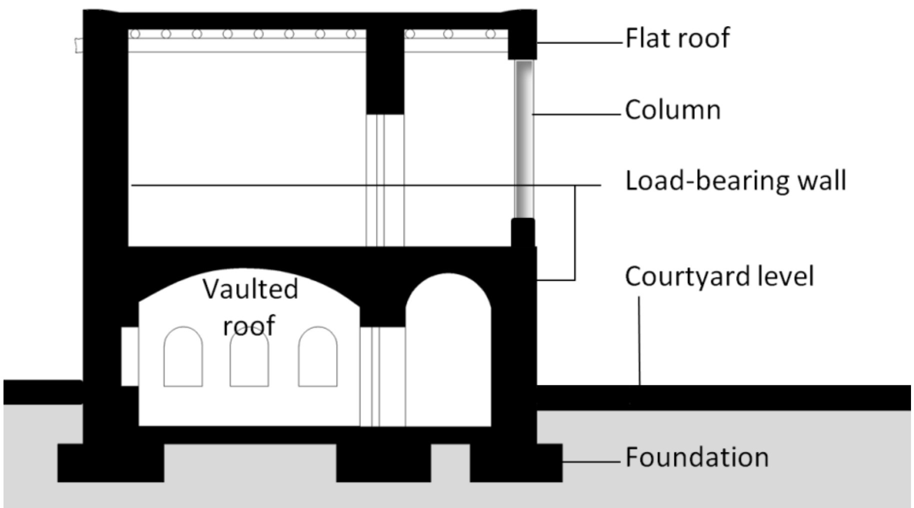


Figure 6-8: schematic structure of typical two-story Qajar houses in Sabzevar

The following 3D wall-section presents the material layers of a typical two-story Qajar house in Sabzevar. Materials and techniques may vary with individual houses. These differences are discussed in detail in chapter 6.8.

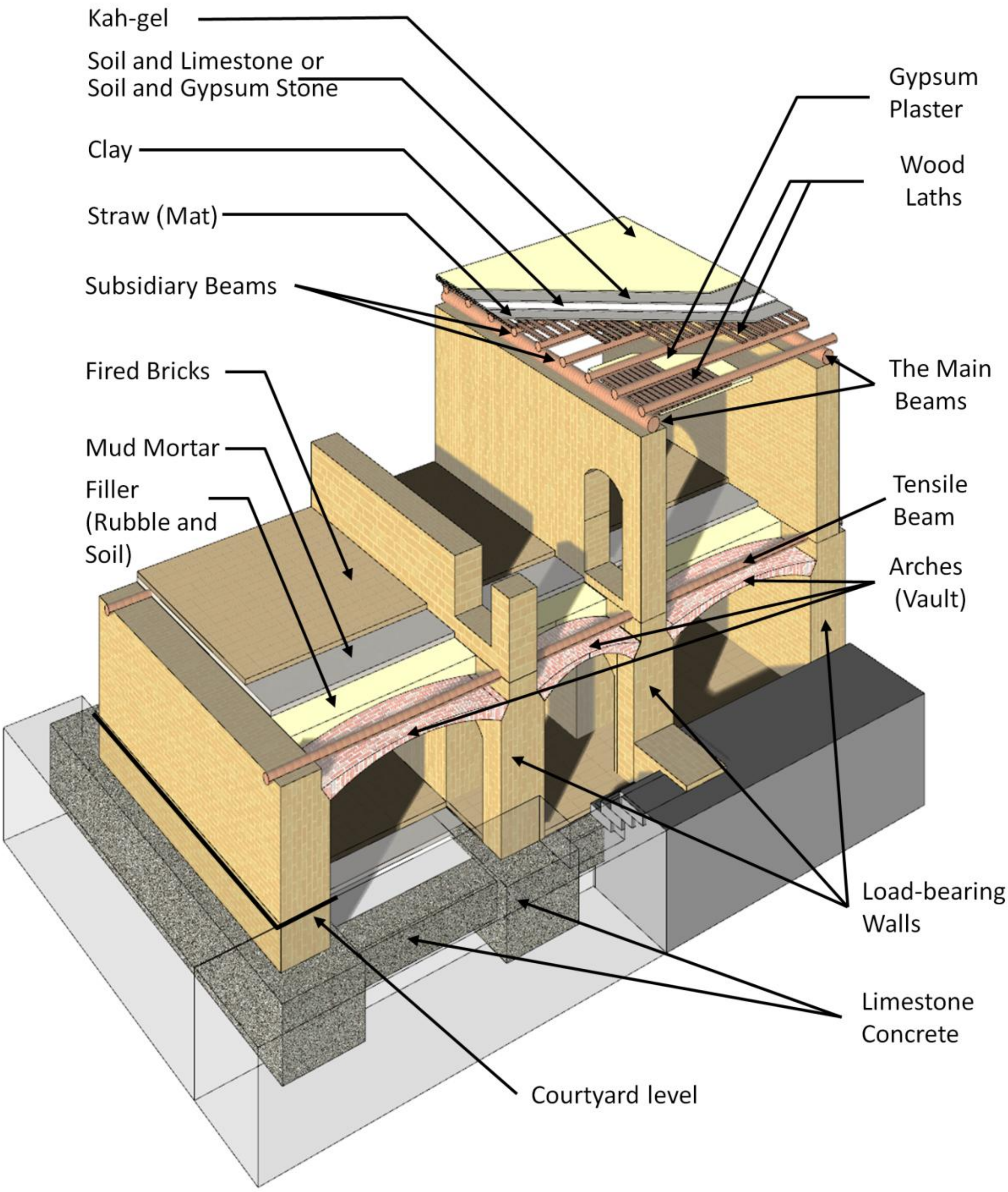


Figure 6-9: a schematic 3D wall section of a typical two-story Qajar house in Sabzevar

6.3 Common spaces in Traditional Iranian Houses

Andaruni and Biruni: The large traditional houses in Qajar period featured two separate zones. The Andaruni (andarūnī) ('inside' or 'innards,') was reserved for women and religiously permitted men and biruni (bīrūnī) ('outside' or 'public,') for men (Djamalzadeh, 1985, Mahdavi, 2009). In this study, the terms of private and family zone are used for andaruni, and the public or guest zone for biruni.

Hayat (courtyard) is the core of traditional houses; it is the main circulation space that provides access to the different parts of the house. It was also a place for playing, living and sleeping in summer, family and neighborhood gatherings, celebrations, religious ceremonies and similar functions.

Hashti (vestibule) is an intermediary space that connects the outdoor to the inner spaces. This space limits the direct view into the house and facilitates access to different parts of house. (Figure 6-10)

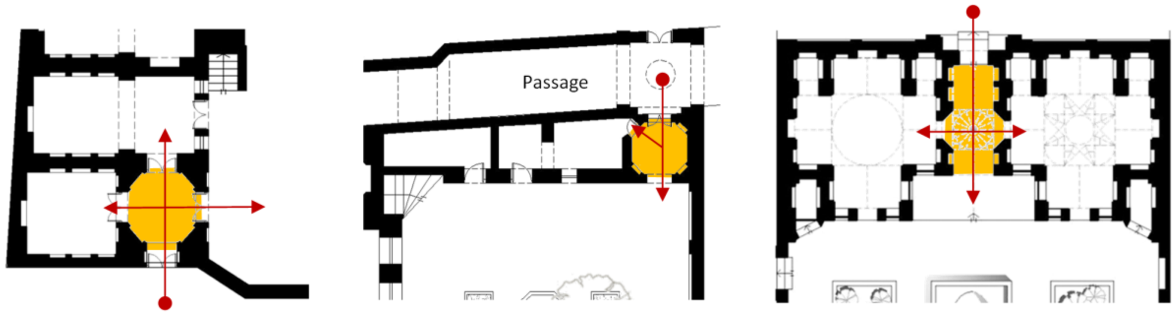


Figure 6-10: vestibule (Hashti) of the Aldaqi, Kian and Mashhadi houses (Sabzevar)

Mahtabi or Bahar-khab: Mahtabi in Persian means 'a place that is used during the moonlight' and 'Bahar-Khab' means 'a place for sleeping in the spring.' It is a roofless space higher than the level of the courtyard that is closed from three sides and facing the courtyard (Figure 6-11). It was used for afternoon family gathering and sleeping in the night in the mild seasons.

Figure 6-11: two terraces (Mahtabi) of Eslami house, source of section:(Estaji, 2010, Towhidi-Manesh, 2001b) and the local archives of ICHTO, with corrections

Eivan is a semi-open space that faces the courtyard on one side. The roof of this space can be vaulted or flat. In wide Eivans some columns carry the weight of the flat roof that in Persian is called 'Eivan-e-sotondar', pillared veranda or pillared portico. (Figure 6-12)

Figure 6-12: left: pillared portico (veranda) of Baqani house (Kermani-Moqaddam, 2002b), center: simple Eivan (flat roof) of Cheshomi house, source: the local archives of ICHTO in Sabzevar, right: vaulted Eivan of The Mashhadi house (Estaji, 2010)

Rooms of traditional houses usually are open to the courtyard and have different names depending on the number of openings. The number of windows is usually an odd number; three, five, and seven. This is due to the fact that in Iranian architecture the main axes of rooms must be open and have direct view to the courtyard.

Seh-Dari (three door-windows) and **Pandj-Dari** (five door-windows) are the common rooms in traditional houses. If the accesses to a five or seven windows room are from two sides, these main halls are called '**Talar**' in Persian. From the end of Qajar under the influence of European architecture, rooms with two and one opening were also common. (Figure 6-13)

Figure 6-13: different types of rooms in traditional houses in Sabzevar

Howz-khaneh (pool room) is a large room with a central pool that usually is connected to the other spaces. (Figure 6-14)

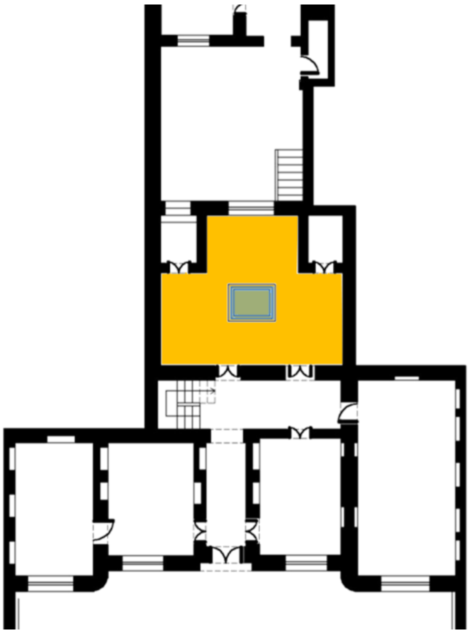


Figure 6-14: pool room (howz-khaneh) of Eslami house in Sabzevar

Matbakh (kitchen) is a mono-functional room for preparing meals and fresh bread.

6.4 Passive Cooling and Heating Methods in Traditional Iranian Houses (in the case of Sabzevar)

In this study, the term 'passive method' means the use of natural processes to achieve balanced interior conditions without using any energy and mechanical or electrical devices (active systems). Before the invention of electricity, there was not any active cooling system in buildings. Providing comfortable conditions in summer was the main problem that traditional architects faced. In winter, the residents burnt wood in fixed fireplaces, or used movable ovens that worked with charcoal or oil for heating; it was easier to control the air temperature during the cold days. That is why traditional Iranian architecture in hot and dry regions focused more on passive cooling than on heating strategies. In the following some time-tested passive strategies in housing design are listed.

6.4.1 Vertical and horizontal movements of residents in traditional houses

The traditional Iranian houses in hot and dry regions were designed according to simple climatic principles: avoiding the sun on hot days and taking maximum advantage of solar heat on cold days. For this purpose, traditional houses provide a flexible spatial configuration and allow the residents to move between spaces. These movements can be performed in two ways: daily and seasonally, and from a spatial point of view: vertically and horizontally (Figure 6-15). (Estaji, 2014)

In this region, the south-facing facades benefit from solar heat during the winter and the north- facing facades are shaded throughout the entire year. Therefore residents spend the hottest days in the basement, which is cooled by the huge thermal mass of the natural ground. In the hottest nights of the year, they stay on the first floor, which has the best ventilation. The shaded side of the house is preferred during summer, the sunny side during winter.

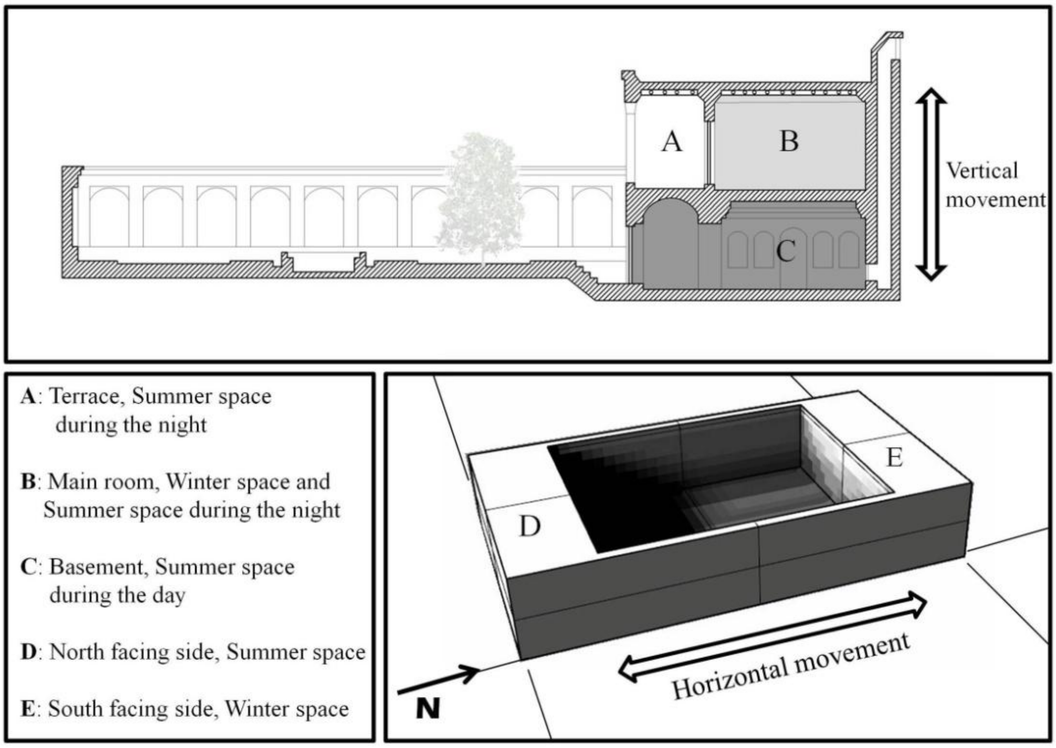


Figure 6-15: vertical and horizontal movements in Iranian traditional houses (Estaji, 2014)

6.4.2 Solar Control (Shading Strategies)

Another strategy based on avoiding sun in the summer and taking maximum advantage of solar heat in winter is designing the openings according to the seasonal changes of the sun position.

Due to the different paths of the sun in winter and summer, projecting roofs or semi-open vaulted spaces block the sun's heat energy in summertime and allow the sun to warm up the building in winter (Figure 6-16).

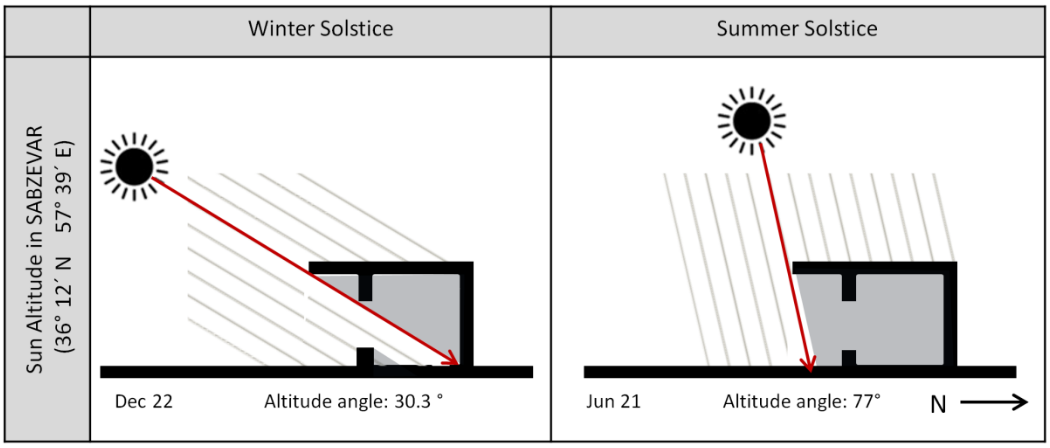


Figure 6-16: the position of sun in summer and winter (in the noon)

In the traditional houses in Sabzevar these specific structural elements are not only designed to provide shade during the hot season but also serve as multi-functional semi-open spaces: as sitting and sleeping rooms in summer and as circulation areas. There are two kinds of fixed shading spaces: eivan and veranda. The eivan is a semi-open space with walls on three sides and open to the courtyard, the veranda ('Eivan-e-sotondar') is a rectangular columned space that connects the closed spaces to the yard (Figure 6-17).

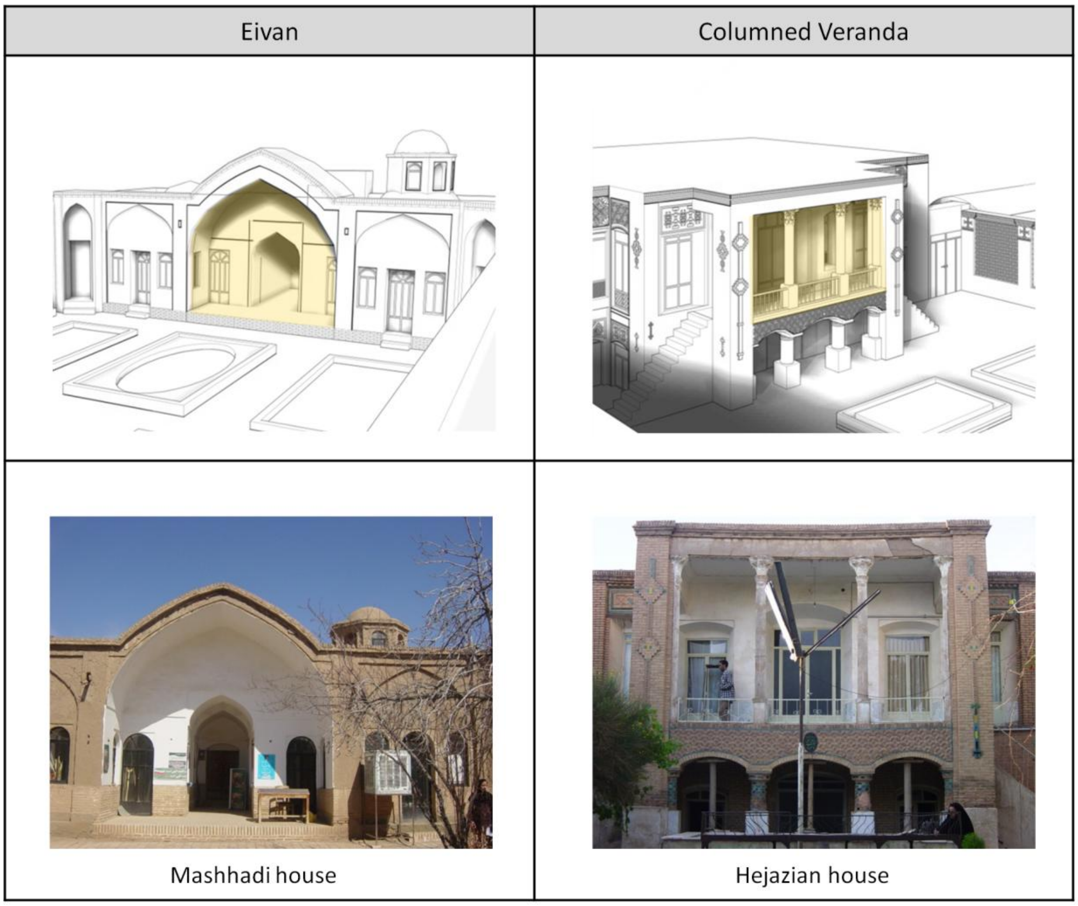


Figure 6-17: two examples of north-facing, semi-open spaces, left: eivan, right: veranda. Photos: (Estaji, 2010)

The following image (Figure 6-18) shows a veranda facing to the east. In this case, the closed space of the house is protected from direct sunlight from 9:30 on thanks to the great depth of the veranda; in the south of a building, the veranda could also be less deep and serve the same function. The orientation of the building, the height of the ceiling, and the depth of the veranda or eivan can serve to control the exact time of shading.

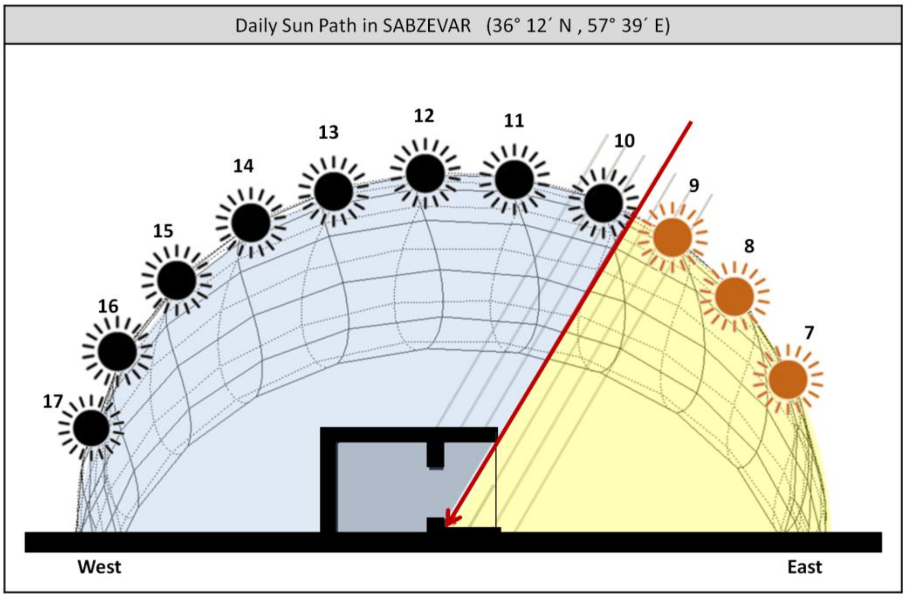


Figure 6-18: the shade position of an East facing Veranda during a day (in summer)

For a detailed study of the thermal behavior of the buildings, I modeled the house orientation and generated shades in the morning and afternoon for two solstices (June 21 and December 22) and two equinoxes (March 20 and September 22). Moreover, the Vertical Sky Component (VSC) for each window was calculated.

In addition to structural sun protection measures, plants can work as shading devices. Deciduous trees block the sun's heat in summer and allow the windows and house facades to benefit from the sun during winter, when they are without leaves. Planting of grape trees was and still is very popular in Sabzevar; even today it is very common in courtyard houses. The residents made wooden trellises as horizontal supports for the foliage of grape trees. These simple structures provide a cool micro-climate in summer (Figure 6-19).

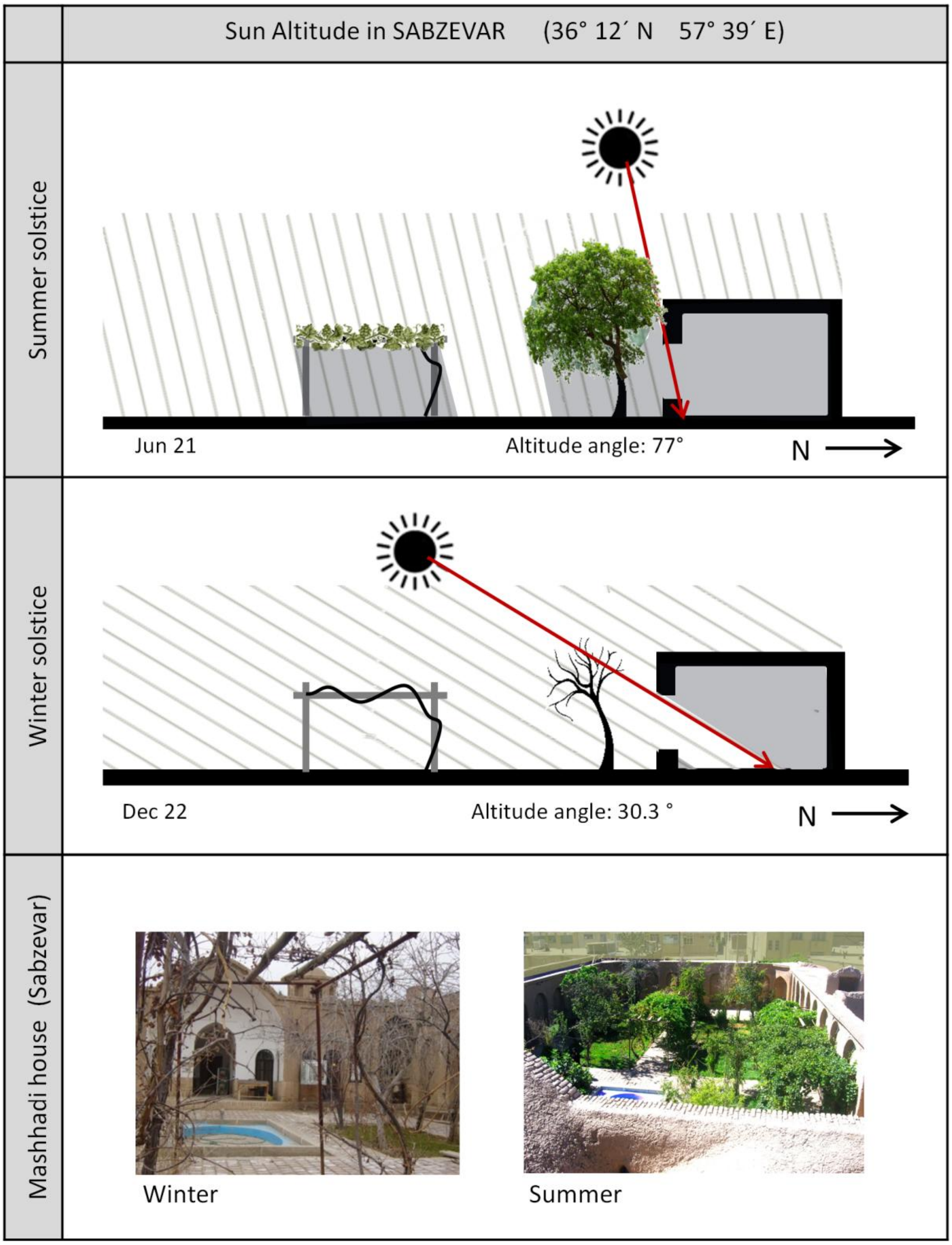


Figure 6-19: Vegetative shading, photos:(Estaji, 2010)

6.4.3 Evaporative Cooling

In Sabzevar the average amount of evaporation in July is eight times the precipitation in March, which is the month with maximum rainfall (see chapter 4.1.1.4, figure 4.10). This huge amount of ETo indicates the heat and dryness of Sabzevar in summer. On the other hand, it points to the huge potential of this region for the use of passive evaporative cooling system on hot days. For water evaporation, around 2,500 Jules of heat energy per gram is consumed (Havenith et al., 2013). Indoor and outdoor pools, wetted surfaces, grass and leaves of trees provide water for evaporation (Figure 6-20). The flooring materials in traditional houses (bricks and clay floor) and the garden soil in courtyards absorb water, for this reason, wetting the floor surface in the afternoon was a regular chore that was usually done by children as a game. The evaporation of wetted floors helps to reduce heat and simultaneously improves air quality by increasing the humidity. The evaporative cooling method is even more efficient in combination with wind and natural ventilation.

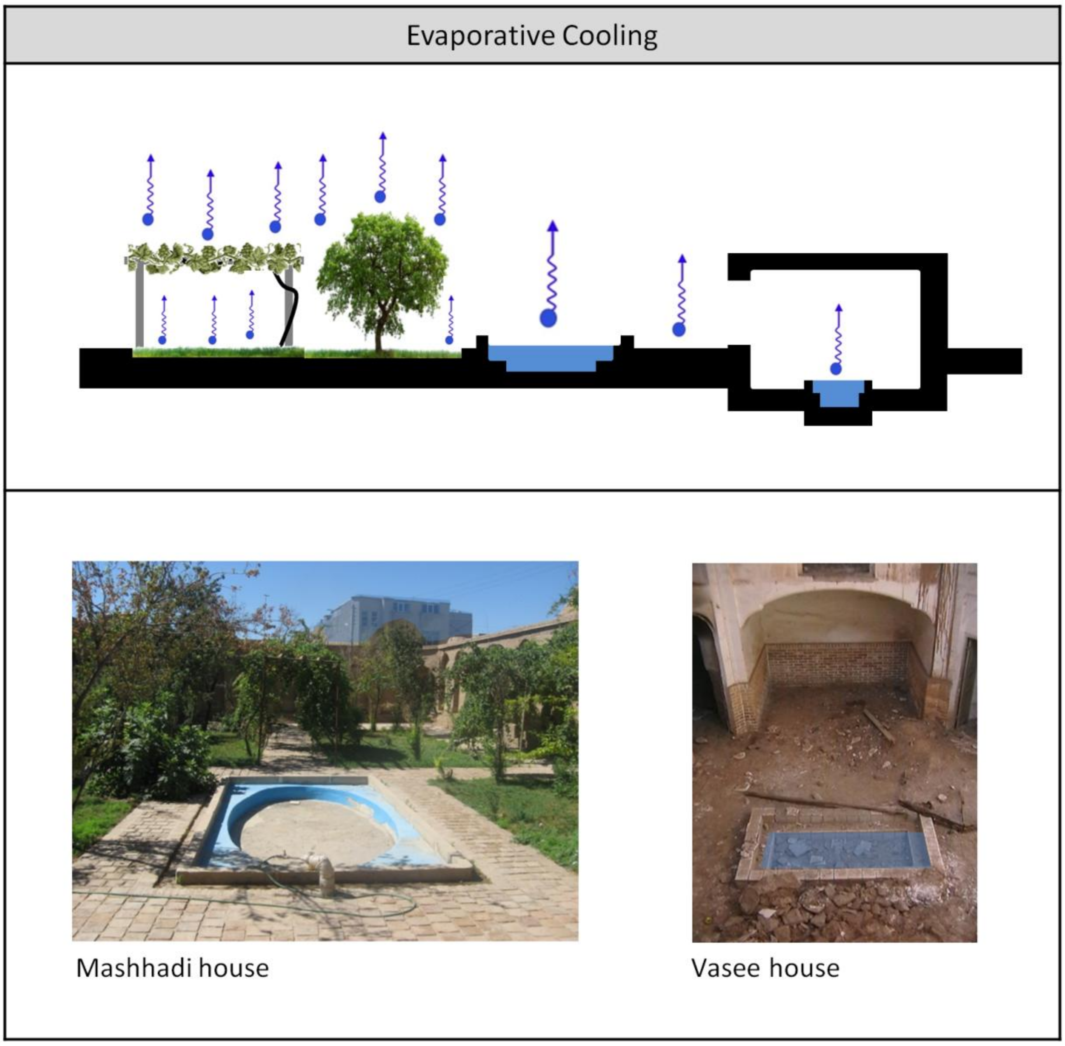


Figure 6-20: evaporative cooling, photo (bottom-right) by Abdollahzade-Sani

6.4.4 Natural Ventilation

Sabzevar benefits from the permanent wind with the fixed direction (see 4.1.1.5 Wind Direction and Speed) In addition to the usual ventilation from doors and windows, the traditional architects in Sabzevar were able to make the air move between spaces (Figure 6-21) by creating differences in the air pressure between inside and outside, resulting from the wind. The combination of natural ventilation and evaporation cooling provides fresh air for the indoor spaces.

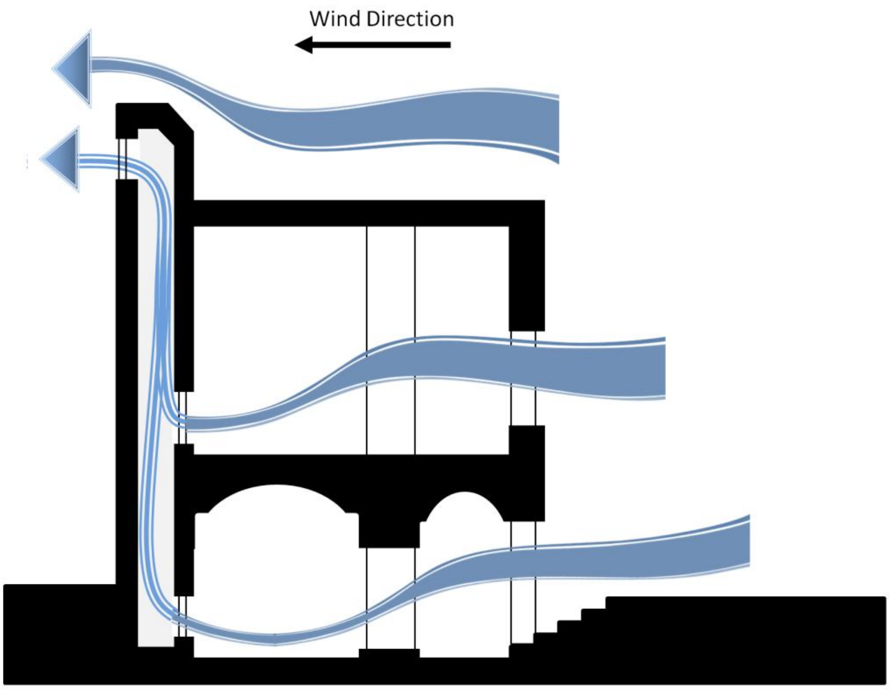


Figure 6-21: natural ventilation resulting from the air-pressure differences

Air movement is also induced by air-temperature differences between the floor and ceiling. Hot air rises and cold air stays near to the ground. Making a high roof was another strategy for overcoming the heat in this region. Dome roofs usually had some openings at or near the apex to drive out the hot air from the building. The combination of wind and stack ventilation accelerates air ventilation (Figure 6-22).

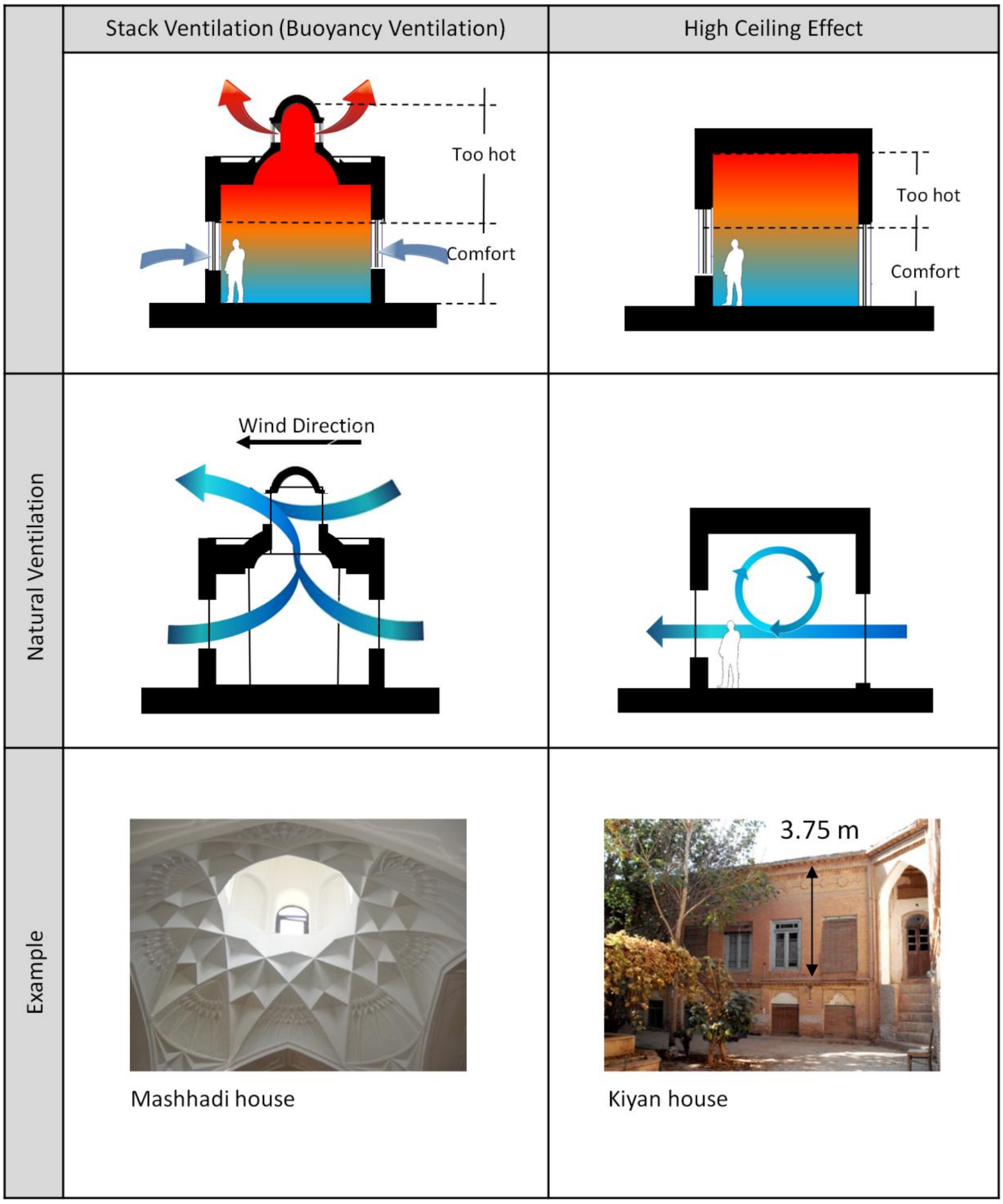


Figure 6-22: stack ventilation and high-ceiling effect

Another strategy was to provide a connection between the semi-sunken story and the first floor to use the cold air resulting from the earth cooling effect. This connection was provided either by an opening in the floor or a ventilation shaft in the wall (Figure 6-23). On cold days, the residents could easily block the air draft by closing the small door of the ventilation shaft or by covering the floor opening with a carpet.

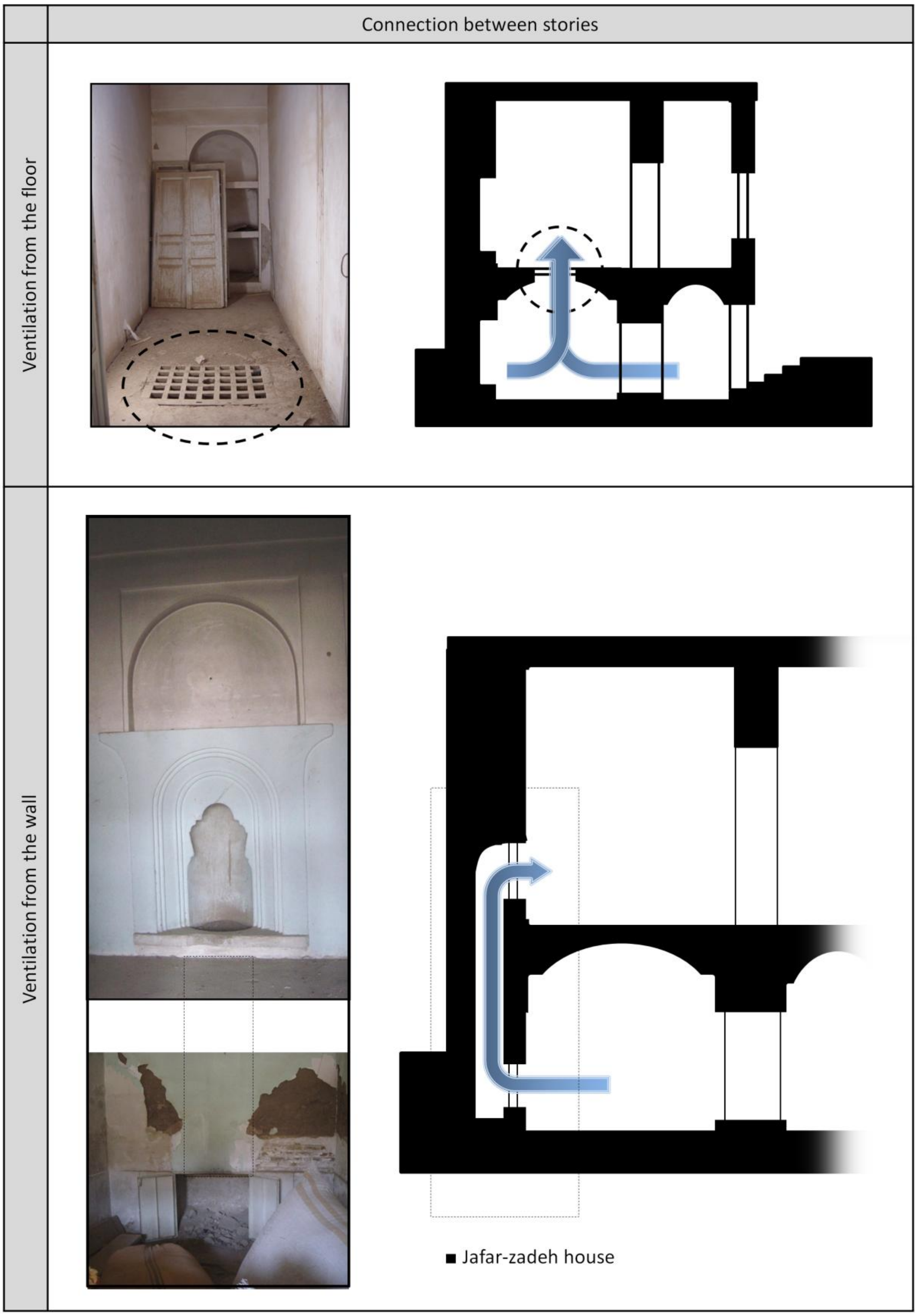


Figure 6-23: ventilation from the floor and wall

6.4.5 High Thermal Mass

Adobe is a material with a high heat capacity. It absorbs and stores thermal energy during a hot day and then releases it gradually during the cold night hours. Using high thermal mass material in housing shifts the temperature peak of warm or cold hours. This reduces high daily temperature fluctuations and temperature peaks and delays them (time lag). This effect is known as the 'thermal flywheel' effect (Baggs and Mortensen, 2006).

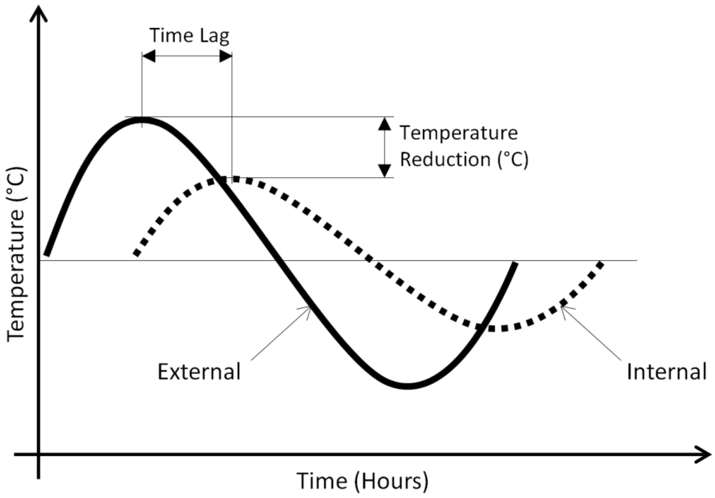


Figure 6-24: time lag and temperature reduction in space surrounded by high thermal mass (Baggs and Mortensen, 2006)

Earth materials such as adobe, bricks and clay are suitable as thermal mass due to the high specific heat capacity. All of the traditional houses in Sabzevar benefited from this effect. To investigate the thermal behavior of traditional adobe constructions I modeled a simple south-facing room with adobe walls, a small window and a wooden door. (Figure 6-25)

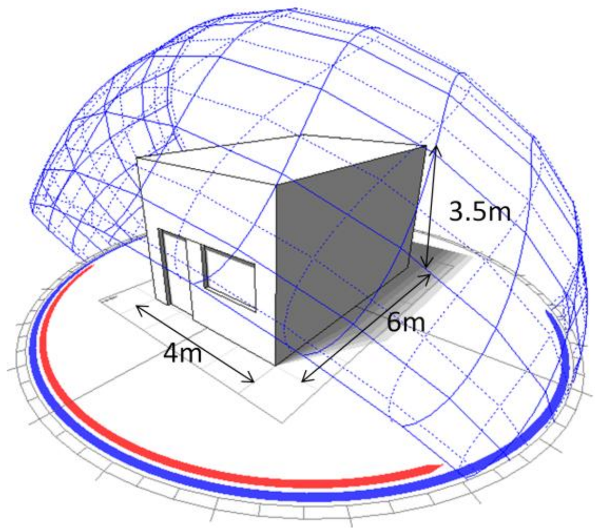


Figure 6-25: modeled simple room

Three different wall thicknesses were modeled: 30, 60 and 90 cm. The thickness of the roof equates the thickness of the walls, but the floor consists of 30 centimeters limestone concrete, 10 centimeters clay, 5 centimeters brick tile, and a carpet in all of the alternatives. In this study 'Energyplus' software was used to simulate the models. The results show that the room with the thicker walls (red) has less indoor temperature fluctuations as compared to the other alternatives. (Figure 6-26)

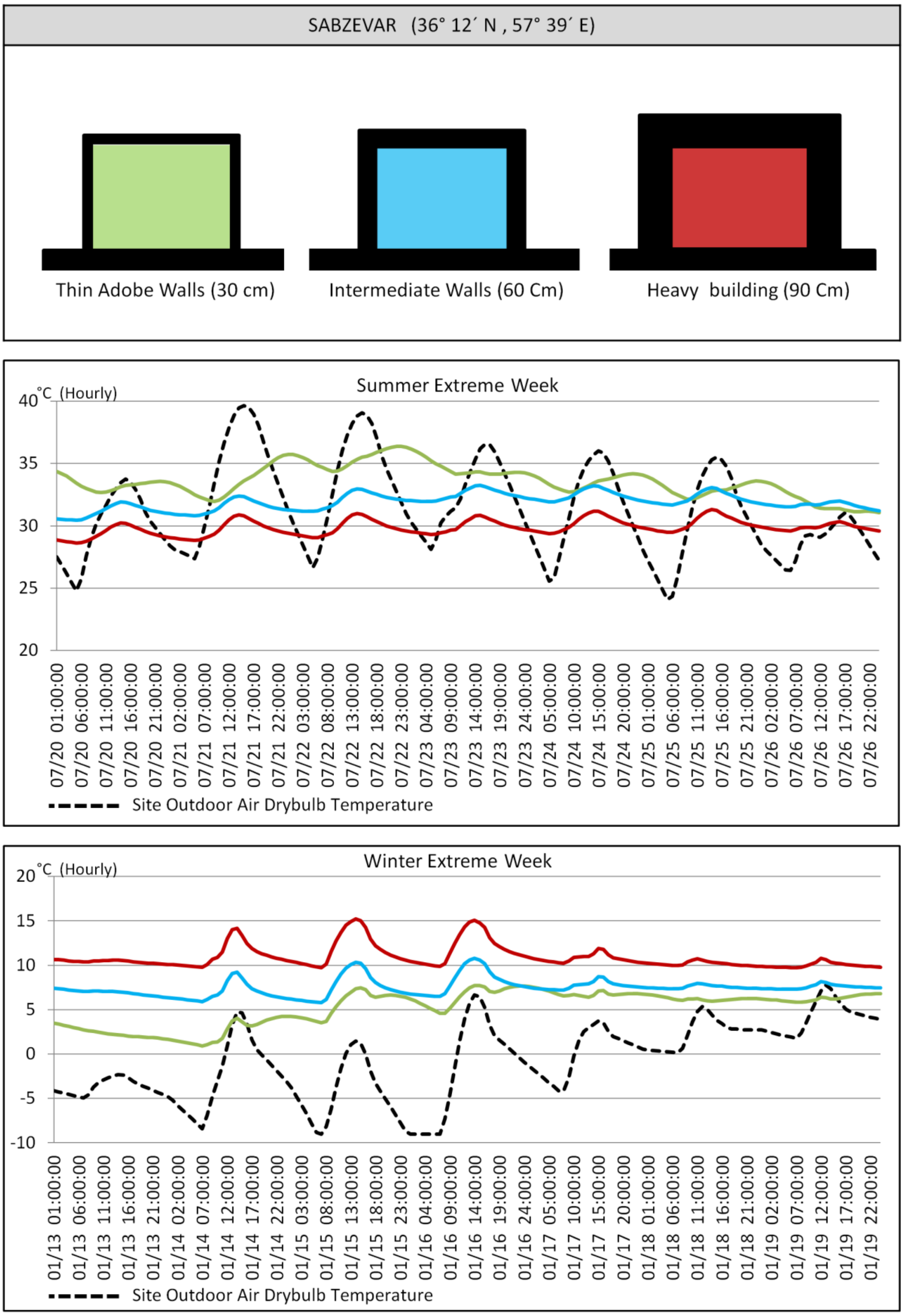


Figure 6-26: hourly temperature fluctuations for different construction alternatives

The graphs show the hourly temperature fluctuations for the three different simulation set-ups in the extreme weeks of summer and winter. The room with the thickest walls (red) performs better during both warm and cold days.

The following graph (Figure 6-27) shows the outdoor and indoor hourly temperature fluctuations simulated for the model room with the thickest walls and roof (red) over a whole year in Sabzevar. It visualizes the low indoor temperature fluctuations in comparison with high outdoor temperature changes. The greatest advantage of using the high thermal mass is being able to reduce the hourly indoor temperature fluctuations during the year. In fact, this ability provides a stable base for using a combination of other passive cooling and heating methods.

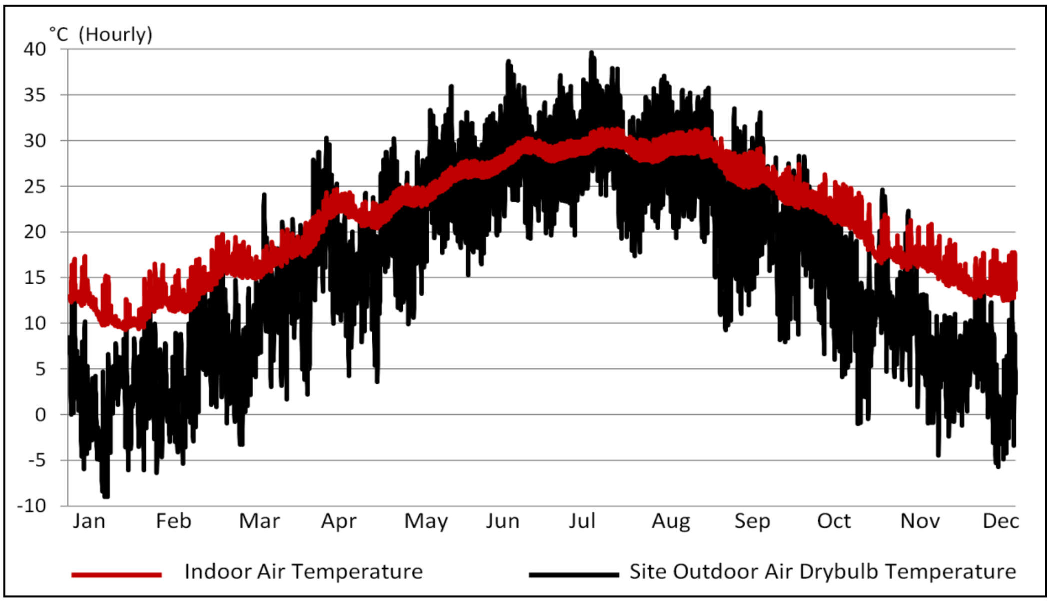


Figure 6-27: outdoor and indoor hourly temperature fluctuations of the heavy sample room during a typical year in Sabzevar simulated by Energyplus

6.4.6 Earth Cooling

"Warm in winter, cool in summer, the earth is where mankind first sought shelter, and for good reason." (Green, 1979, p. 9)

Underground construction is common in hot and arid regions. The primary purpose of this strategy is to ensure protection of the building from the direct sun and hot winds. However, more importantly, when a building is located in the earth, the ground serves as thermal mass for the underground floor. (Figure 6-28)

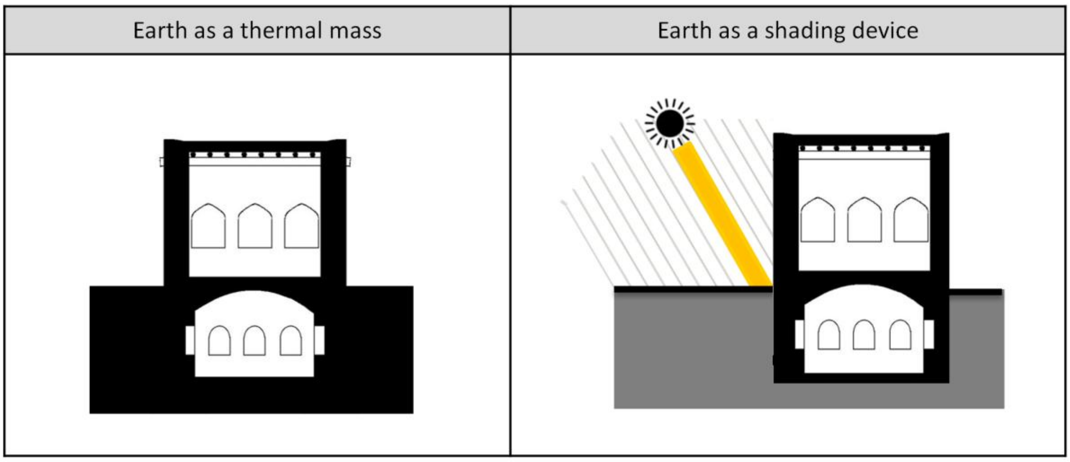


Figure 6-28: the functions of the earth

The monthly averages of ground temperatures in Sabzevar in different depths show how the earth decreases the range of temperature fluctuations and shifts the heat and cold peaks. By only going down two meters in the ground in Sabzevar, the temperature will be in the range of comfort (under 25 °C) on hot days. By going down four meters, the maximum of air temperature is shifted from mid-June to September and the minimum of temperature from December to March. (Figure 6-29)

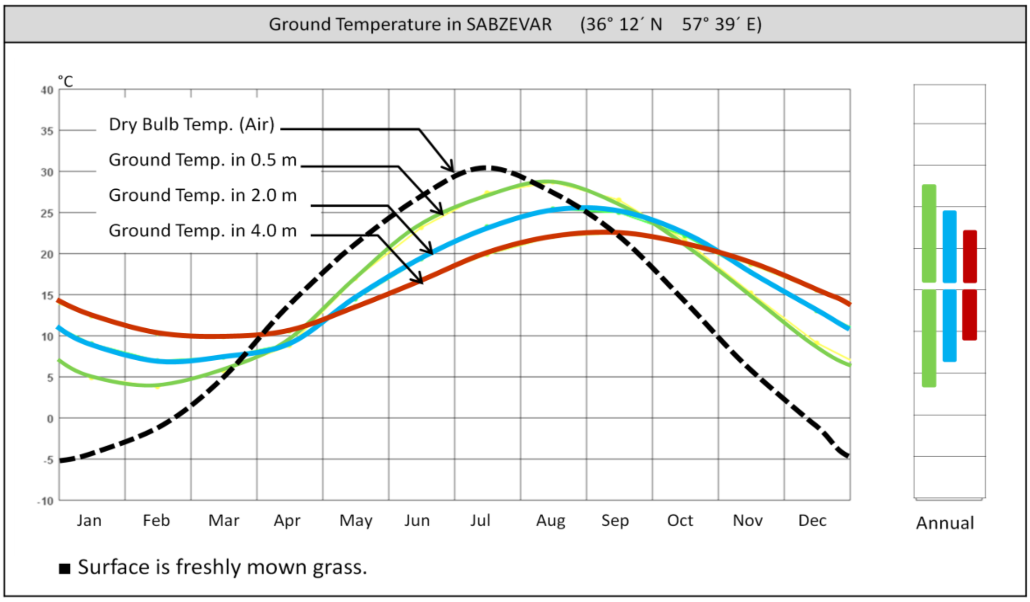


Figure 6-29: ground temperatures in Sabzevar in different depths, calculated by Climate Consultant 6 [12]

The earth cooling strategy alone can provide comfort conditions for the house users in Sabzevar in summer. It shows the importance of reusing this forgotten strategy in contemporary housing design in Sabzevar and similar regions.

6.5 Active Heating Methods in Traditional Iranian Houses

Undoubtedly, in the Qajar period special attention was paid to keeping residential buildings cool. But how did the residents heat their rooms with high ceilings, a large number of openings and simple wooden windows on cold days? They did not heat their rooms; they only provided heat for themselves. This point is central to understanding the thermal behavior of traditional houses –something that is usually neglected in simulations, restoration, and rehabilitation.

6.5.1 Kursi; a Micro-climate Comfort Zone in a Room

Kursi (also Korsi) was a low wooden table on a charcoal brazier that was covered with a large thick quilt and surrounded by mattresses and cushions. In some cases, a pit was formed on the

[12] Climate Consultant 6 was developed by Robin Liggett and Murray Milne of the UCLA Energy Design Tools Group, with technical support from Don Leeper and Carlos Gomez. More information is available on www.energy-design-tools.aud.ucla.edu

ground to accommodate the charcoal brazier in winter. In summer the pit was filled with soil (Figure 6-30). The people slid their legs under the table and at night lay down under the quilt. The following illustration shows that they made a small comfort zone instead of heating the entire room.

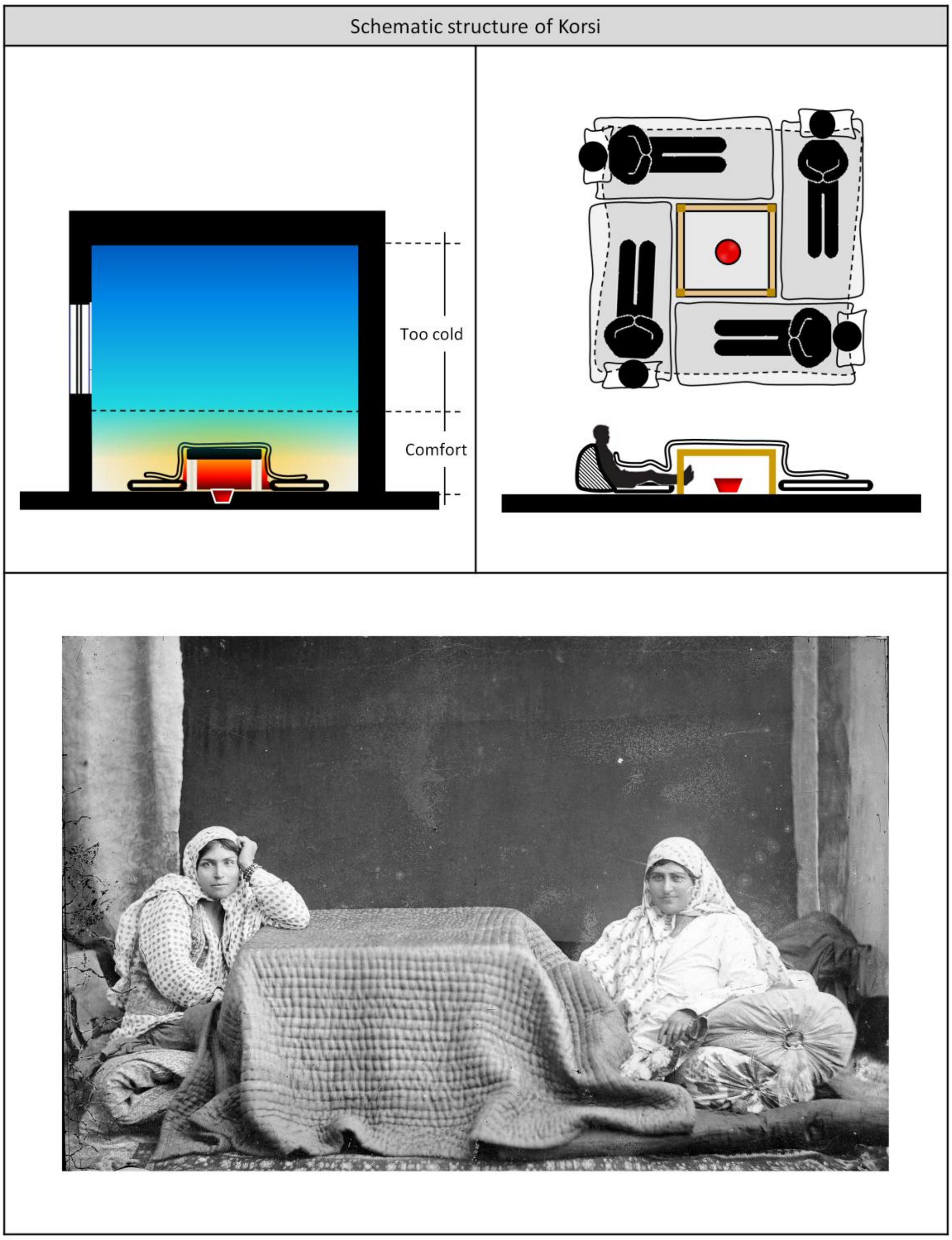


Figure 6-30: top- the structure of a Kursi, Down-Two Qajar women seated on either side of a Kursi, photo by Antoin Sevruguin,(1890?)

6.5.2 Cooking in the Living Room

In traditional houses the kitchen was the main place for cooking, but on cold days, the residents moved their stove or brazier to the room that they wanted to use in the following hours to benefit from the heat of charcoal burning. Since 1908 oil has increasingly become the source of energy for cooking in Iran. Moving the kerosene stove was very easy. Using the water boiler (Samavar) in the living room for preparing fresh tea was a tradition, too. Boiling the water in the room increased the relative humidity of the ambient air. The high relative humidity prevented rapid body evaporation, and so the residents felt warmer and more comfortable.

6.6 House Typology

> "Buildings and cities exist for us in two ways: as the physical forms that we build and see, and as the spaces that we use and move through." Bill Hillier (2005, p. 2)

The first approach deals with physical form, while the second one is concerned with the relationship between spatial layout and users. This section introduces and classifies the traditional houses in Sabzevar with regard to the position and relation of building mass and courtyard (closed and open spaces). Also, the space syntax theory is applied to study the spatial configuration of houses and the relation between spaces and users in detail for each house.

6.6.1 Massing Typology; Physical Form

The primary role of the courtyard in the traditional houses in this region is to create a tolerable microclimate in harsh weather conditions. It protects the house from direct sun and dusty winds and increases humidity by providing a green space. Most of the main spaces in traditional houses have direct access to the courtyard, for this reason, it was the main circulation space in the house.

The following image (Figure 6-31) shows the various types of traditional houses in Sabzevar in terms of the position of open and closed spaces on a land plot[13].

[13] This typology has been adapted from the following research project for different cities in Iran or other countries. (Edwards, 2006, Golpayegani and Einifar, 2004, Memarian, 1991, Memarian, 1993)

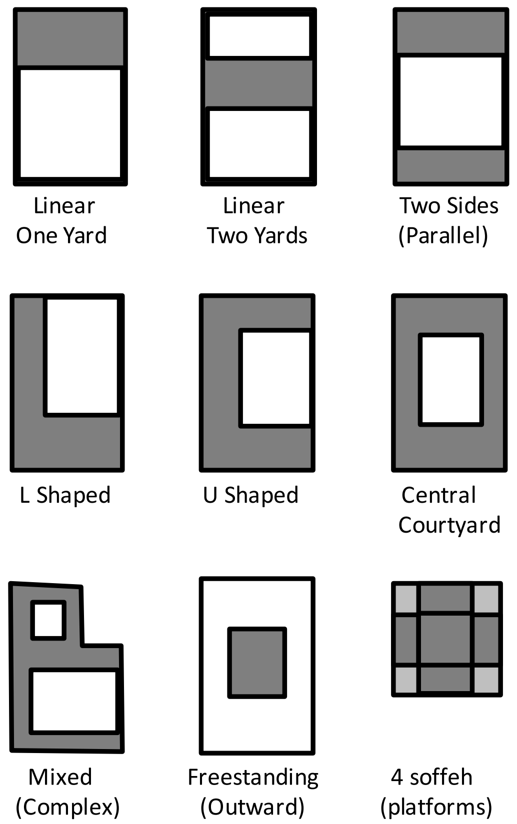


Figure 6-31: Massing Typology in traditional houses in Sabzevar (Edwards, 2006, Golpayegani and Einifar, 2004, Memarian, 1991, Memarian, 1993) with modifications

In addition to the position of mass and courtyard, the house orientation and the position of semi-open spaces as intermediate spaces are other factors considered for house classification. These factors form a matrix to classify houses in different categories.

6.6.2 Space Syntax

Space syntax is a theory and a set of methods about space that according to Hiller (2005) is based on two ideas:

1- “Space is not a background to activity, but an intrinsic aspect of it” (Hillier and Vaughan, 2007, p. 207). Humans interact with spaces in three ways: moving through space, interacting with other people in space and seeing space from a point in it. (Figure 6-32)

2- Human space is not about one space, but about the inter-relations between the many spaces that make up a whole system. Hiller called it the “*configuration of space*.”

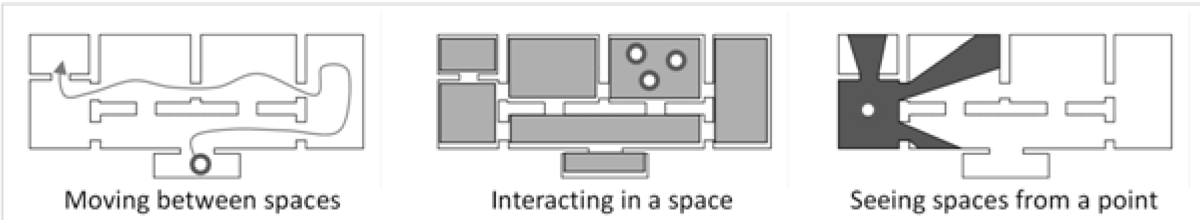


Figure 6-32: fundamental attributes of space in space syntax theory

The relationships between spaces help to quantify the properties of spatial arrangements, such as symmetry, asymmetry, distributedness, and non-distributedness. Symmetry/ Asymmetry is about the integrating/segregating (less private/more private) effects of space in relation to other spaces (Moser et al., 2002). The terminology used in space syntax theory differs from conventional architecture and everyday terminology. In the following paragraphs these terms are defined.

The "distributedness refers to the degree of control spaces exert on a system as a whole" (Tipple, 2000, P. 5), in other words it is about the possibility of entering space in more than one way (Moser et al., 2002). It depends on the number of rings in the system. The ringiness of the convex[14] system is the number of islands (obviously the number of islands and the number of rings is the same) in the system as a proportion of the maximum possible planar rings for that number of spaces (Hillier and Hanson, 1984, P. 100). It is calculated on the basis of:

convex ringiness =I/(2k-5)

In this formula, (I) is the number of islands (rings) and (k) the number of spaces in the system. The ringiness is a number between 0 and 1; that 1 indicates the maximum distributedness of a system with respect to itself.

"The measure of relative asymmetry [RA] generalises this by comparing how deep the system is from a particular point with how deep or shallow it theoretically could be." (Hillier and Hanson, 1984, P. 108)

In the following, some essential definitions and formula to quantify the relation between spaces are cited. [15]

Connectivity is the direct connections of spaces.

Depth "is defined as the least number of syntactic steps in a graph that are needed" to get from one space to another. (Klarqvist, 1993, P.11)

"Mean Depth (MD) is calculated by assigning a depth value to each space according to how many spaces it is away from the original space, summing these values and dividing by the number of spaces in the system less one (the original space)". (Hillier and Hanson, 1984, p 108)

MD= $(\sum D.n)$/(k-1)

Where, $(\sum D.n)$ is the total Depth from the original space and K is the total number of spaces in the system.

Relative Asymmetry (RA) or **Integration** describes the average depth of a space to all other spaces in the system (Klarqvist, 1993). The highest value indicates the most integrated and the lowest value shows the most segregated space in the system. It is calculated by:

RA=2(MD-1)/(k-2)

Real Relative Asymmetry (RRA)

---

[14] A 'convex space' is a space which no straight line drawn between any two points goes outside the space. Hillier, B. & Hanson, J. 1984. The social logic of space, Cambridge university press Cambridge. pp.97-8

[15] For more details and calculation methods see: ibid.

In addition to the arrangement of spaces in a system, the size of the system affects the value of Relative Asymmetry. This makes it more difficult to compare two different systems with different sizes. Hillier and Hanson (1984) suggested Real relative asymmetry (RRA) for comparisons across systems of various sizes. RRA compares the RA value of a particular space with the RA value for the root of a diamond-shaped system (D-value)[16] with the equal spaces. In the diamond-shaped justified map[17], there are n spaces at mean depth level n/2 at one level below and above n/4 at two level below and above and so on until there is one space at the root of the system (Ferguson, 1996, p. 19). Figure 6-33 presents a sample diamond-shaped justified graph for a system with 22 spaces. The following formula calculates the D-value for systems of different sizes.

$$D_k = \frac{2[k\{\log_2((k+2)/3) - 1\} + 1]}{(k-1)(k-2)}$$

(Kruger, 1989)

RRA = RA/Dk

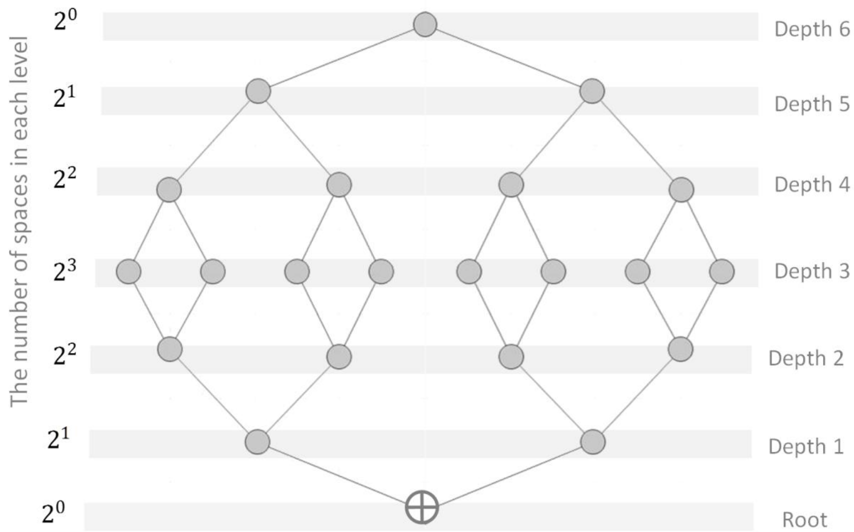


Figure 6-33: diamond-shaped justified graph for a system with 22 spaces

For a better understanding, the following graphs (Figure 6-34) present four different spatial configurations with six spaces that result in different systems with maximum symmetry, asymmetry, distributedness, and non-distributedness.

[16] For more information about different scaling ways see: Krüger, M. & Vieira, A. P. 2012. Scaling relative asymmetry in space syntax analysis. *The Journal of Space Syntax,* 3, 194-203.

[17] " A justified map/graph is one in which a node is drawn at the base, and the all points of depth 1 from that point are aligned horizontally immediately above it, all points at depth 2 from that point above those at depth 1, and so on until all levels of depth from that point are accounted for." (Hillier and Hanson, 1984, p. 106)

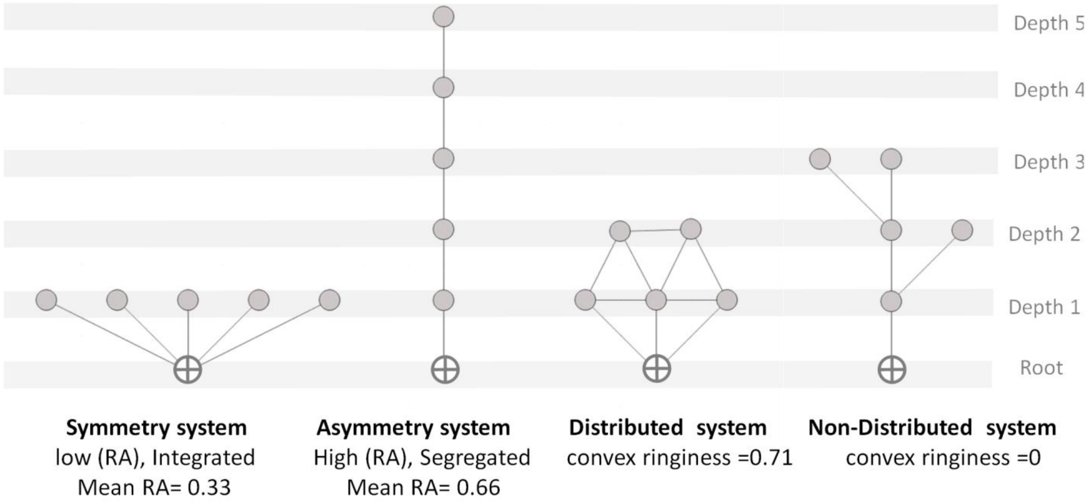


Figure 6-34: various spatial configurations with six spaces, adapted from Ferguson (1996) with modification

Integration

In general, integration shows how close a considered space is to all other spaces in a system. It is calculated by the reciprocal function of RRA. (Hillier and Hanson, 1984)

Integration [HH][18] =1/RRA

6.7 Investigating Houses in Their Context

This part of the study tries to provide a realistic image of the selected residential buildings in their original context in the past, while also investigating the changes that have taken place over time. After presenting the maps, plans, elevations, sections, photos and sketches of selected houses, each house is studied under the following aspects:

- The position of the house in the old city taking into account the important urban elements in different periods to study the changes during the time
- Details and materials
- House orientation
- The position of the sun and generated shades in the morning and afternoon for the two solstices (June 21 and December 22) and two equinoxes (March 20 and September 22)
- The shading mask[19] and the stereographic diagrams of the Vertical Sky Component (VSC)[20] for each window
- The impact of house orientation on the comfort conditions for each space in different periods

At the end, by using the space syntax tools the relations between spaces and house users for each house are analysed in detail.

[18] Normalization on Hillier and Hanson (1984) according to D-value

[19] Shading masks is a sun path diagram in Ecotect to visualize when a point will be shaded.

[20] The Vertical Sky Component (VSC) is "ratio of the direct sky illuminance falling on the vertical wall at a reference point, to the simultaneous horizontal illuminance under an unobstructed sky" *Littlefair, P. J. 1991. Site layout planning for daylight and sunlight. Building Research Establishment Report.*

6.7.1 Simple One-Side Houses

The simplest type of house is the linear house with the building located on one side of the plot and the courtyard on the other side.

6.7.1.1 The Afchangi House: A Collection of Decorative Brickwork

Figure 6-35: decorated Afchangi house entrance (Estaji, 2010), hand drawing by Minoo Qasemi

This house is located in the historical center of Sabzevar, behind the Grand Mosque. The house was constructed in the late Qajar and early Pahlavi periods, around 1925. Figure 6-36 shows the city's development stage in 1956, the position of the house in the city and its relationship to the main routes, the old city wall, the old Bazaar and the Grand Mosque.

Figure 6-36: the situation in 1956 and the position of the Afchangi house,
base photomosaic map:(Zanganeh, 2003a)

The plot is accessed via a narrow lane. The house is located on the west side of the plot. The main windows and doors face east (Figure 6-37). There are only two windows to the south (Figure 6-38).

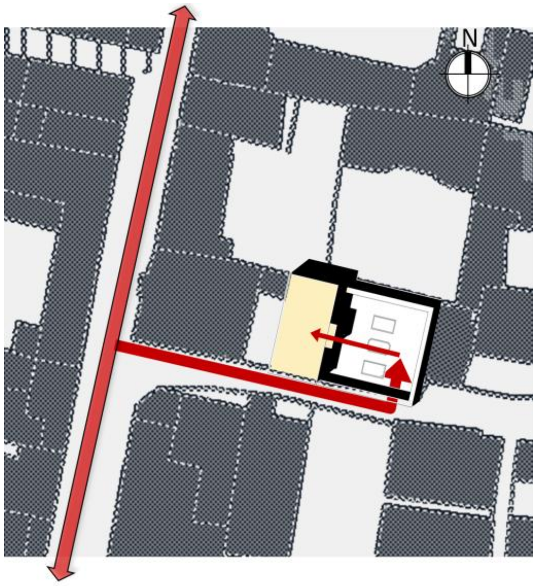


Figure 6-37: access hierarchy from alley to the rooms in the Afchangi house

External double stairs from the courtyard give access to the building. The landing is covered by a roof which, in turn, is supported by two cylindrical brickwork columns (ca. 3.5 m high) and elegant brick arches (Figure 6-35, Figure 6-38). An entrance hall as a circulation area connects the staircase to the main rooms and kitchen.

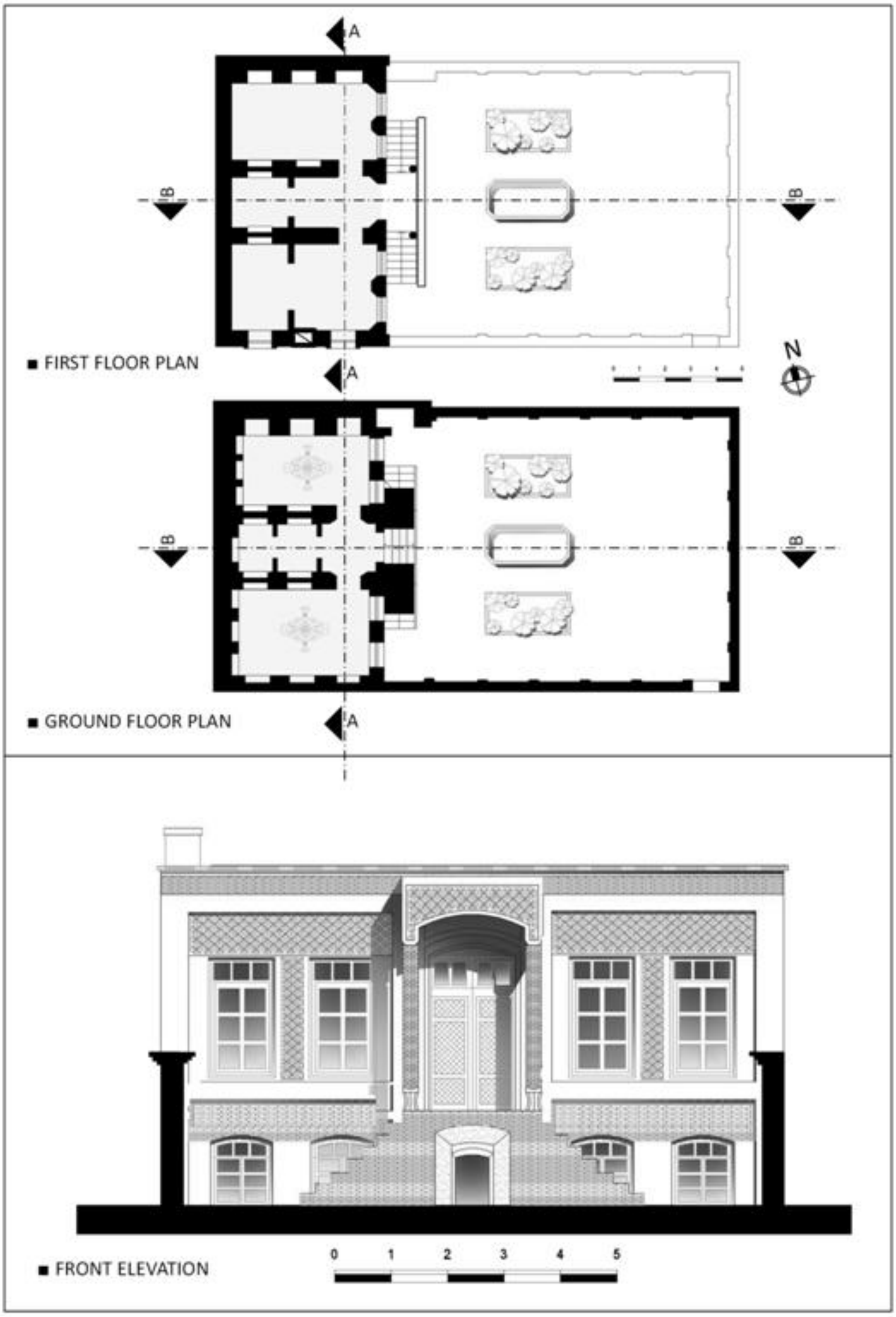


Figure 6-38: plans and elevation of the Afchangi house
(Estaji, 2010, Kermani-Moqaddam, 2002a)

Figure 6-39: Afchangi house photos (Estaji, 2010)

A few small steps in the central axis lead to the basement vestibule and on to the basement rooms (Figure 6-38, Figure 6-40). The floors above these rooms are constructed as shallow barrel vaults with the bricks laid in a decorative pattern. (Figure 6-41)

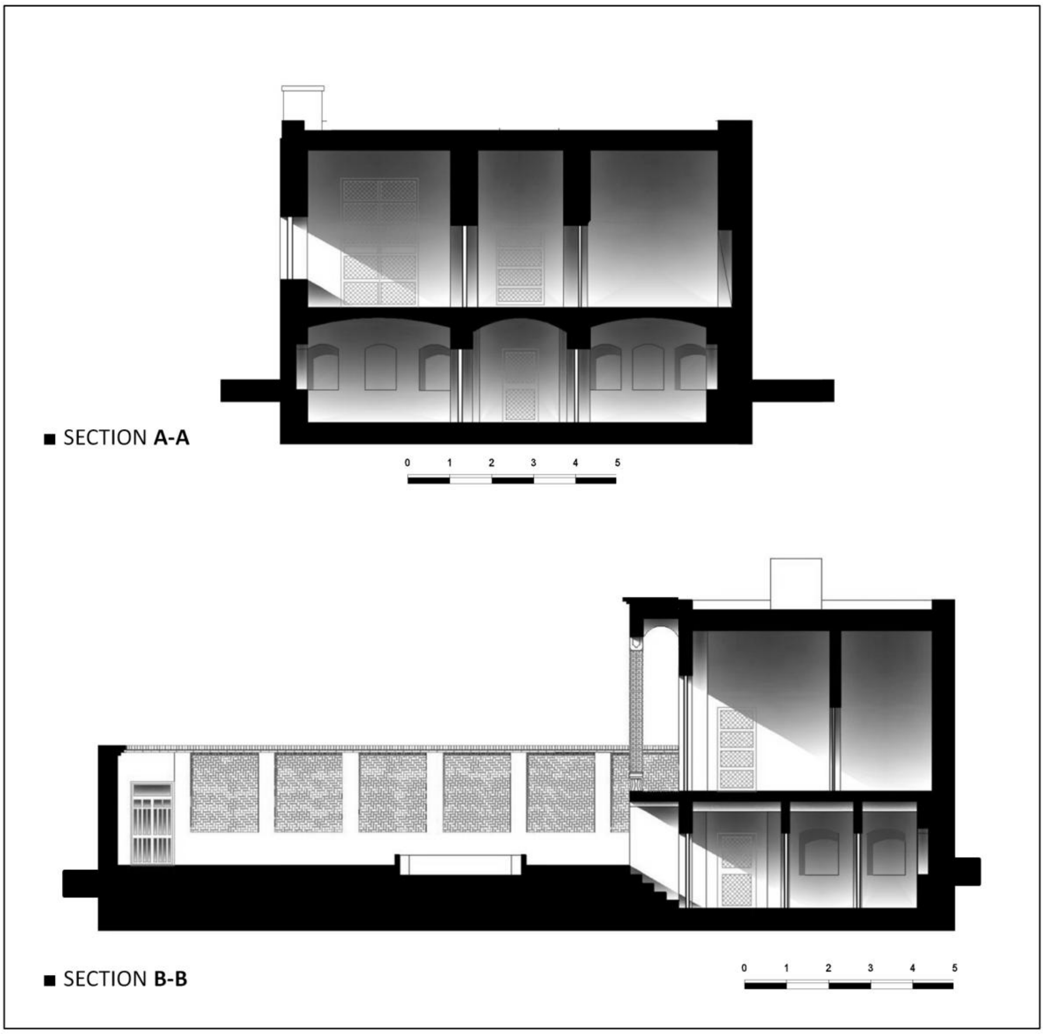


Figure 6-40: sections of the Afchangi house (Estaji, 2010, Kermani-Moqaddam, 2002a)

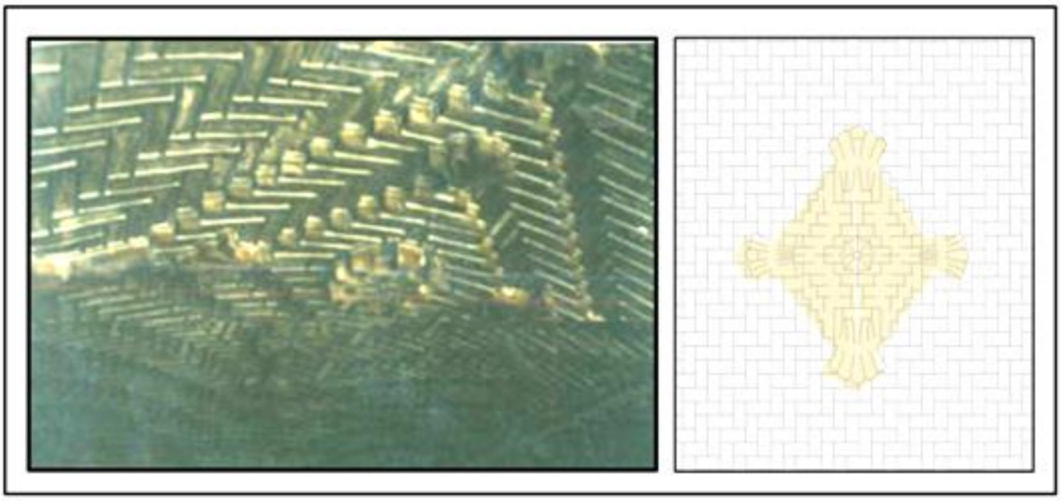


Figure 6-41: left-the ceiling of the basement (Kermani-Moqaddam, 2002a)
right- reverse ceiling plan

6.7.1.1.1 House Orientation and Sun Position

The Afchangi House is oriented to the east with eight degrees rotation to the south (Figure 6-42). The following graphs (Figure 6-42) show the path of the sun and the position of shades in the morning and afternoon for the two solstices (Jun 21 and Dec 22) and two equinoxes (March 20 and Sep. 22).

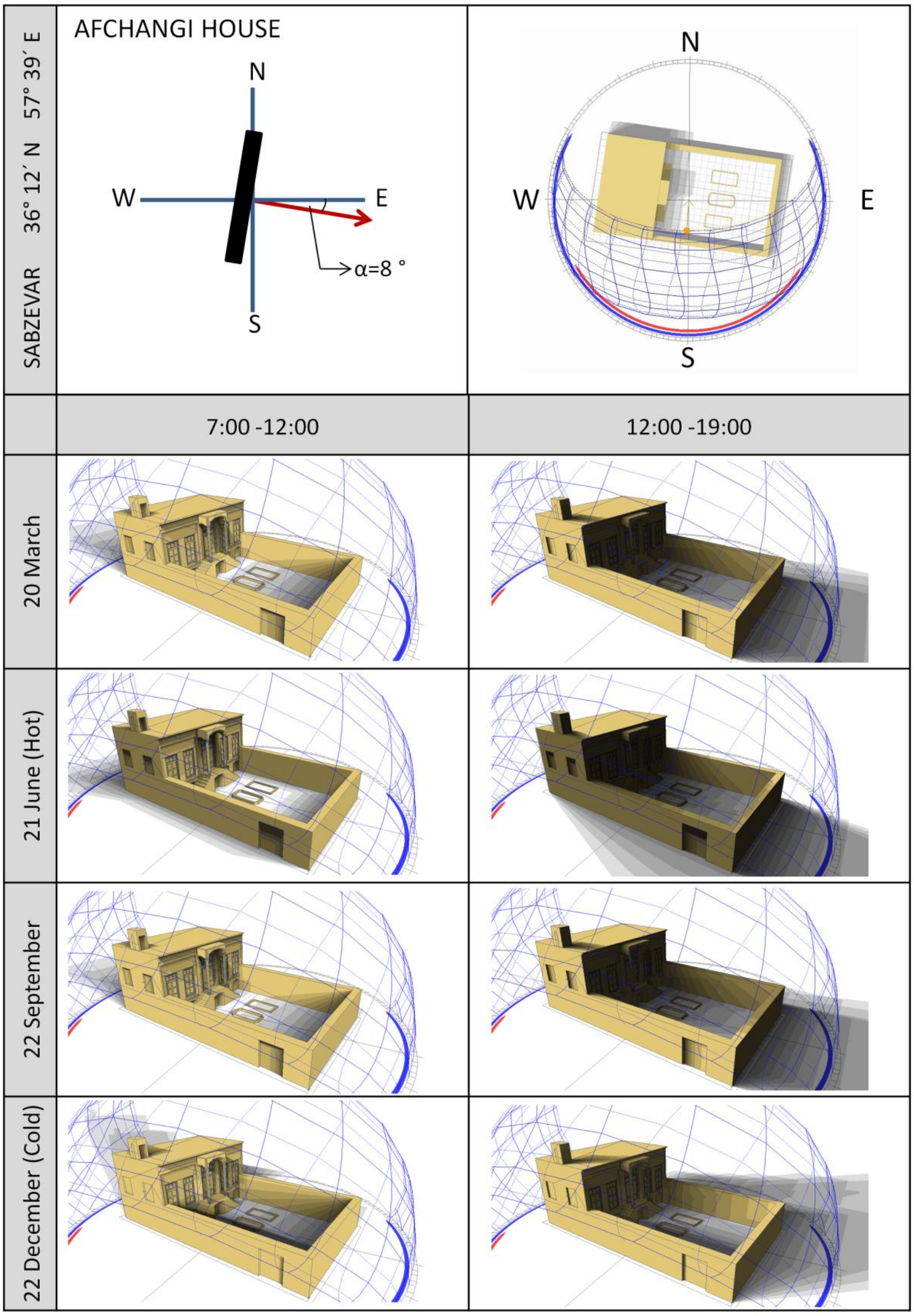


Figure 6-42: the position of shades in the morning and afternoon for the two solstices and two equinoxes

For a detailed study, the sunlight received by each window is investigated separately. The shading mask for the middle of each window is simulated in a model. Due to the thick walls of houses, the position of windows in the wall, e.g., set back into the depth of wall or flushing with the façade, has a great impact on the shading on the windows. For this reason, windows are generally modeled taking the exact location of the house into consideration.

The stereographic diagrams of the Vertical Sky Component (VSC) for each window help to understand exactly when the windows are shaded (Figure 6-43).

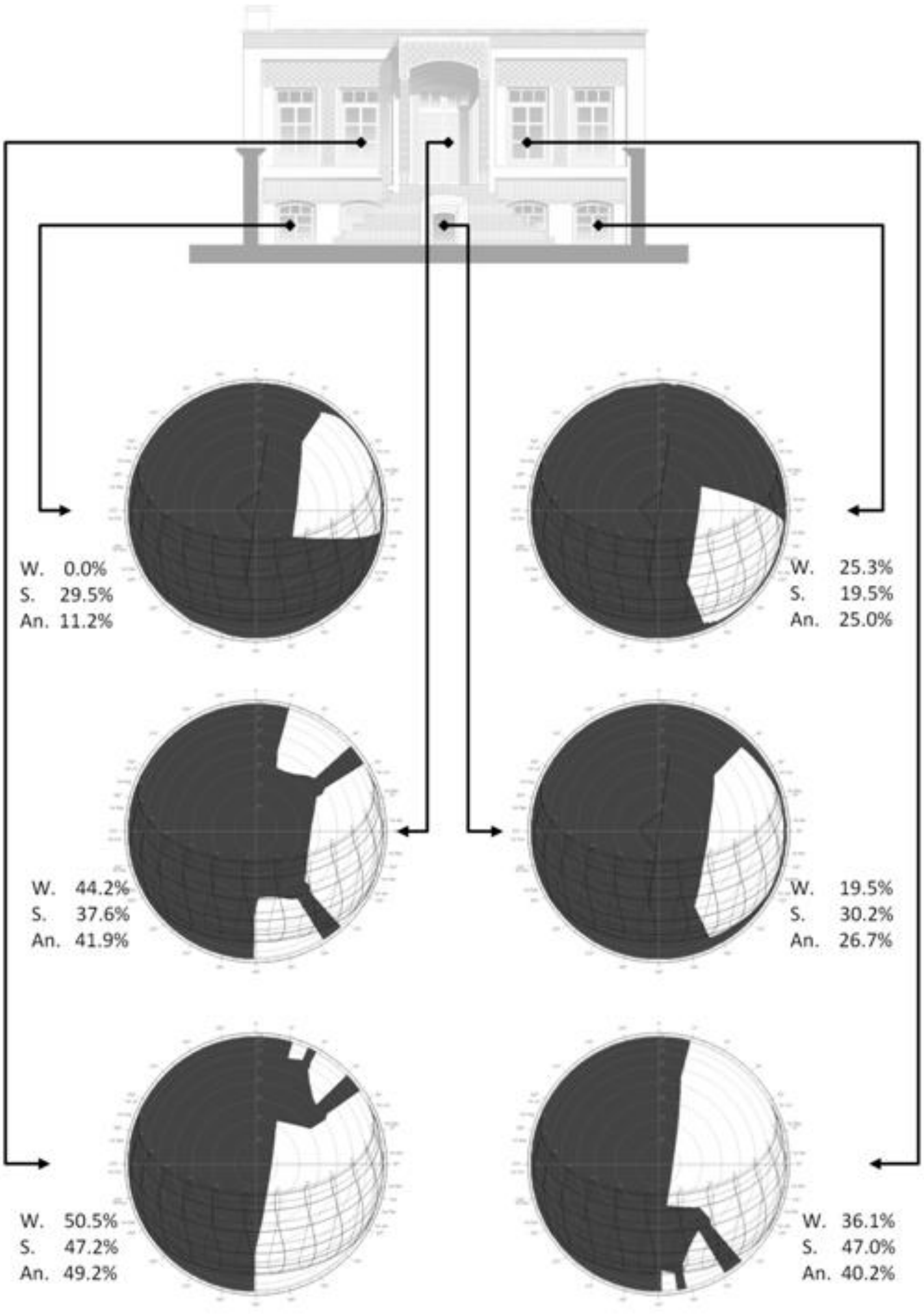


Figure 6-43: Shading Mask and Effective Shading Coefficients of Afchangi windows in winter, summer and annually

The diagrams indicate that on warm days the spaces behind these windows can benefit from the house orientation in the afternoons, but it is not suitable for the morning on warm days.

There are only two south-facing windows in the Afchangi house. The diagram shows the suitable position of the windows in the summer and winter. The Effective Shading Coefficient is 11.9% in the summer and 93.9% in the winter (Figure 6-44).

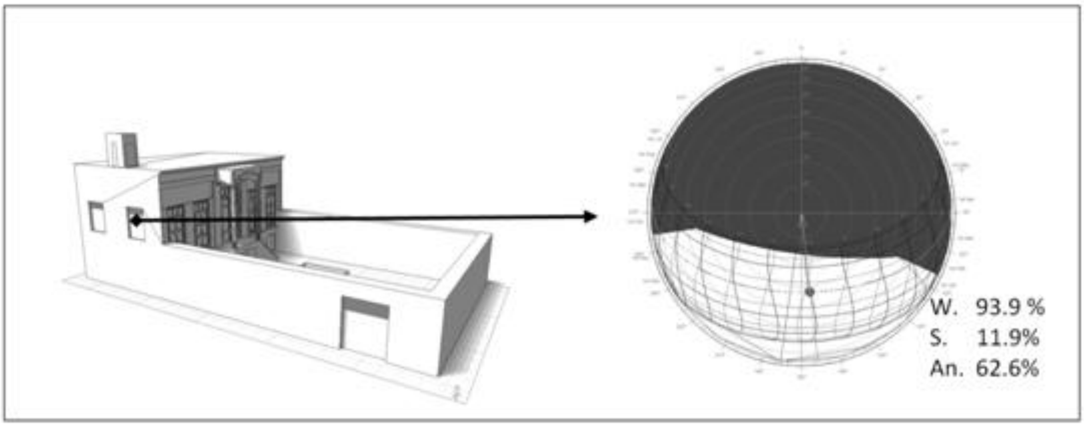


Figure 6-44: Shading Mask and Effective Shading Coefficients of south-facing Afchangi windows

The following table summarizes the impact of house orientation in the comfort conditions for each space in different periods (Table 6-1).

Table 6-1: the impact of house orientation in the comfort conditions in the Afchangi house

	Warm days		Cold days	
	Morning	Afternoon	Morning	Afternoon
First floor	Negative	Positive	Positive	Negative
Basement	Positive	Positive	Negative	Negative
South room	Positive	Positive	Positive	Positive

The key climatical strategy of the Afchangi house was to avoid direct sunlight in the afternoon on hot days. The daily movement of residents between the basement and the first floor helped them to overcome the hot weather in the mornings. On the other hand, the house users worked outside the house in the warm season, this kind of lifestyle minimized the occupancy rate of rooms before noon. In the afternoon the residents cooled down the rooms that were heated by the solar radiation during the morning until noon by using natural ventilation or a combination of ventilation and evaporative cooling.

6.7.1.1.2 Spatial Configuration

The Afchangi house consists of sixteen convex spaces (including the circulation spaces) on two stories; four main rooms, four subsidiary rooms, two vestibules, and two stairs. The ground floor which is sunken by 120 cm includes the summer rooms, and the first floor is used the entire year. The summer room was a multifunctional space in traditional houses; it was used as a living room in summer and storage space for agricultural products during winter. This multifunctionality increased the flexibility of the house with regard to the seasonal changes of use. Due to lifestyle changes in recent years, the Afchangi house is not used in accordance with its original concept anymore; the new lifestyle does not require large storage spaces, and now with the use of electrical and mechanical heating and cooling systems seasonal movements are no longer necessary. The breakup map (Figure 6-45) and justified graph of the Afchangi house (Figure 6-46) help to investigate the potential of the house to be reconfigured in response to the changes (possible scenarios).

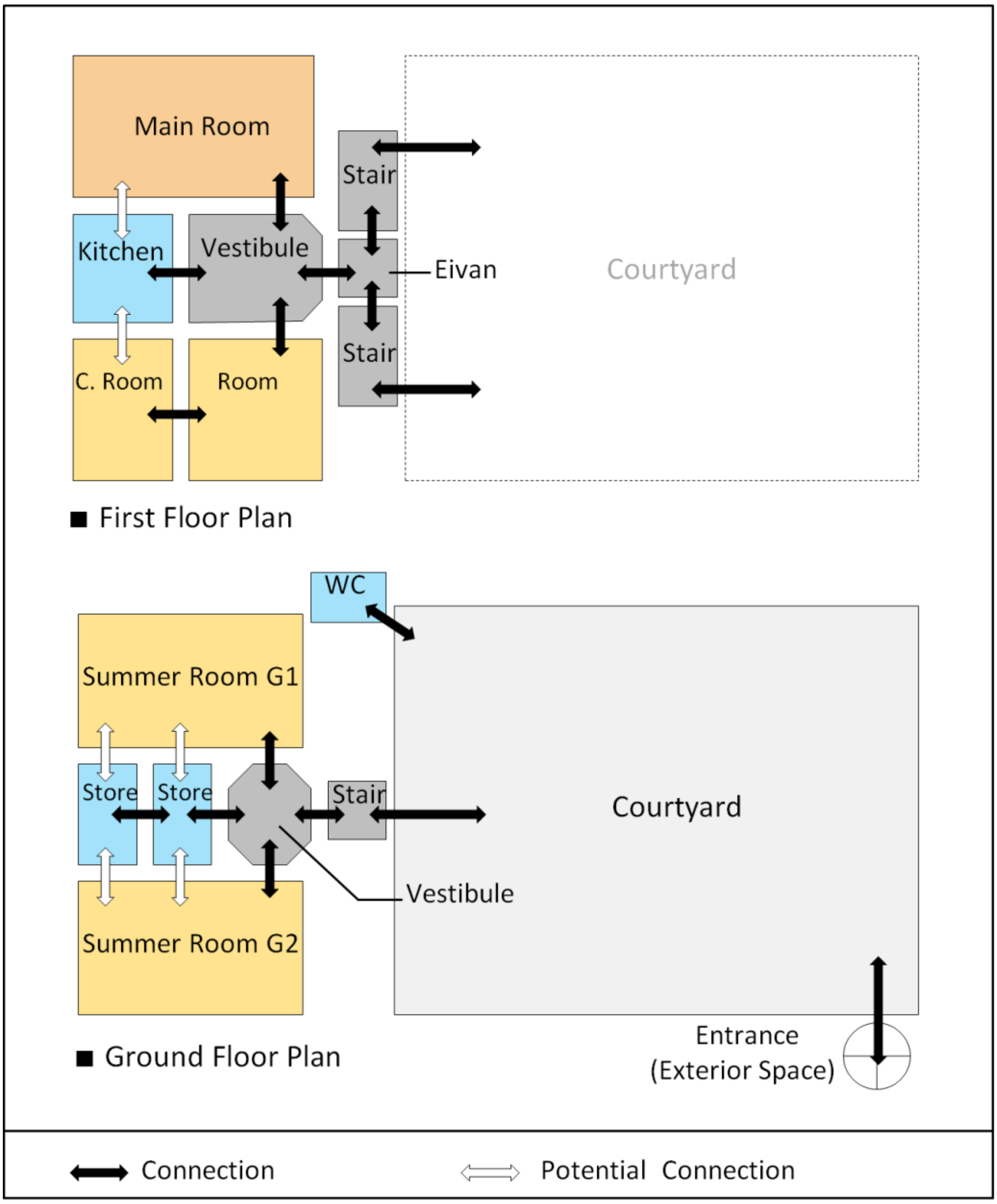


Figure 6-45: Break-up map[21] of the Afchangi house

[21] 'Break-up map' or more precisely 'Convex space breakup map' "indicates a process of decomposing the continuous structure of open space into separate convex spaces." (Hillier and Hanson, 1984, pp.98, 105)

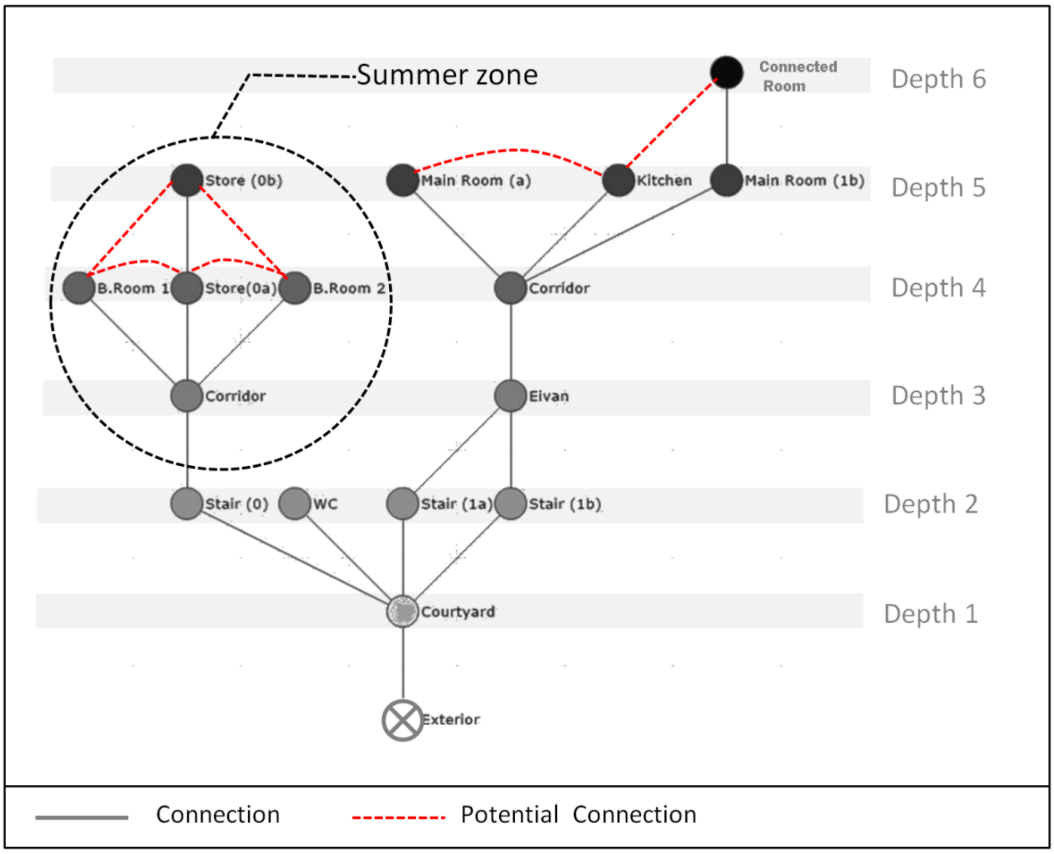


Figure 6-46: Justified graph of the Afchangi house

At first glance, the spatial configuration of the Afchangi house seems to be a rigid system. There is only one loop in the system that could not help to change the arrangement of the spaces. But there are six potential openings in the load-bearing walls (Figure 6-38) that enable the house users to rearrange the spaces with minor structural modifications (Figure 6-45, Figure 6-46). These potential openings make six possible loops in the system. The number of loops has a direct proportion with the distributedness of the system. On the other hand, the high range distributedness (between zero and one) shows the high capability of the system to reach a specific space from different ways. These various ways of increasing the building's flexibility for future changes and enable the house to response to the different scenarios that might happen in the house during its lifecycle. Table 6-2 indicates the difference between existing and potential distributedness of the Afchangi house.

Table 6-2: existing and potential distributedness

THE AFCHANGI HOUSE						
The number of spaces	Mean Connectivity	Potential openings	Number of loops		Distributedness (Convex ringiness)	
			Existing conditions	Considering the potential openings	Existing conditions	Considering the potential openings
16	2.06	6	1	7	0.04	0.26

The calculation of integration and the choice of each space show the importance of the courtyard in the house (Appendix A 1). It is the main circulation space that has the maximum connectivity, choice, and integration.

The following diagram (Figure 6-47) orders the spaces according to the integration value. It reveals a strong spatial discipline in the Afchangi houses. As can be seen in the picture, the first seven spaces are the circulation spaces, followed by the main rooms and finally the private rooms, kitchen, and stores. In fact, the access hierarchy of the Afchangi house reflects the degree of the spaces' privacy. The Afchangi house presents a typical access hierarchy in the traditional houses of the Qajar period. (Figure 6-48)

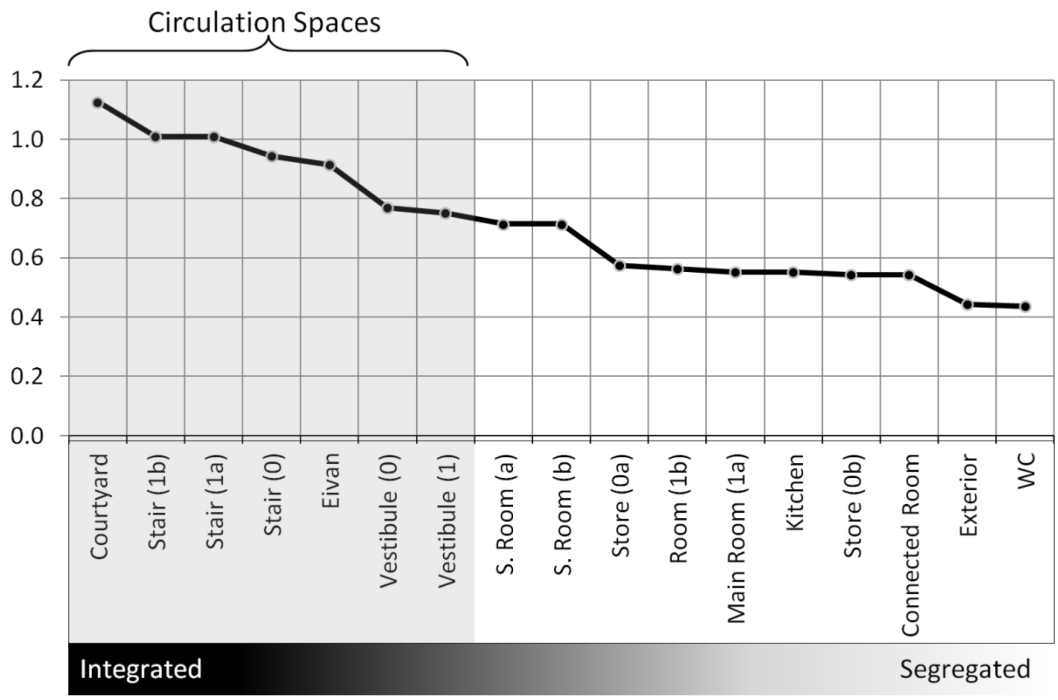


Figure 6-47: integration value of Afchangi spaces

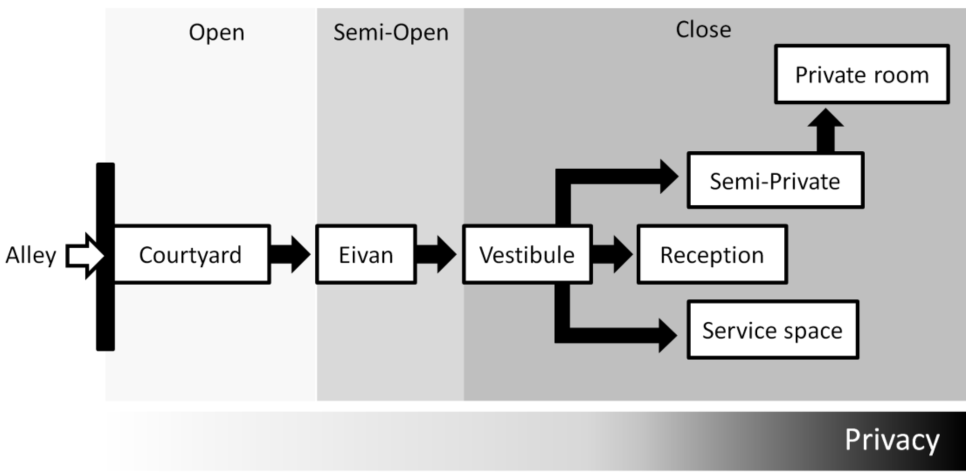


Figure 6-48: Schematic access hierarchy of the Afchangi house

6.7.1.1.3 Adaptation to a New Lifestyle

The new residents of traditional houses would prefer not to use external stairs between the living spaces. This, in addition to the use of new mechanical and electrical cooling and heating devices, has resulted in the basements and underground spaces being used only as storage space. The existing spaces could be adapted to the current way of life by connecting them by means of an internal staircase.

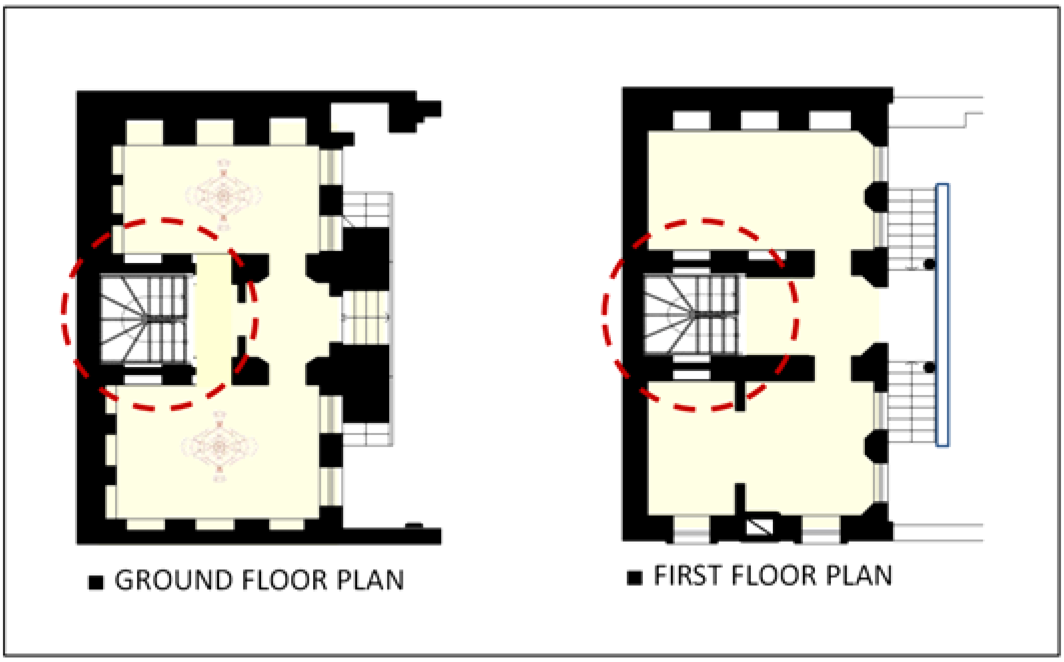


Figure 6-49: new internal stairs to make a direct connection between floors

The Afchangi house could also be divided into two separate living units. For this purpose, a vertical connection between the two floors is needed in each unit; two light staircases can replace the storage rooms on the ground floor (Figure 6-50). A small bathroom and a kitchenette at the end of the main rooms (on the ground or first floor) provide comfortable living conditions in the old structure. This building has the potential to be turned into a small office as well.

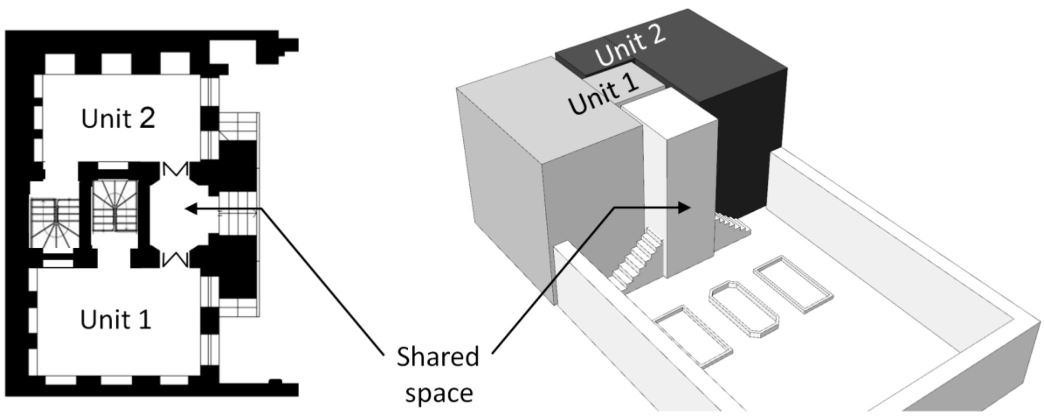


Figure 6-50: the convertibility of the Afchangi house into two independent units

6.7.2 One-Side House with Vaulted Portico (Eivan)

6.7.2.1 The Mashhadi building: a house or a family tomb?

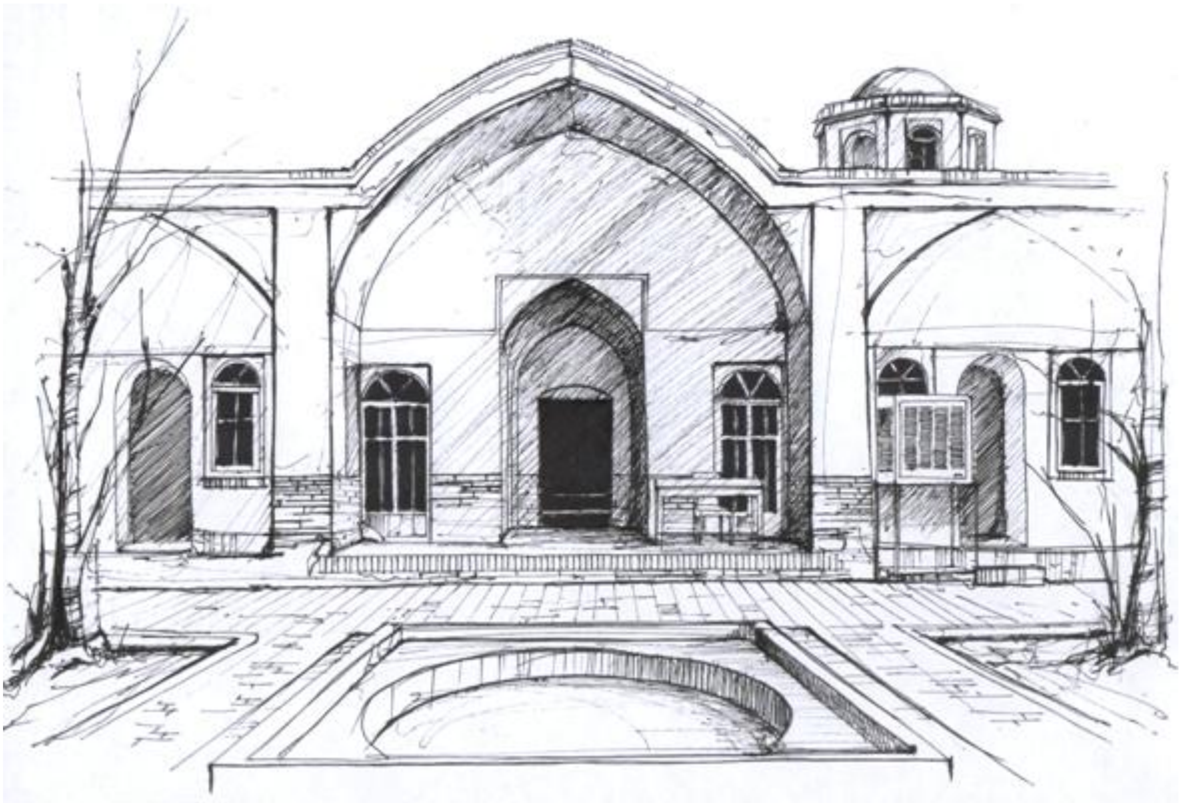


Figure 6-51: hand drawing of the Mashhadi house (Estaji, 2010), Drawn by Minoo Qasemi

The Mashhadi house (Figure 6-51) is a unique Qajar house in Sabzevar. It is a set of different spaces, building technologies, natural light inlets, and openings that create various spatial qualities. The building was constructed outside the old Sabzevar city wall around the end of the Qajar period (1925). Figure 6-52 shows that in 1956 the house was a single building surrounded by agricultural lands, whereas in 2015 it is part of a dense urban fabric.

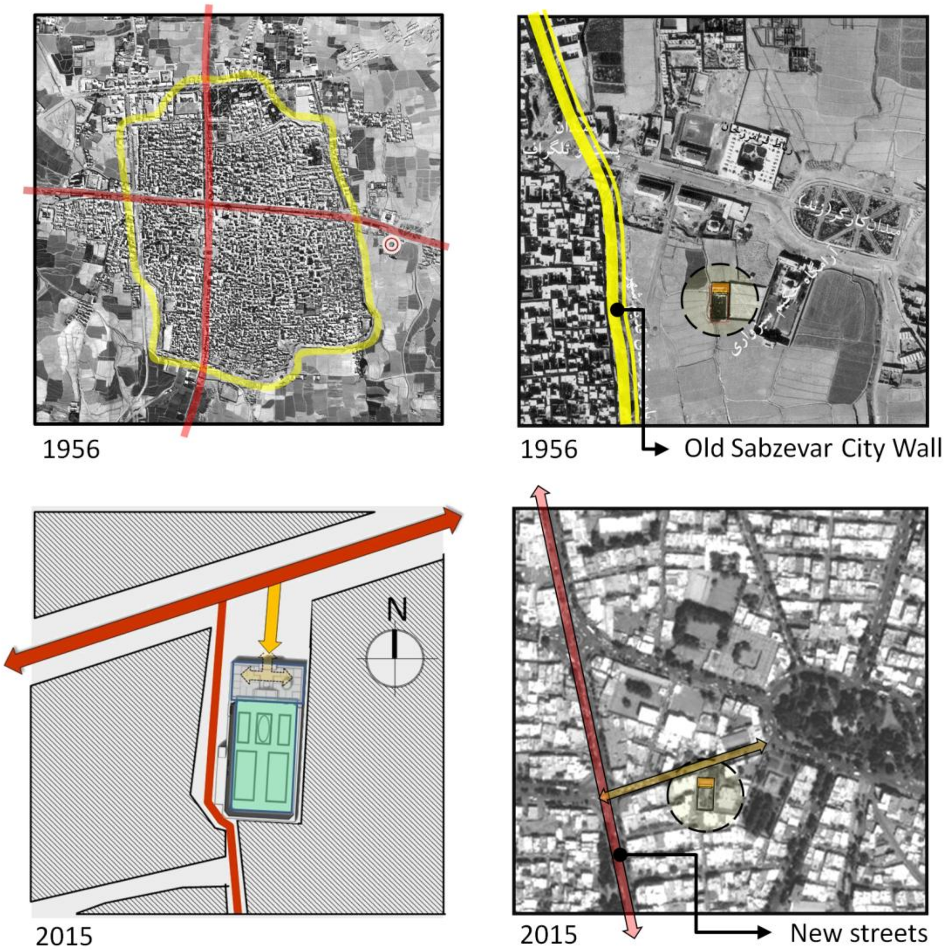


Figure 6-52: the position of The Mashhadi house in 1956 and 2015
base photomosaic maps of 1956:(Zanganeh, 2003a), 2015 aerial map: (Google Earth, 2015)

A stone inscription on the Mashhadi house (Figure 6-53) says that the famous merchant Haji Mohammad Sadegh Amin-o-Tojjar Mashhadi was buried in this tomb on July 8, 1916.

Figure 6-53: stone inscription on the Mashhadi House

The existence of this tombstone in the building raises the question whether the family of Mashhadi lived in this building before his death.

There are only two main rooms in the building. The houses belonging to the rich people in Qajar period were extended houses with several spaces (rooms) that usually were located in two or more courtyards. Therefore the Mashhadi house could not be a permanent residence for a businessman. On the other hand, the building was built outside the city walls. Security issues (danger of burglary and looting) and lack of access to urban facilities thus make the use of the Mashadi building for residential purposes impossible.

The assumption that the structure was not a residential building raises another question: why was the family tomb designed like a country house?

The answer is that they needed a building for family gatherings on the weekends, religious ceremonies, cooking food for votive offerings and as permanent living space for servant and gardener. They built a multifunctional building that allowed different functions to become more prominent in different periods. (Figure 6-54)

The children and grandchildren of the Mashhadi family were buried in this building until 1970. Almost from this time the urban fabric started to surround the building, with the religious function of this building receding into the background and its residential function becoming more pronounced. The building never lost its religious function altogether but it was possibly undermined in some periods. In 2001, the Mashadi family transferred the management of the building to a cultural heritage organization, and the cultural heritage organization used it as an office.

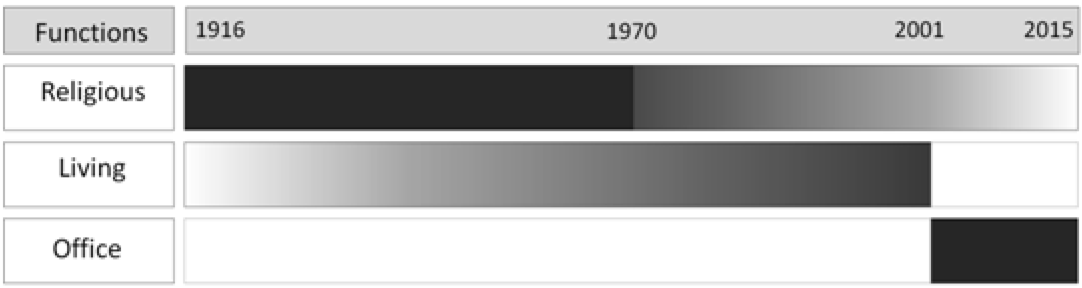


Figure 6-54: functions of the Mashhadi building during the time

In addition to the functional changes, the access hierarchy and the location of the entrance have been modified several times. In 1916, agricultural lands surrounded the building; there was a narrow pathway that ran parallel to the water canal allowing access to the building. The entrance to the building was located in the main axis of the building. The Mashhadi house was erected alongside a water stream. A small stream branched from the main stream (Figure 6-55). This canal that passed through the middle of the courtyard irrigated the garden and filled the pool. About 1975, the main water stream dried up and was converted into an alley. A new street cut through the land plot that was located in front of the building. The family was allocated a private impasse alley to access to the building (Figure 6-55). This change did not last long; the dead-end was blocked by a door (went from being a public space to a private one) and a new direct opening to the courtyard was made in 1980. Figure 6-56 shows the original entrance to the building and the new opening. The last change took place in 2014; the Cultural Heritage Organization decided to restore the original state, they destroyed the building in front of the Mashhadi building and created an open space. As a result, the main facade of the building was once again visible, and the main entrance was restored.

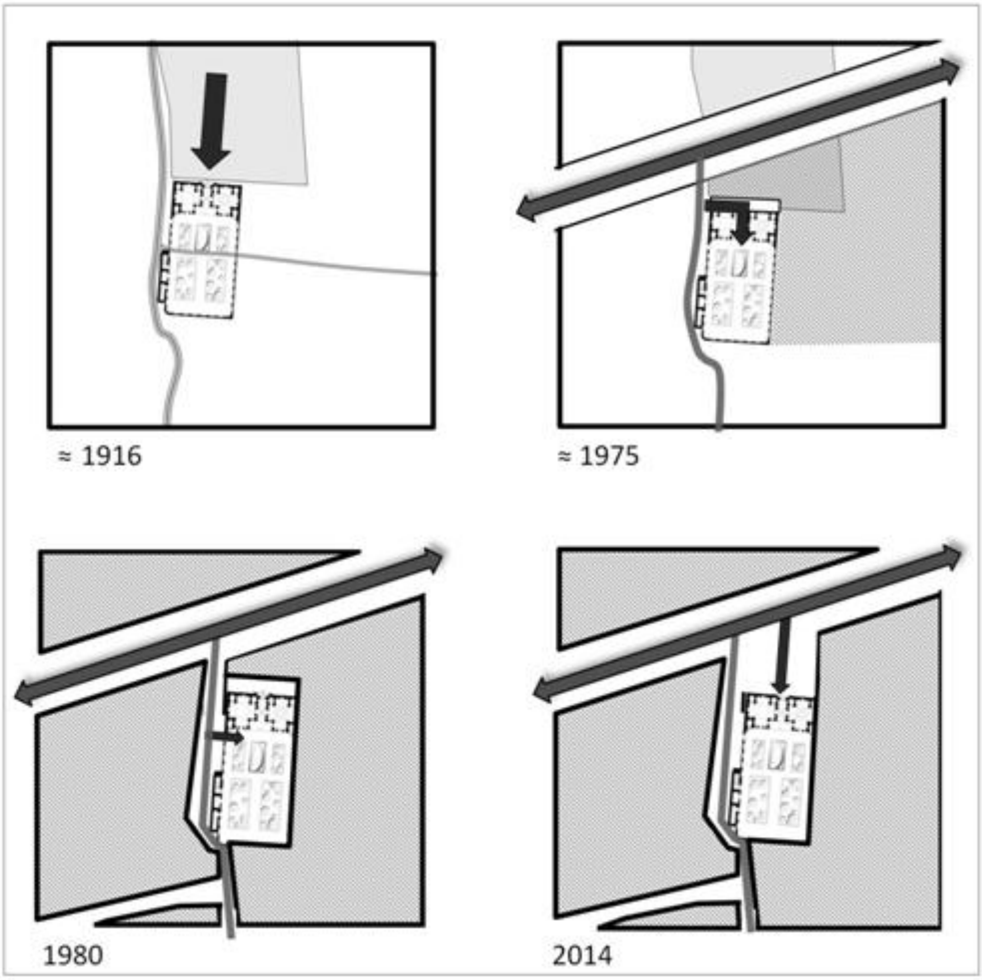


Figure 6-55: access to the Mashhadi building during the time

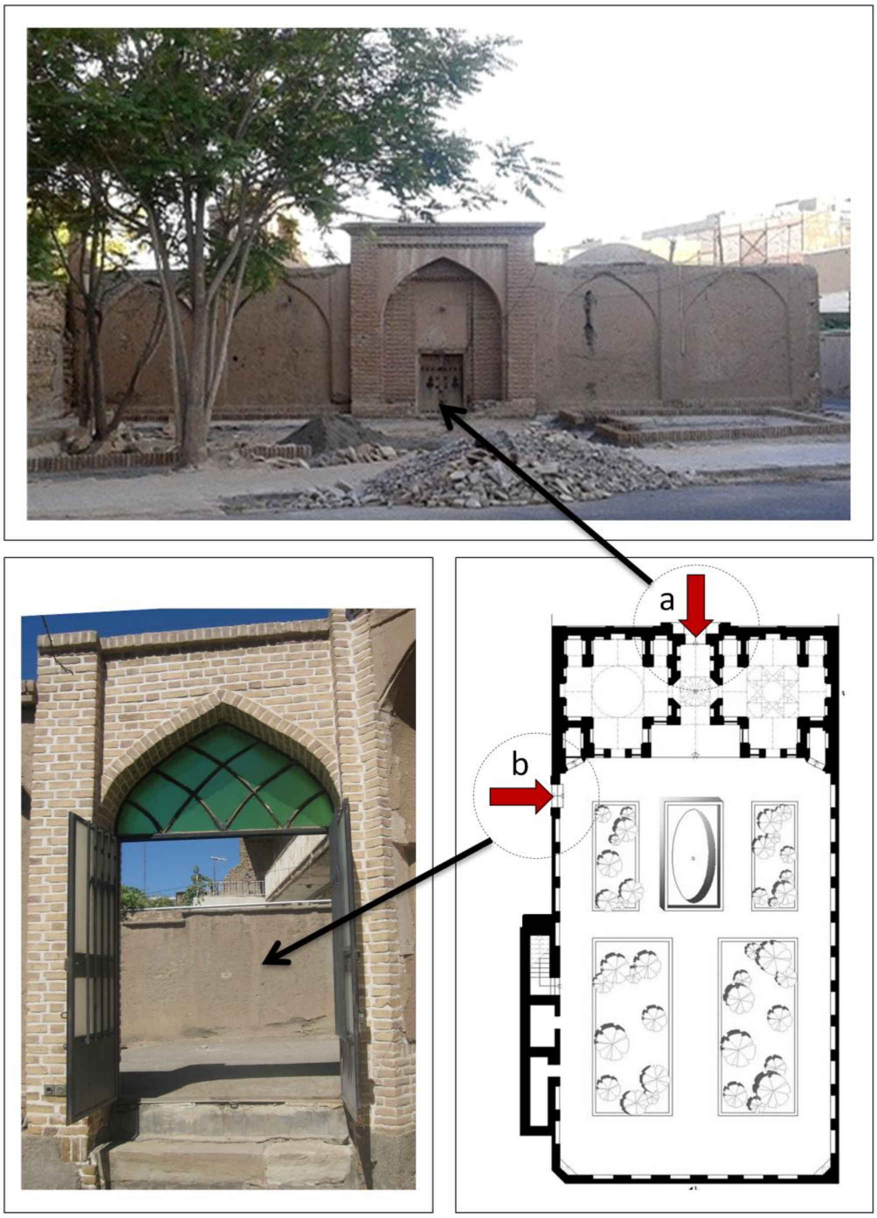
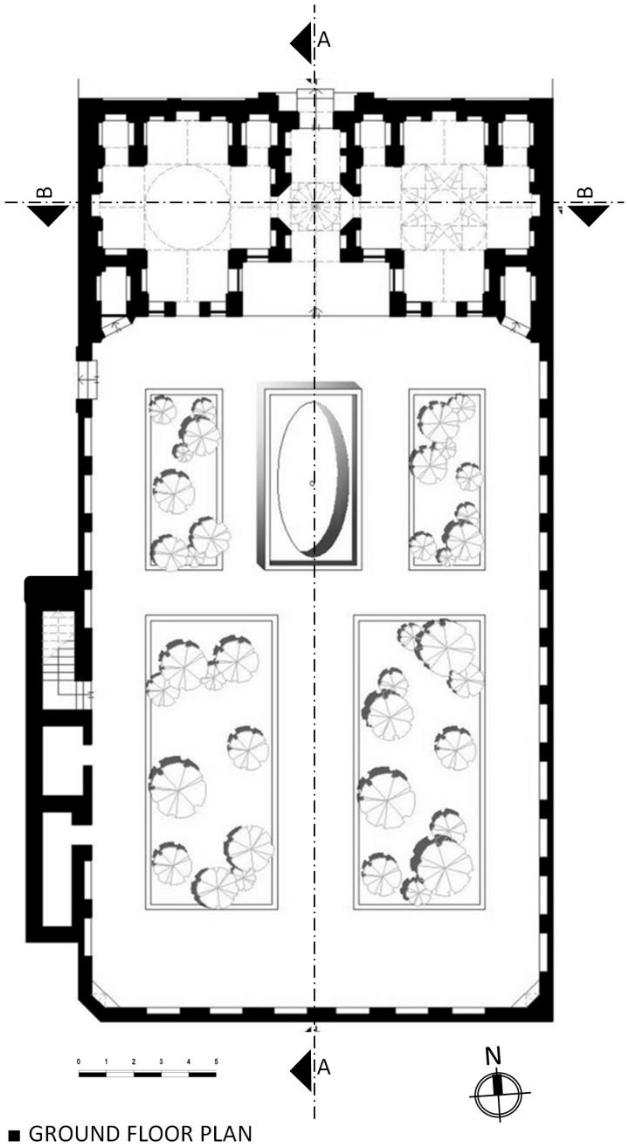


Figure 6-56: the original entrance (a) and the adjunct door (b), top photo by Milad Modarresi (Asrarnameh, 2014)

The main rooms of the Mashhadi house (closed spaces) are located in the northern part of the courtyard. A semi-open vestibule connects the entrance to the main rooms, while an Eivan connects the vestibule to the courtyard. (Figure 6-57, Figure 6-58)



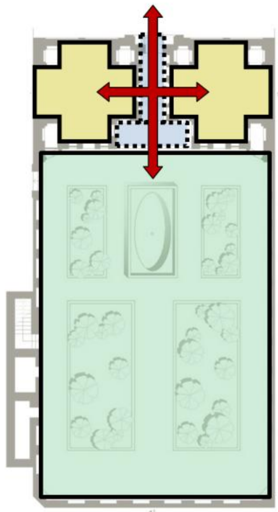


Figure 6-57: plan of the Mashhadi building (Estaji, 2010)

Figure 6-58: section from the main axis (Estaji, 2010)

The two main cruciform rooms are vaulted with two different domes (Figure 6-59): a simple round dome and a polygonal dome with a lantern that provides natural light and ventilation for the room (Figure 6-60).

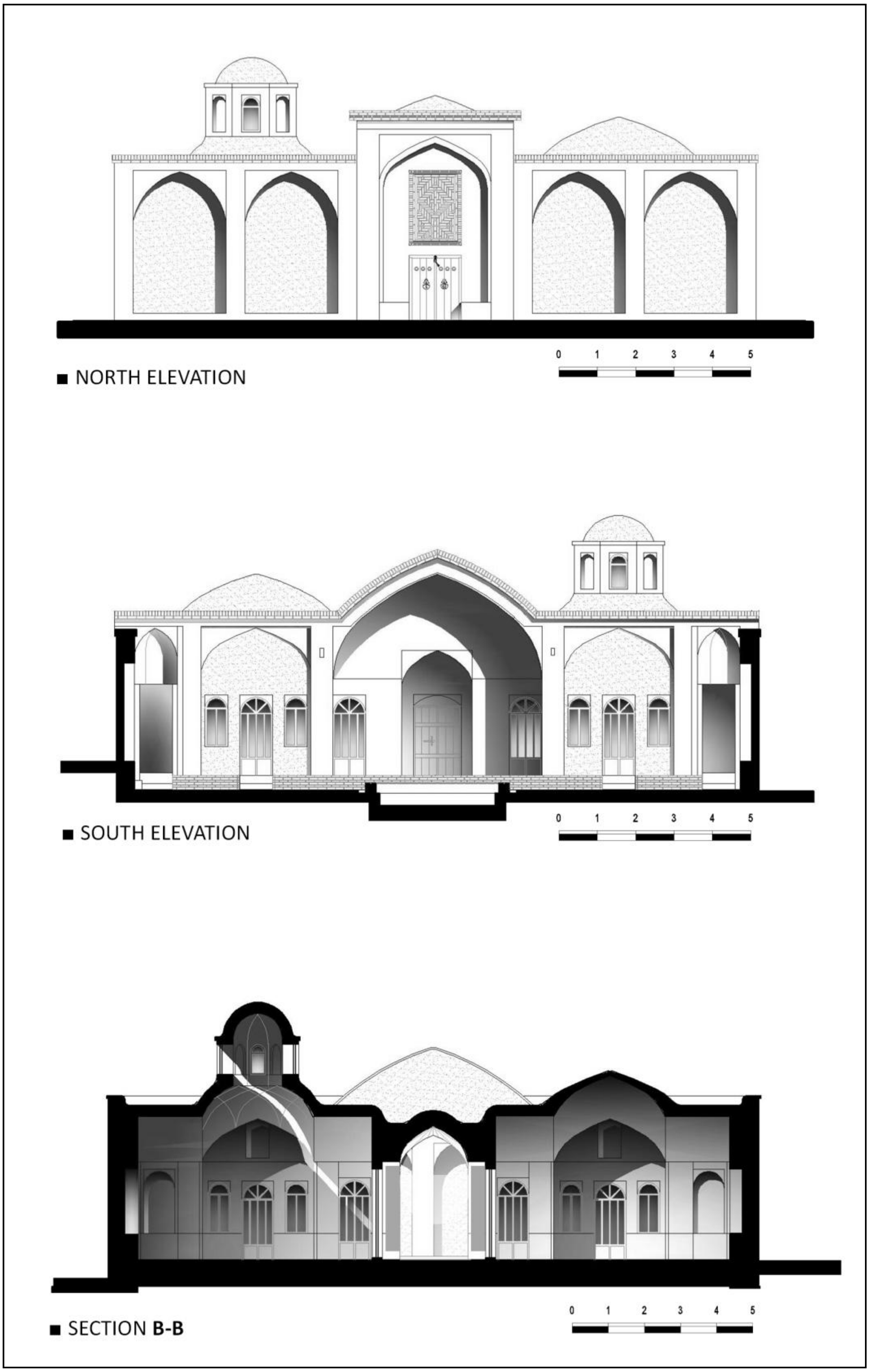


Figure 6-59: elevations and section of the Mashhadi building (Estaji, 2010)

Figure 6-60: polygonal dome with a lantern (Estaji, 2010)

6.7.2.1.1 House Orientation and Sun Position

The Mashhadi House faces the south with four degrees of rotation to the west (Figure 6-61). The main openings (windows) of the building benefit from the sunlight from morning till afternoon throughout the entire year. The following graphs (Figure 6-61) display the eminent role of Eivan as a semi-open space in controlling solar radiation on hot days.

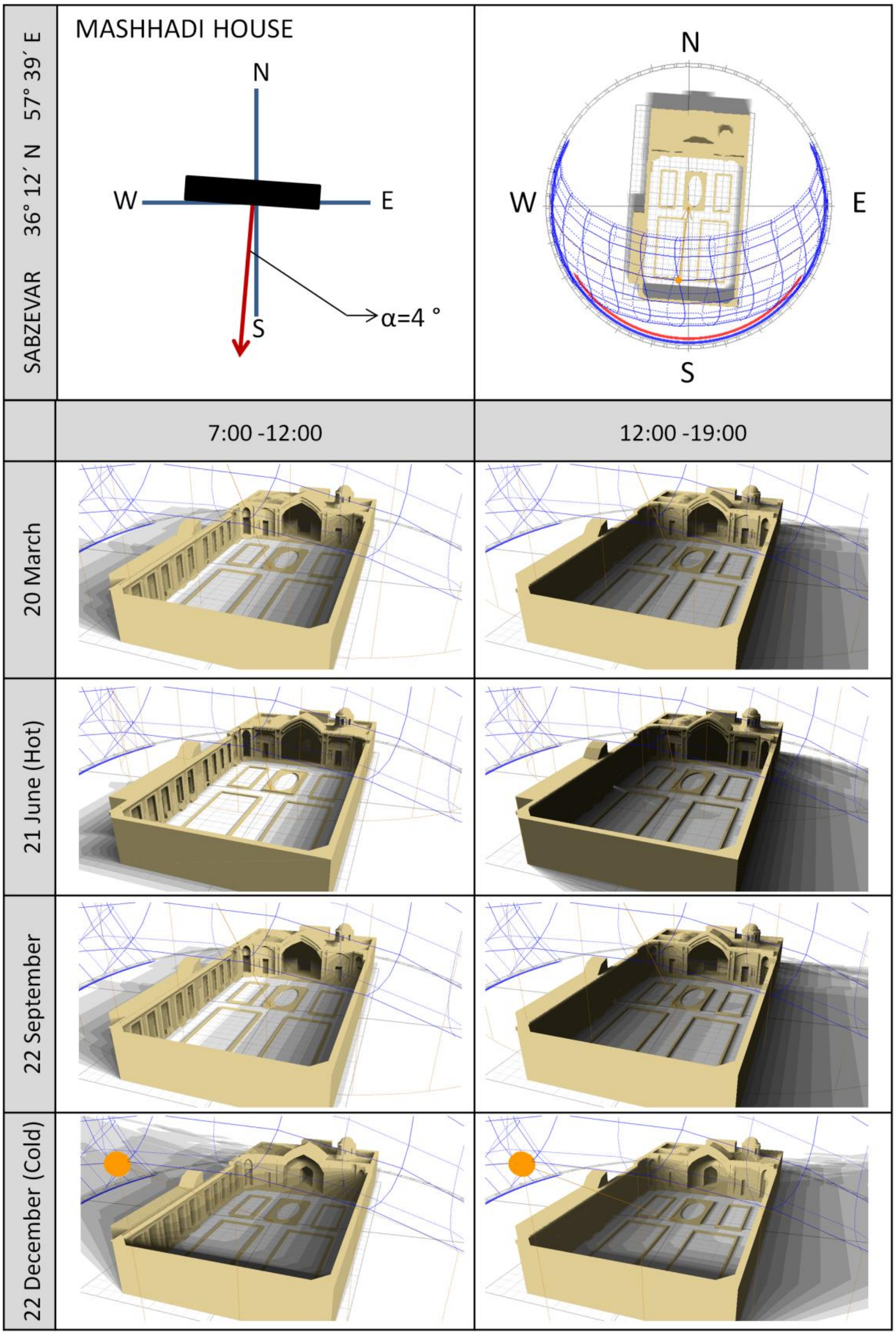


Figure 6-61: the position of the sun and shade in the morning and afternoon for the two solstices and two equinoxes

The shading masks for the middle of each window indicate that the spaces behind the windows benefit from the house orientation on cold days. Due to the high altitude angle of the sun in the summer, the Eivan blocks direct sunshine on the windows that open to the

Eivan. In the summer, the effective shading coefficients of these two windows are zero; this means that the Eivan of the Mashhadi blocks the direct sun in the summer completely. (Figure 6-62)

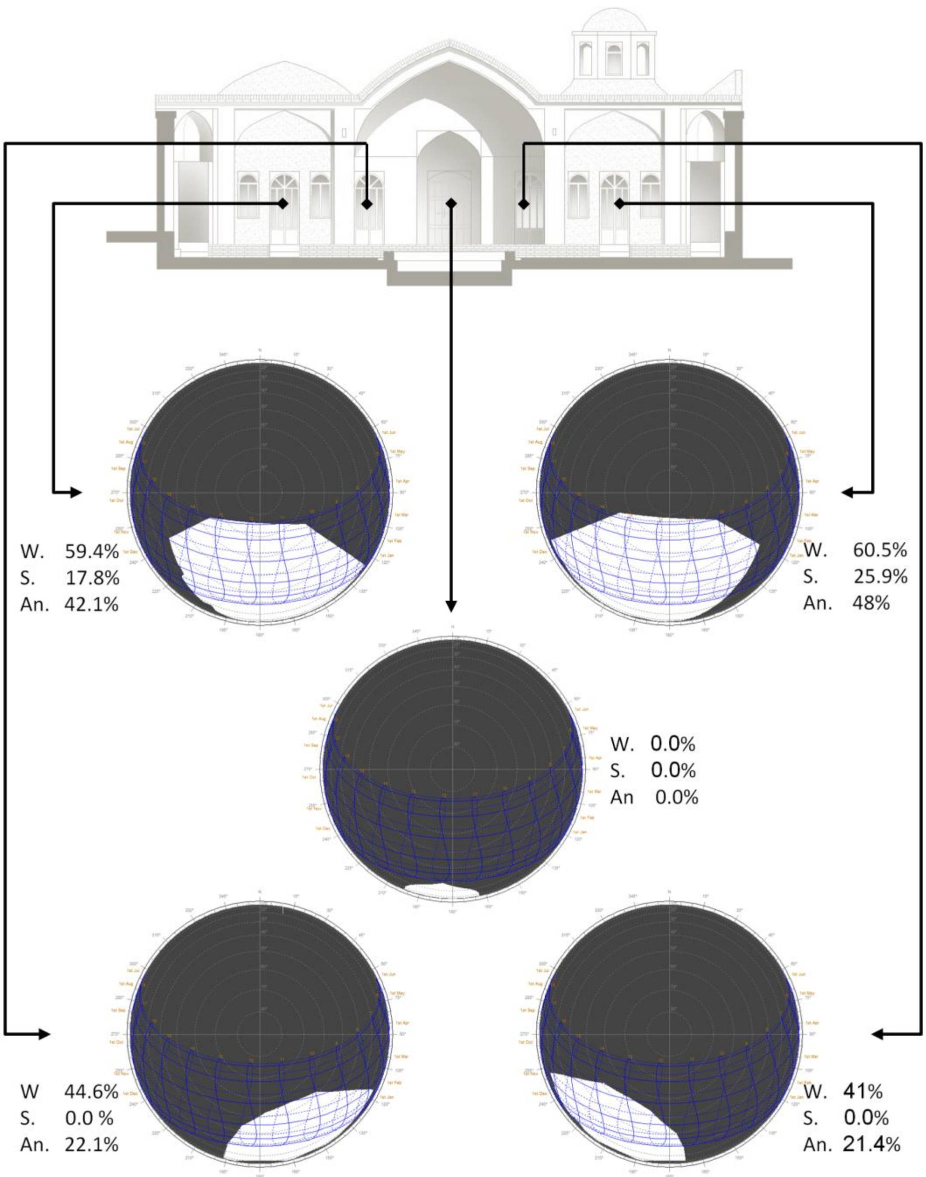


Figure 6-62: Shading Mask and Effective Shading Coefficients of Mashhadi windows in winter, summer and annually

The calculation of incident solar radiation confirms the efficiency of using the semi-open space as a shading device in this building. The vast differences of energy absorbed by the surface of the Eivan and the courtyard in the summer can be seen in the following graphs (Figure 6-63).

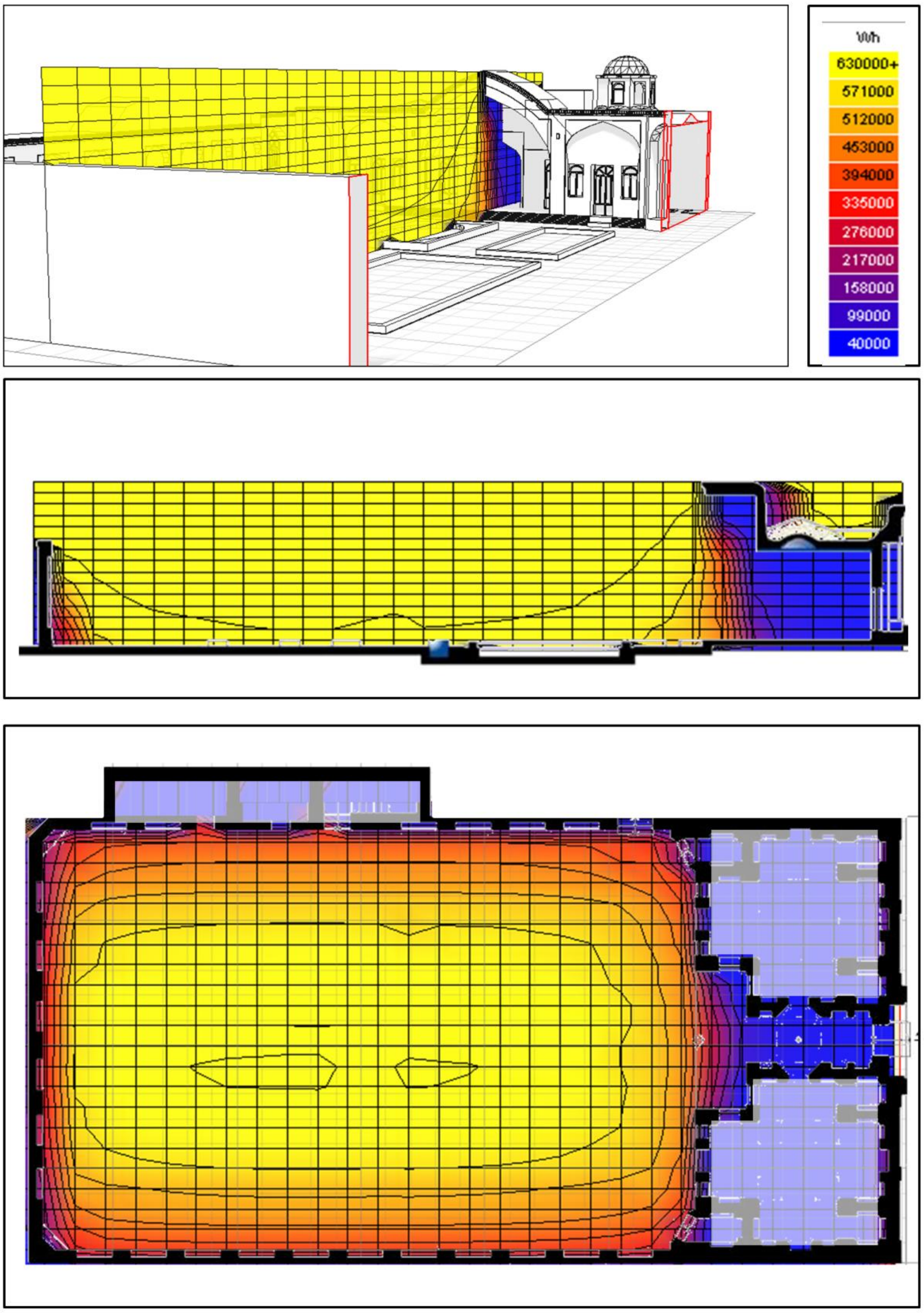


Figure 6-63: the incident solar radiation on hot days

The following table summarizes the impact of the house orientation and semi-open space position on the comfort conditions for the main rooms in different periods (Table 6-3).

Table 6-3: the effects of house orientation on the comfort conditions in The Mashhadi house

	Warm days		Cold days	
	Morning	Afternoon	Morning	Afternoon
Main rooms	Positive	Positive	Positive	Positive

6.7.2.1.2 Spatial Configuration

There are two large multifunctional rooms in the north of the courtyard. They were used as a living room or guest room and places for gathering in religious ceremonies. This multi-functionality increases the flexibility of the house in response to the different functions. The main circulation space is the courtyard with eight connections. In the second rank, the main rooms are linked with five connections to the other spaces. There are three different ways to enter these rooms; through the vestibule, the Eivan or the courtyard. A large number of entrances to spaces increase the flexibility of the system. The users can use the different doors in different situations. Changes to the access to the rooms on the inside impacts the hierarchy of access to the spaces from the outside. I this way, the residents could control the degree of privacy of rooms. If they open the door to the vestibule, the depth of the main room from the main entrance is two, and if they close all the doors and open the door to the courtyard the depth will be four (Figure 6-64, Figure 6-65). The new direct opening to the courtyard made in 1980 changed the relationship between spaces and the depth of spaces from the entrance. These changes are visible in the Justified graphs of the Mashhadi house (Figure 6-65). Figure 6-66 shows the metric step path of the Mashhadi house in four different alternatives by changing the entrance and the access to the main rooms.

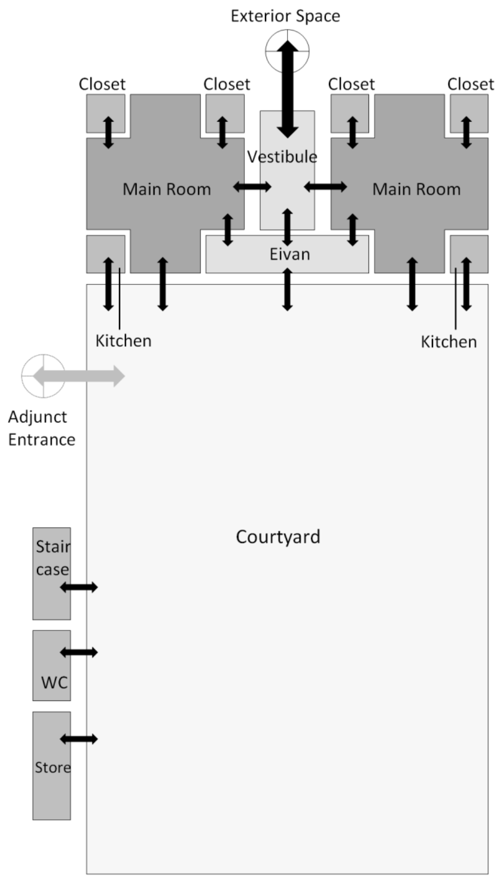


Figure 6-64: Break-up map[22] of the Mashhadi house

[22] With the space syntax methods, all spaces are broken down into the convex spaces so that everything is visible to anyone in the space. But in this case the main room is considered as a space; otherwise it should be split into three convex spaces.

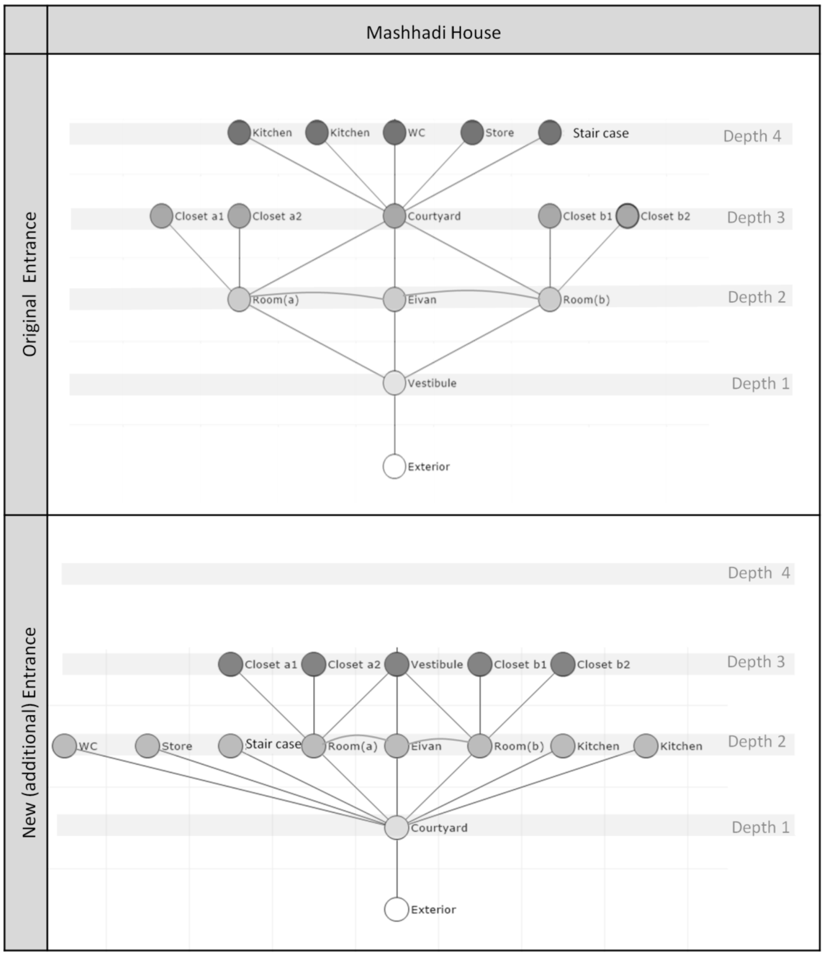


Figure 6-65: Justified graph of the Mashhadi house

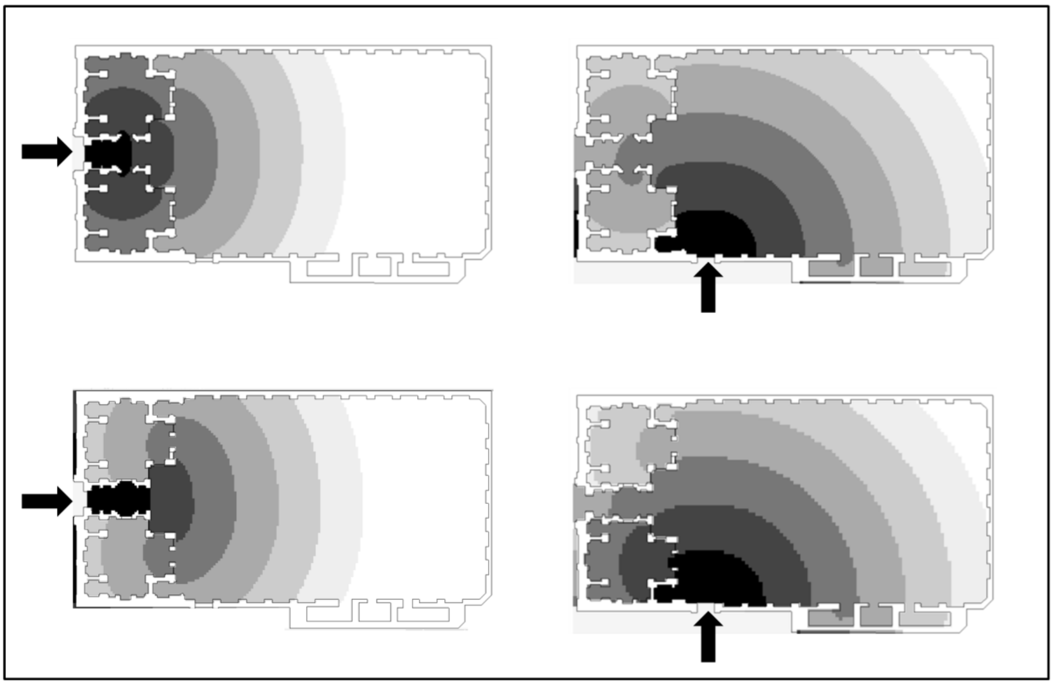


Figure 6-66: metric step shortest path length of The Mashhadi house in four different alternatives, calculated by UCL Depthmap 10 software

There are four loops in the system that could help change the arrangement of the spaces. The Mashhadi house almost applied the maximum possible opening to the main rooms. For this reason, the structure of this house offers no potential opening The distributedness value of Mahhadi house (the original condition of building) is 0.17, which is not high enough for a flexible system (Table 6-4). In general, it can be said there are two extremely flexible spaces (the main rooms) in the semi-flexible system.

Table 6-4: Distributedness, the original condition of building

THE MASHHADI HOUSE (Original entrance)				
number of spaces	Mean Connectivity	Potential openings	Number of loops	Distributedness (Convex ringiness)
14	2.5	0	4	0.17

The calculation of integration and choice for each space shows the importance of courtyard in the house. It is the main circulation space that has the maximum connectivity, choice, and integration. (Appendix A 2)

The following diagram (Figure 6-67) arranges the spaces according to the integration value. In the traditional houses it is often expected that the circulation spaces be more integrated than the living spaces. However, in this case, the integration value of the main multifunctional rooms is bigger than the vestibule. On the other hand, the quick and direct access to the living spaces from the entrance (just two steps) challenges the privacy of the house. In fact, the access hierarchy of The Mashhadi building does not correspond to the degree of privacy in the spaces (Figure 6-68). It contrasts with the importance of privacy in living spaces in the traditional houses of the Qajar era.

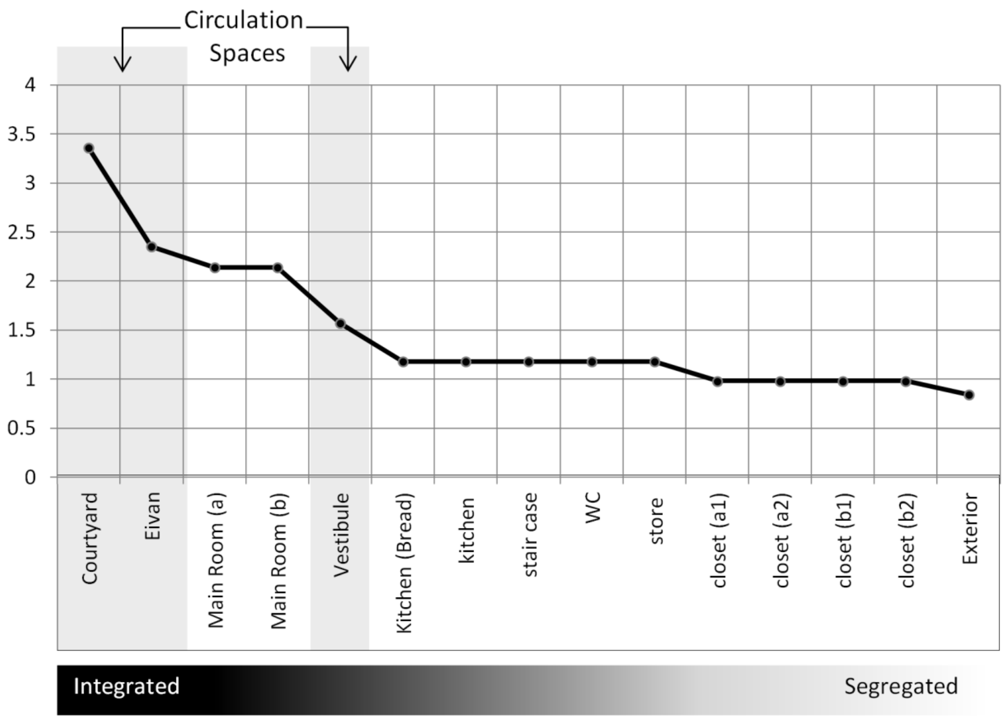


Figure 6-67: integration value of Mashhadi spaces

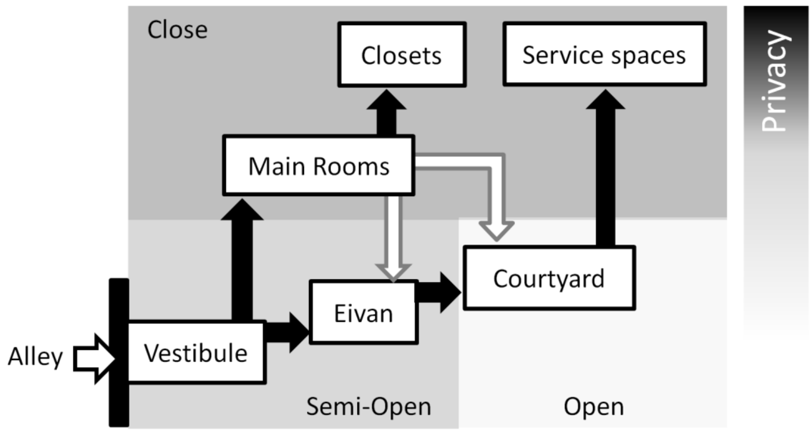


Figure 6-68: Schematic access hierarchy of the Mashhadi house

6.7.2.1.3 Adaptation to New Functions

Due to the architectural and historical value of the building, this building is one of the main tourist attractions in Sabzevar. The large number of visitors who visit the building limits the functions of the building; therefore using it for residential purposes would not make sense.

According to an agreement made between Sabzevar Cultural Heritage Organization (SCHO) and Hakim Sabzevari University (HSU) in 2014 the houses were to be turned into a practical restoration site for students and to be opened to visitors after restoration was completed. The house can be used as a tourist information site and exhibition space. Before this refurbishment it was used as a research office and small library.

6.7.3 One-Sided House with Pillared Portico (Eivan)

6.7.3.1 The Hejazi House

Figure 6-69: hand drawing of pillared portico Hejazi house (Estaji, 2010), drawn by Minoo Qasemi

The Hejazi house was constructed in the late Qajar and early Pahlavi periods, around 1930. It is located in old Sabzevar, next to the main historical north-south road. Figure 6-70 shows the location of the house in the city of Sabzevar in relation to the main routes and the old city wall in 1956.

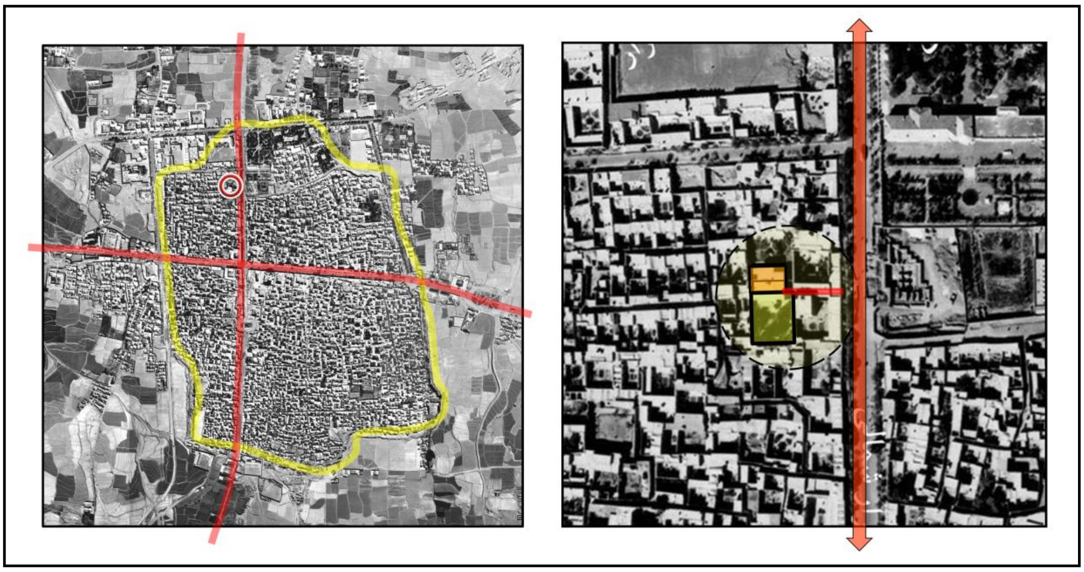


Figure 6-70: the location of the Hejazi house in 1956, base photomosaic map:(Zanganeh, 2003a)

The house is situated at the end of a blind alley with a covered passage connecting it to the historic main street (Figure 6-71). There are two entrances to the house; a direct access to the building from the side and another access to the main entrance via the courtyard. There is access from the courtyard to the first floor by way of two symmetrical external stairs leading to a lofty portico with slender columns. Another lower portico connects the courtyard to the closed spaces on the ground floor. (Figure 6-69, Figure 6-71)

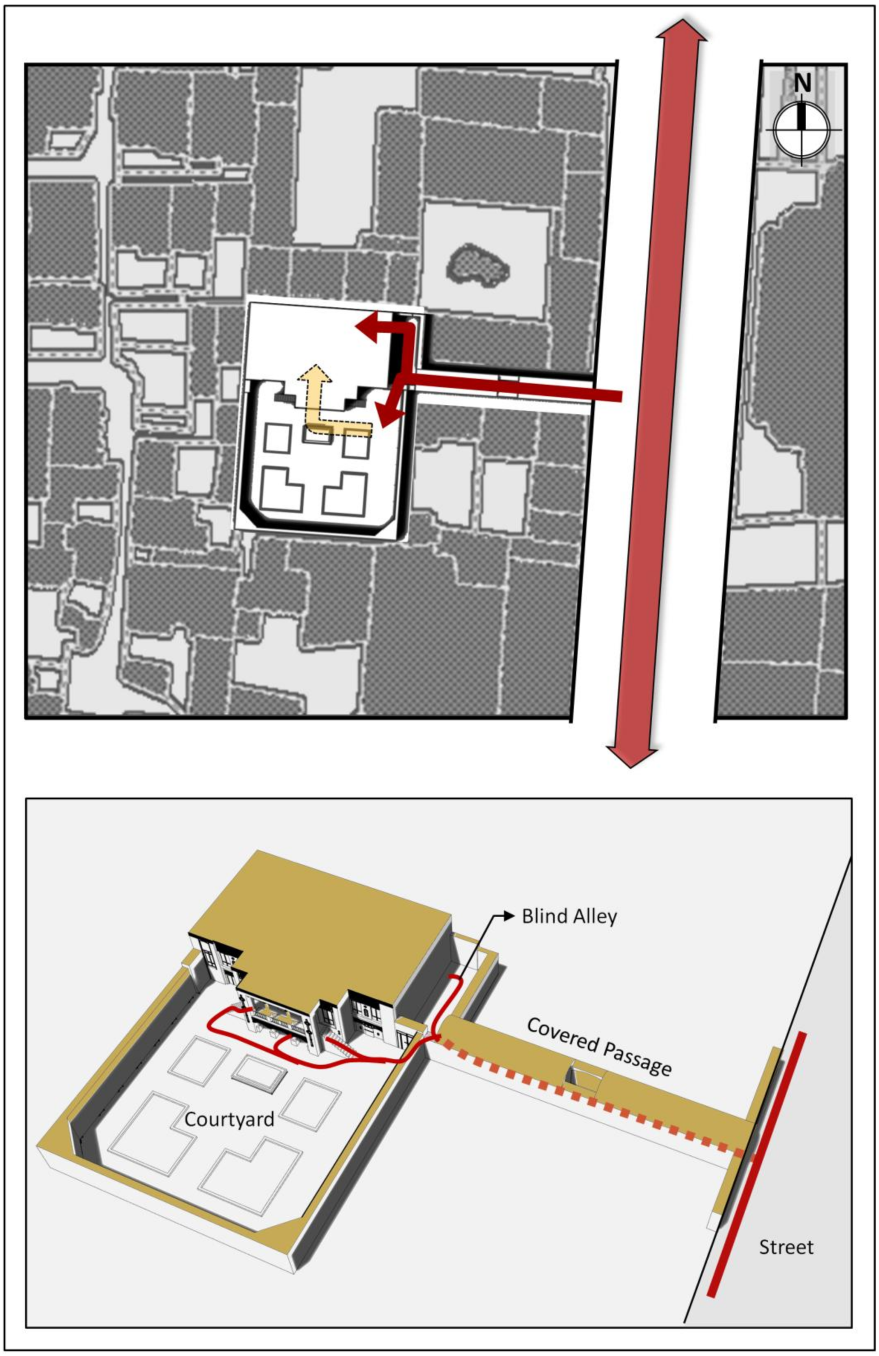


Figure 6-71: access hierarchy from street to the Hejazi house

The following maps show the current state of the house (Figure 6-72, Figure 6-73); the residents made three interventions to adapt the building to the new lifestyle: they added a bathroom, a toilet and broke large openings into a load-bearing wall to create a wide space. Before communal water supply was provided, the people of this region used the public baths. Moreover, for religious and health reasons the toilets were originally situated farthest away from the living spaces, usually in the corner of courtyards. The introduction of the modern water distribution network in Sabzevar around 1965 changed the situation and affected the lifestyle of people: the house users usually had a private bathroom in their houses. The introduction of tap water eased health concerns and gradually it became common practice to build toilets close to the living quarters. The residents of the Hejazi house blocked off the western corridor and transformed it into a toilet and a store for the kitchen and installed a bathroom in the corner of the kitchen on the first floor.

The load-bearing wall was reinforced with a steel beam and large openings were created. Around 1975, after the wooden roof above the two rooms in the north-eastern part of the building was damaged, the wooden beams were replaced with steel beams, while the load-bearing wall was replaced with two steel columns. The largest room (the guest room on the first floor in the back) was rather dark; during this renovation the house owner replaced the small window of the room with a new wider iron window (information based on an interview with the son of Hejazi family). Figure 6-72 shows these changes and Figure 6-74 provides an overview of the original state of the house prior to these changes.

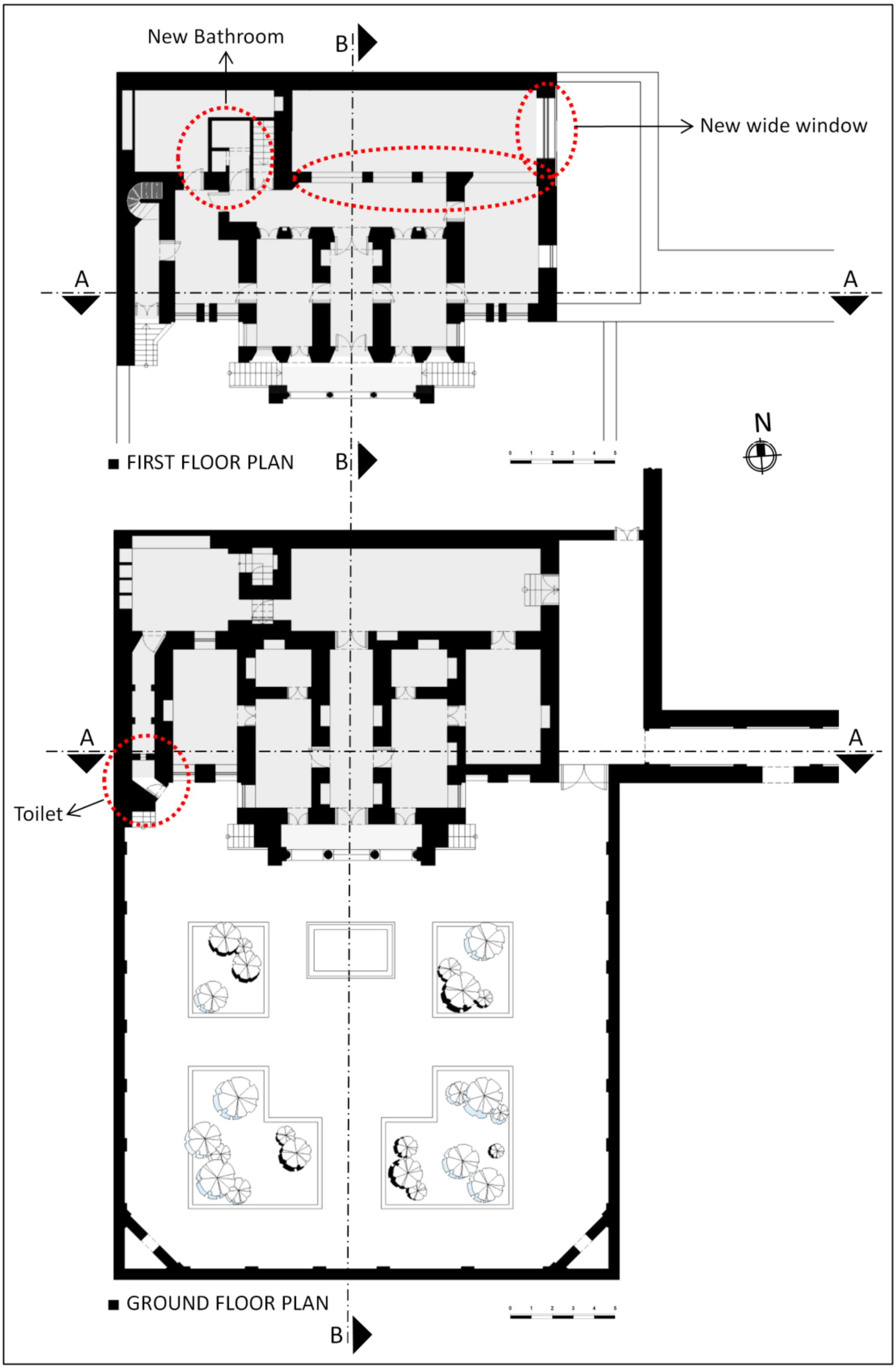


Figure 6-72: current condition of the Hejazi house (Estaji, 2010, Kermani-Moqaddam, 2001)

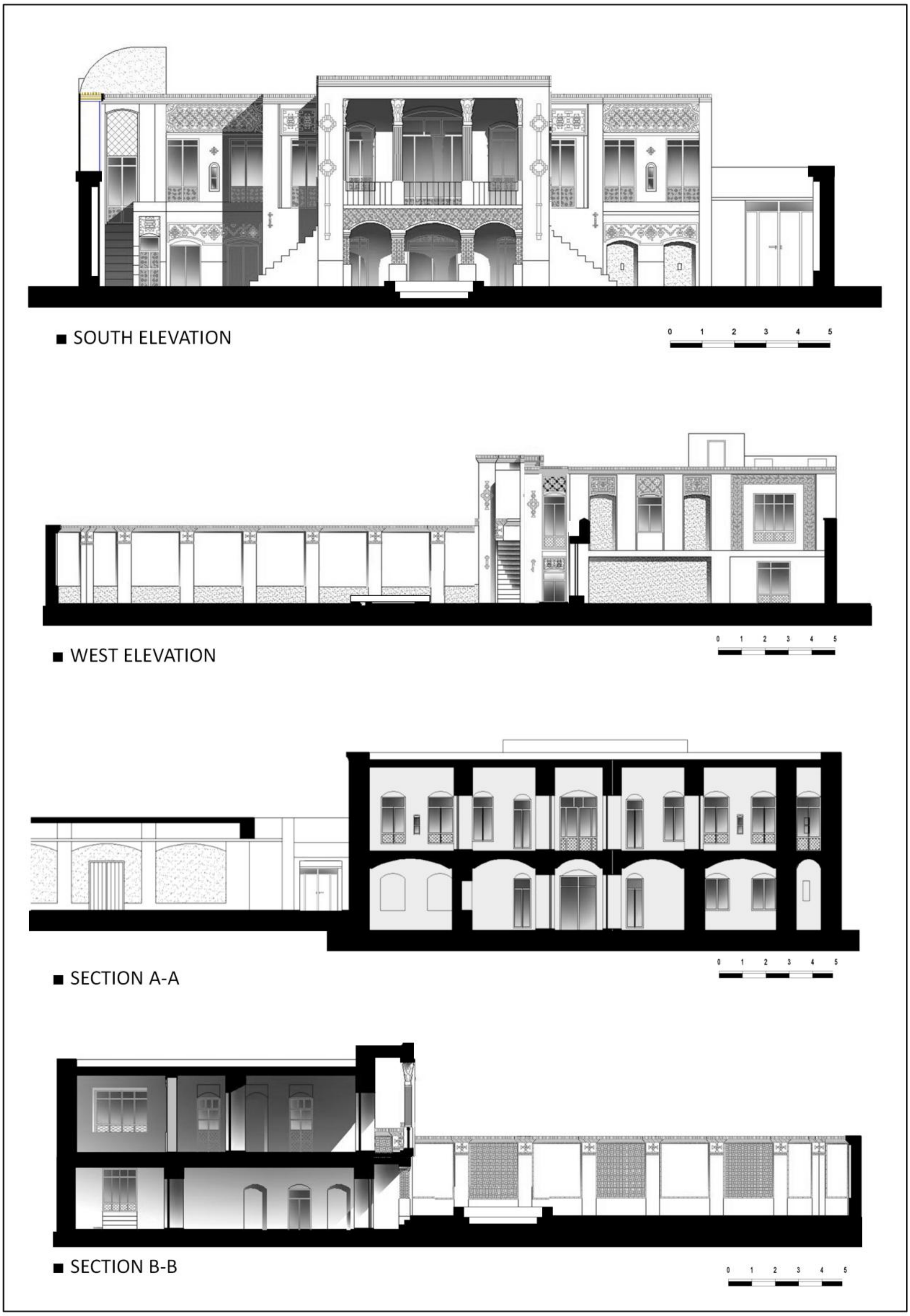


Figure 6-73: Elevations and sections of the Hejazi house (Estaji, 2010, Kermani-Moqaddam, 2001)

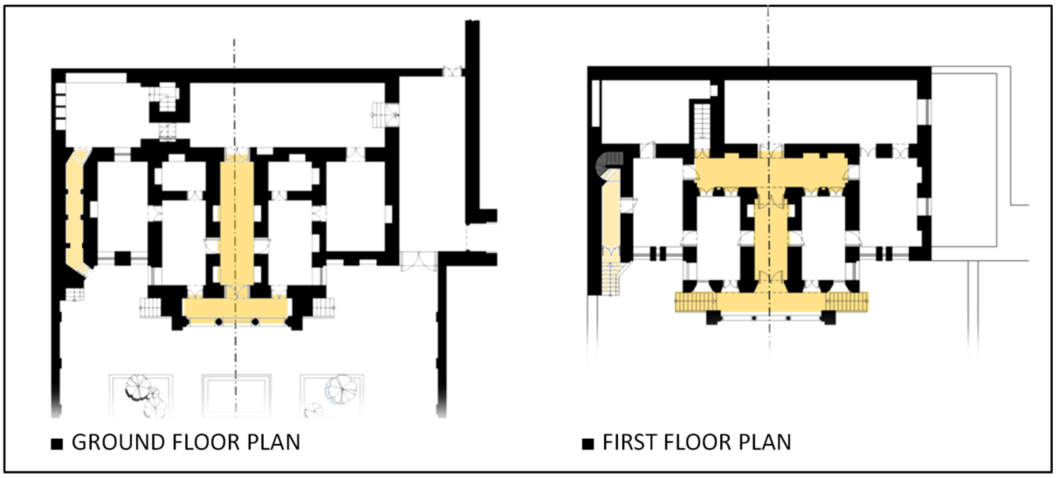


Figure 6-74: The Hejazi house before the changes

6.7.3.1.1 House Orientation and Sun Position

The Hejazi House faces the south with four degrees of rotation to the west (Figure 6-75). On cold days, the main windows of the building benefit from sunlight. The following graphs (Figure 6-75) show the positions of shades in the morning and evening for the two solstices and two equinoxes. The graphs illustrate the role of the Eivan as a semi-open space in controlling solar radiation on hot days.

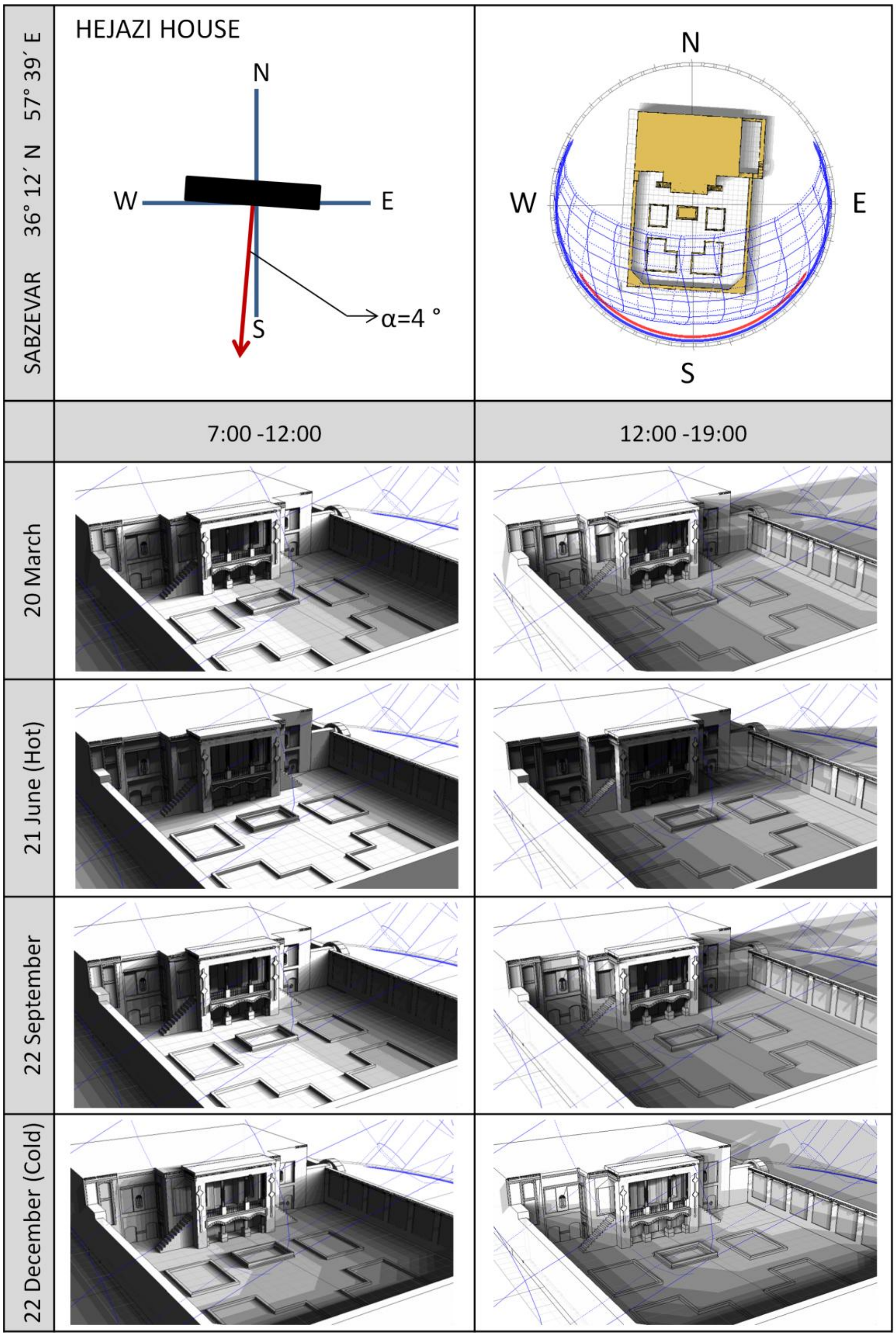


Figure 6-75: the position of the sun and shades in the morning and afternoon

The particular shape of the building blocks the sunlight in various hours of the day in different rooms. In fact, the façade of the building serves to provide vertical shading. For a detailed study, the sunlight received by each window is investigated separately. The shading masks for the middle of each window indicate that the spaces behind the windows benefit from the house shape and the house orientation on cold days. The summer effective shading coefficients of these four windows on the ground and first floors amount to zero - which means that the Eivans completely block the direct sunlight in the summer (Figure 6-76, Figure 6-77). Figure 6-76 shows the different scenarios in different windows, some of which are shaded during the morning and others during the afternoon with various shading coefficients. This diversity increases the flexibility of the building because at different times of the day and the year. At least one of these spaces is located in the thermal comfort range and residents can easily move to that space.

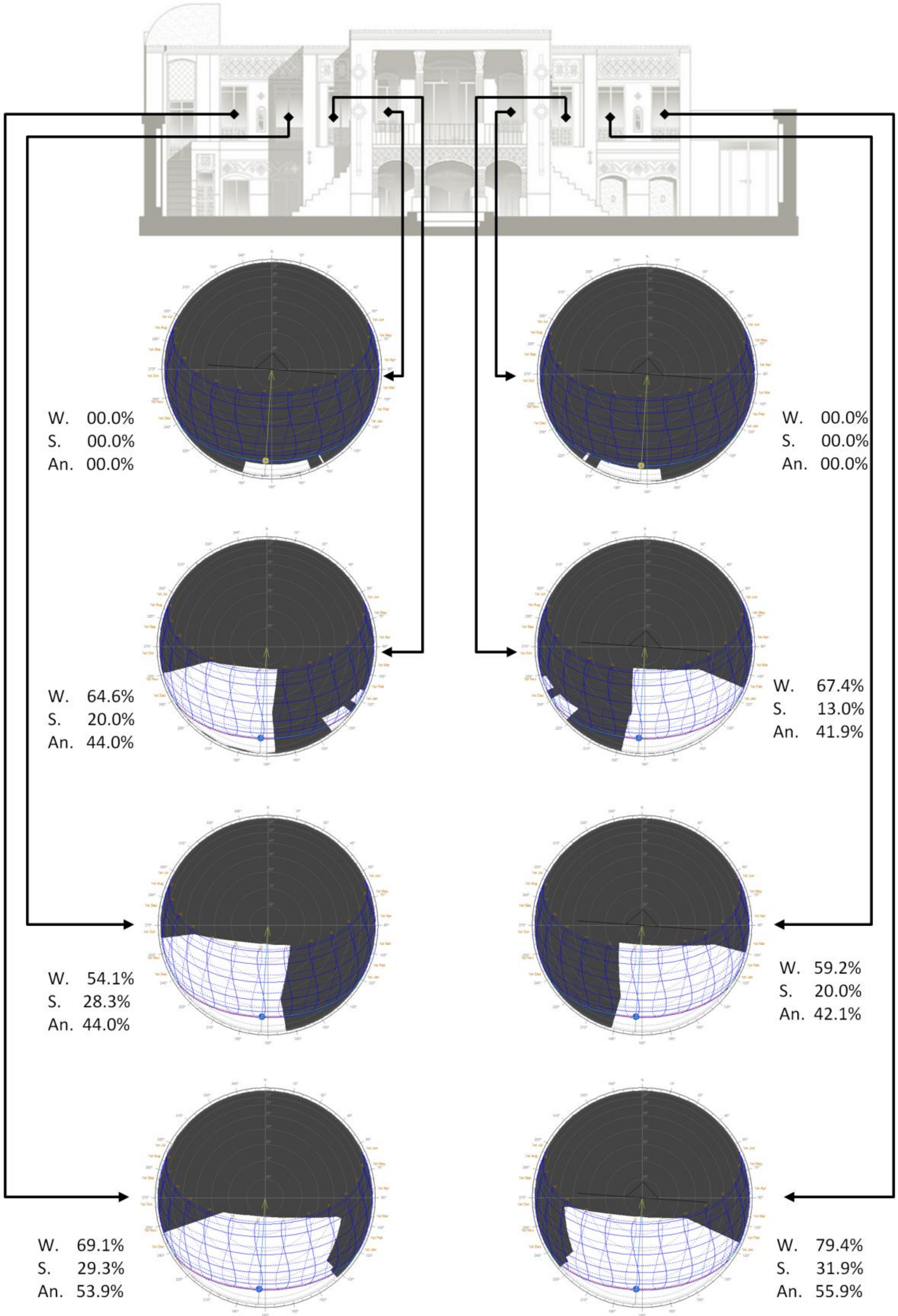


Figure 6-76: Shading Mask and Effective Shading Coefficients of Hejazi windows (first floor) in winter, summer and annually

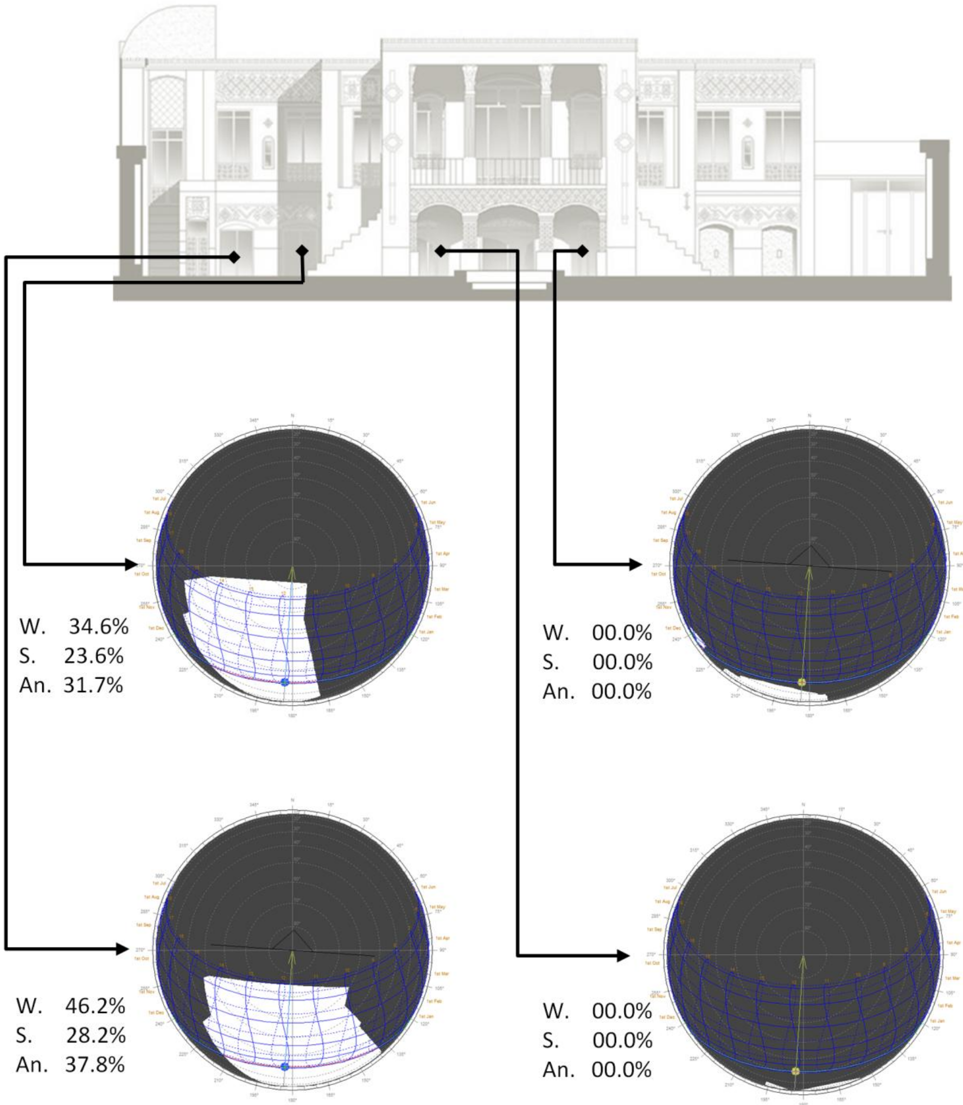


Figure 6-77: Shading Mask and Effective Shading Coefficients of Hejazi windows (ground floor) in winter, summer and annually

There are three windows facing east in the Hejazi house. These windows are exposed to the sun from morning till noon and are completely in the shade during the afternoon. The diagrams (Figure 6-78) indicate that the spaces behind these windows on warm days benefit from the house orientation in the afternoons, but they were not suitable for the morning on warm days. These rooms have been allocated to guests. As a result, these rooms were generally used in the afternoons and at night.

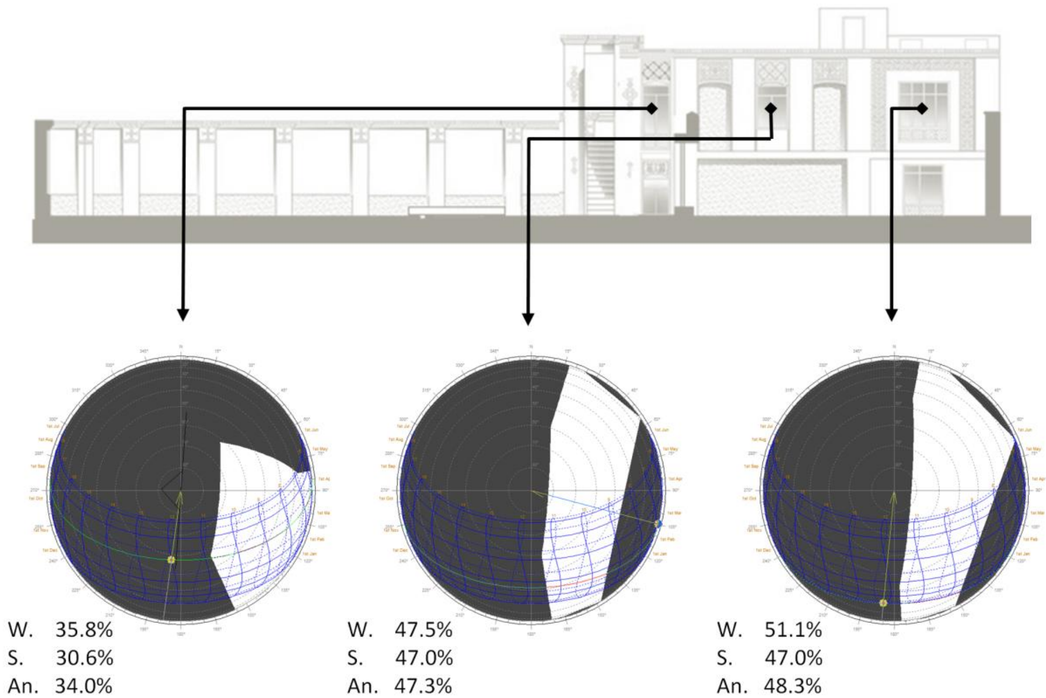


Figure 6-78: Shading Mask and Effective Shading Coefficients of east facing windows, The Hejazi house

The following table summarizes the impact of house orientation and building form on the comfort conditions for each space in different periods (Table 6-5).

Table 6-5: the effects of house orientation on the comfort conditions in the Hejazi house

	Warm days		Cold days	
	Morning	Afternoon	Morning	Afternoon
First floor	Positive	Positive	Positive	Positive
Basement	Positive	Positive	Positive	Positive
East facing rooms	Negative	Positive	Positive	Negative

6.7.3.1.2 Spatial Configuration

The Hejazi house consists of eight main rooms, two kitchens, two pillared Eivans, a large storeroom, and other suporting and circulation spaces on two stories. The ground floor, which has been lowered by 75 cm, includes the summer rooms and storage rooms, and the first floor is used throughout the whole year. The summer rooms were used as living spaces in the summer and for storing agricultural products in the winter. Due to the changes in lifestyle in recent years and the use of active cooling systems, the ground floor is currently not used as living space. However, it could serve this purpose again, if some changes are made. The eastern room on the ground floor (d0) is a dark storage room with two potential openings in its wall that could be easily converted into two windows so the room can be made into a bright living room. (Figure 6-79)

Figure 6-79: two potential openings that could be easily changed into two windows

The main characteristic of the house is the large number of spaces with maximum connectivity. This selective connectivity, along with the multi-functionality of rooms and a large number of entrances to the building, increases the flexibility of the house. The break-up map (Figure 6-80) and justified graph of the Hejazi house (Figure 6-81) help to investigate the potential of the house to be rearranged in response to the changed requirements.

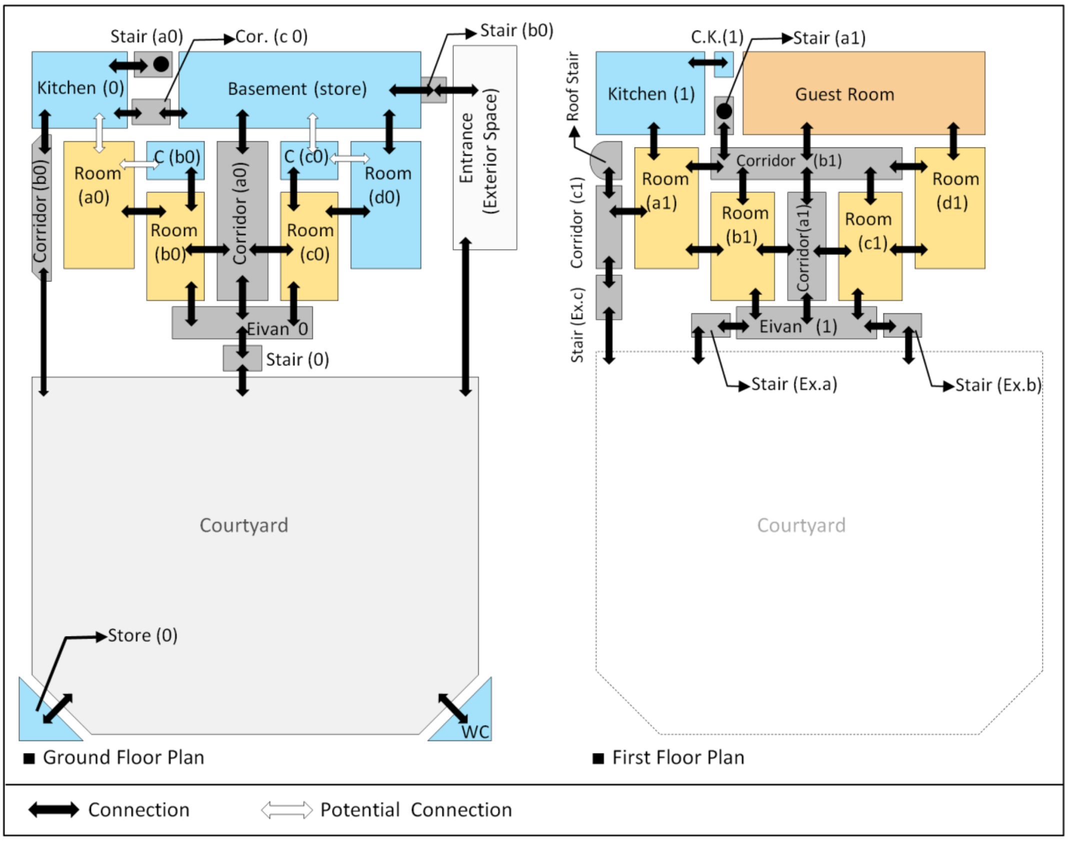


Figure 6-80: Break-up map of the Hejazi house

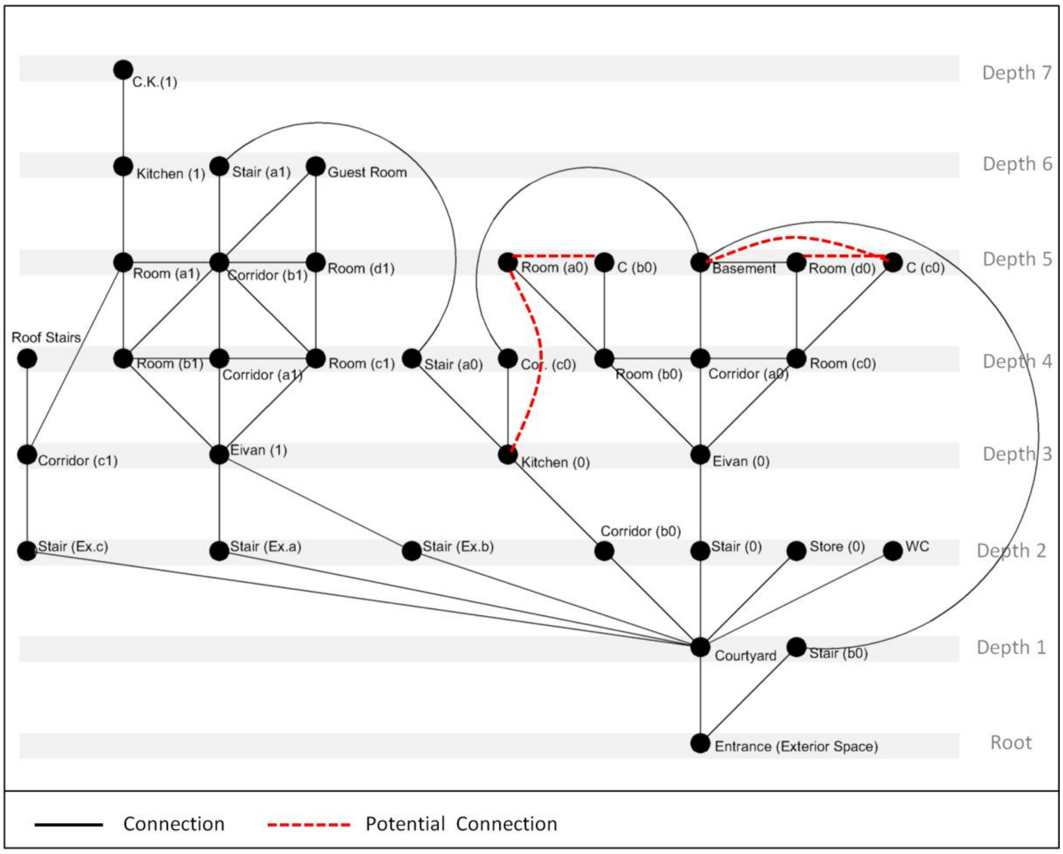


Figure 6-81: Justified graph of the Hejazi house

Fifteen loops in the Hejazi house could help to change the arrangement of the spaces. Also, four potential openings in the load-bearing walls enable the house users to rearrange the spaces with minor modifications in the building according to their new needs (Figure 6-81). On average there are three (2.82) openings to each space (Table 6-6).

Table 6-6: existing and potential Distributedness of the Hejazi house

THE HEJAZI HOUSE						
Number of spaces	Mean Connectivity	Potential openings	Number of loops		Distributedness (Convex ringiness)	
			Existing conditions	Considering the potential openings	Existing conditions	Considering the potential openings
33	2.82	4	15	19	0.25	0.31

By blocking the connection (locking some doors or even making a wall) the howe owners can change the relationship between spaces or split the house into smaller units in a simple way.
The calculation of integration and choice shows the importance of the courtyard and corridors in the Hejazi house (Appendix A 3). They act as the backbone of the house and form a coherent spatial organization.
The integration value of spaces reveals a strong spatial discipline in the Hejazi house. As can be seen in the picture (Figure 6-82), the first ten spaces are the circulation spaces (the only

space ranked eighth is the kitchen), followed by the main rooms and finally the private rooms, and storerooms. There are some rooms with high integration values in the system; in some cases they even surpass the subsidiary corridors, because of their numerous doors. However, in practice these doors are not open all the time, but rather serve as selective connections that control the relation between spaces and the degree of privacy of spaces in different situations.

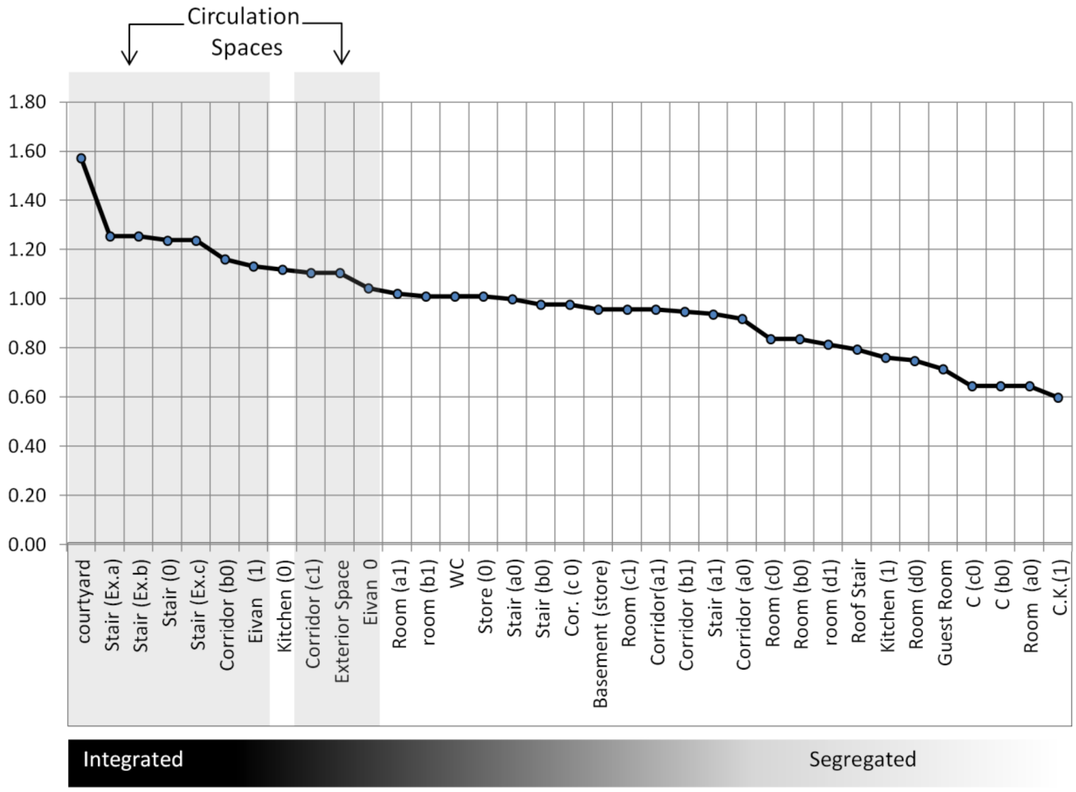


Figure 6-82: integration value of Hejazi spaces

In general, the access hierarchy of Hejazi house corresponds to the required degree of privacy. This hierarchy is coordinated according to the type of spaces in terms of open, semi-open, and closed space. The Hejazi house is a good example of the typical access hierarchy in simple one-courtyard houses from the Qajar period. (Figure 6-83)

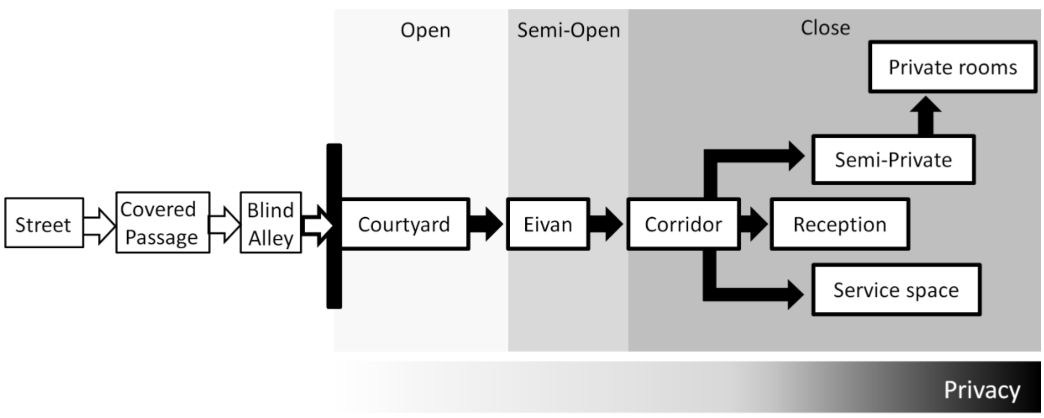


Figure 6-83: Schematic access hierarchy of Hejazi house

6.7.3.1.3 Adaptation to New Lifestyle and New Functions

The large number of entrances to the closed spaces from the courtyard enables the houses to be split up into small units. By introducing two internal connections between floors (there is one internal staircase in the house) the ground floor spaces could be rehabilitated and adapted to the new life style. The following picture (Figure 6-84) shows one of these alternatives, which divides the house into three separate units with independent entrances.

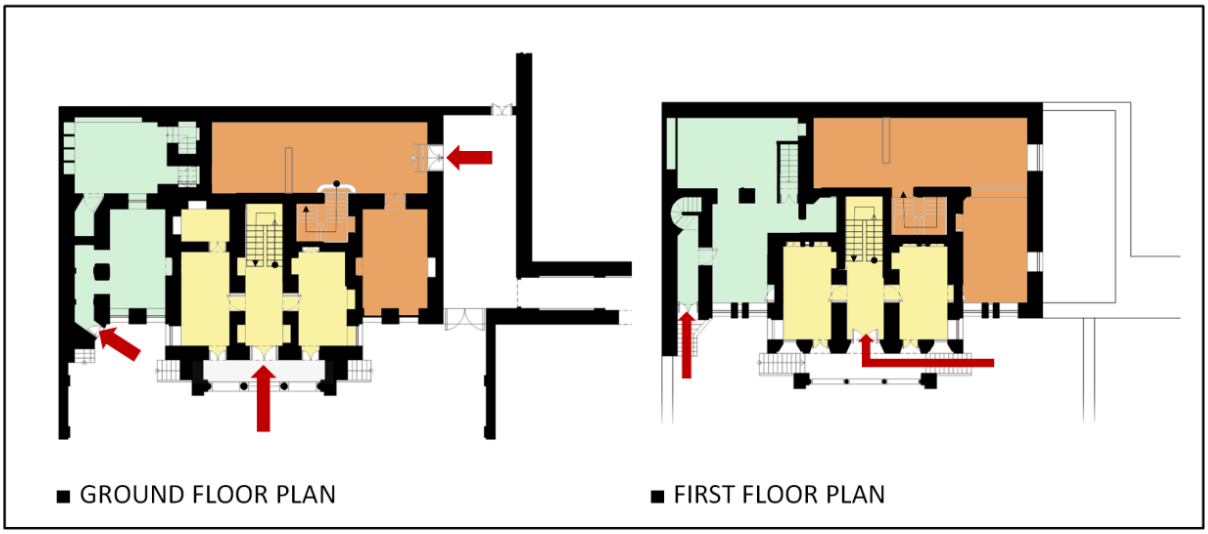


Figure 6-84: divisibility of the Hejazi house

Rehabilitating the ground floor and adapting the house to the new lifestyle will not satisfy the house owner in the long term. The house could only be saved if it were transformed into a commercial building. The large number of rooms and service spaces enable the house to be turned into a boutique hotel and restaurant with minor structural changes. The Hajazi family currently runs a small hotel in Sabzevar; it means that they are familiar with this business. If administrative barriers and inflexible legal rules were done away with and some financial incentives provided, they would certainly welcome this change.

6.7.3.2 The Amiri (Sadidi) House

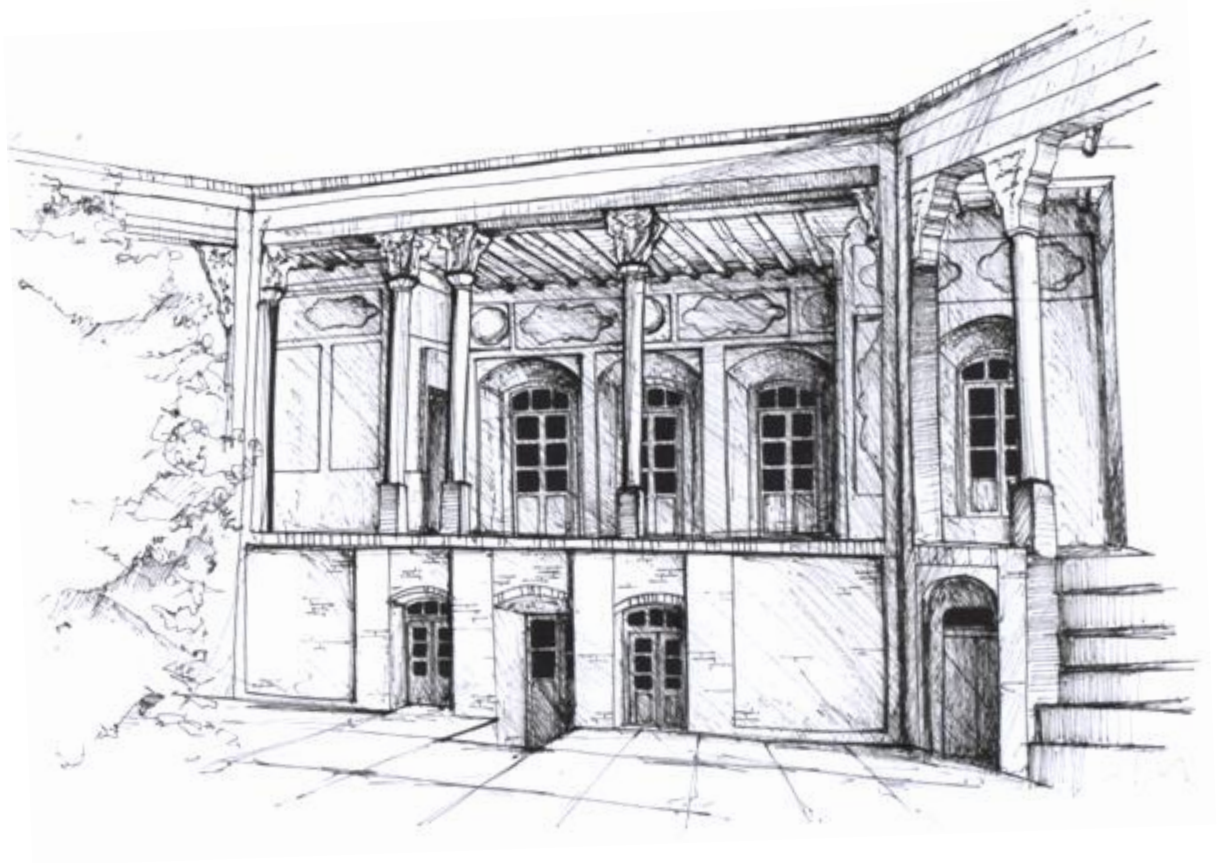


Figure 6-85: pillared portico of the Amiri house (Estaji, 2010), hand drawing by Minoo Qasemi

The Amiri house is located in the old urban fabric of Sabzevar. The house was constructed in the late Qajar around 1920. Figure 6-86 shows the position of the house in the city in 1956. The house belonged to the Amiri family but is now owned by Mr. Sadidi.

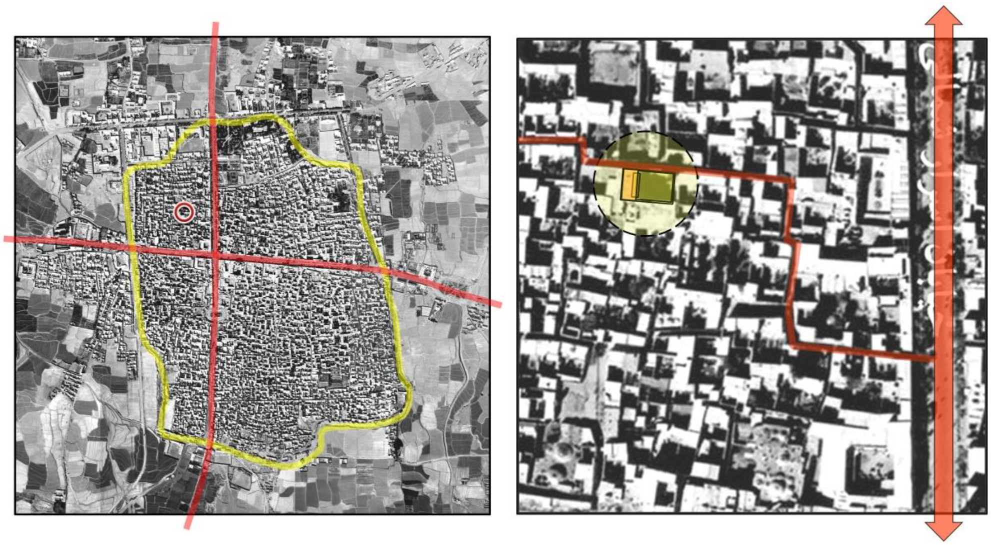


Figure 6-86: the position of the Amiri house in 1956, base photomosaic maps (Zanganeh, 2003a)

The house is entered via the courtyard, which serves as the main circulation space in the house. There are three staircases on the ground floor connecting the courtyard to the summer room, kitchen, and storerooms. Two symmetrical stairs connect the courtyard to a large Eivan on the first floor and the main rooms behind it. The roof of this Eivan is supported by two brick columns and six wooden columns which are covered and decorated with gypsum plaster (Figure 6-87). The following maps and photos provide a detailed depiction of the house.

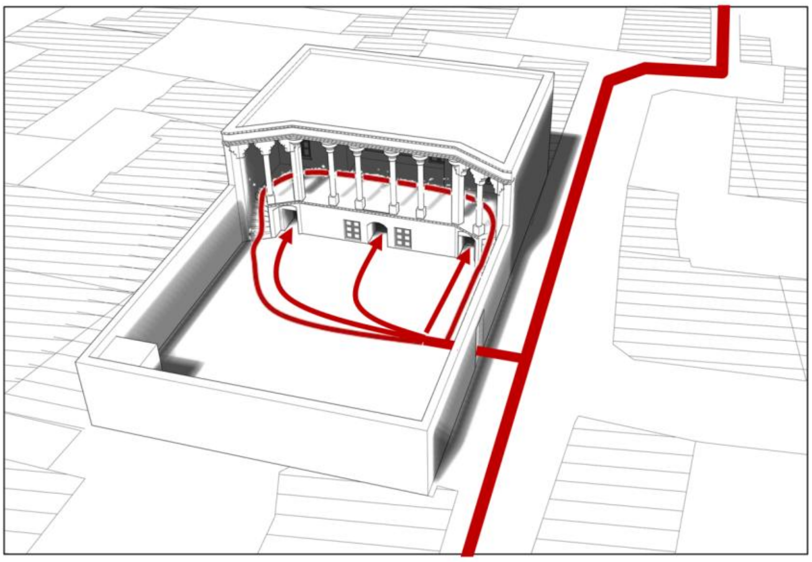


Figure 6-87: access hierarchy from alley to closed spaces

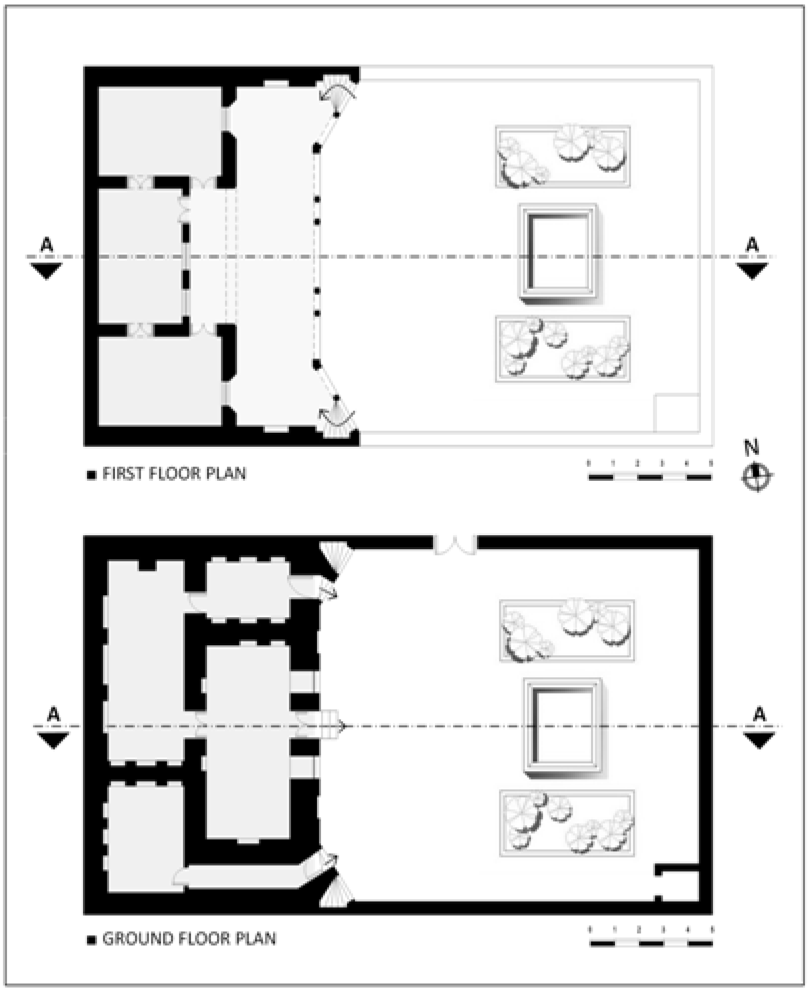


Figure 6-88: Plans of the Amiri house, (Estaji, 2010, Kermani-Moqaddam, 2002b) and the local archives of ICHTO

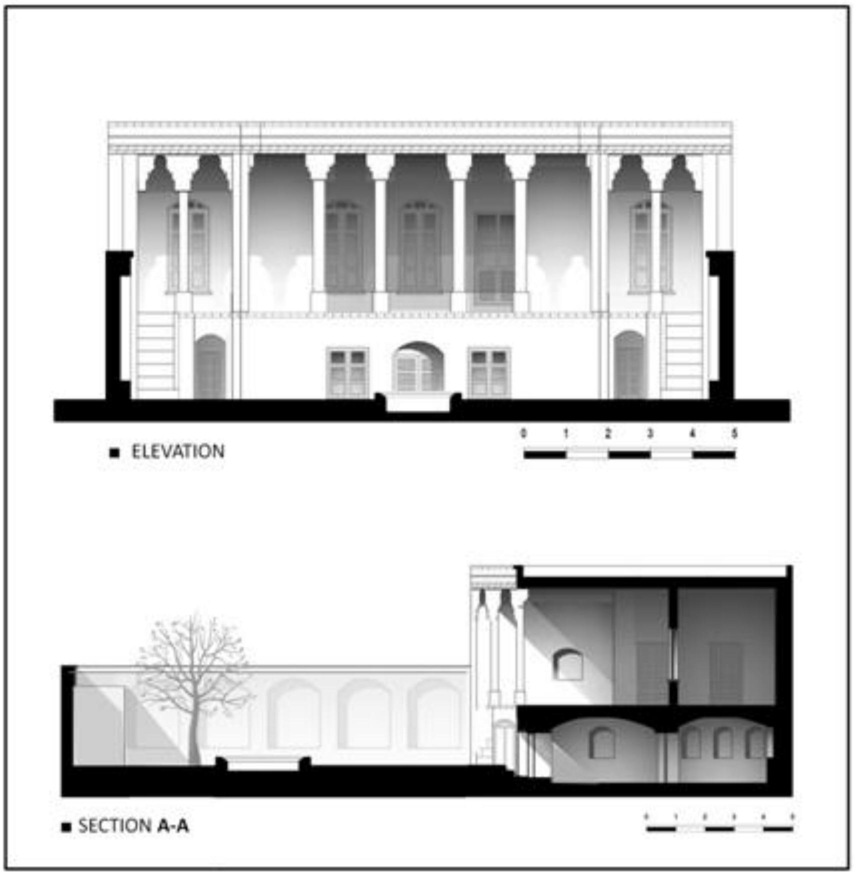


Figure 6-89: elevation and section of the Amiri house, source:(Estaji, 2010, Kermani-Moqaddam, 2002b), the local archives of ICHTO

Figure 6-90: photos of the Amiri House, source: the local archives of ICHTO

6.7.3.2.1 House Orientation and Sun Position

The Amiri house faces the east with eight degrees of rotation to the south (Figure 6-91). The rooms of the Amiri house benefit from sunlight only in the early morning and are completely in the shade during the day. (Figure 6-91)

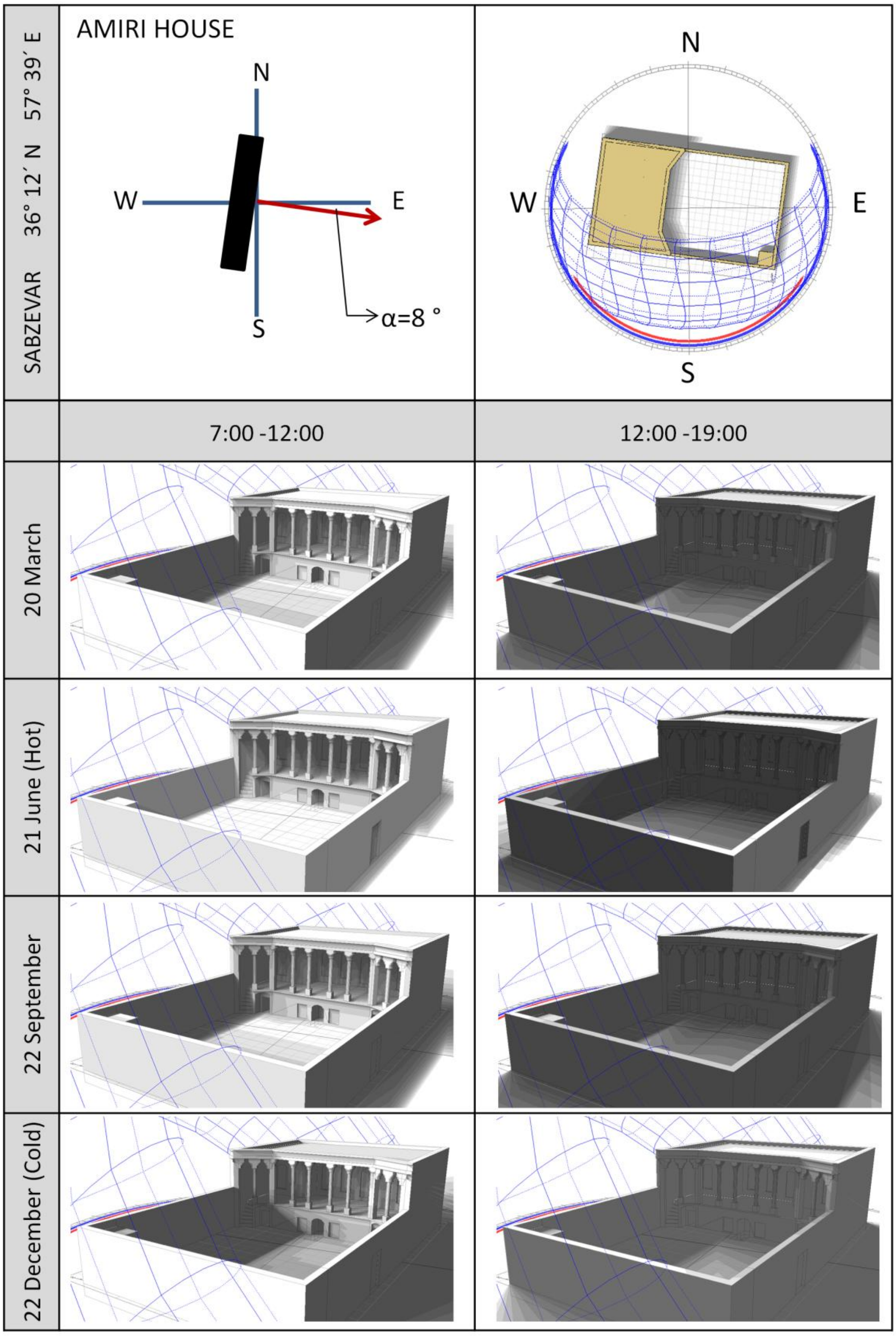


Figure 6-91: the position of shade in the morning and afternoon

In the Amiri house, the deep veranda (columned Eivan) serves to control the direct sunshine in the morning up until noon. The Effective Shading Coefficients (ESC) of the windows that are located behind the veranda amount to about ten per cent (Figure 6-92). The low ESC value shows the effectiveness of the projecting roof for the control of direct sun radiation. Figure 6-92 clearly shows the difference in shading masks between the ground floor windows without awnings and the windows that are located behind the porch.

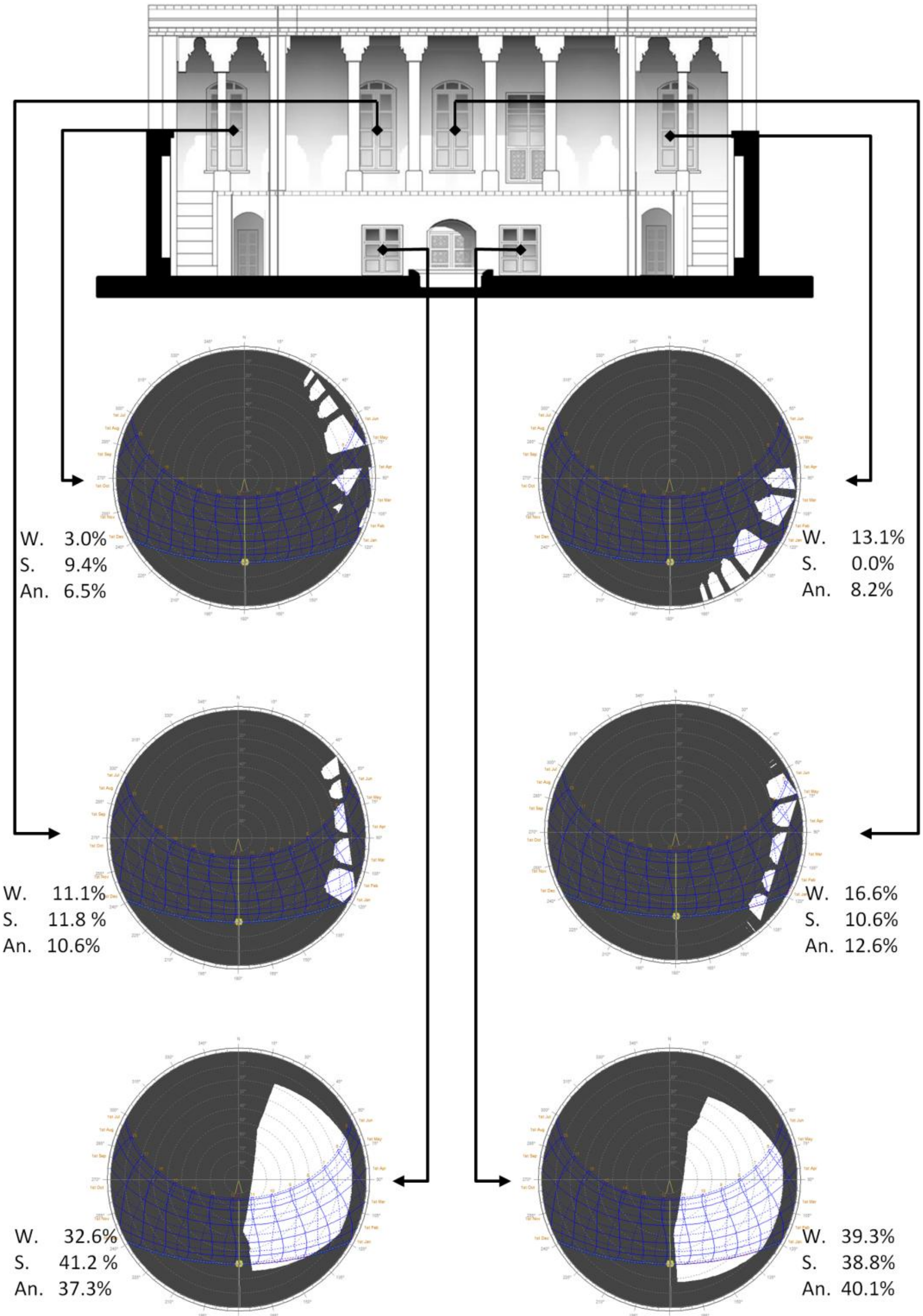


Figure 6-92: Shading Mask and Effective Shading Coefficients of Amiri windows

For a detailed study of the role of the veranda in controlling the sun, the shading masks of three main points of the covered terrace are compared. The middle of Eivan, the end of it, and the middle of windows are protected from direct sun at 9:15, 7:30, and 6:30 a.m., respectively, in the summer (Figure 6-93). The Amiri house quite successfully avoids direct sunlight on hot days.

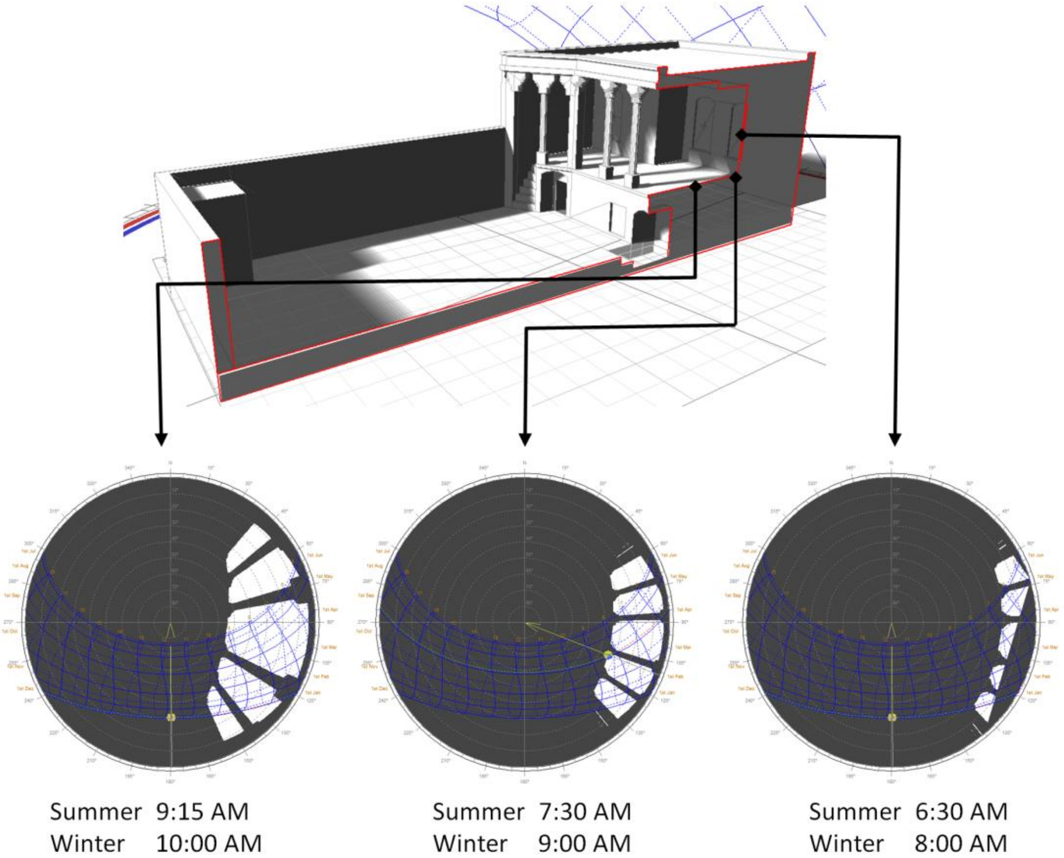


Figure 6-93: comparing the shading masks of three different points of Amiri veranda and the starting time of shade in summer and winter

6.7.3.2.2 Spatial Configuration

The ground floor of the house includes the summer room, a kitchen, and two storage spaces; the main multifunctional rooms are located on the first floor. Nested rooms with several openings to the other spaces increase the flexibility of the house.

Four loops in the Amiri house could help to change the arrangement of the spaces. Also, four potential openings in the load-bearing walls allow the house users to rearrange the spaces with minor structural modifications according to their new needs. (Figure 6-94, Figure 6-95)

One main challenge in adapting traditional houses to accommodate a new lifestyle is providing new functions for the dark spaces behind the rooms. These spaces were used as storage area in the past but they could now be transformed into new service spaces. They could accommodate internal stairs, bathroom, toilet, wardrobe, storage rooms for residential use. In case of transformation to an office – they could change into the archive and wet-rooms.

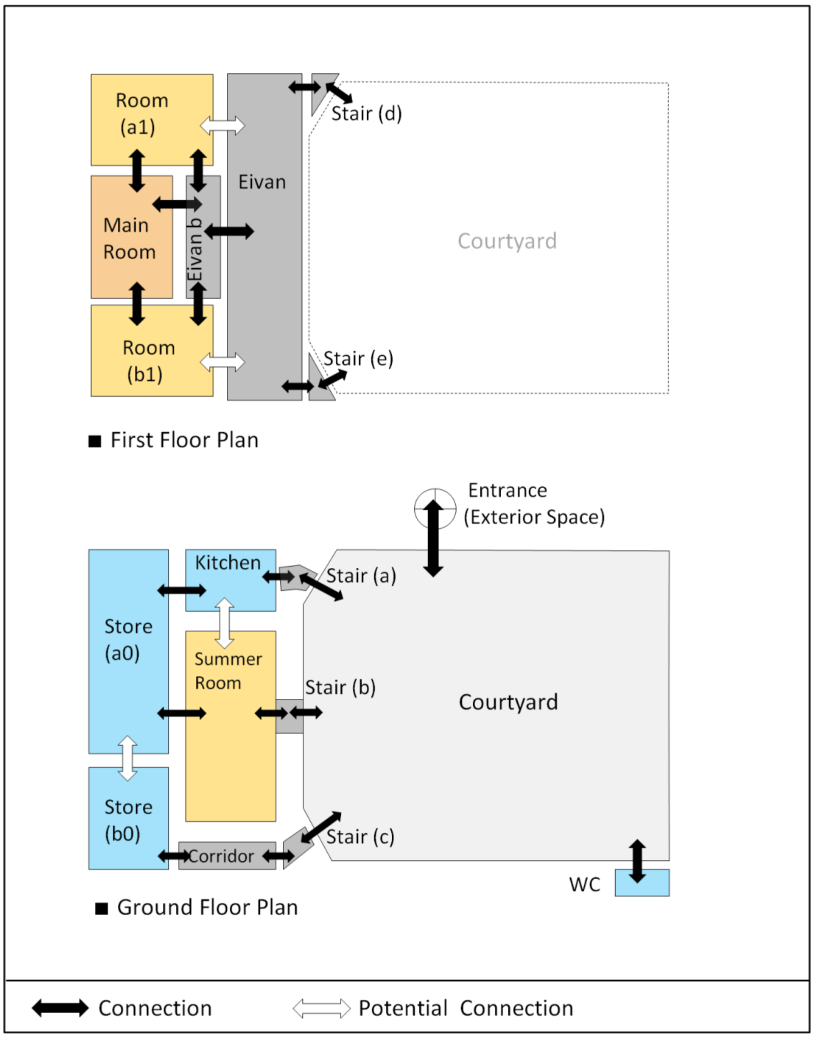


Figure 6-94: Break-up map of the Amiri house

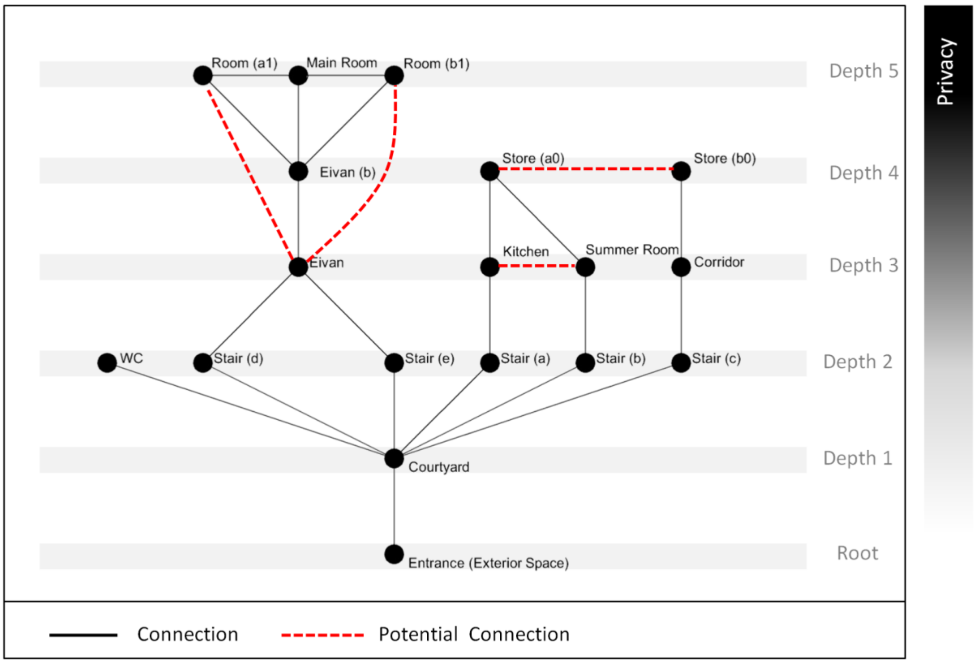


Figure 6-95: Justified graph of the Amiri house

On average, there are 2.41 openings per space (Table 6-7). The selective connectivity between the main rooms on the first floor enables the house to respond to various needs.

Table 6-7: existing and potential Distributedness of the Amiri house

THE AMIRI HOUSE						
Number of spaces	Mean Connectivity	Potential openings	Number of loops		Distributedness (Convex ringiness)	
			Existing conditions	Considering the potential openings	Existing conditions	Considering the potential openings
17	2.41	4	4	8	0.14	0.28

The calculation of integration and choice shows the importance of courtyard and Eivan in the Amiri house. They act as organizers of the spaces (Appendix A 4). The following diagram (Figure 6-96) ranks the spaces according to integration value. It reveals a strong spatial discipline in the Amiri houses; the first eight spaces with maximum integration values are the circulation spaces, followed by the main rooms and finally the private rooms.

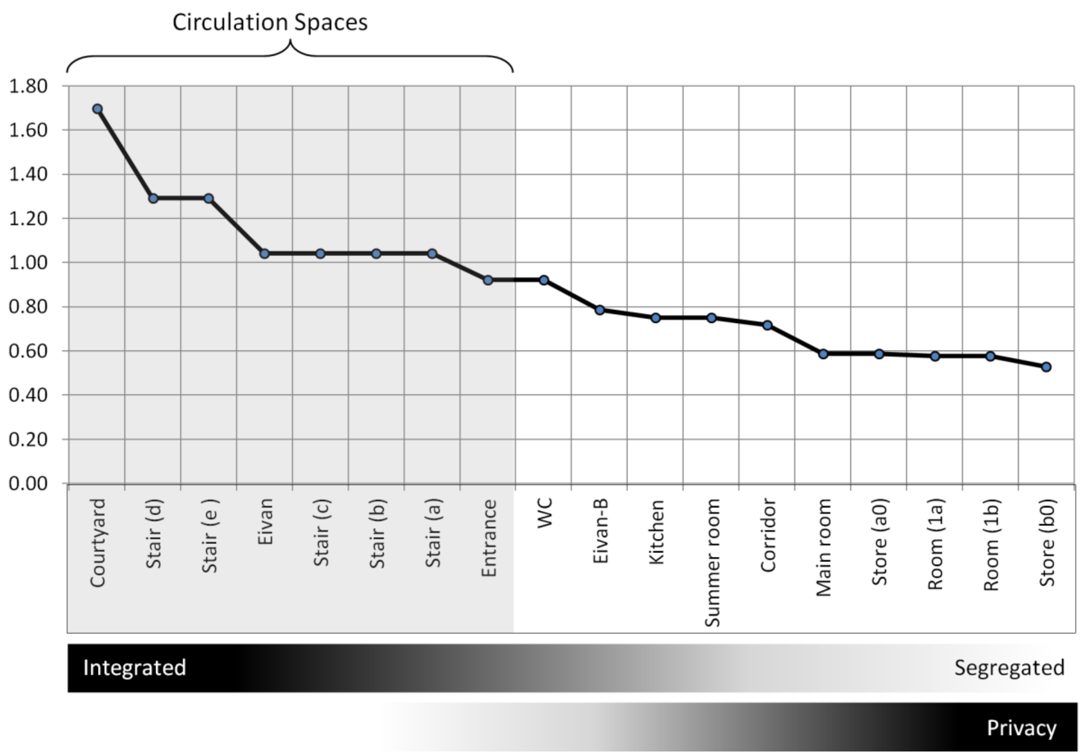


Figure 6-96: integration value of Amiri spaces

Figure 6-97 shows the conceptual access hierarchy of the Amiri house. The access hierarchy of the Amiri house corresponds to the degree of space privacy and also to the type of spaces in terms of open and closed spaces.

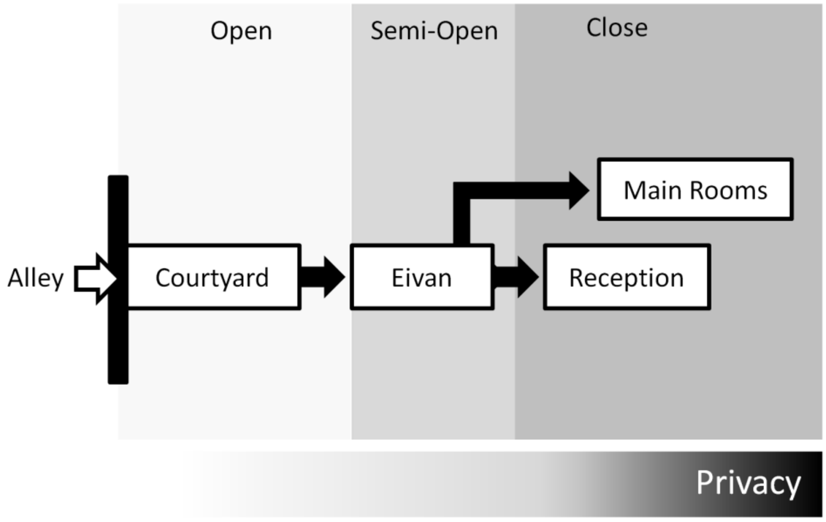


Figure 6-97: Schematic access hierarchy of the Amiri house

6.7.3.2.3 Adaptation to New Conditions

Due to the high costs of conservation and maintenance of these historic buildings, private house owners in most cases cannot afford to use them as residences. They require financial support (grants or low-interest loans) from the government.

The building can be used after restoration and slight modifications as an office or as cultural space. The conservation of small traditional buildings in a residential zone is not cost-efficient, so it is better to form a chain or a network of small buildings with a centralized management. This solution is described in detail in the next chapter.

6.7.3.3 The Baqani House

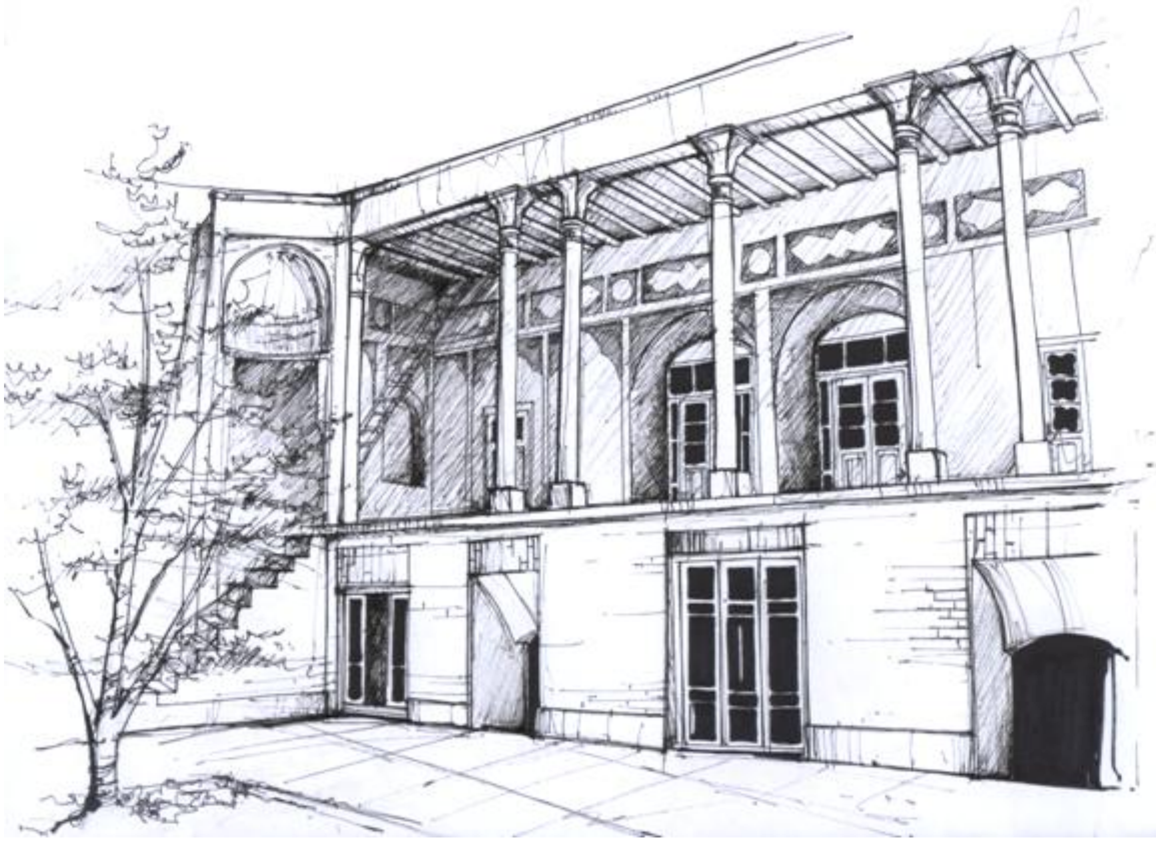


Figure 6-98: pillared portico, the Baqani house (Estaji, 2010), hand drawing by Minoo Qasemi

The Baqani house was constructed around 1920 within the old Sabzevar city walls (Kermani-Moqaddam, 2002b). Figure 6-99 shows the stage of the city's development in 1956 and the current situation of the building in the city. Around 1965, the old eastern city wall was demolished and turned into a street; in 1980 a main new street was constructed that cut through the old urban fabric of Sabzevar. These cuts changed the hierarchy of access to the house.

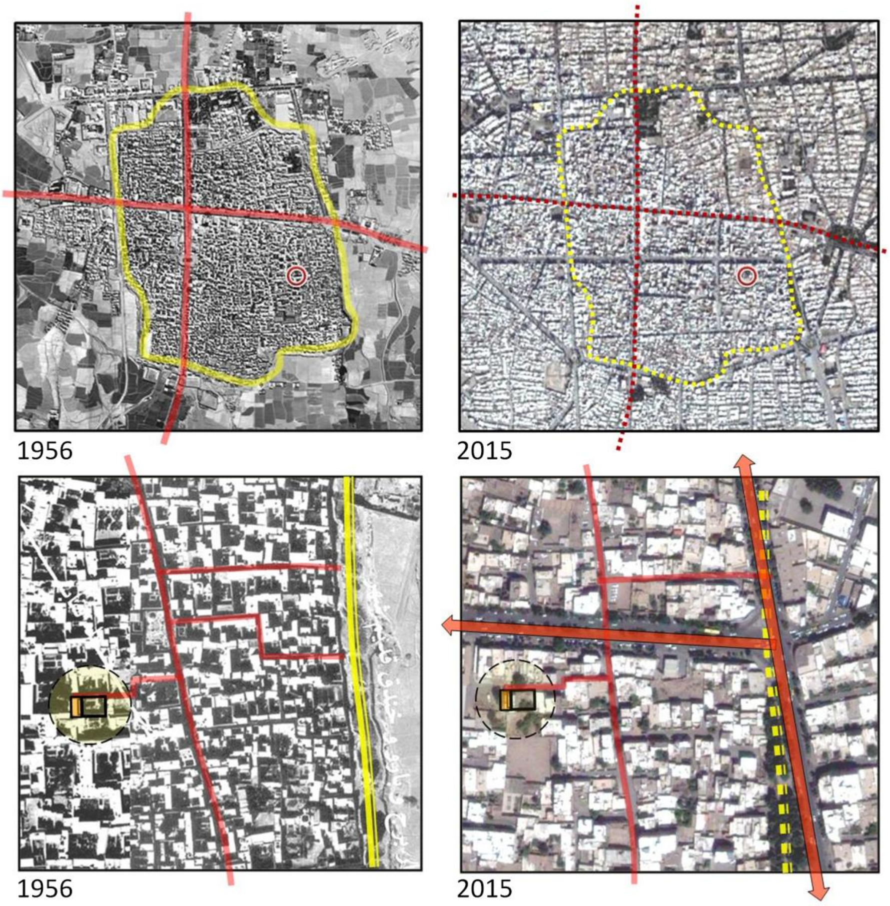


Figure 6-99: the position of Baqani house in 1956 and 2015
base photomosaic maps of 1956:(Zanganeh, 2003a), 2015 aerial map: (Google Earth, 2015)

The house is situated at the end of a blind alley. Originally the building could be accessed via a vestibule that connected the alley to the courtyard. This vestibule has already been destroyed and the yard can now be directly entered from the alley. Two vestibules form thresholds between the courtyard and the summer spaces on the ground floor. Two external stairs lead from the courtyard to the main rooms on the first floor. (Figure 6-100)

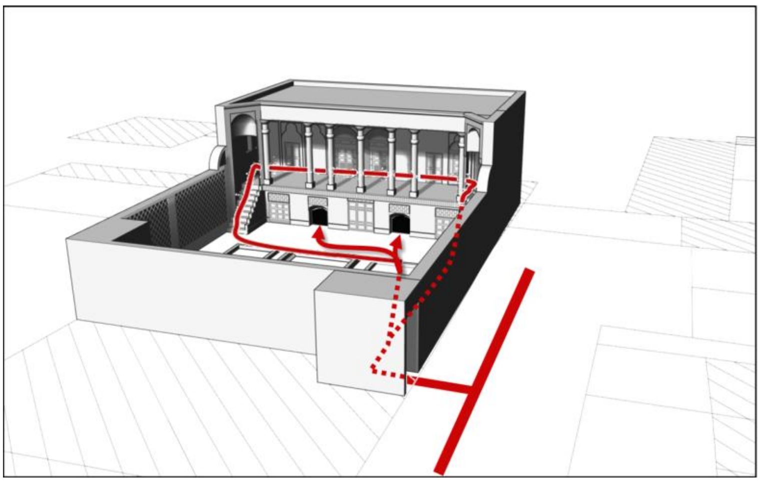


Figure 6-100: access hierarchy from alley to close spaces

A large columned veranda forms a semi-open space between the courtyard and the main rooms on the first floor. Seven wooden columns bear the weight of the roof; these columns are covered and decorated by gypsum plaster (Figure 6-98, Figure 6-103). The photos also show steel stairs to the roof that added later or has replaced an old wooden stairs. (Figure 6-104)

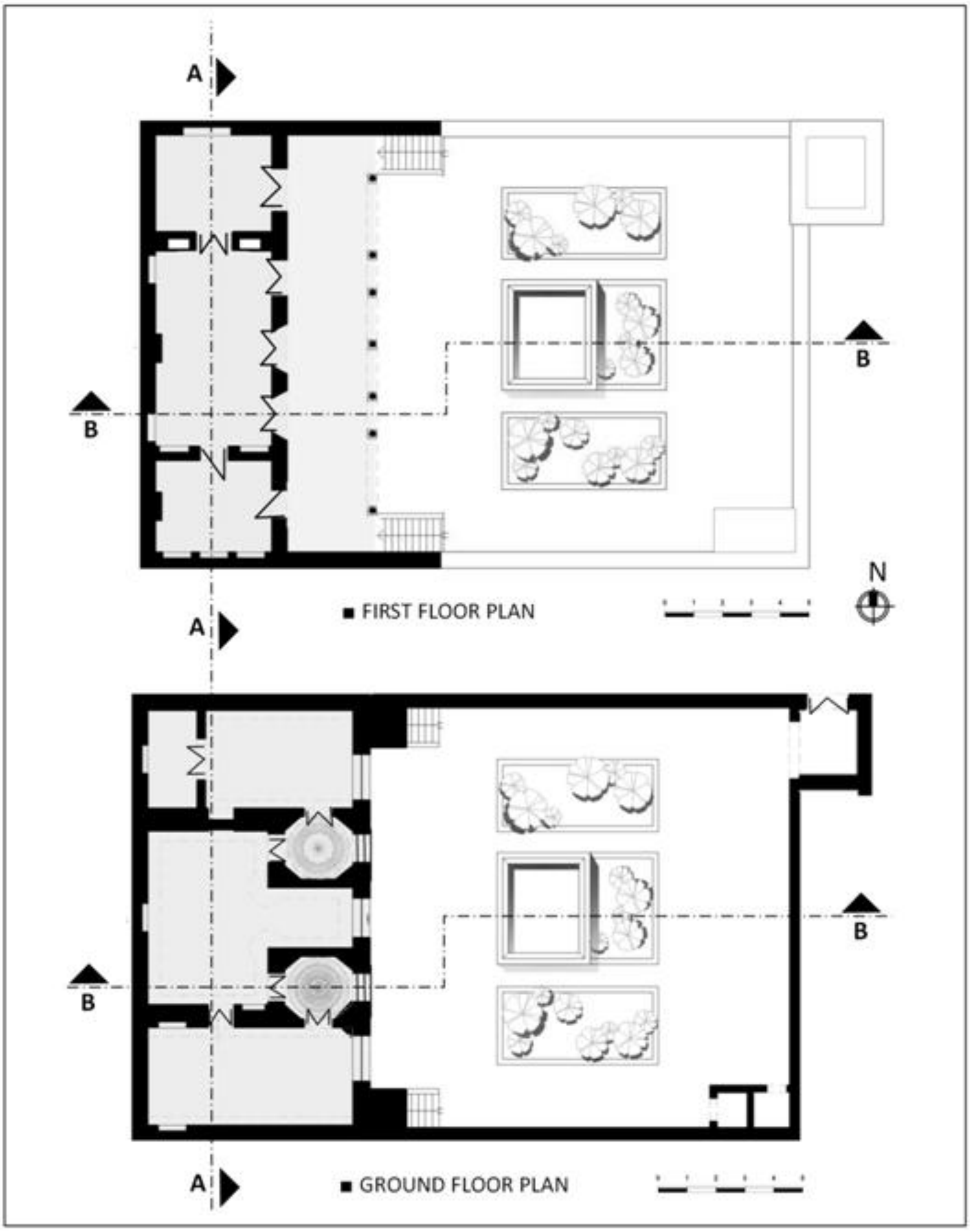


Figure 6-101: Plans of the Baqani house (Estaji, 2010, Kermani-Moqaddam, 2002b)

Figure 6-102: elevation and sections of the Baqani house (Estaji, 2010, Kermani-Moqaddam, 2002b)

Figure 6-103: photos of the Baqani house (Kermani-Moqaddam, 2002b)

Figure 6-104: ornamented vaulting of the Eivan (Kermani-Moqaddam, 2002b)

6.7.3.3.1 House Orientation and Sun Position

The Baqani House is oriented to the east. The main rooms benefit from sunlight only in the early morning and are completely shaded during the day (Figure 6-105).

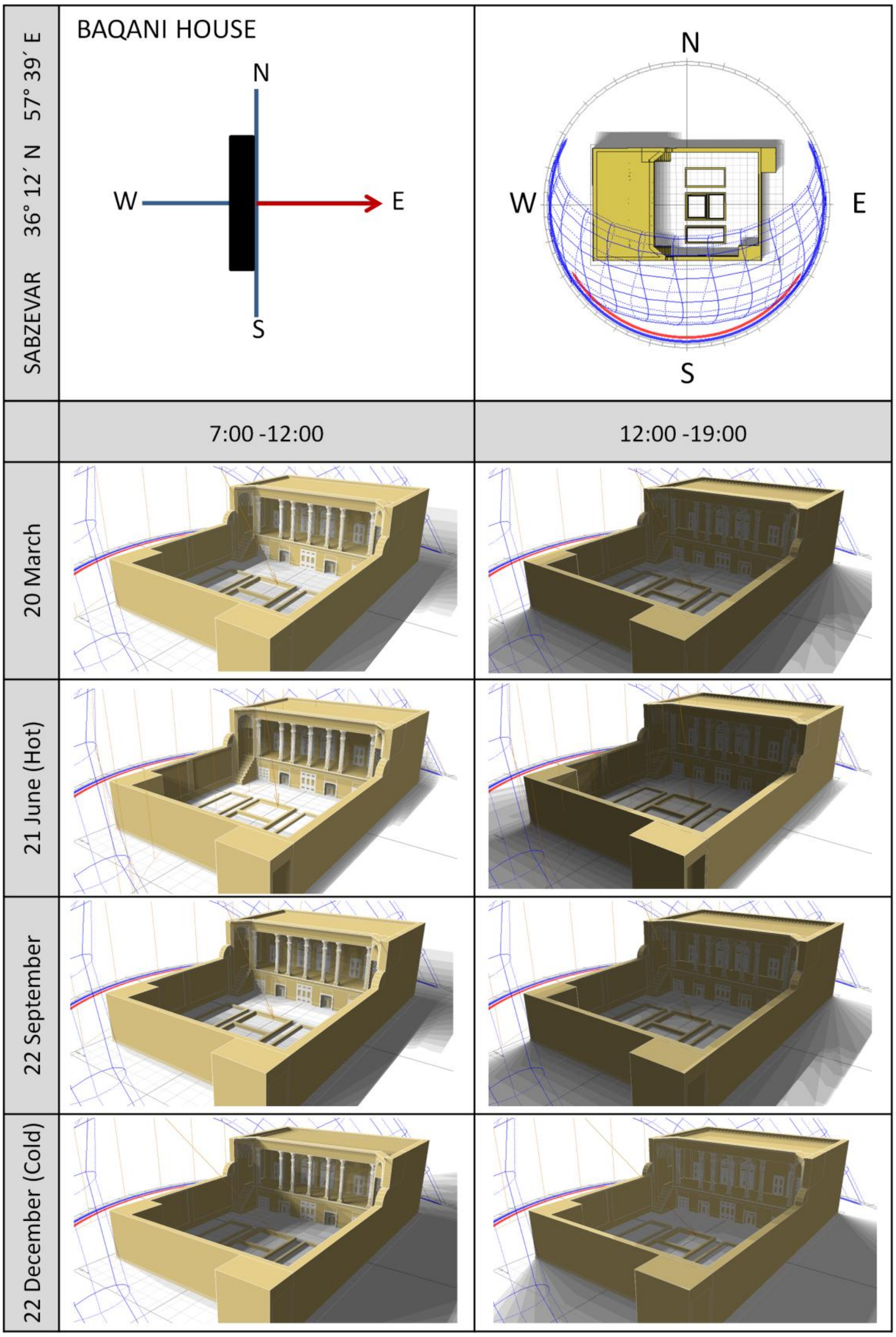


Figure 6-105: the situation of shades in the morning and afternoon

The shading masks for the middle of each window indicate that on warm days in the afternoons the spaces behind the windows benefit from the house orientation, but it is not suitable for the mornings on warm days. However, the Baqani house solved this problem by using a very deep veranda. The Effective Shading Coefficients (ESC) of Baqani windows that are located behind the veranda are around fifteen percent; the low value of the (ESC) emphasizes the effectiveness of the Eivan in controlling direct sunlight. (Figure 6-106)

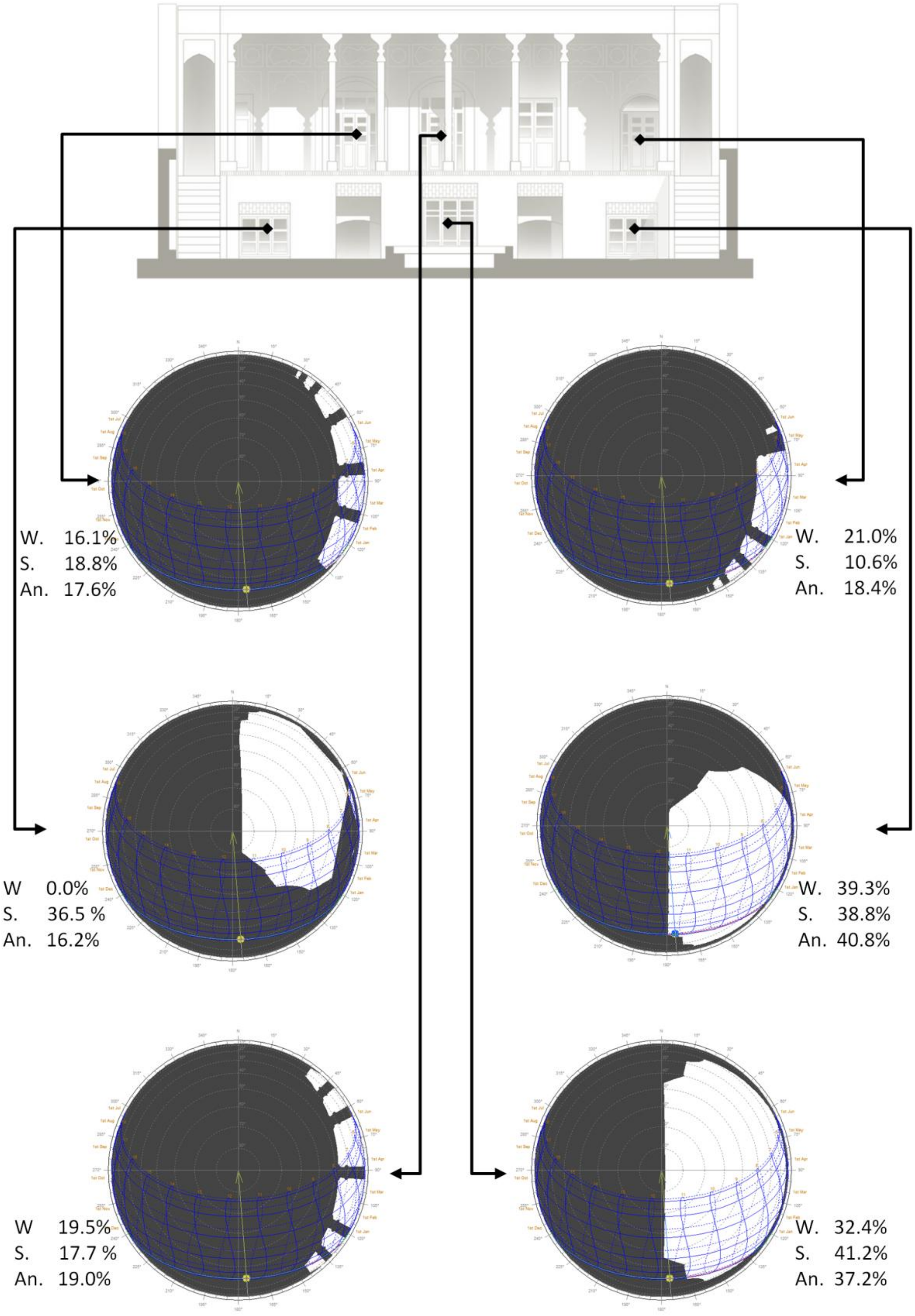


Figure 6-106: Shading Mask and Effective Shading Coefficients of Baqani windows

For a detailed study, the following graphs (Figure 6-107) investigate the shading masks of three main points: in the middle of the veranda, at the end of the veranda, and in the middle of the windows. These points are protected from direct sun from 10:00, 8:45, and 7:50 AM, respectively.

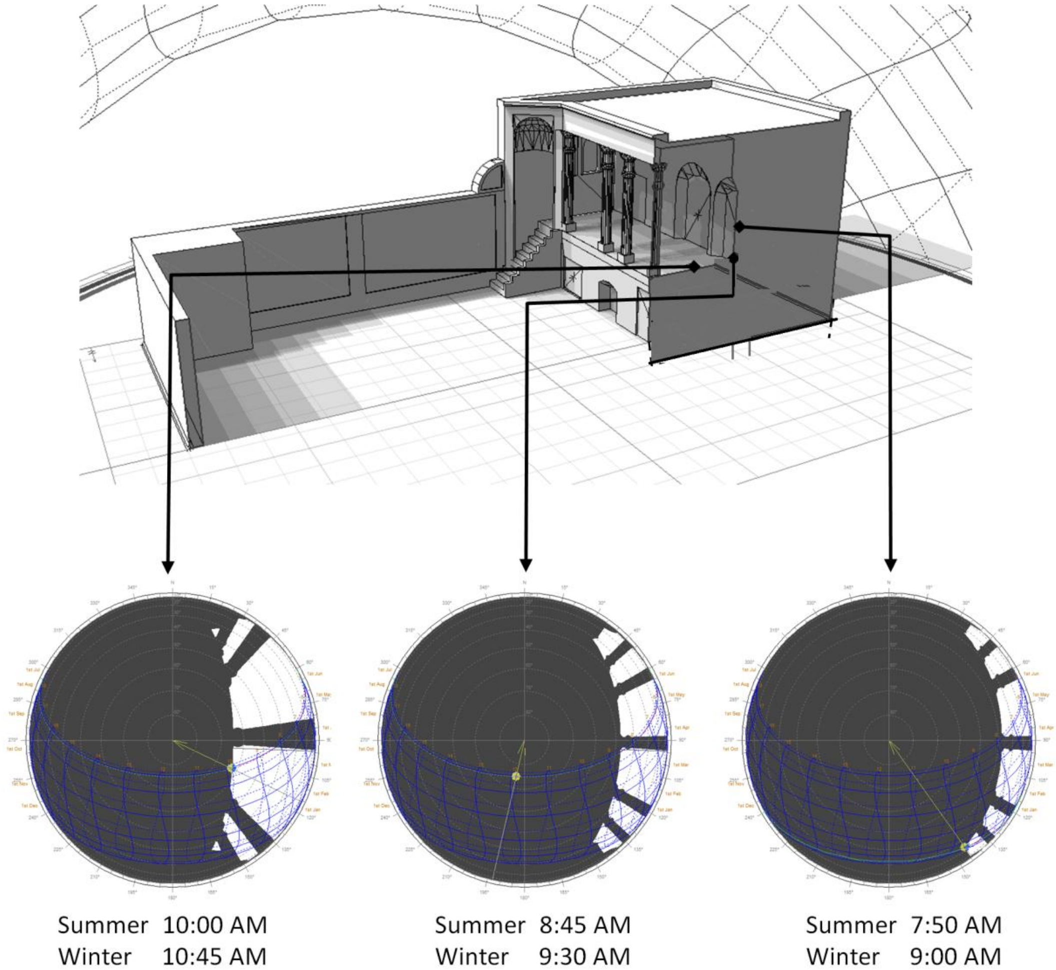


Figure 6-107: comparing the shading masks of three different points of the Baqani veranda and the starting time of shade in summer and winter

6.7.3.3.2 Spatial Configuration

The Baqani house consists of five rooms: a kitchen, a large veranda, and two vestibules on two floors. The ground floor includes the summer rooms and a kitchen, and the first floor is used throughout the whole year. (Figure 6-108, Figure 6-109).

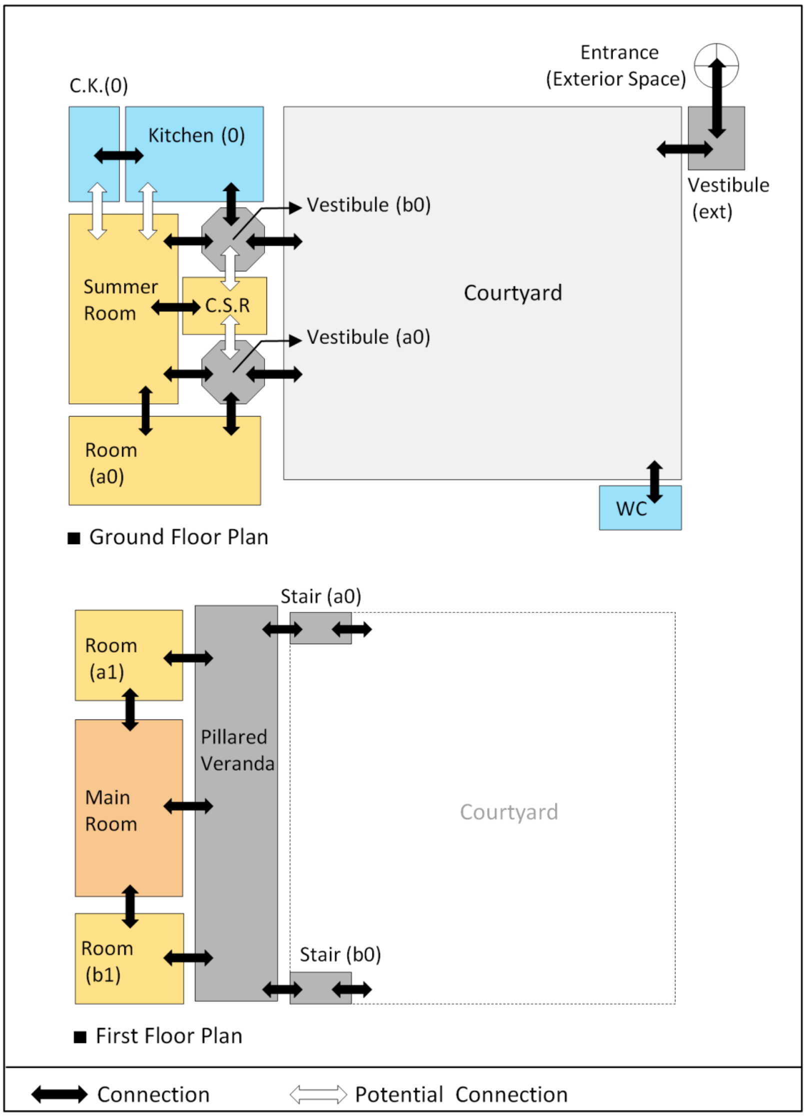


Figure 6-108: Break-up map of the Baqani house

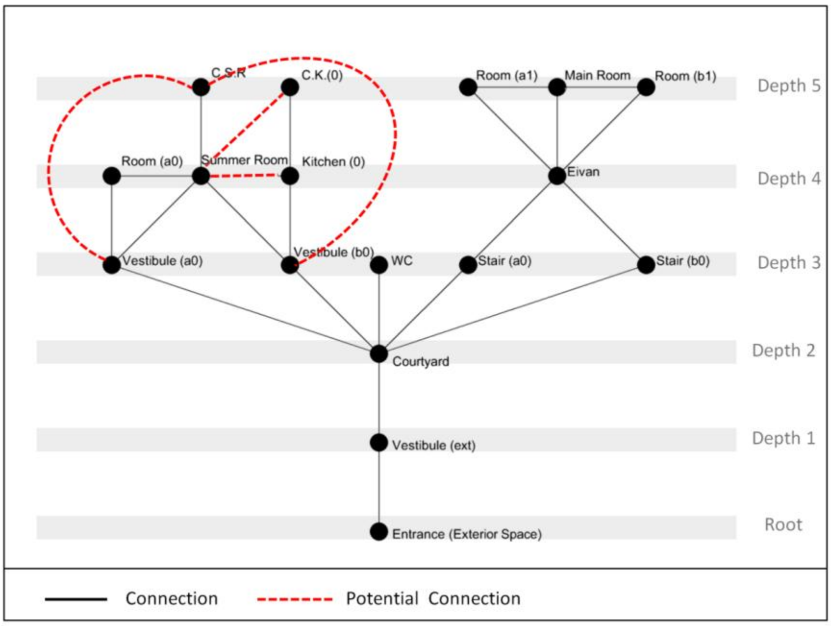


Figure 6-109: Justified graph of the Baqani house

On average, there are around two and half (2.56) openings per space (Table 6-8). The large number of doors enables the residants to control the relationship beween spaces, e.g.,by locking the doors between the main room and the room(a1) and room(b1). The house users can allocate these rooms to guests for sleeping or - by opening all the doors on the first floor - prepare a large space for religious ceremonies and celebrations.(Figure 6-110)

Table 6-8: existing and potential Distributedness of the Baqani house

THE BAQANI HOUSE						
Number of spaces	Mean Connectivity	Potential openings	Number of loops		Distributedness (Convex ringiness)	
			Existing conditions	Considering the potential openings	Existing conditions	Considering the potential openings
16	2.56	4	5	9	0.19	0.33

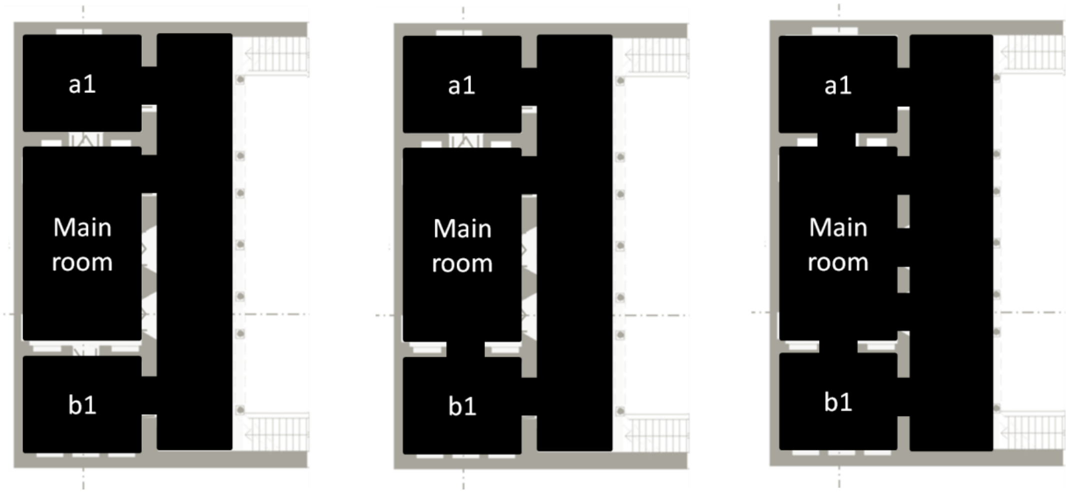


Figure 6-110: three possible scenarios for the first floor rooms

The integration value and choice of spaces reveal a strong spatial discipline in the Baqani house (Appendix A 5). As can be seen in the picture (Figure 6-111), the first seven spaces are the circulation spaces, followed by the main rooms and finally the private rooms.

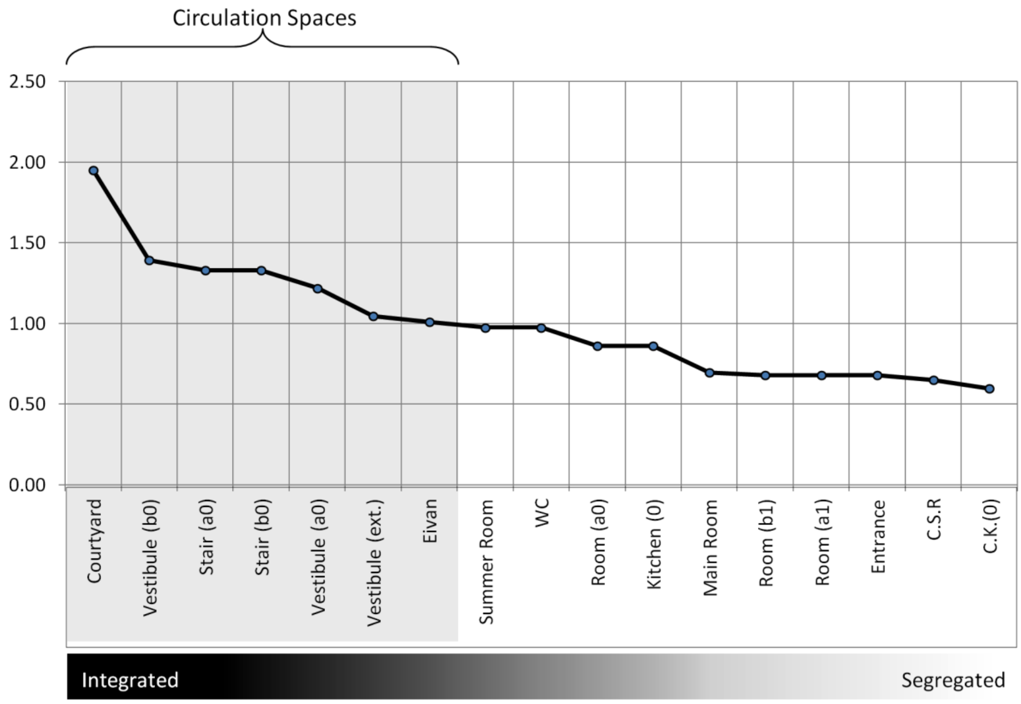


Figure 6-111: integration value of the Baqani spaces

Figure 6-112 shows the schematic access hierarchy of the Baqani house. The exterior vestibule acts as a joint between the public space and the house; it blocks the direct view from the outside to the courtyard. The other spaces, more private in nature, are located inside the house. (Figure 6-112)

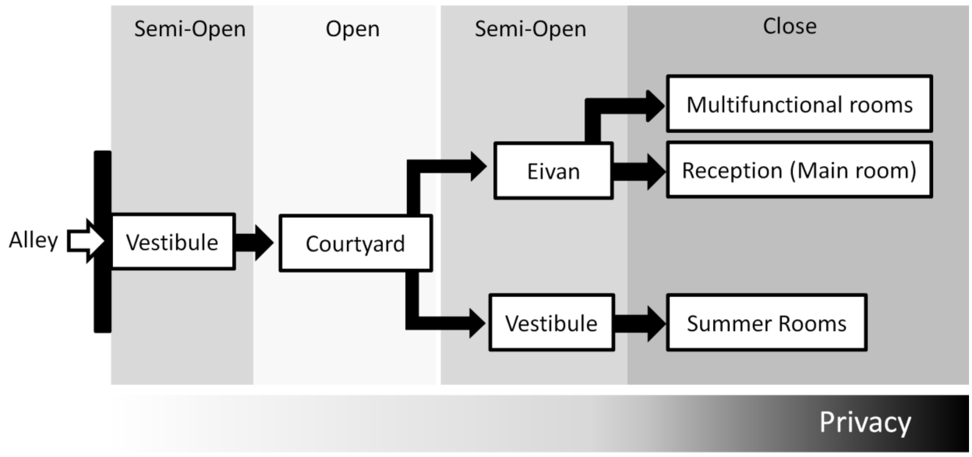


Figure 6-112: Schematic access hierarchy of the Baqani house

6.7.3.3.3 Adaptation to New Functions

The condition of the Baqani house is similar to the Amiri house; these small single buildings are more in danger of being demolished, because the independent commercial use of them is nearly impossible. They can be used as a part of a commercial building group. In this model each independent building acts as a piece of a puzzle that together form a complex. The Baqani house after restoration can be used as an office, small cultural or educational center.

6.7.4 Two-Side House (Parallel)

In this type of house, the building consists of two parts that face each other on either side of the courtyard.

6.7.4.1 The Aldaqi House

Figure 6-113: pillared portico Aldaqi house (Estaji, 2010), hand drawing by Minoo Qasemi

The Aldaqi house was constructed in the late Qajar and early Pahlavi periods, around 1925 (Towhidi-Manesh, 2001a). The building was located behind the city wall. Figure 6-52 shows the city's state of development in 1956, the position of the house in the city and its relationship to the main routes and the old city wall.

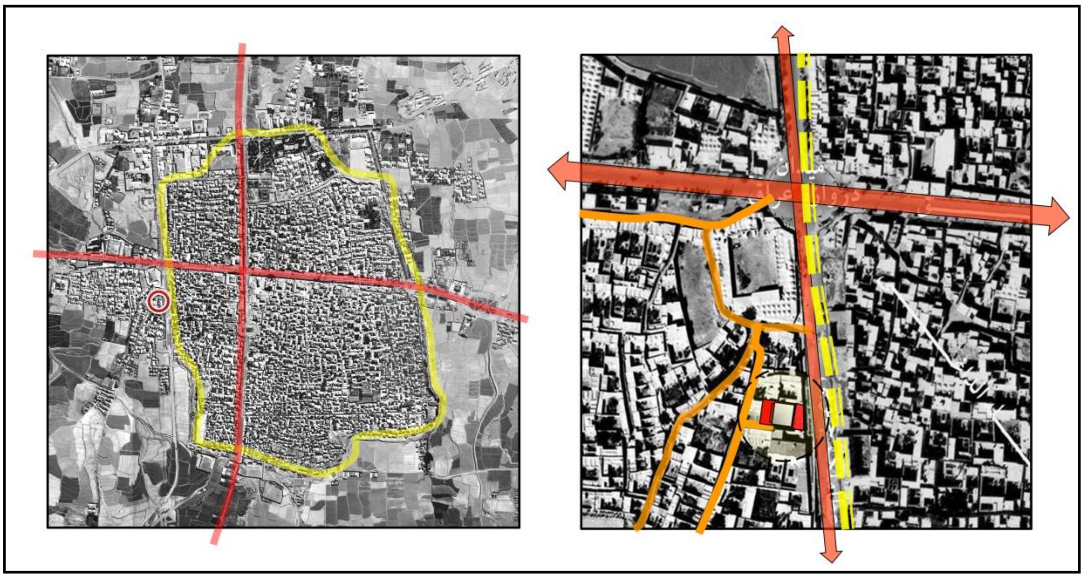


Figure 6-114: the location of the Aldaqi house in 1956, base photomosaic map:(Zanganeh, 2003a)

The house is entered through an octagonal vestibule which connected the courtyard to a blind alley behind the house. In the eastern part of the house, there was a small pathway running parallel to the old wall. This part of the city wall was demolished and turned into a street around 1960. After this change, the old entrance was blocked and the main entrance to the building was moved to the new street. The following map shows the changes in the hierarchy of access to the house over time. (Figure 6-115)

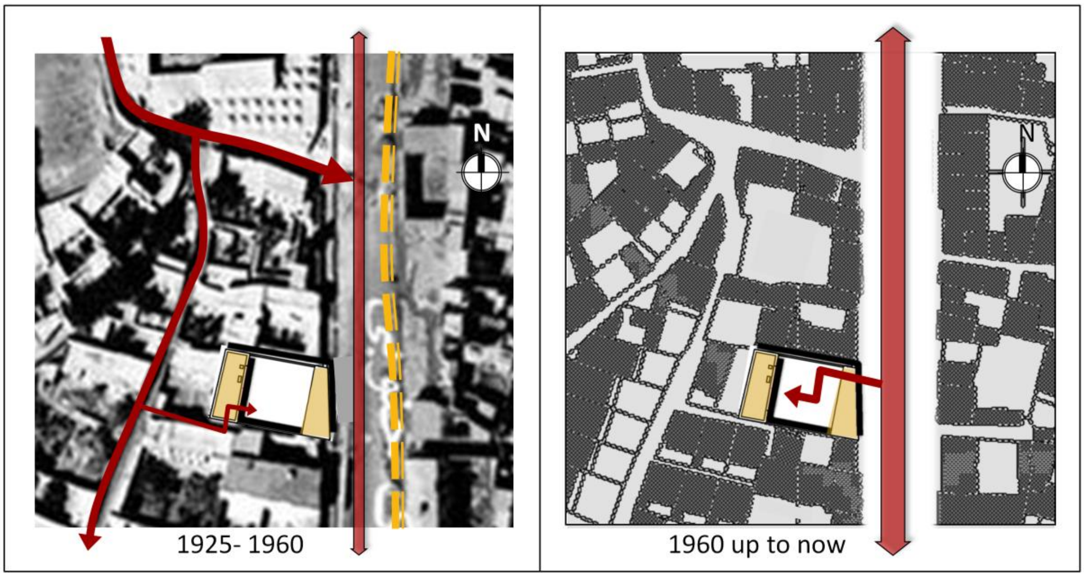


Figure 6-115: access hierarchy from street to the Aldaqi house

In addition to changing the location of the main entrances (1960), the function and the opening of the rooms on the eastern side were changed dramatically. Originally these rooms were used to store agricultural products and farming equipment and were accessible from the courtyard. Later these doors were blocked, new wide doors were opened to the street and the spaces were turned into shops. These shops are active up to the present (information based on an interview with the daughter of Mr. Aldaqi). (Figure 6-116)

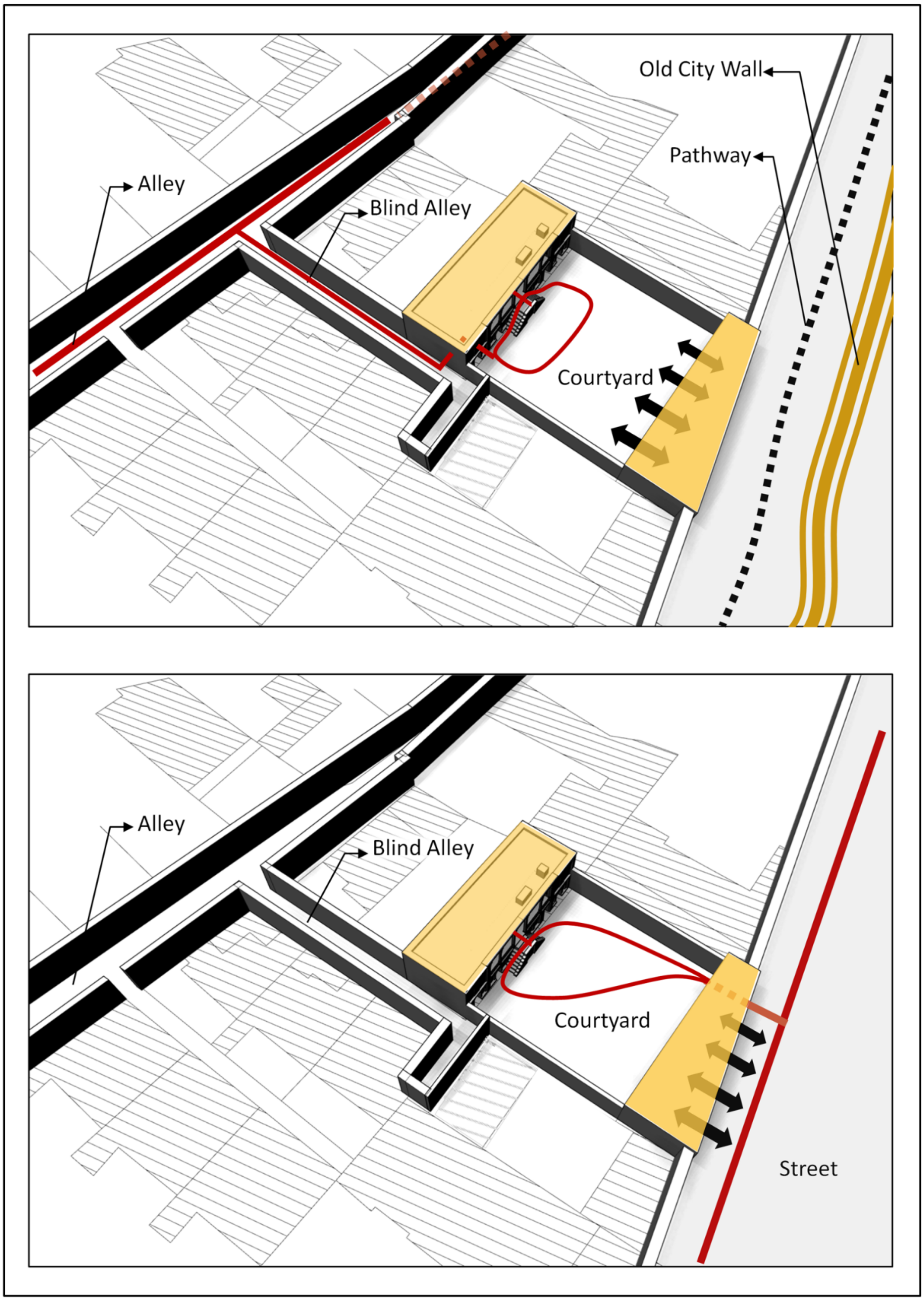


Figure 6-116: changing the entrance and orientation of spaces over time

The closed living space in the western part could be entered through the courtyard. A vestibule connects the courtyard to the summer spaces on the ground floor that is sunken by 90 cm and a bilateral staircase provides access to the pillared portico (Eivan) on the first floor. The Eivan as a circulation space facilitates the connections between main rooms. The following maps depict the original condition of the Aldaqi house. (Figure 6-117, Figure 6-118)

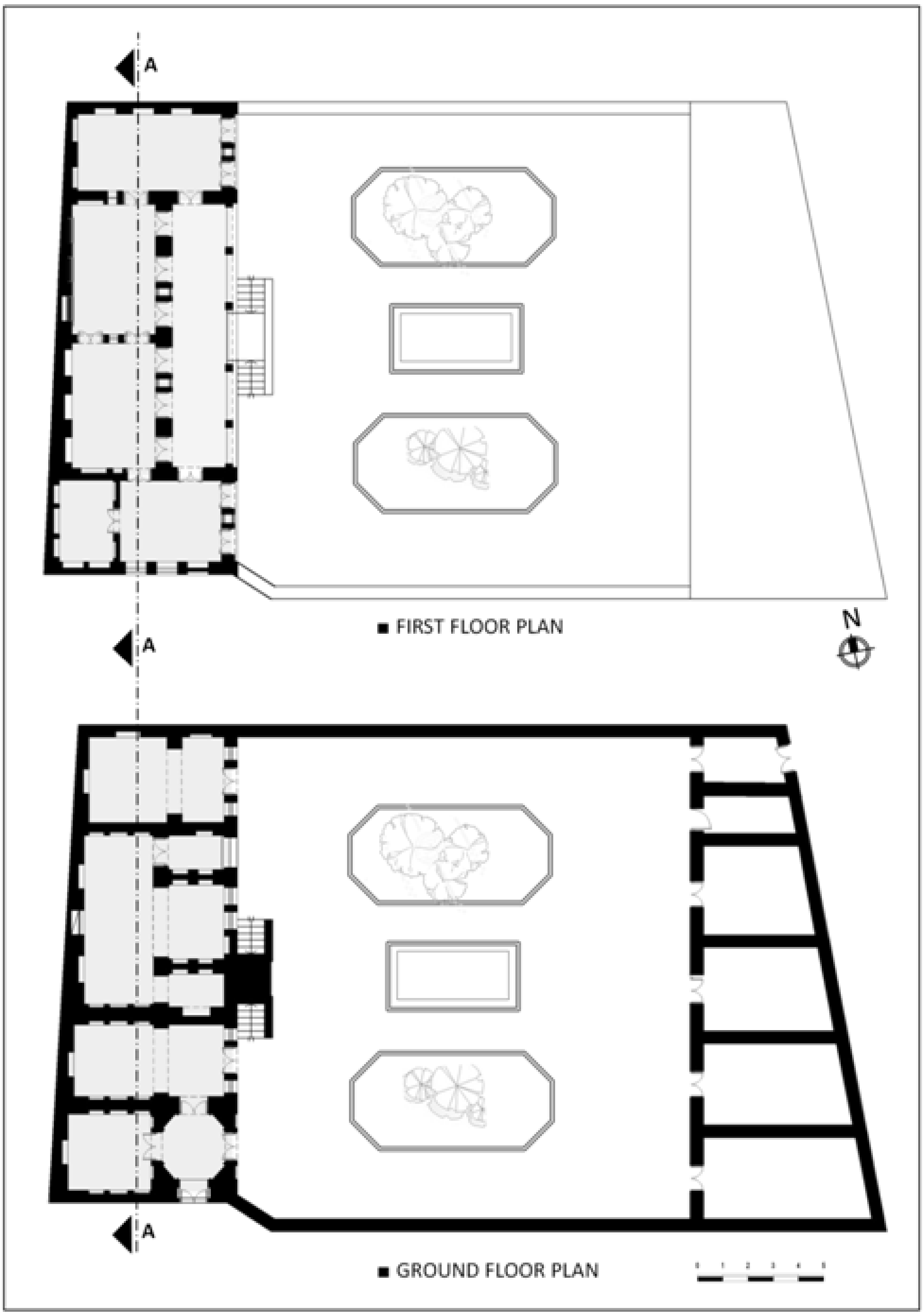


Figure 6-117: original condition of the Aldaqi house (before 1960) (Estaji, 2010, Towhidi-Manesh, 2001a) with modifications

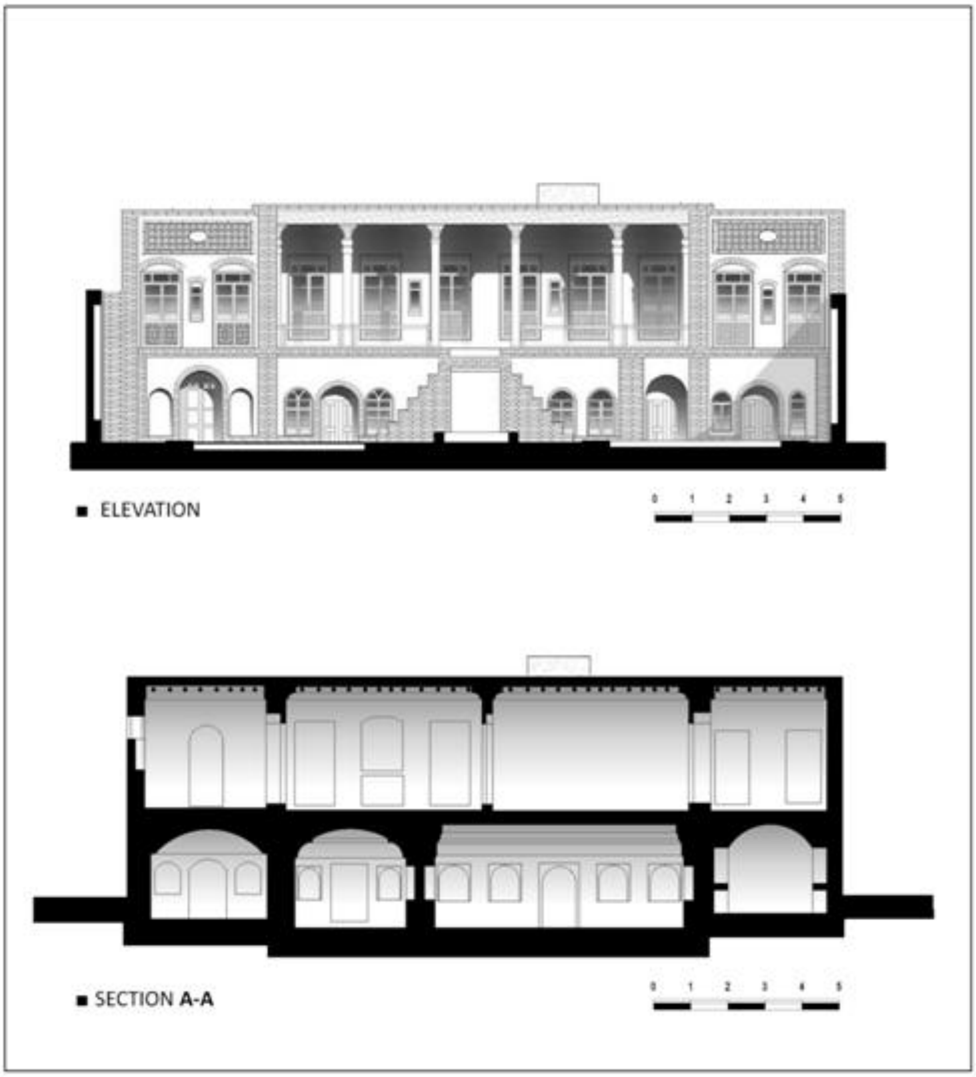


Figure 6-118: Elevation and section of the Aldaqi house (Estaji, 2010, Towhidi-Manesh, 2001a) with modifications

Figure 6-119: photo collage of the main facade, base photo by Mojtaba Kavian (taken 2015), edited by the author

Figure 6-120: the main room (top photos) and the (T) shaped summer room, photo by Mosarreza Tabasi (taken in 2013)

6.7.4.1.1 House Orientation and Sun Position

The Aldaqi House mainly faces the east with a twelve-degree rotation to the south (Figure 6-121). The west part of the house that was used as living space is exposed to sunlight from morning till noon and is then completely in the shade in the afternoon. The east part that faced the west until 1960 was used as storage space without any windows to the courtyard; after being changed so that it faced the east it was used as commercial space (local shop).

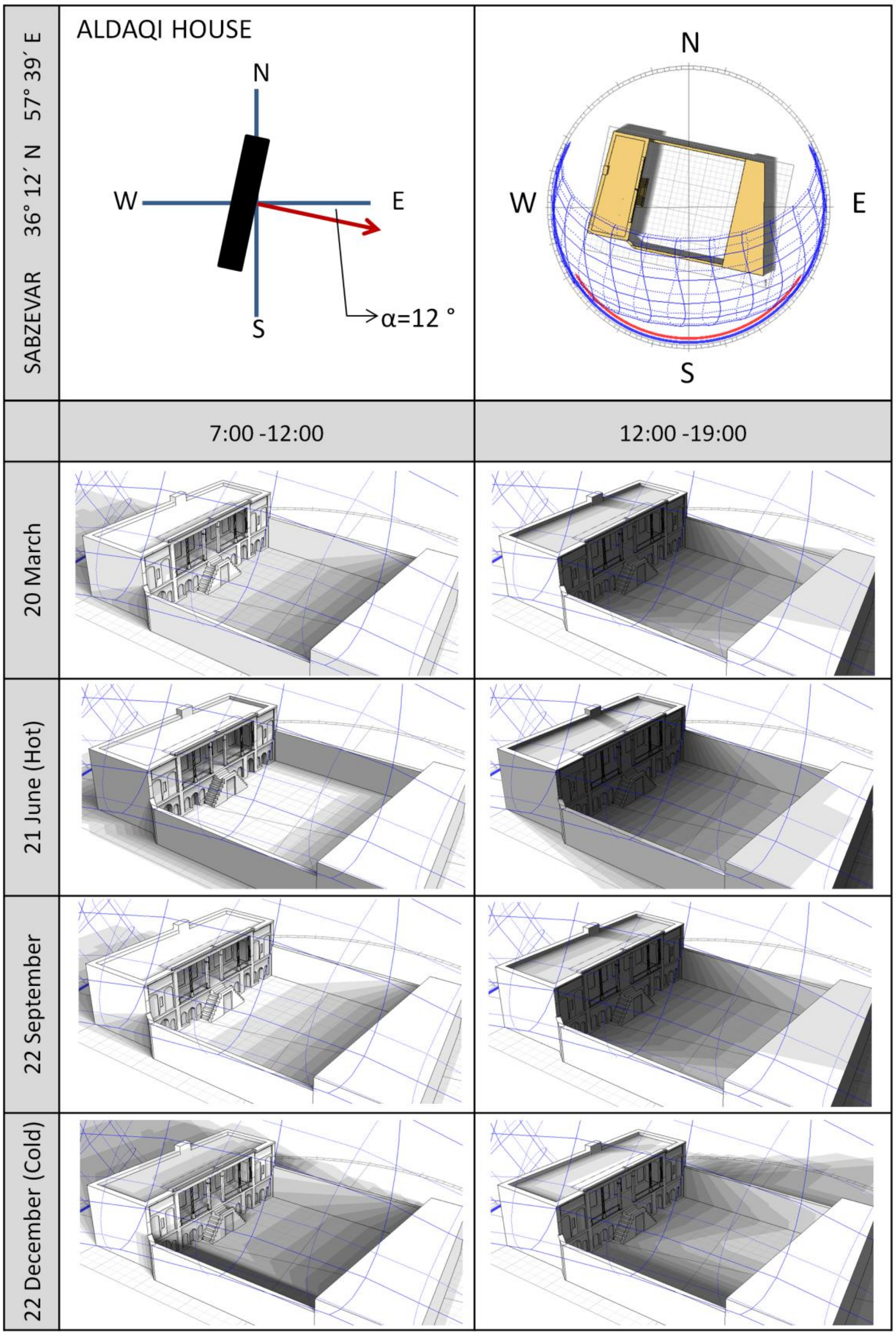


Figure 6-121: the position of shades in the morning and afternoon

The Aldaqi house, like other houses facing the east in this region, controls direct sunshine on hot days by using the deep veranda. The Effective Shading Coefficients (ESC) of the Aldaqi windows located behind the veranda are around twenty per cent. (Figure 6-122)

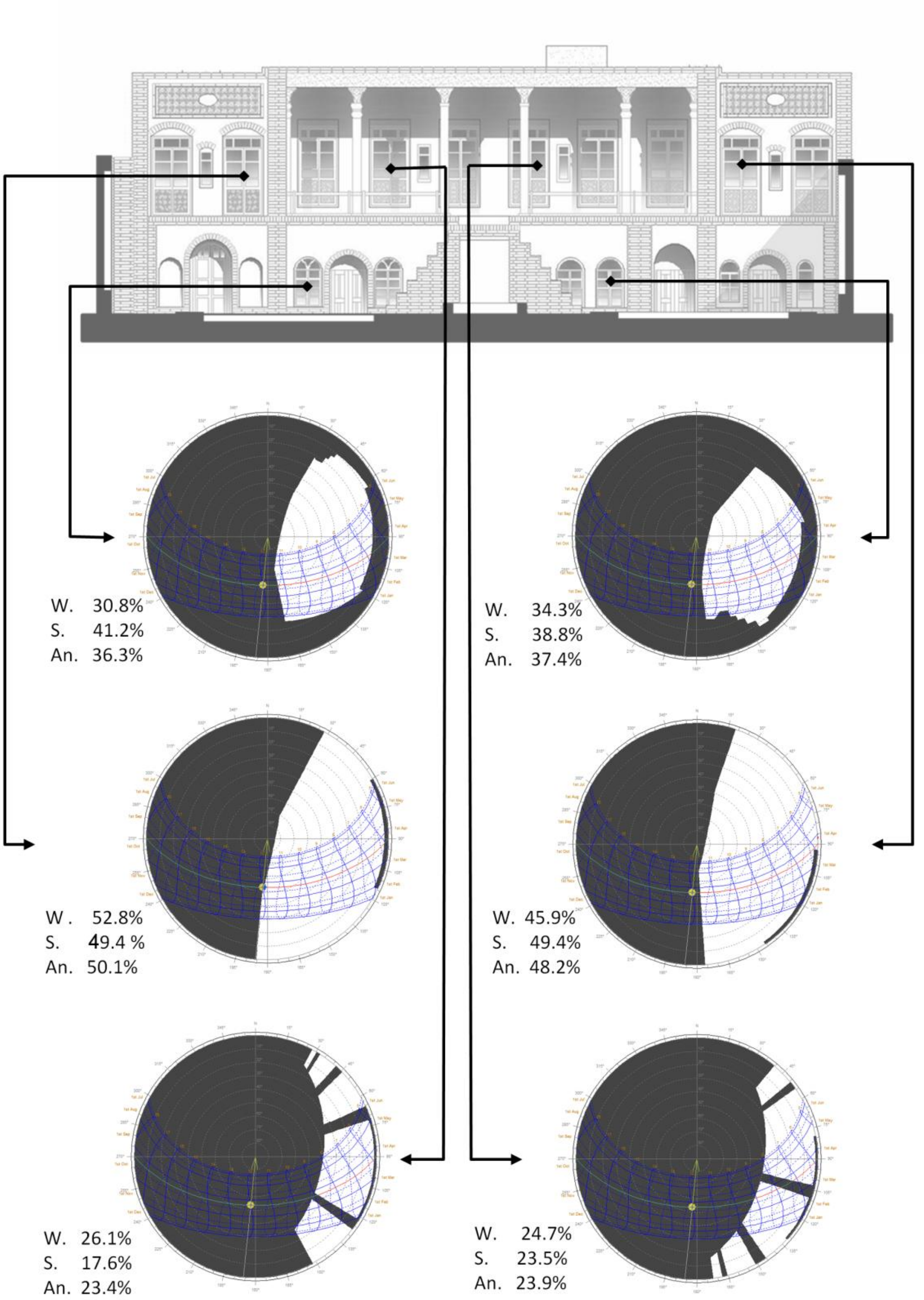


Figure 6-122: Effective Shading Coefficients of the windows facing the east in the Aldaqi house

6.7.4.1.2 Spatial Configuration

The ground floor of the Aldaqi house includes the entrance, stable, kitchen and summer rooms and the first floor includes main multifunctional rooms that are used throughout the entire year (Figure 6-123, Figure 6-124). Although the house was built on two sides of the yard, and given the fact that only the west side is used as living space, the spatial layout of the Aldaqi house is similar to the linear house type in this region.

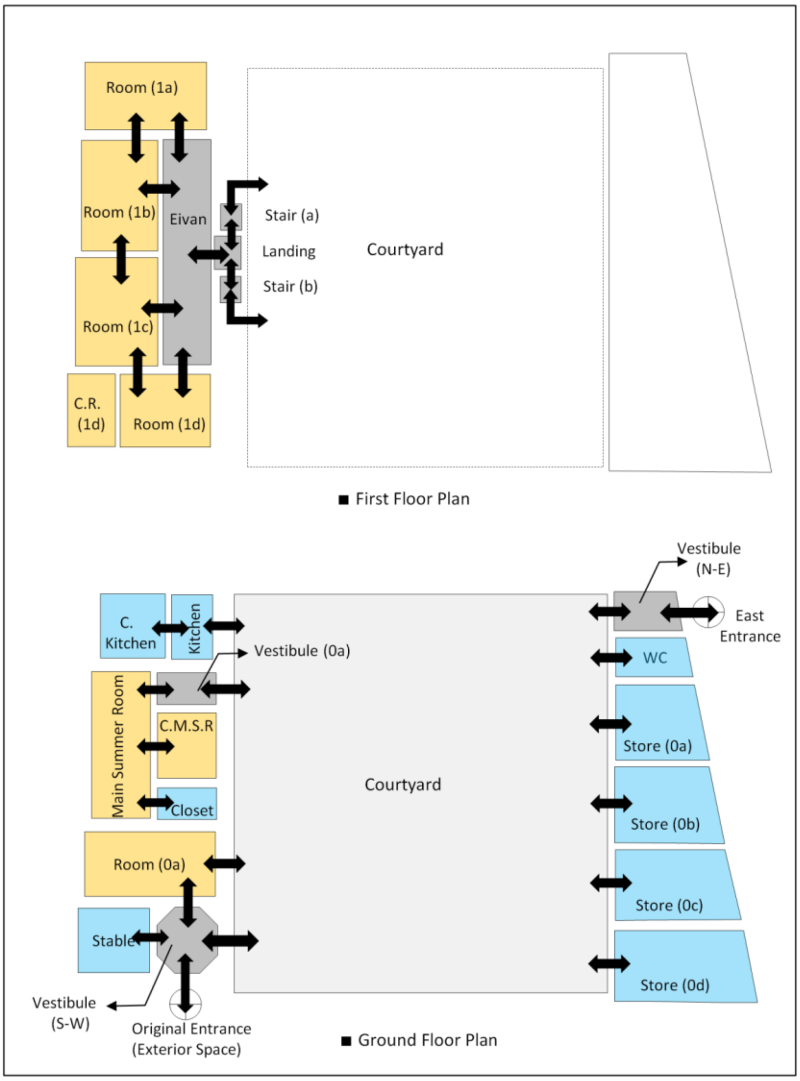


Figure 6-123: Break-up map of the Aldaqi house

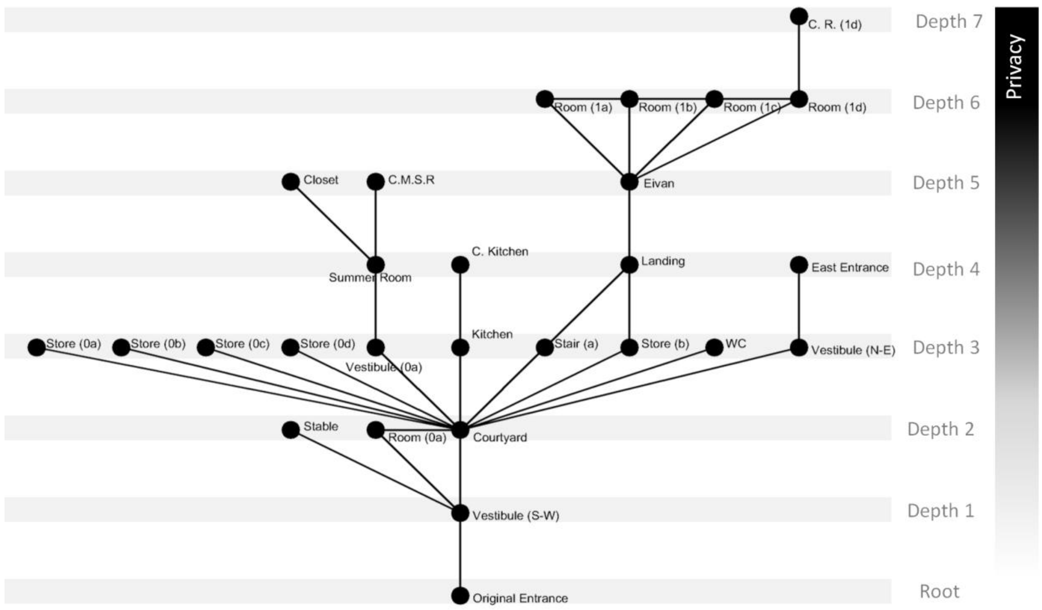


Figure 6-124: Justified graph of the Aldaqi house

The first floor of the Aldaqi house has a pillared portico, four large rooms and a connected room. Due to the large number of access doors to each room, this house is able to change its spatial configuration; some of these possible alternatives are presented in following graph (Figure 6-125).

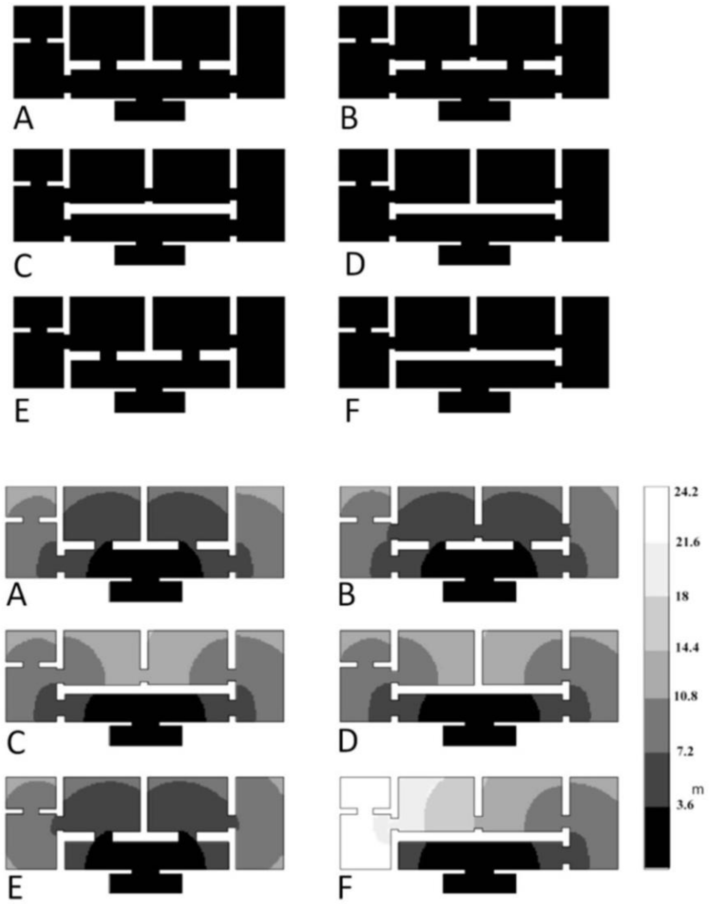


Figure 6-125: Possible scenarios for the first floor and metric step shortest-path length of them (Estaji, 2014)

At first glance, all of them together are similar but from a spatial configuration point of view they are very different. The justified graph of these alternatives reveals these major differences. In this example, the staircase is considered as the root of spatial system. (Figure 6-126)

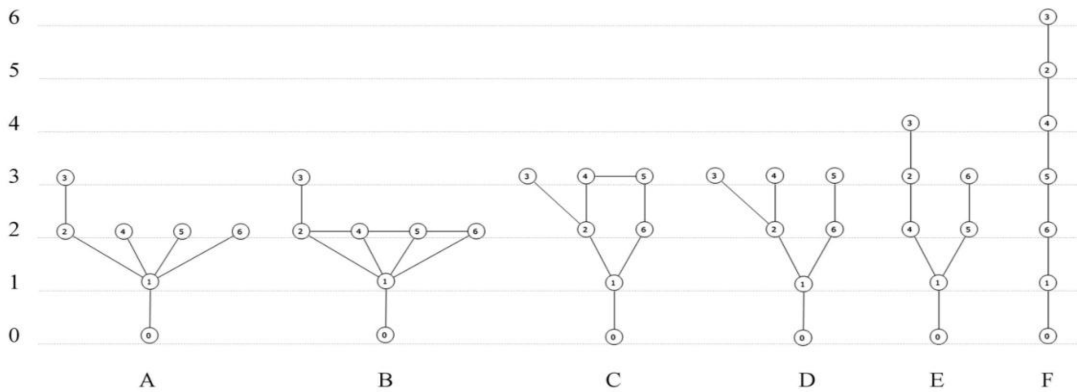


Figure 6-126: justified graph maps of different alternatives (Estaji, 2014)

In Figure 6-125 (bottom) UCL Depthmap software has been used to calculate a metric step, shortest-path length of the alternatives. Alternative F has the maximum step path length; it can provide the maximum privacy for this layout in comparison to other choices. The calculation of the integration value shows the diversity of spatial configuration clearly. (Figure 6-127)

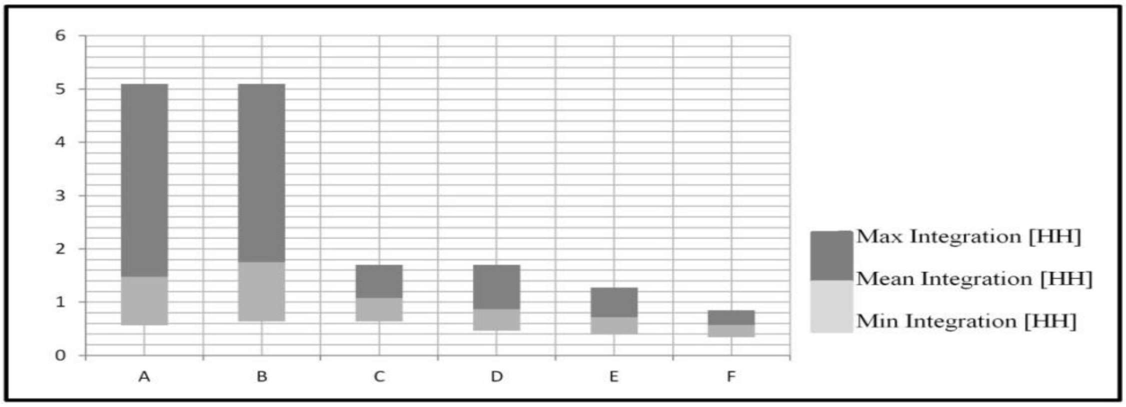


Figure 6-127: Integration values of different alternatives (Estaji, 2014)

These alternatives can respond to different probable scenarios:

A: each room is dedicated to one of the family members or guests.

B: by opening all doors and connecting the rooms to the portico a large common space is ready for guests at summer.

C: communal space for guests at winter.

D, E: the house is sub-divided to create two Independent living units. Or the family opts for compact living in hard winter, only heating two rooms and leaving the other rooms unheated. (Estaji, 2014)

F: it is only an example of spatial variation; otherwise this scenario is unlikely in practice, because all rooms are converted into a circulation path.

The integration value and choice number of all spaces in the house reveals the main role of courtyard as a circulation space and strong spatial discipline in the Aldaqi houses (Appendix A 6). As can be seen in the Figure 6-128, the first six spaces are the circulation spaces, followed by the main rooms and finally the private rooms. The outcomes of the integration value calculation confirm to the access hierarchy of the Aldaqi house. (Figure 6-129)

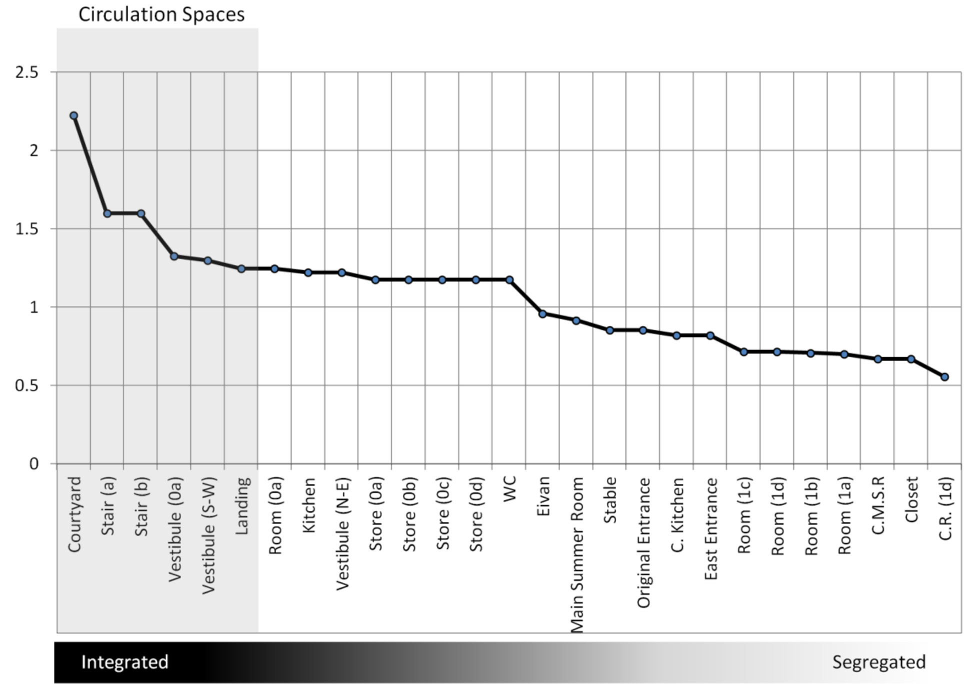


Figure 6-128: integration value of the Aldaqi spaces

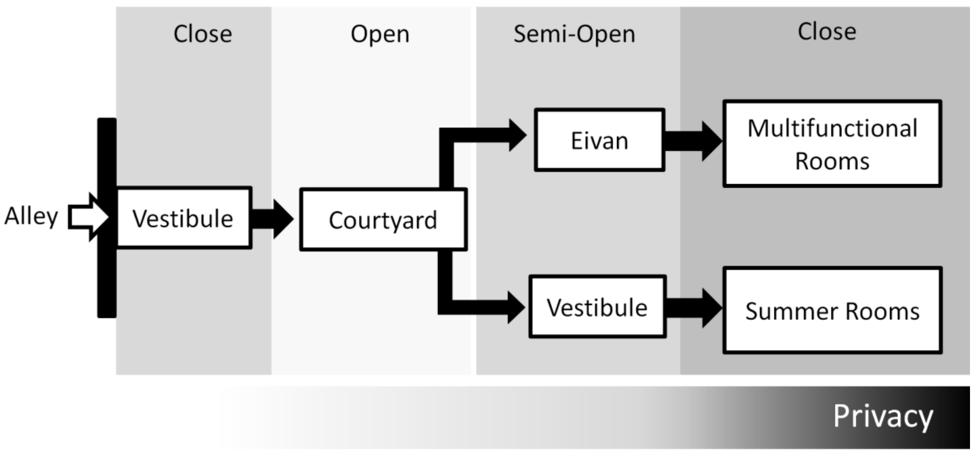


Figure 6-129: schematic access hierarchy of the Aldaqi house

6.7.4.1.3 Adaptation to New Functions

The Aldaqi house was a successful example of adaptation to new condition. By changing the lifestyle of the Aldaqi family from agriculture to business around 1960, they changed the function of the eastern side of the house, with the storerooms now becoming shops. Business in the shops and renting out some of them were and continue to be a stable income source for the family. For this reason, the house owner had no problem paying for maintenance of the building until 2005. From this date, with the aging of the building and increasing maintenance costs, the residential zone (west part) was abandoned. As a result, in 1960 the unusable spaces were converted into commercial spaces, and the abandoned residential zone needed to be given a new function. The building is located on a main commercial street in the city center. Direct access to the street and the flexible spatial configuration of the building allow for changes in the way the building is used. Given the large number of spaces (rooms) in the building, the house can be transformed into a large office. Currently, negotiations are underway between the Aldaghi family and the municipal authorities that, if possible, the site can be leased to the municipality (based on an interview with Mr. Aldaqi's daughter). The ground floor can be used as a small exhibition hall and the first floor can be converted into an office.

The building has the potential to be changed onto a stand-alone commercial unit; it can also be a key element of the network of old houses that can support the smaller units.

6.7.5 Two-Side House (L) Shape

6.7.5.1 The Kian House

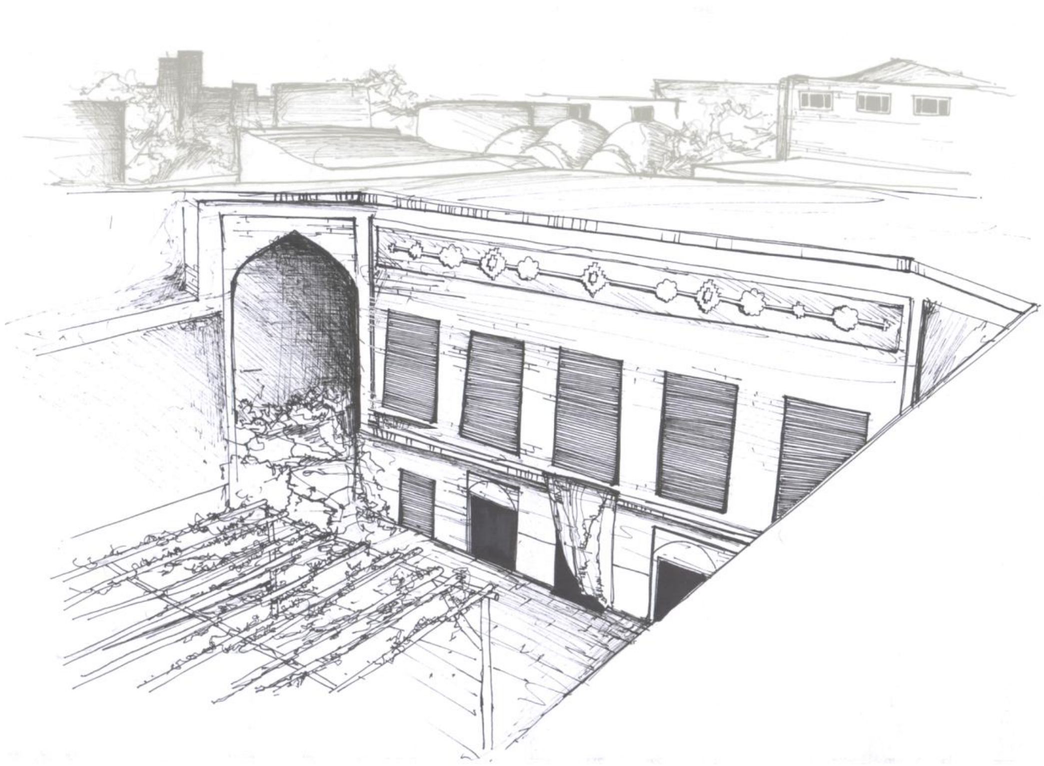


Figure 6-130: the Kian house (Estaji, 2010), hand drawing by Minoo Qasemi

The Kian house was constructed within the old Sabzevar city wall (Figure 6-131). The exact time of construction is not clear. In the registration document of the house, it is only mentioned that it belongs to the Qajar period (1785 to 1925) (Abbas-Zadeh, 2000), But since it is very similar to other houses in Sabzevar that were built at the end of the Qajar period I conclude that it was constructed around 1900.

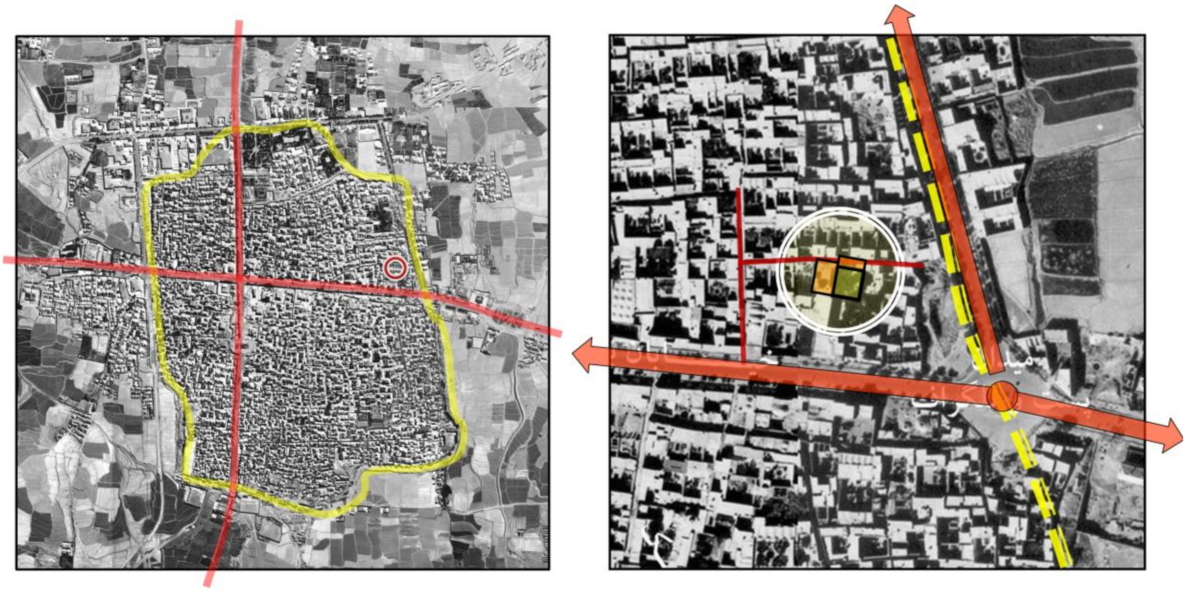


Figure 6-131: the position of Kian house in 1956, base photo-mosaic map:(Zanganeh, 2003a)

Access to the building was through a covered passage, and part of the building is constructed on top of this public covered passage (Figure 6-132, Figure 6-133). A vestibule gives access to the courtyard. Two symmetrical stairs and two vestibules connect the courtyard to the main rooms on the first floor. One of this stairs links the courtyard to a pillared portico (Eivan). Three simple steps provide access from the courtyard to the summer spaces on the ground floor first floor without any intermediate space. (Figure 6-133)

Figure 6-132: access to the Kian house via a public covered passage

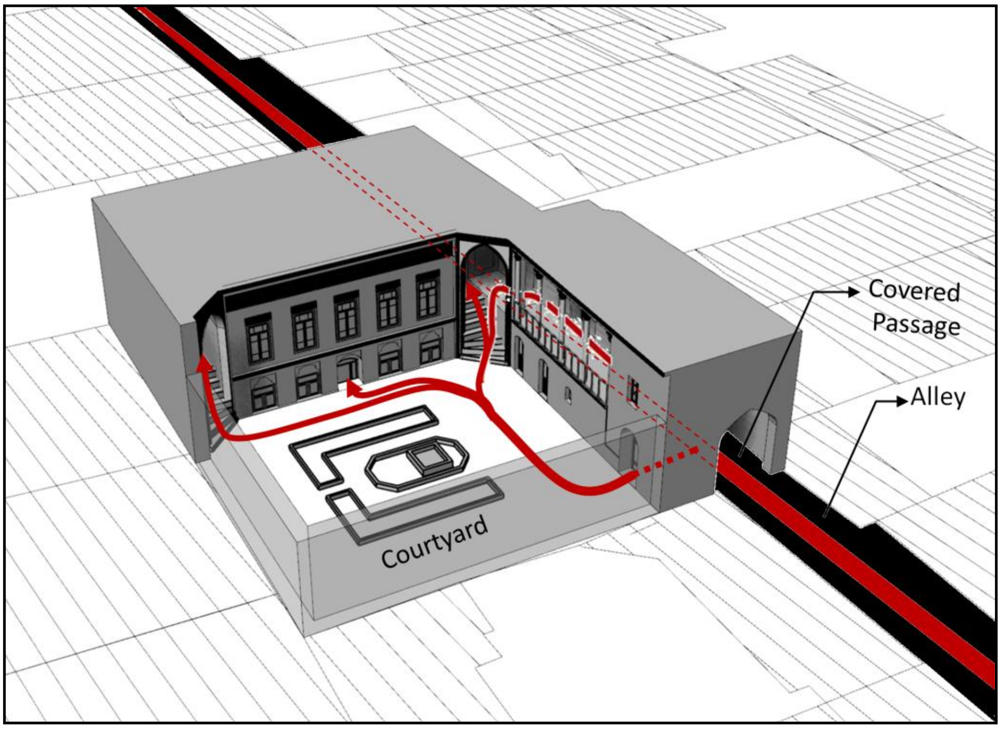


Figure 6-133: access hierarchy from the alley to closed spaces

The following maps and photos depict the house in detail.

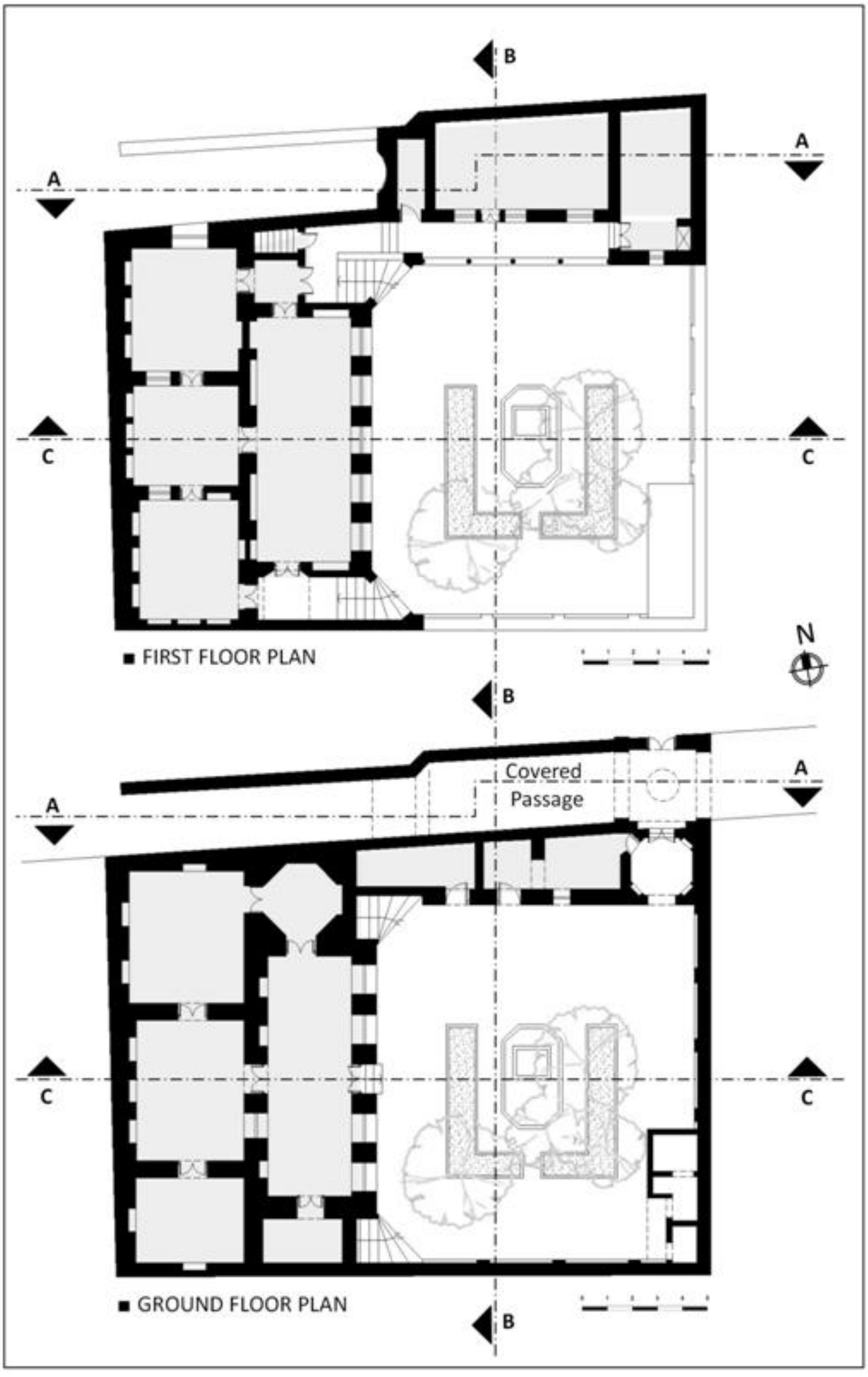


Figure 6-134: Plans of the Kian house, source:(Abbas-Zadeh, 2000, Estaji, 2010) and the local archives of ICHTO with corrections

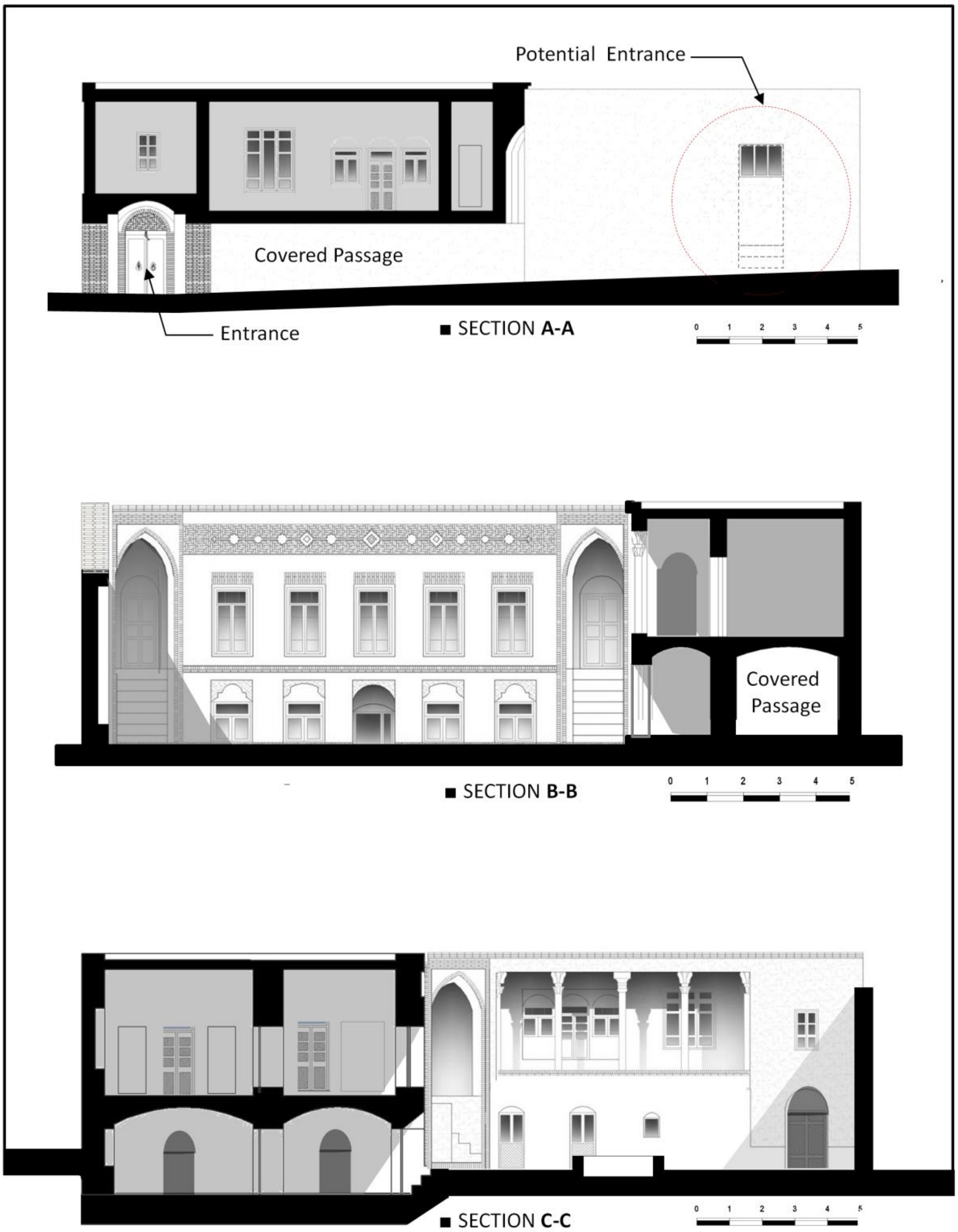


Figure 6-135: elevation and sections of the Kian house, source:(Abbas-Zadeh, 2000, Estaji, 2010) and the local archives of ICHTO with corrections

Figure 6-136: photos of the Kian house (Estaji, 2010)

6.7.5.1.1 House Orientation and Sun Position

The two wings of Kian House face south and east with a ten-degree orientation to the west and east (Figure 6-137). The wing facing east is exposed to sunlight from morning till noon and completely is in the shade during the afternoon. The pillared portico in the part of the house facing south blocks the direct sun in the summer.

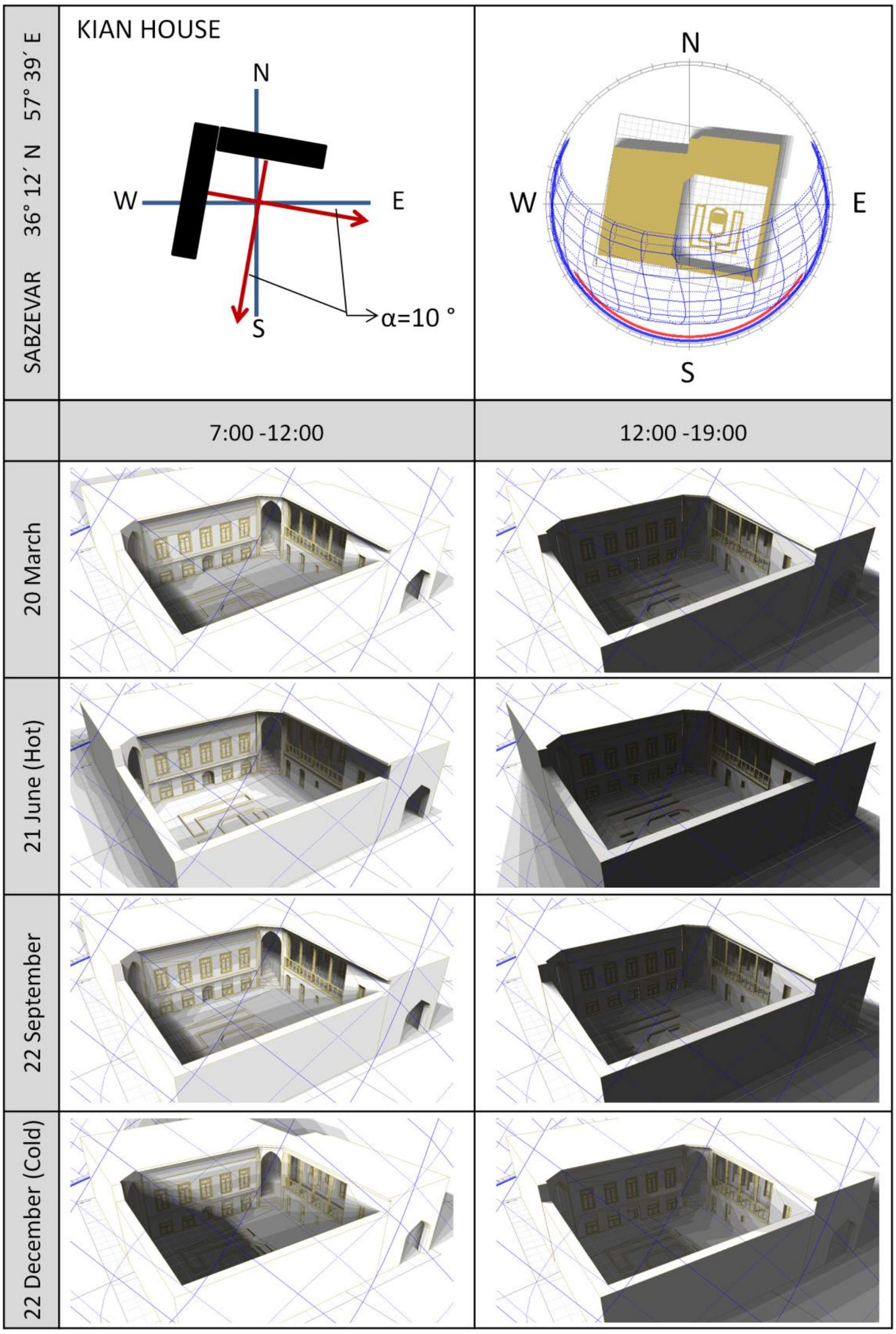


Figure 6-137: the position of shades in the morning and afternoon

The shading masks for the middle of the windows facing east indicate that the wing facing east is exposed to sunlight. This wing benefits from the orientation of the building in the afternoon on warm days, but this orientation is not suitable in the morning on warm days. (Figure 6-138)

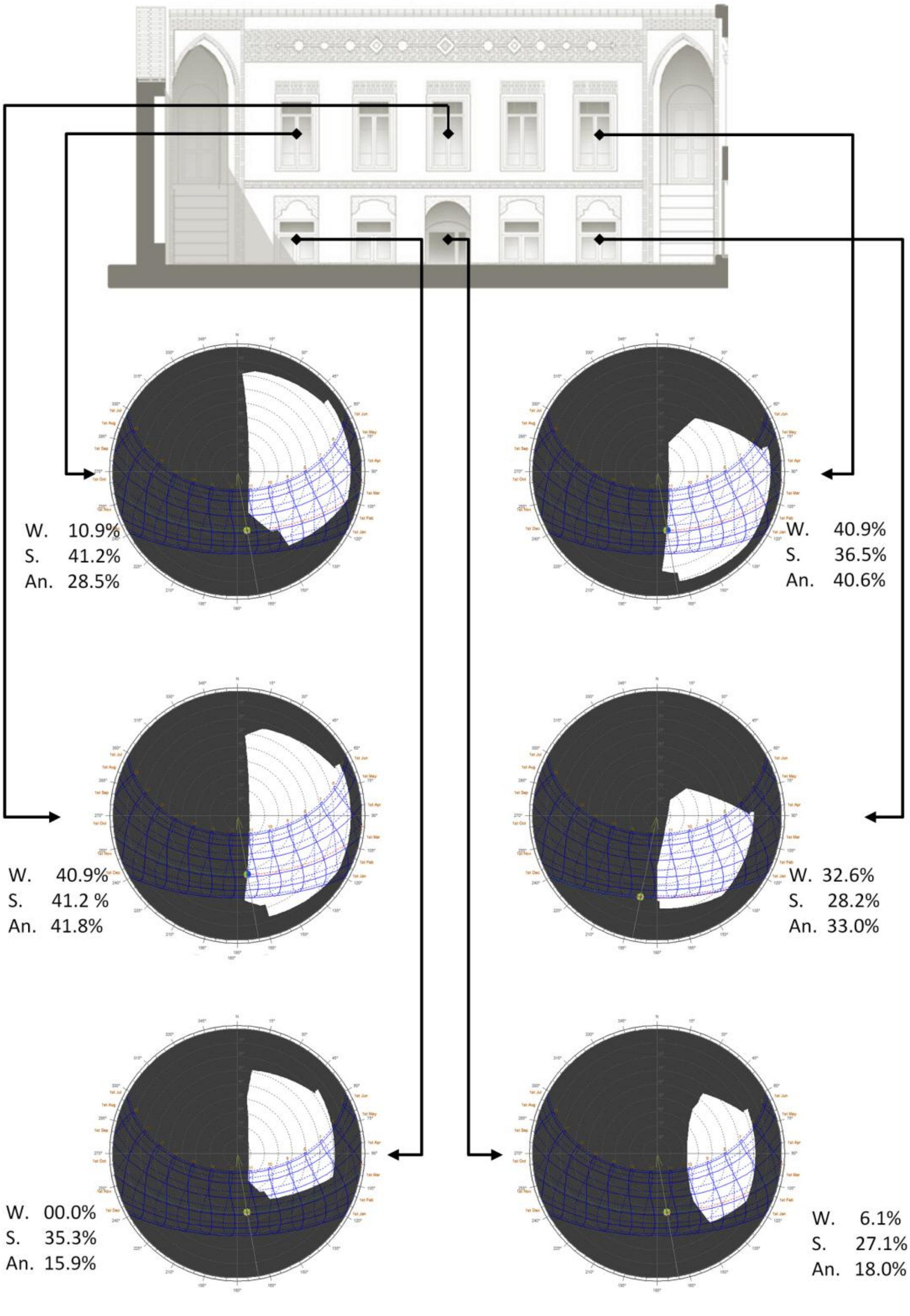


Figure 6-138: Shading Mask and Effective Shading Coefficients of east facing windows

In the case of the Kian house trees were planted to shade the house. Deciduous trees block the sun's heat in the summer and let the windows and house facades benefit from the sun during the winter. In the following photos (Figure 6-139) the shades of trees on the windows and building facades are clearly visible. The trees, in adition to controlling the direct sunlight, increase the humidity of the yard; this combination forms a cooler microclimate in the house.

On the other hand, the high walls protect this man-made microclimate from the hot and dusty winds of Sabzevar on hot days.

Figure 6-139: Vegetative shading and green micro-climate of the Kian house

The summer's effective shading coefficients of these windows are zero, which means the Eivan of the Kian house blocks the direct sun on the windows that open on to it in the summer completely, offering perfect shading. (Figure 6-140)

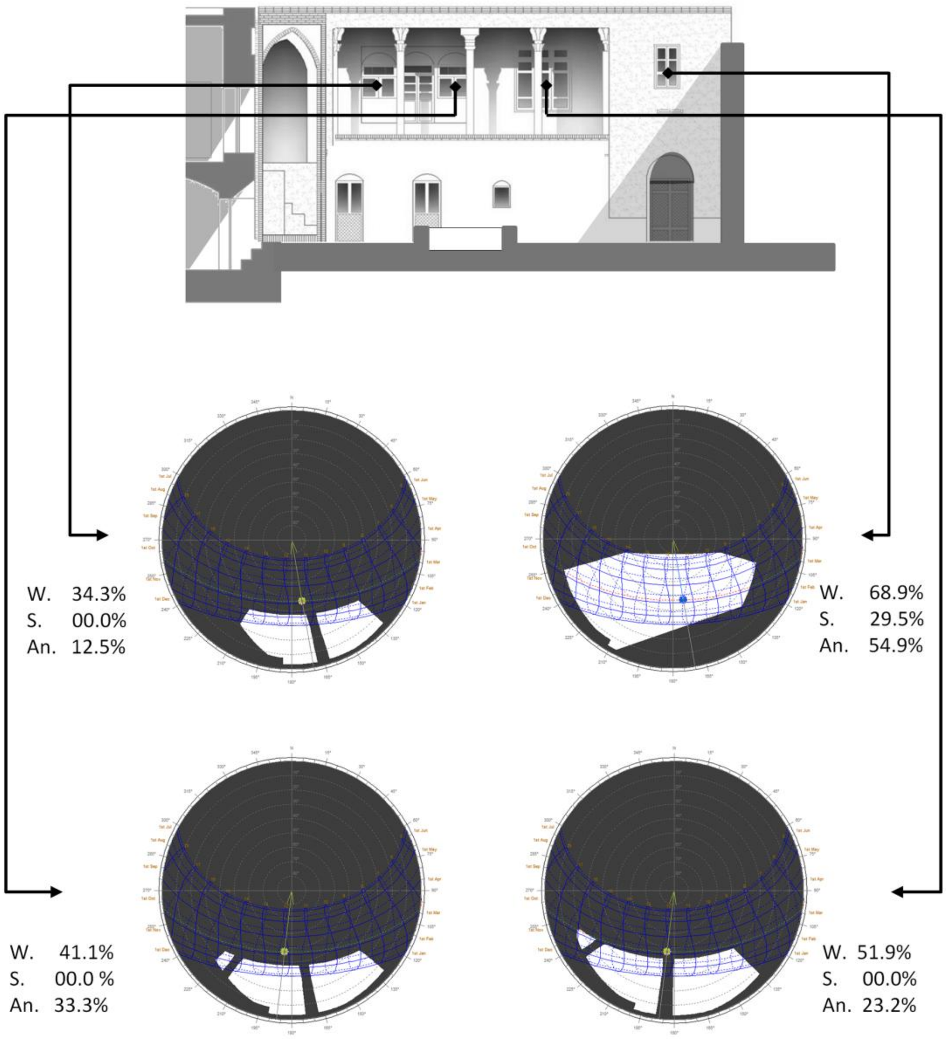


Figure 6-140: shading masks of south-facing windows

6.7.5.1.2 Spatial Configuration

The Kian building was designed as a residential building. The number of spaces and the size of main rooms indicate that the building belonged to a wealthy family. From 1907 to 1917, the Kian house was used as a branch of Russian Discount and Loan Bank in Sabzevar. Having two large halls and several supporting spaces with flexible spatial configuration enabled the building to be reconfigured to serve a new function. For this purpose, a new entrance to the building was created. This new door completely changed the access hierarchy of the building. In the following, the original condition of the house and the changes over time are investigated in detail.

Five loops in the Kian house could help to change the arrangement of the spaces. Four potential openings in the load-bearing walls enable the house users to rearrange the spaces with minor modifications in the building according to their new needs (Figure 6-142). These nine openings and a potential opening belong to the main rooms (Figure 6-141); it means that the main rooms have maximum flexibility. For example, the main hall has five selective openings (Table 6-9).

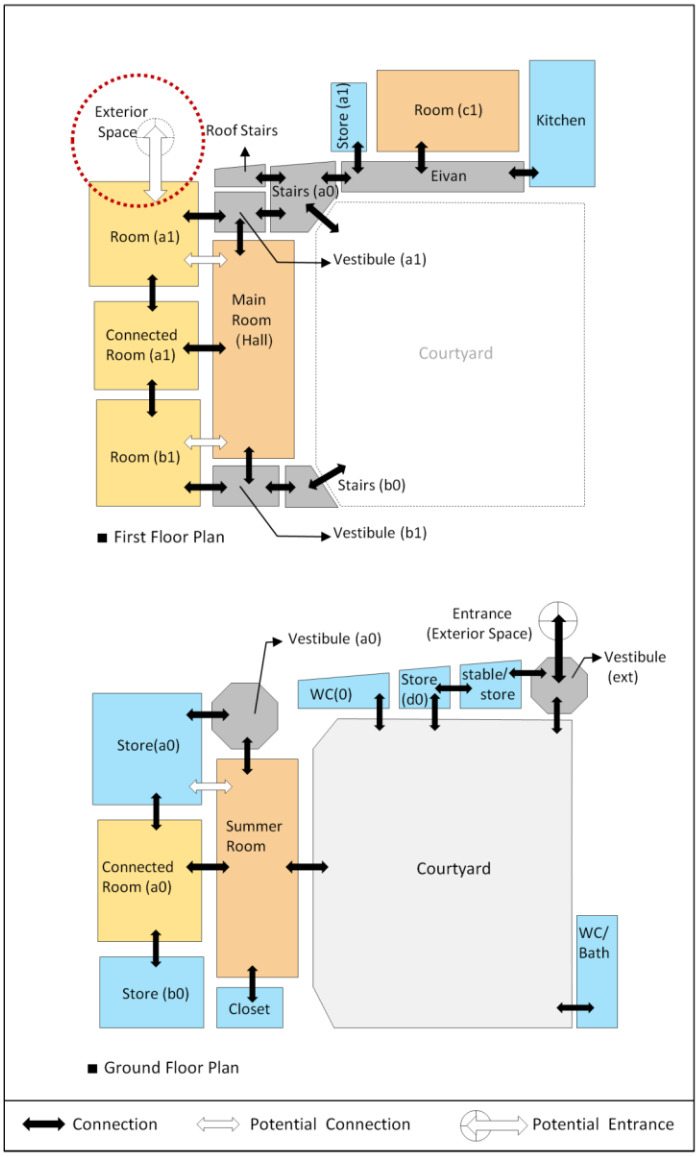


Figure 6-141: Break-up map of the Kian house

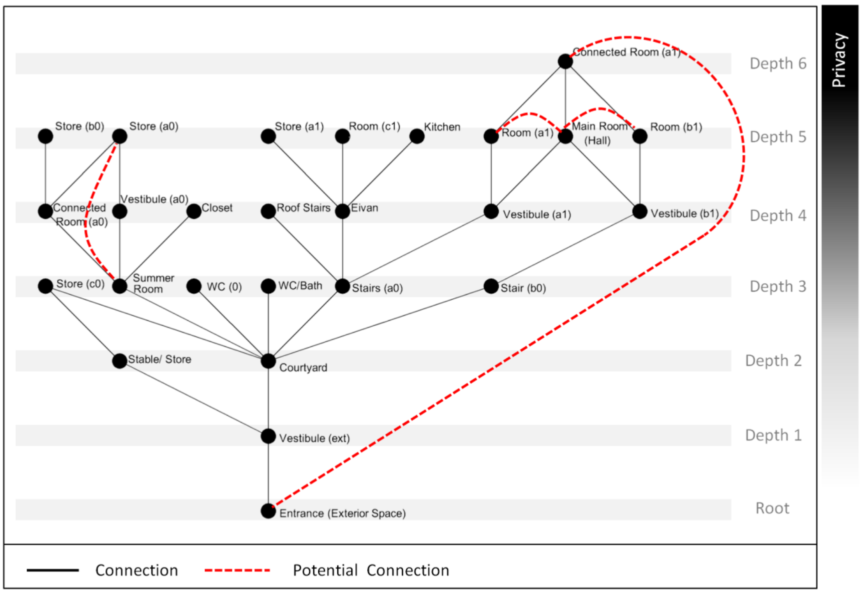


Figure 6-142: Justified graph of the Kian house

Table 6-9: existing and potential Distributedness of the Kian house

THE KIAN HOUSE						
Number of spaces	Mean Connectivity	Potential openings	Number of loops		Distributedness (Convex ringiness)	
			Existing conditions	Considering the potential openings	Existing conditions	Considering the potential openings
25	2.36	4	5	9	0.11	0.20

The selective connectivity and the potential opening enable the house to respond to different possible scenarios in the house. The house underwent one of these functional changes in 1907. A door was created to connect room a1 directly to the alley. (Figure 6-135, Figure 6-141). This room had the maximum depth (six) from the original entrance and, consequently, had the highest privacy in the house before this change (Figure 6-142). This transformation changed the spatial configuration completely. The following graph (Figure 6-143) compares the metric step shortest-path length of the second floor of the Kian house in two different situations. it shows that changing the entrance of the building completely altered the access hierarchy and the degree of privacy of spaces.

Figure 6-143: metric step shortest path length of the Kian house in two different alternatives, calculated by UCL Depthmap 10 software

The calculation of integration and choice shows the importance of the courtyard and vestibules and the summer room in the Kian house (Appendix A 7). In the past, the summer room served both as a circulation and living space and offered a certain degree of privacy. After the conversion of the house into a bank, privacy was no longer needed and it was therefore possible and useful to open this wing of the building directly to the street.
The integration value of spaces reveals this contrast. The summer room is an integrated space; on the other hand, the high integration contrasts with the privacy of space. (Figure 6-144)

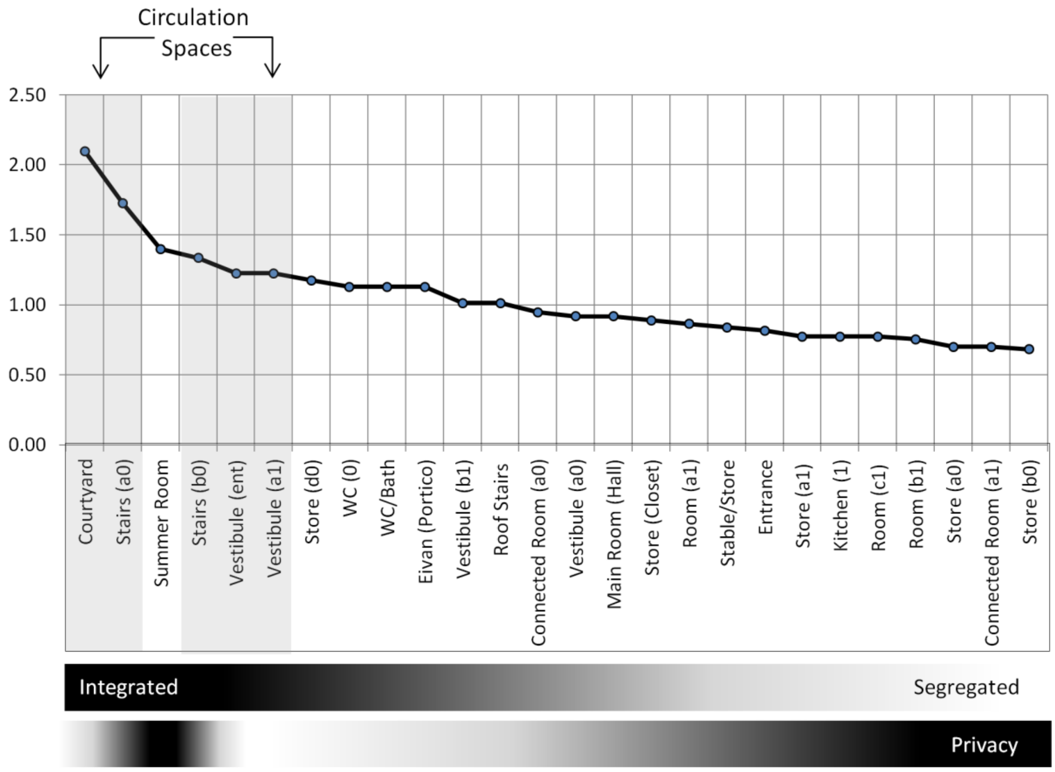


Figure 6-144: integration value of the Kian spaces

Figure 6-145 shows the schematic access hierarchy of the Kian house. The exterior vestibule acts as a joint between the public space and the house; it blocks the direct view from the outside to the courtyard. The Eivan and vestibules as semi-open intermediate spaces connect the closed spaces to the courtyard as is typical in the access hierarchy of the Qajar period. Only the summer room is linked to the open space without any intermediate space. (Figure 6-145)

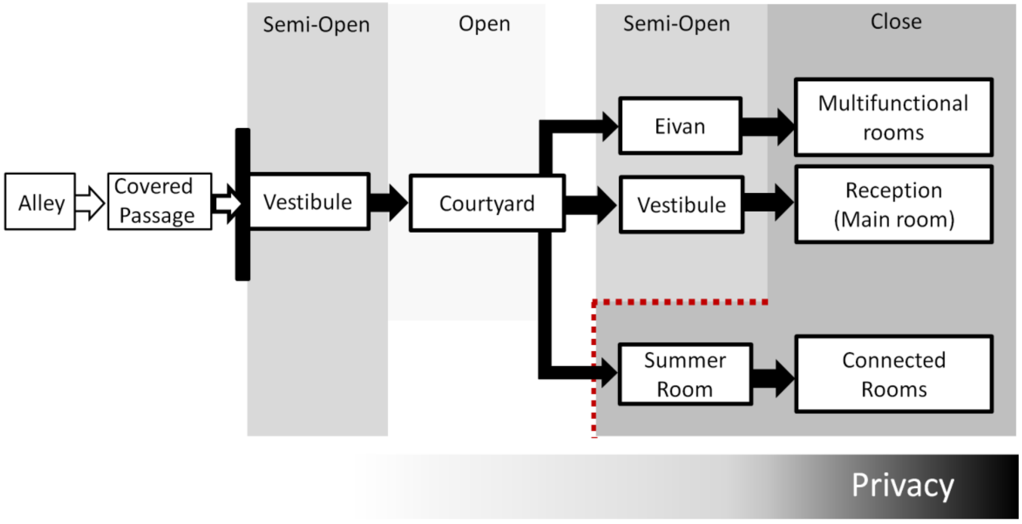


Figure 6-145: Schematic access hierarchy of Kian house

6.7.5.1.3 Adaptation to New Conditions

The Kian house is currently used as a residential building, but the ground floor has been abandoned and the left external staircase destroyed. In general the house is in danger and needs urgent conservation. Due to the high cost of conservation and maintenance of the building, the house owners who have inherited it have not made any effort to restore it and use it as a house. In fact residential use of the building is not cost-effective anymore.

Once, in 1907, the house, which was originally a residential building, was turned into a commercial one (bank office). Now again, after around a century the house needs to be restructured for a new commercial use. Two large halls (Talar) and several supporting spaces with flexible spatial configuration enable the building to be rearranged to serve as a private art gallery or a small museum (Figure 6-146). The building, such as Aldaqi house, has the potential to be changed into a standalone commercial unit and it could also be one of the main building in the network of old constructions.

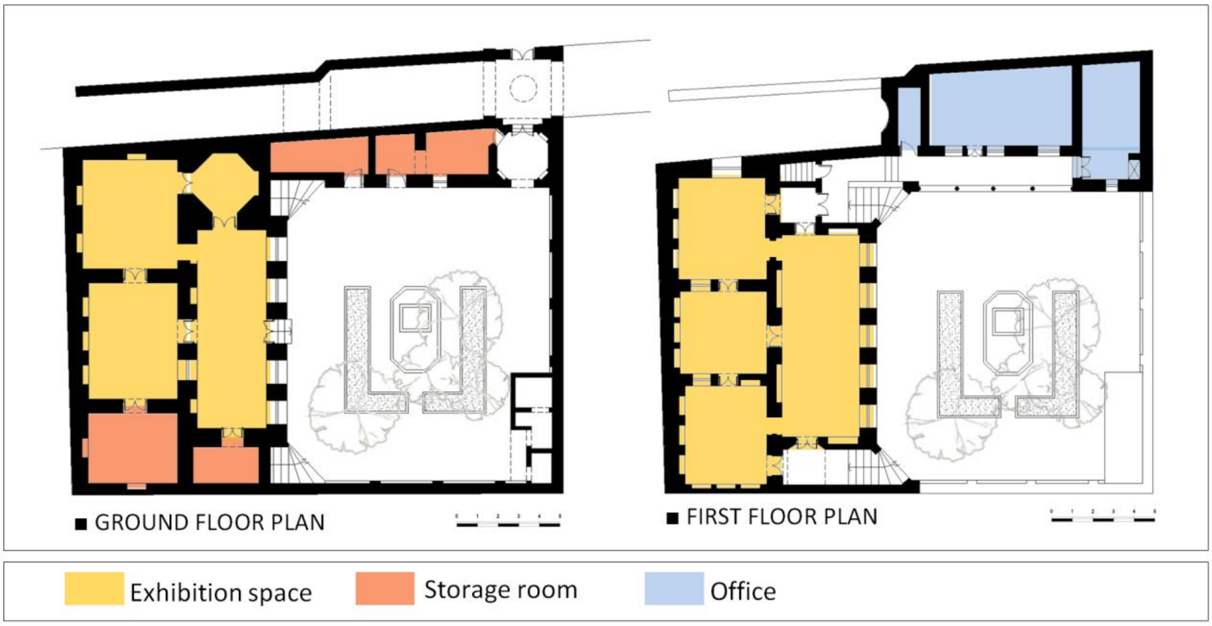


Figure 6-146: a proposal for changing the Kian house into an art gallery or a small museum

6.7.6 Two Courtyards Houses

6.7.6.1 The Moslem House

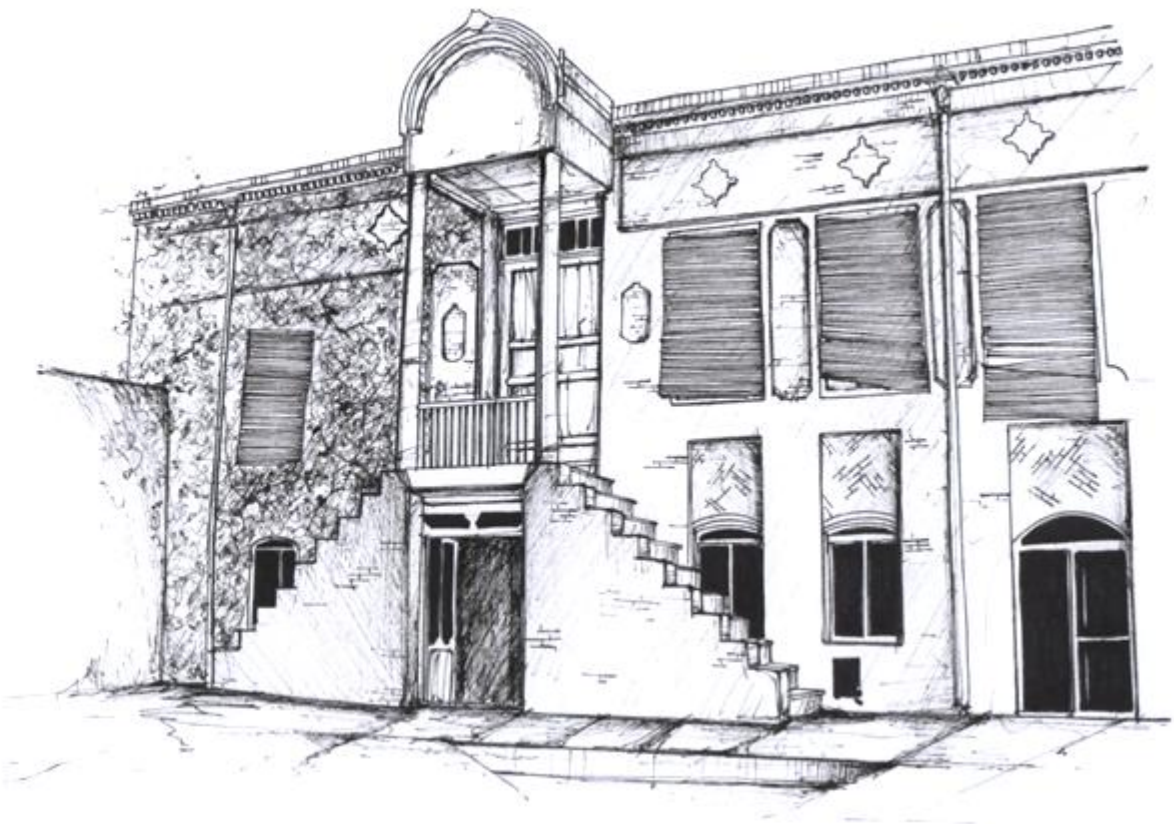


Figure 6-147: The Moslem house (Estaji, 2010), hand drawing by Minoo Qasemi

The Moslem house was constructed within the old Sabzevar city wall in the late Qajar period around 1920. Figure 6-148 shows the location of the house in 1956. The house was located in an alley, which was indirectly connected to the main east-west route of Sabzevar. In 1975, the alley was extended to create a direct connection to the main route. This cut changed the nature of this neighborhood; the residential area was gradually converted into a commercial street. Initially, the owner of this Moslem house resisted change and so it remained a residential building. The building typically consisted of two separate zones, i.e., a more public reception courtyard and a family courtyard with a more private character. Between 1990 and 1998 the reception zone was turned into a “doctor’s office” (kermani-Moqaddam, 2002c). The rapid rise in the price of land and building on this street motivated the house owner to replace this traditional building with shops and office units. The house was demolished in 2012. The aerial photo of this area in 2015 shows the structural framework of the new building that occupies hundred percent of the ground level.

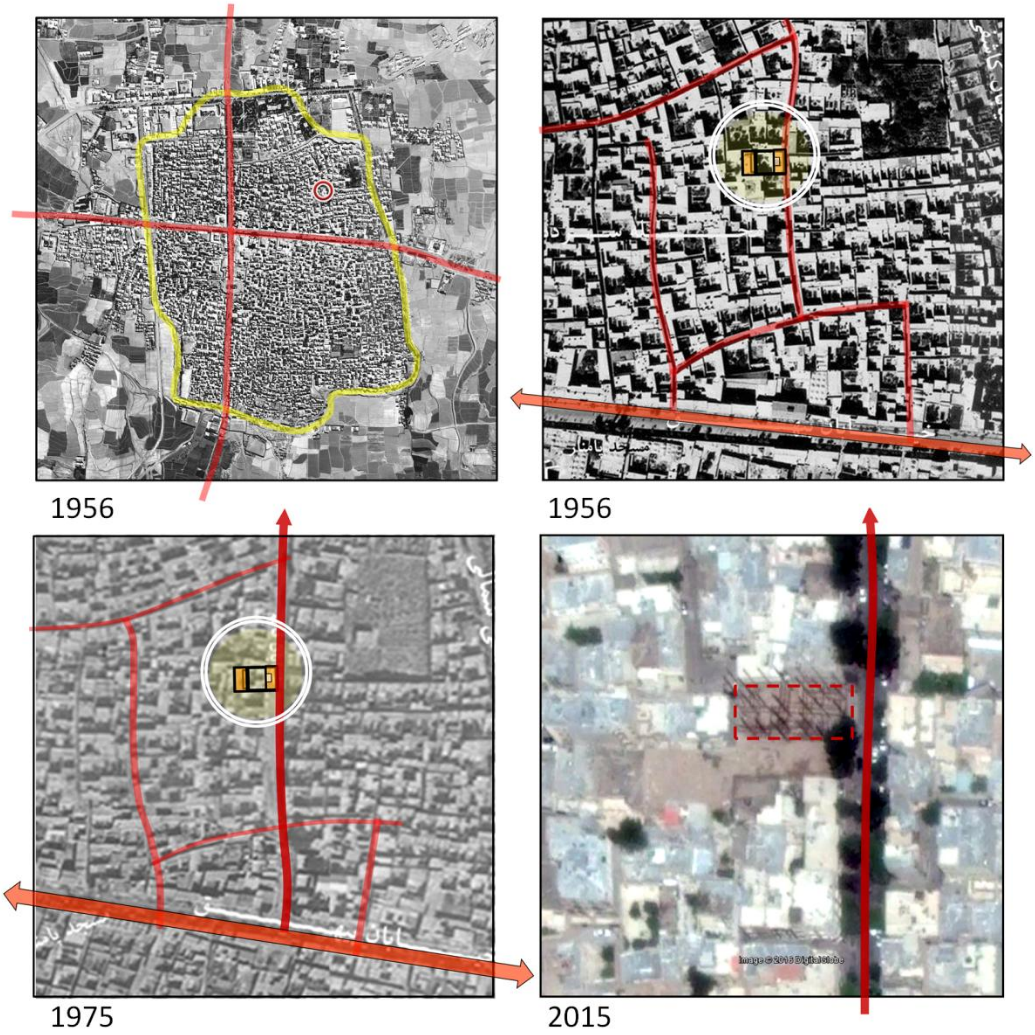


Figure 6-148: the position of the Moslem house in 1956, 1975 and 2015, base photomosaic maps: (Zanganeh, 2003a, c), 2015 aerial map: (Google Earth, 2015)

Access to the building was via vestibule that connected the street to the public courtyard. Two symmetrical stairs led to the summer and winter reception spaces. The summer room was located on the south of the public courtyard and the winter room on the north. A joint space in the corner of public courtyard provided an access to the private zone. Two vestibules connected the courtyard to the summer spaces and storerooms on the ground floor, while two symmetrical external staircases provided access from the private courtyard to the main rooms on the first floor in the private wing (Figure 6-149). The following maps and photos depict the house in detail.

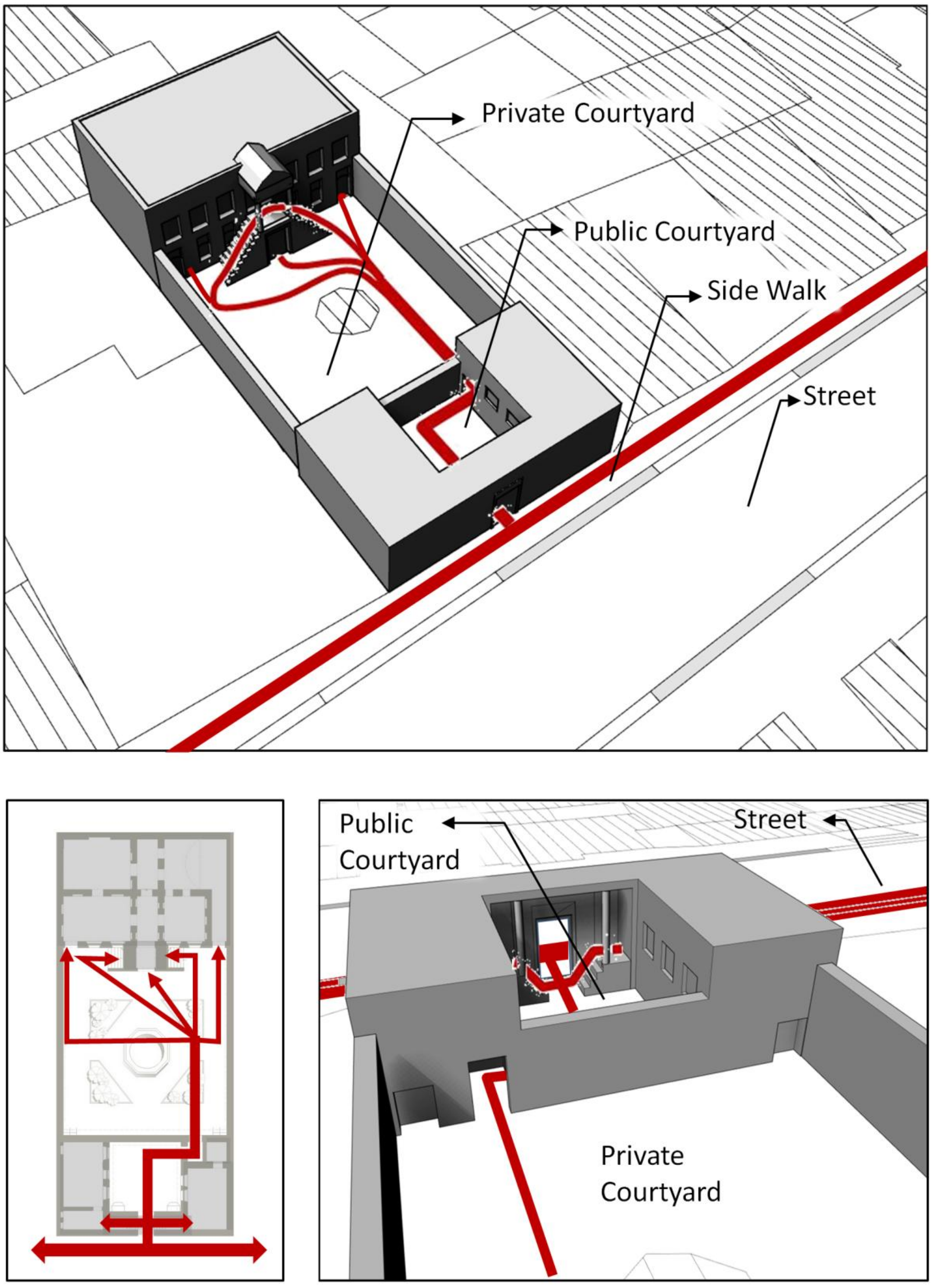


Figure 6-149: access hierarchy from street to closed spaces

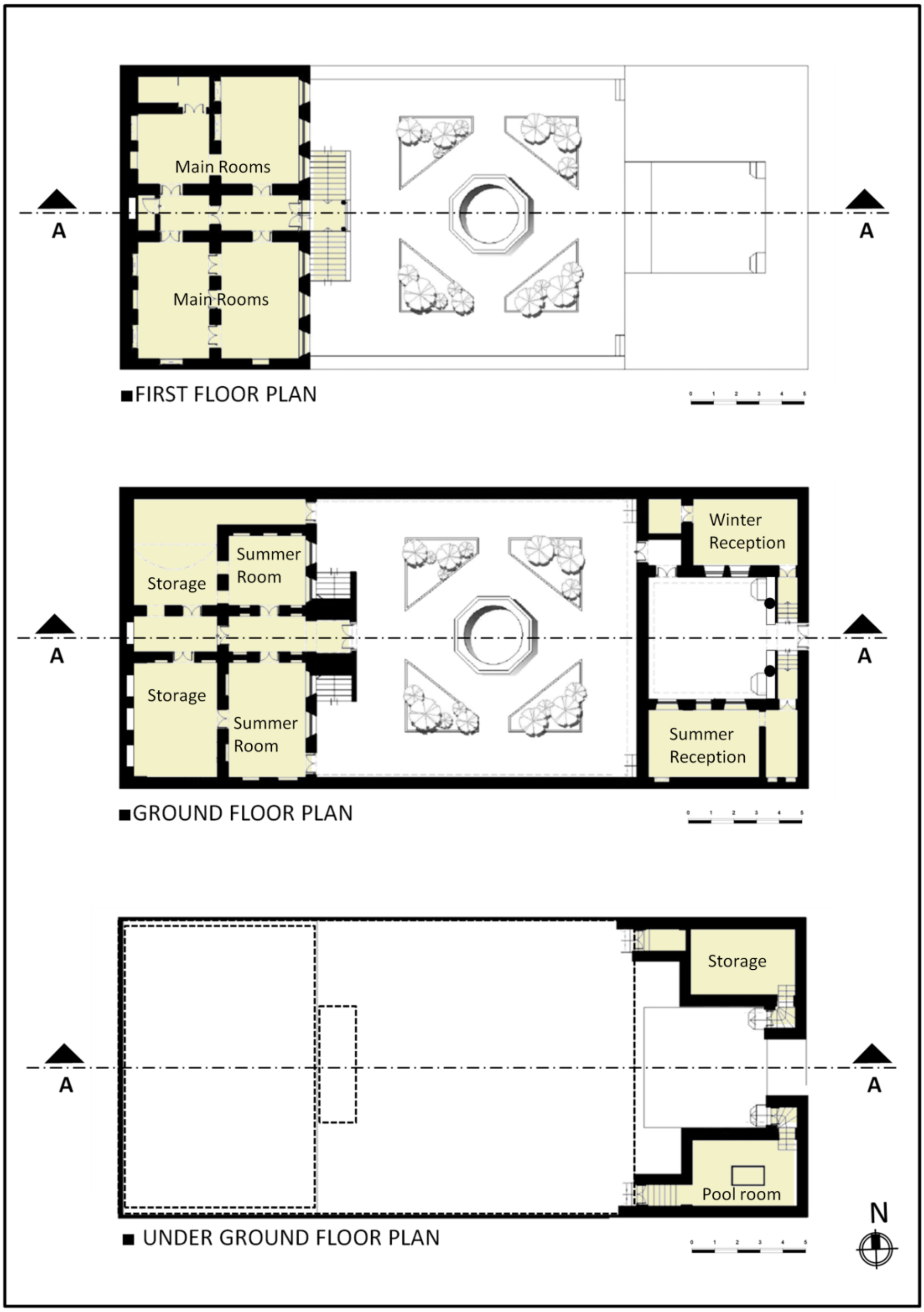


Figure 6-150: plans of the Moslem house (Estaji, 2010, kermani-Moqaddam, 2002c) with corrections

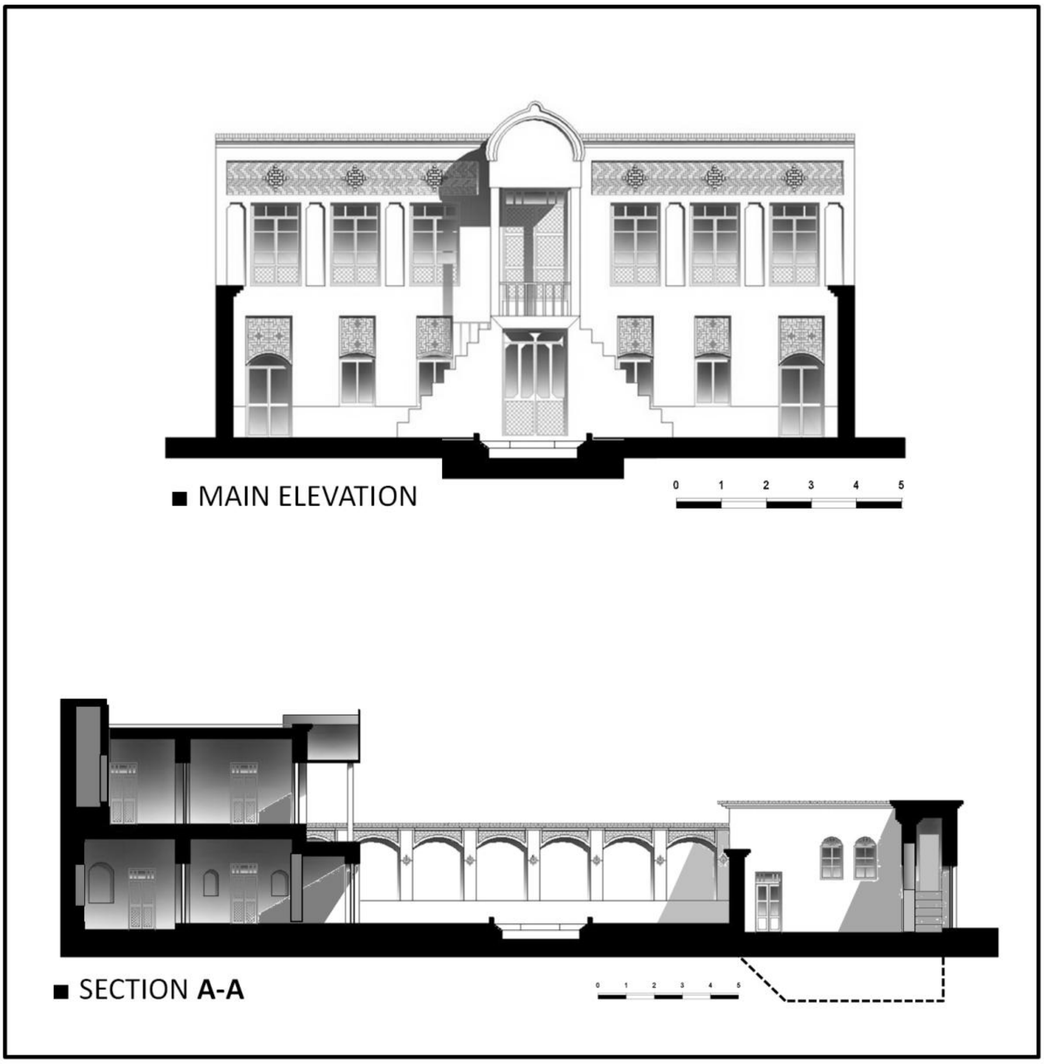


Figure 6-151: elevation and section of the Moslem house
(Estaji, 2010, kermani-Moqaddam, 2002c) with corrections

Figure 6-152: photos of the Moslem house; source: the local archives of ICHTO

6.7.6.1.1 House Orientation and Sun Position

The main wing of the Moslem House faces east with a rotation of two and half degrees to the south (Figure 6-153).

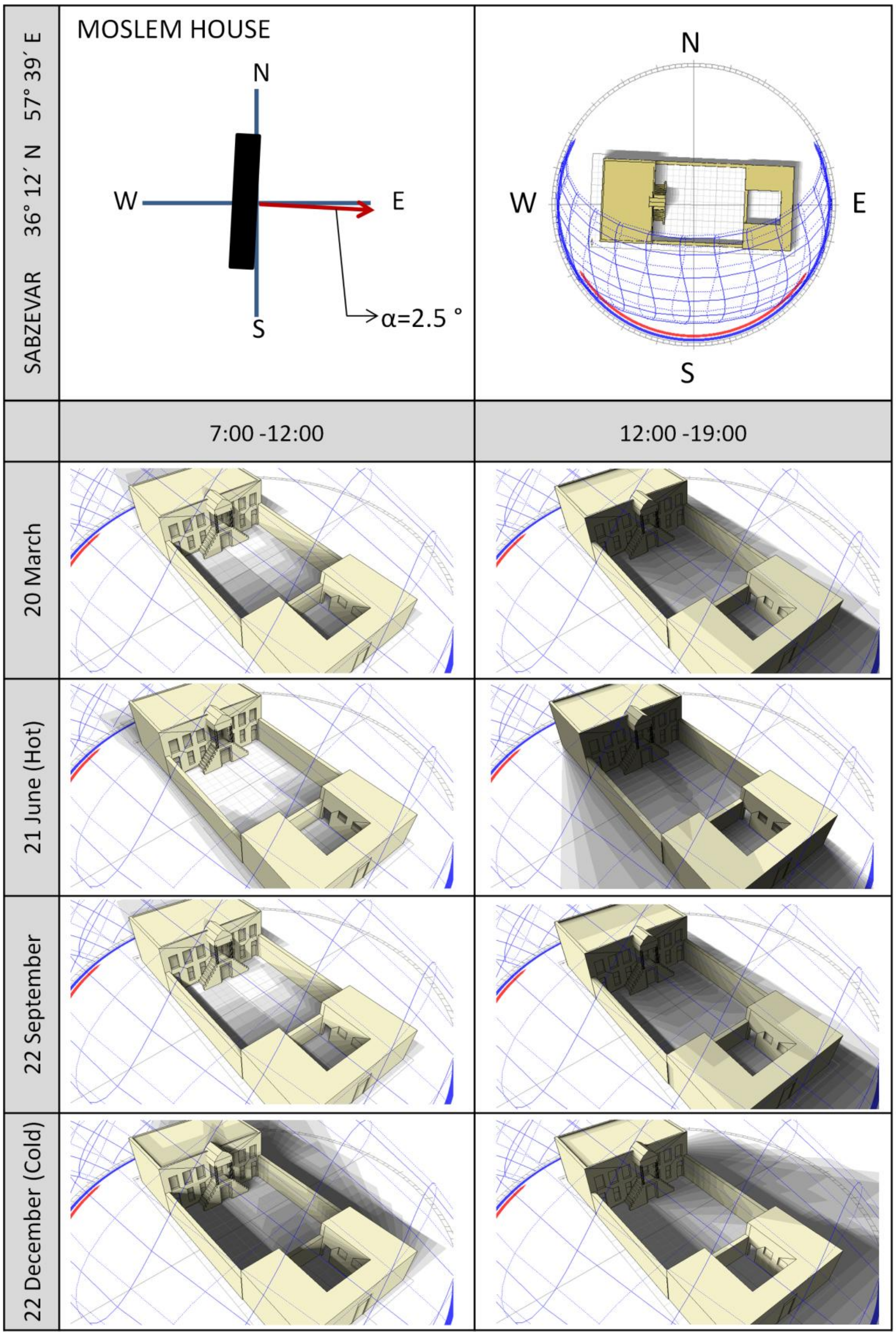


Figure 6-153: the position of shades in the morning and afternoon

Figure 6-154 shows the shading masks for the middle of each window on the east-facing façade of the main wing.

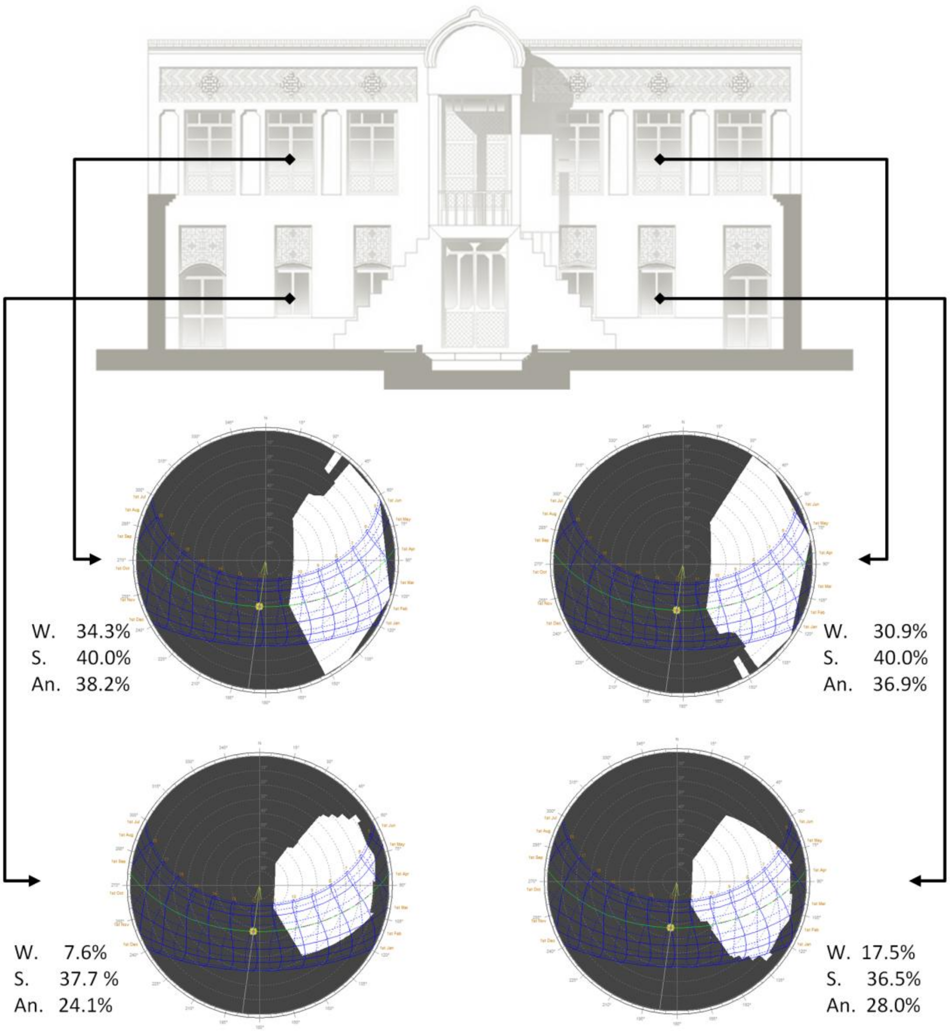


Figure 6-154: Shading Mask and Effective Shading Coefficients of private zone

In the east wing there were two reception rooms, one of which faced the north and the other the south. The north-facing room was completely in the shade all year round. For this reason, it was used as a summer space, while the other one benefited from direct sunshine around 70% in the winter and was suitable for winter reception. (Figure 6-155)

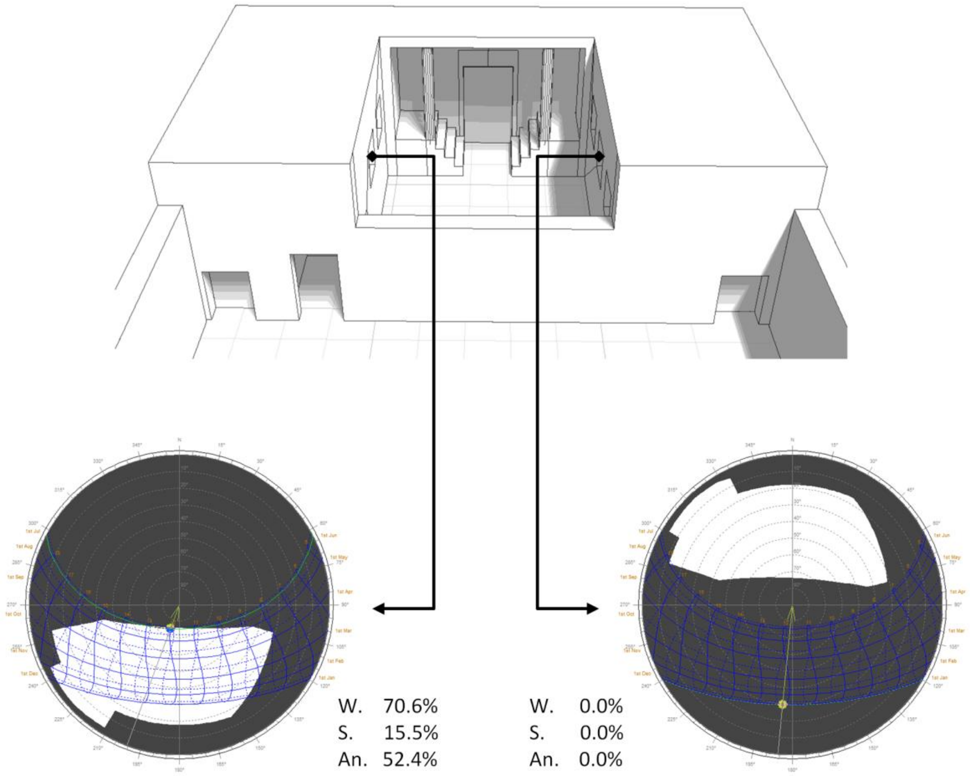


Figure 6-155: comparing the shading masks of the north and south-facing rooms of the Moslem house

The vertical and horizontal movement between spaces helped the residents to overcome hot weather in the summer and cold weather in the winter. The disadvantage of this strategy is that the ground level is used more intensively with it thus becoming necessary to build further spaces.

6.7.6.1.2 Spatial Configuration

The first characteristic of this house was the separation between summer and winter spaces. Figure 6-156 shows the different spaces of the main wing of the Moslem House. The dark rooms on the ground floor were used as storage area and kitchen rooms in the summer and winter, while the light east-facing rooms on the ground floor were used as living rooms in the summer and as storage space in the winter. And finally the rooms on the first floor that in Persian literature are called “winter spaces” were suited for winter (day and night) and summer use at night.

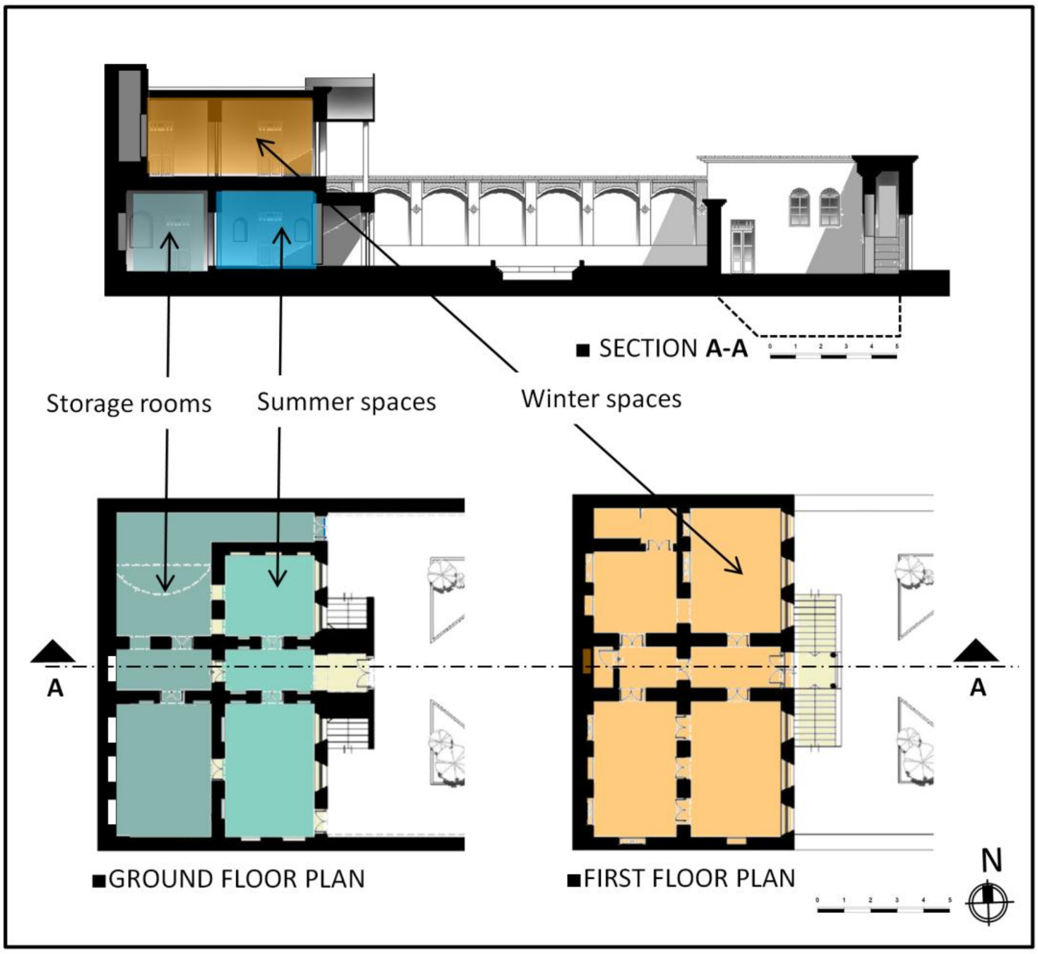


Figure 6-156: different spaces of the main wing of the Moslem House.

The other characteristic is complete separation between reception and family spaces. The public zone was usually used just by men, while the family part was a place for women who could live here without being seen from the outside. The women hosted their female guests in this part of the building. The break-up map (Figure 6-157) and justified graph of The Moslem house (Figure 6-158) indicate this seperation.

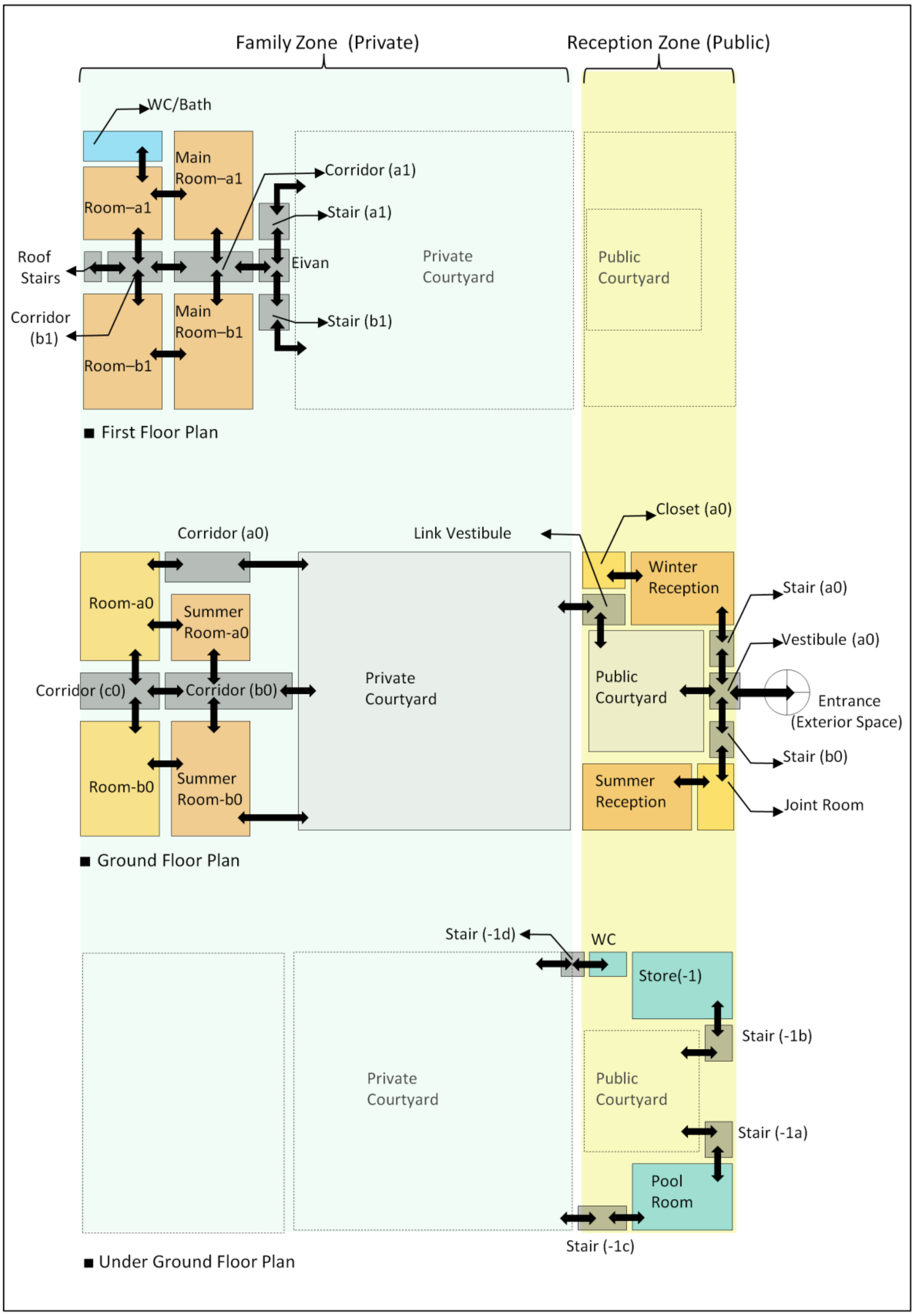


Figure 6-157: Break-up map of the Moslem house

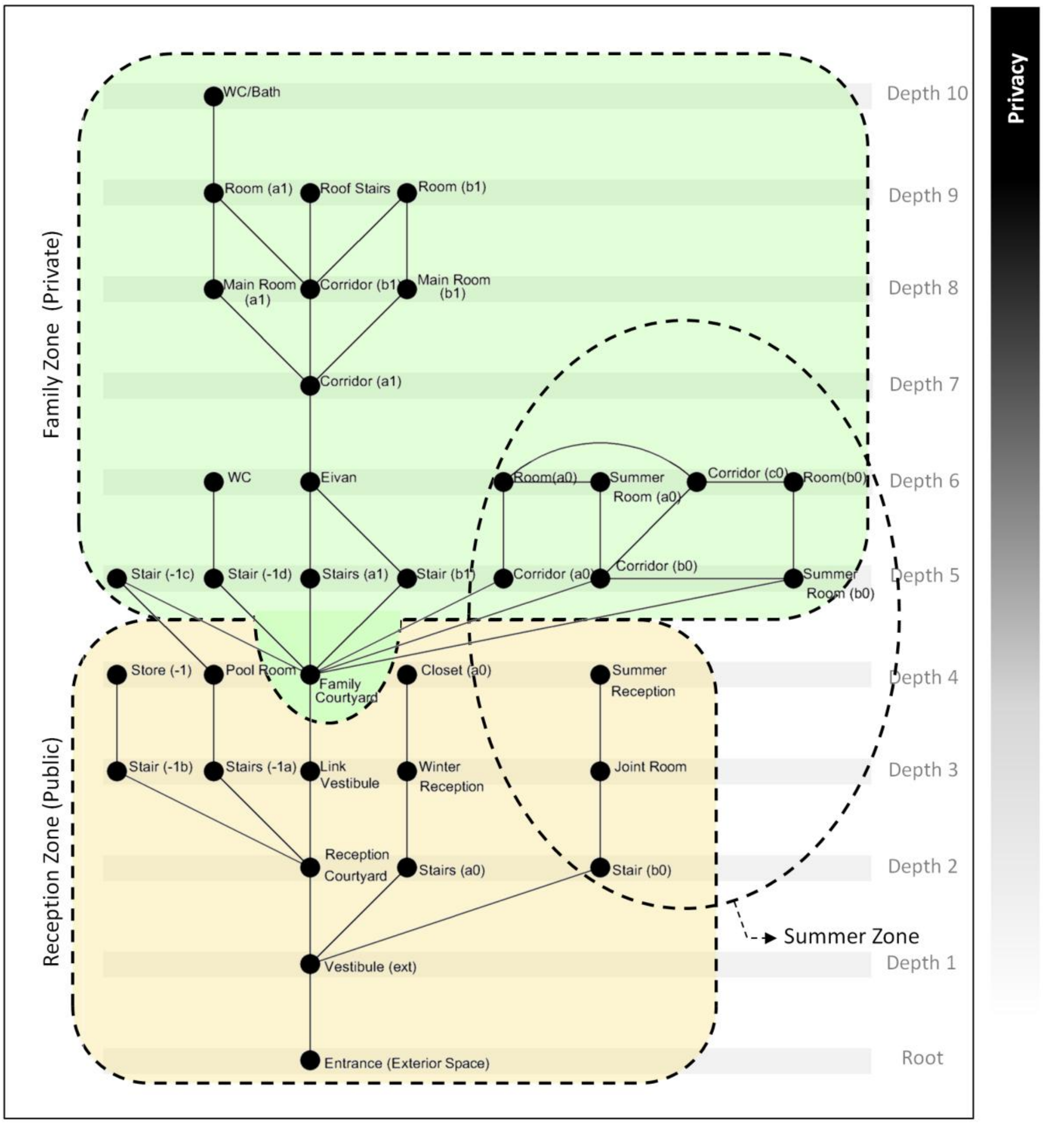


Figure 6-158: Justified graph of the Moslem house

Eight loops in the Moslem house could help change the arrangement of the spaces (Figure 6-158). On average there are around two and half (2.43) openings to each space (Table 6-10).

Table 6-10: Distributedness of the Moslem house

THE MOSLEM HOUSE			
Number of spaces	Mean Connectivity	Number of loops	Distributedness (Convex ringiness)
35	2.43	8	0.12

The selective connectivity enabled the residents to control the relationship of spaces, e.g.,in this house, there were three doors between 'main room-b1' and 'room-b1' that enabled the residents to make a large room for hosting a party. (Figure 6-159)

Figure 6-159: doors as room dividers in the Moslem house, source of photo: the local Archives of ICHTO

The calculation of the integration value and the selection of the number of spaces reveal a strong spatial discipline in the Moslem houses (Appendix A 8). As can be seen in the picture (Figure 6-160), the first fifteen spaces (only the summer room-b0 and the pool room were located in the rank seventh and thirteenth) are the circulation spaces, followed by the main rooms and finally the private rooms.

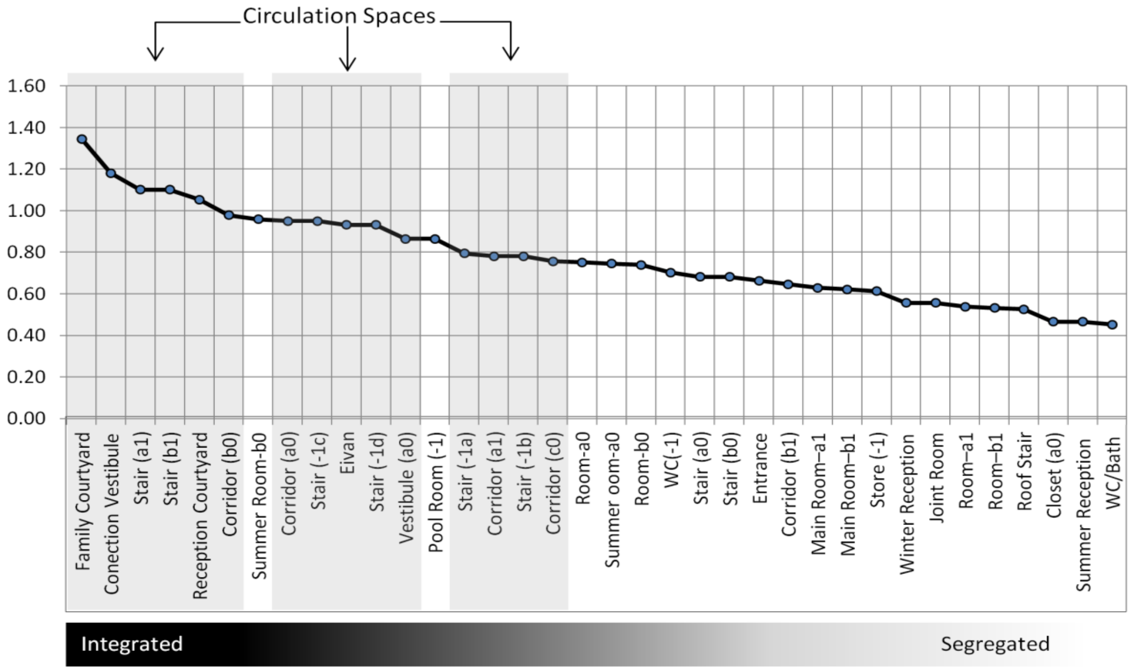


Figure 6-160: integration value of the Moslem spaces

Figure 6-161 shows the schematic access hierarchy of the Moslem house. The reception zone worked as a buffer that blocked direct access and view from the outside to the private courtyard. The connector vestibule with two doors provided access between two courtyards.

The family zone had its own access hierarchy; the spaces in this part of the building were arranged according to their degree of privacy. This house was a representative example of a house type with two courtyards which was quite common in this region.

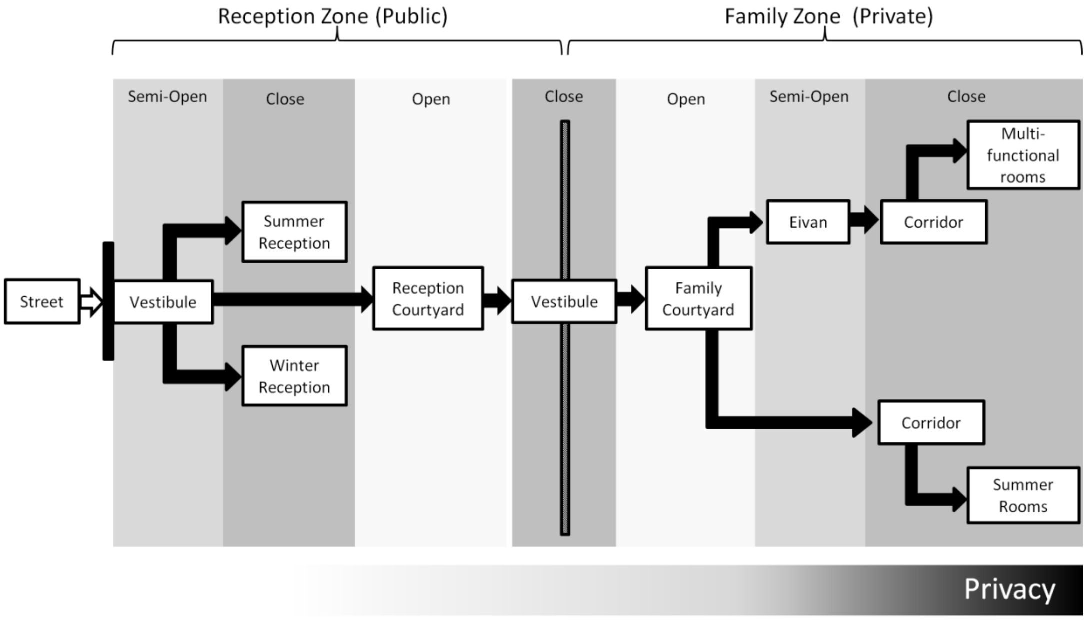


Figure 6-161: Schematic access hierarchy of the Moslem house

6.7.6.2 The Jafar-Zade House

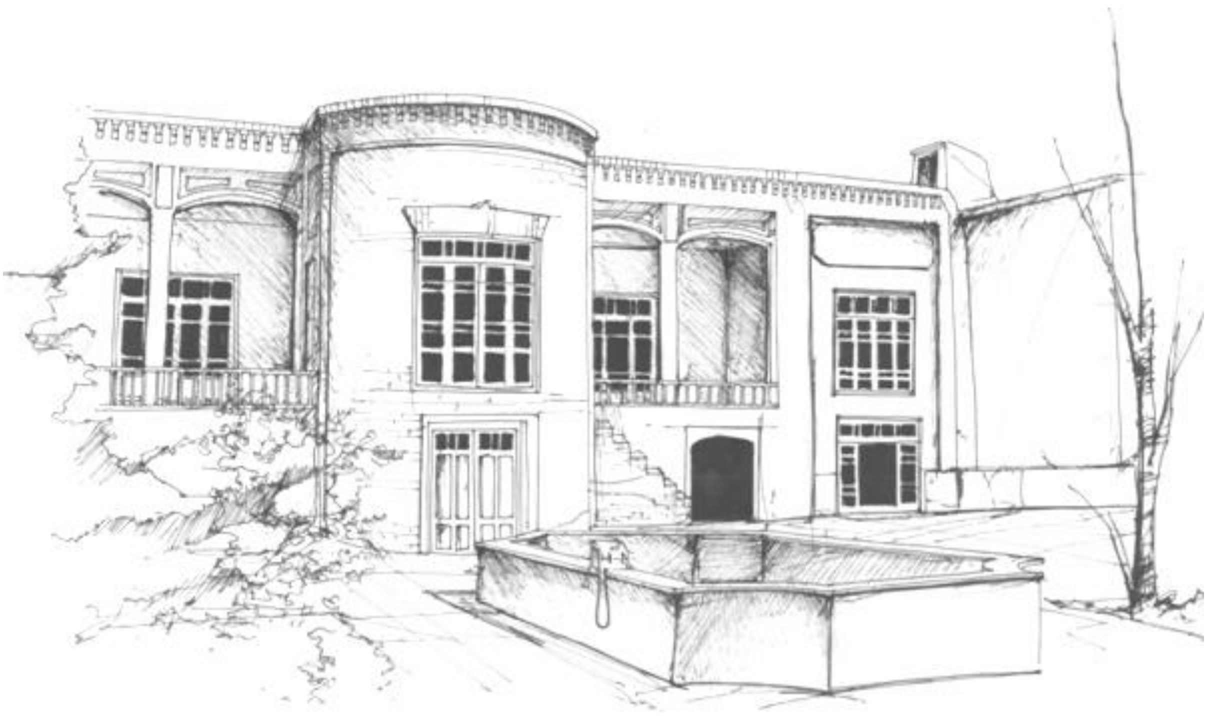


Figure 6-162: The Jafar-Zade house (Estaji, 2010), hand drawing by Minoo Qasemi

The Jafar-Zade house was constructed within the old Sabzevar city walls. The registration documents only mentioned that it dates from the Qajar period (ICHTO, 2001). However, the building structure and the similarity to the other houses from the end of the Qajar period in Sabzevar suggest that this house was built approximately at the same time, around 1920. Figure 6-163 shows the location of the house in 1956. This house was used as a residential building until around 1995. Little by little some parts of house were abandoned and some of the roofs were damaged; only a small part of the public zone was inhabitable. In 2001 the house was registered in the Iranian National Heritage list (ICHTO, 2001) and four years later (2005) Sabzevar Cultural Heritage Organization bought the house. Following some initial restoration of part of the building (2008), it was used as a cultural center for training and research on traditional handicrafts. Now the building is undergoing general restoration (based on information provided by the Sabzevar Cultural Heritage Organization) .

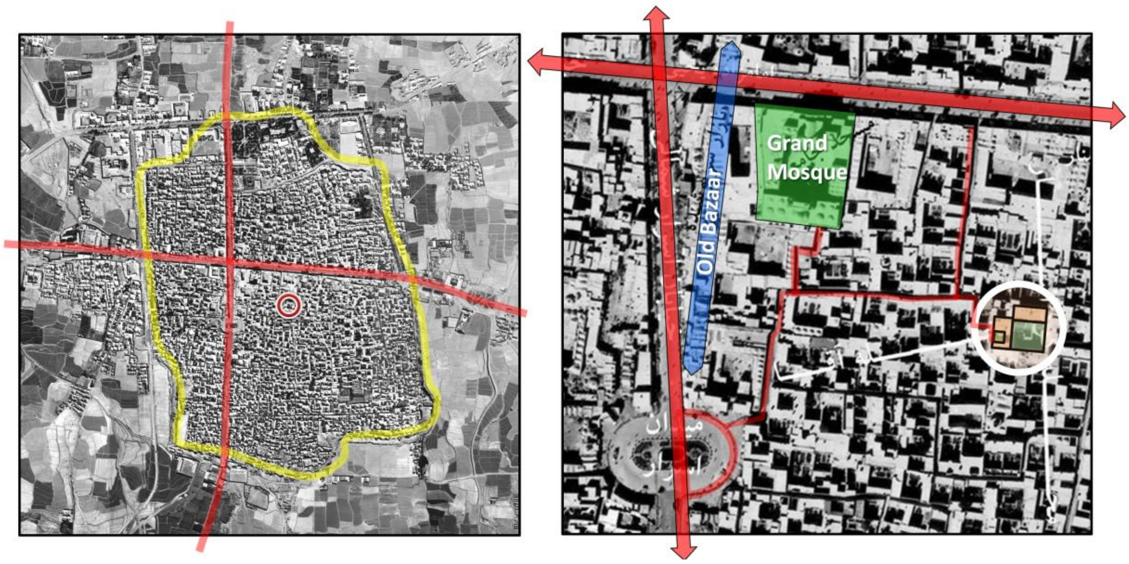


Figure 6-163: the location of the Jafar-Zade house in 1956 base photomosaic maps: (Zanganeh, 2003a)

The house is located at the end of a blind alley. The Jafar-Zade house consists of two separate zones, i.e., reception (public) courtyard and family courtyard. The building can be accessed through a covered passage; this semi-private path connects the blind alley to a vestibule which provides two separate entrances to the public and private courtyards. (Figure 6-164)

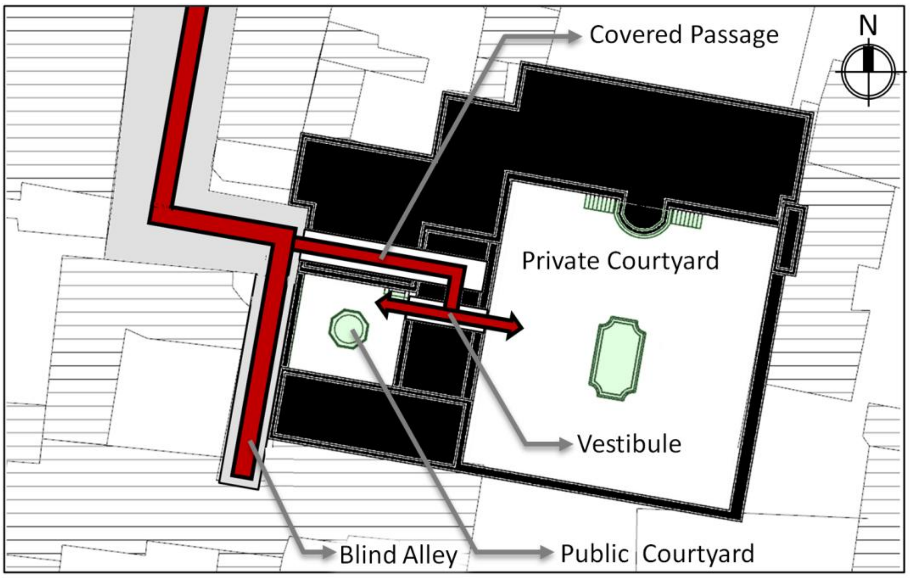


Figure 6-164: access hierarchy from street to close spaces

Part of building is constructed on top of the covered passage and a part of neighbour's house, as the following maps and photos show in detail. (Figure 6-165, Figure 6-166)

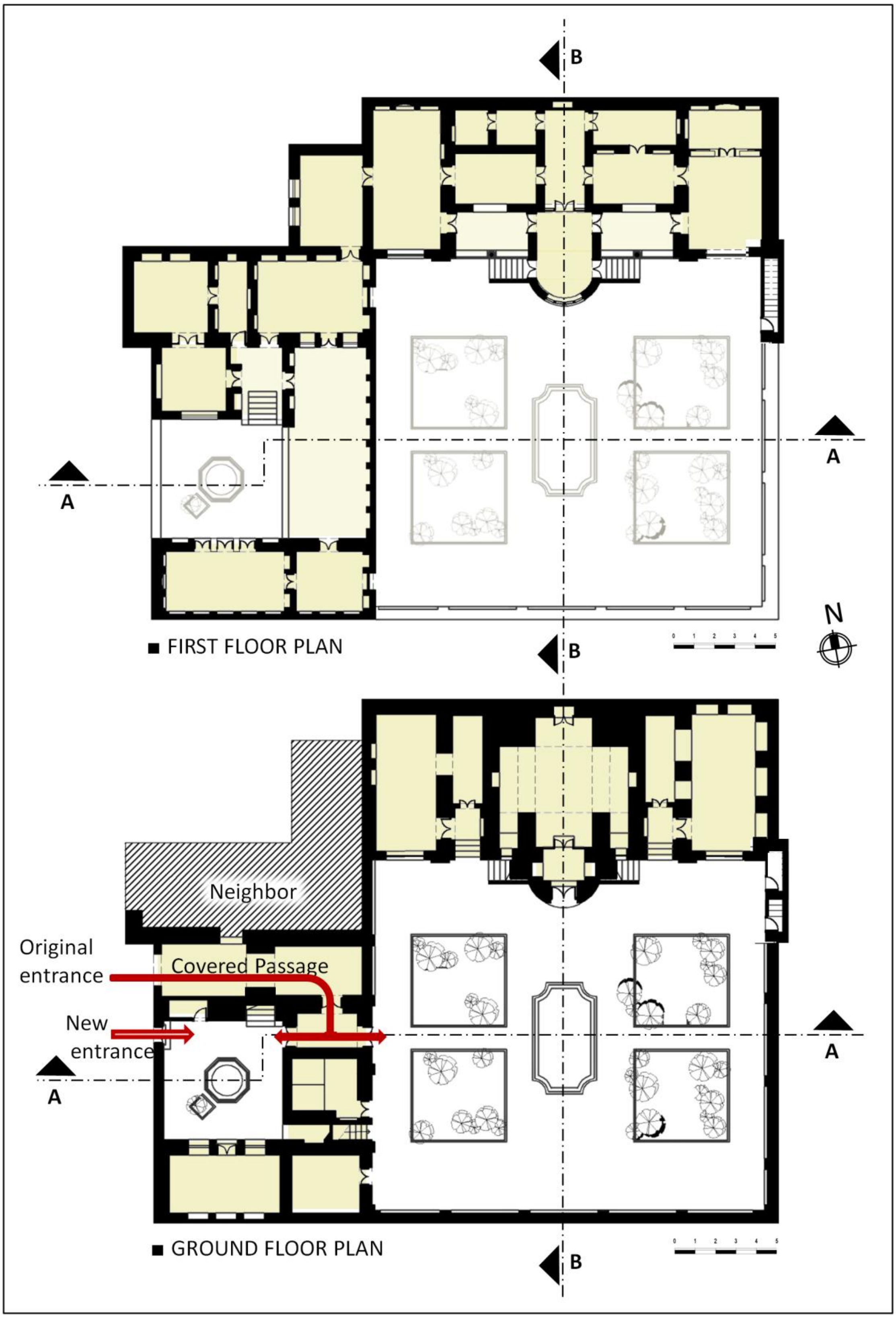


Figure 6-165: plans of the Jafar-Zade house (Estaji, 2010, ICHTO, 2001) and the local archives of ICHTO in Sabzevar with corrections

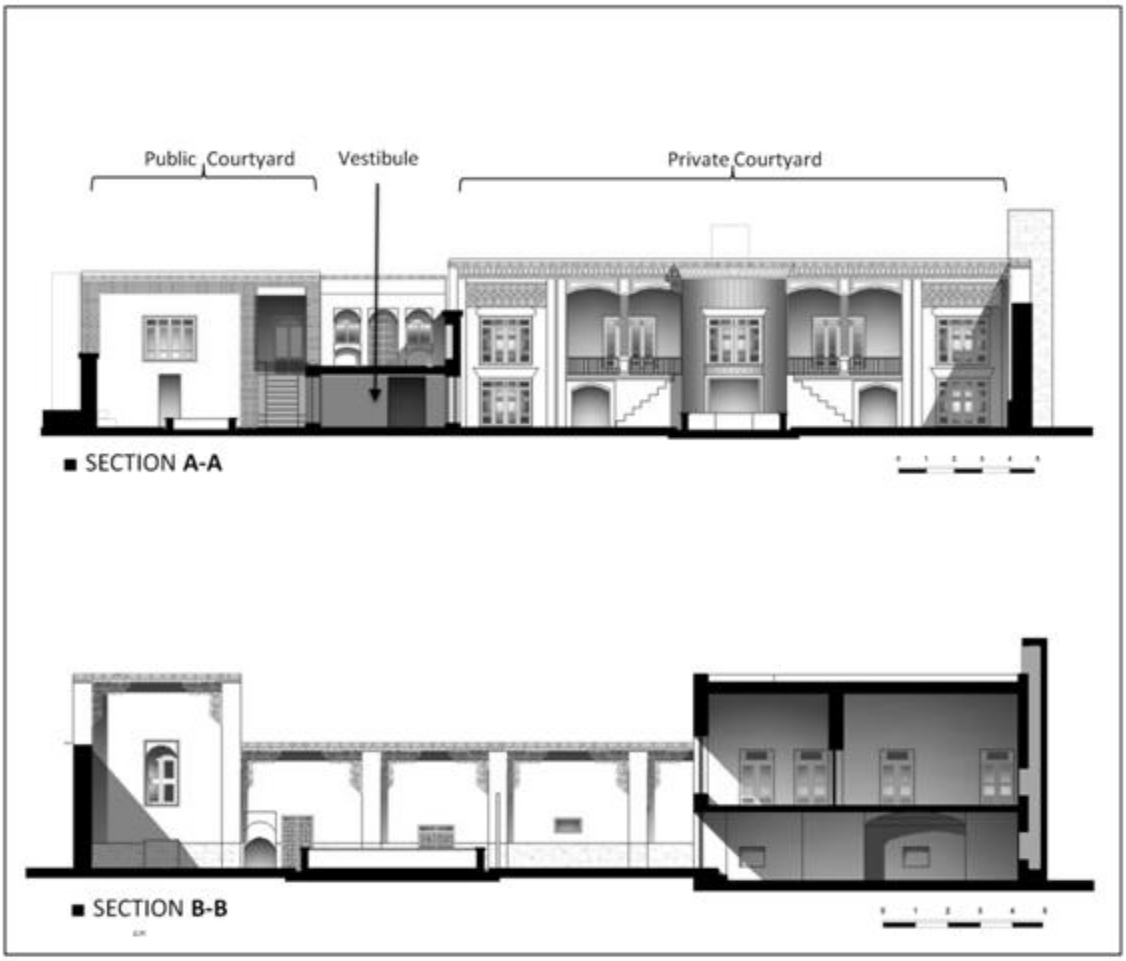


Figure 6-166: sections of the Jafar-Zade house (Estaji, 2010, ICHTO, 2001) and the local archives of ICHTO in Sabzevar with corrections

Figure 6-167: photo collage of the main facade, base photos (Estaji, 2010), edited by author

Reception courtyard

Servants rooms

Terrace facing to the public courtyard

Reception rooms

Figure 6-168: photos of the reception zone (Estaji, 2010)

Figure 6-169: left- details, (the local archives of ICHTO), right- the ground floor rooms (Estaji, 2010)

6.7.6.2.1 House Orientation and Sun Position

The Jafar-Zade House faces the south with a ten-degree rotation to the west (Figure 6-75). The windows of private zone and the north part of reception zone face the south and only two reception rooms face the north.

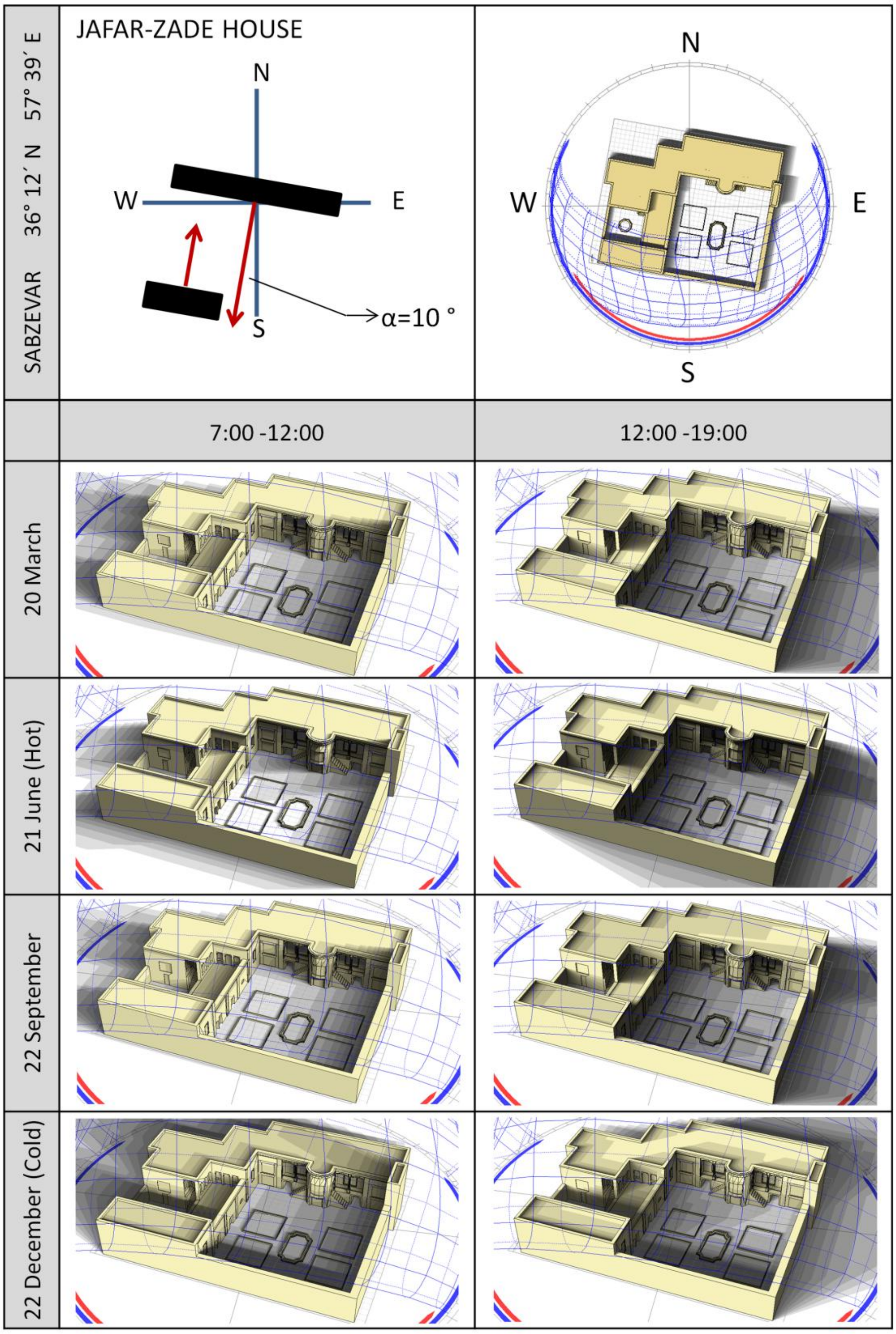


Figure 6-170: the position of shades in the morning and afternoon

Two rooms that are located behind the two-pillared portico are in the shade on summer days (ESC=0), while the other rooms benefit from direct sunlight in the winter more than the summer. (Figure 6-171)

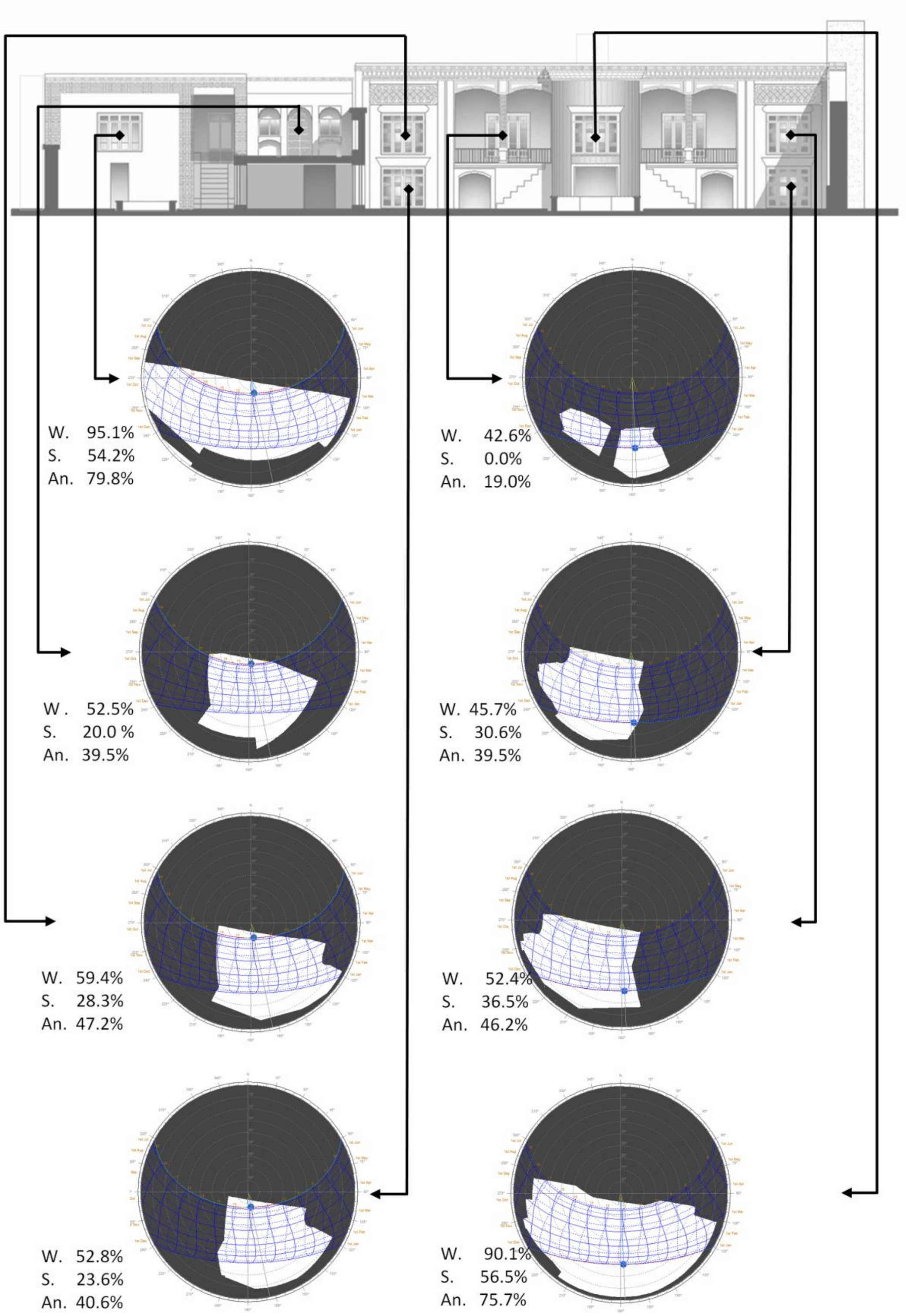


Figure 6-171: Shading Mask and Effective Shading Coefficients of south-facing spaces

Two reception rooms that face the north are completely in the shade all year round. For this reason, they were used as summer reception rooms.

6.7.6.2.2 Spatial Configuration

The family area of the Jafar-Zade house contains the summer rooms and storerooms on the ground floor and the main rooms at the first floor. The reception zone is made up of two parts, i.e., reception rooms and servant's quarters. The servant's zone includes a kitchen for preparing food for receptions and family members and living space; it was a space that served both zones, since there was access to the reception rooms and private rooms (via room f1).

A vestibule on the ground floor separated the reception and family courtyards. Unlike the Moslem house, it was not necessary to cross the public zone to reach the family areas, as these two zones were entirely separated. The public zone has a direct entrance from the alley. The break-up map (Figure 6-172) and justified graph of Jafar-Zade house (Figure 6-173) show the relationship of spaces.

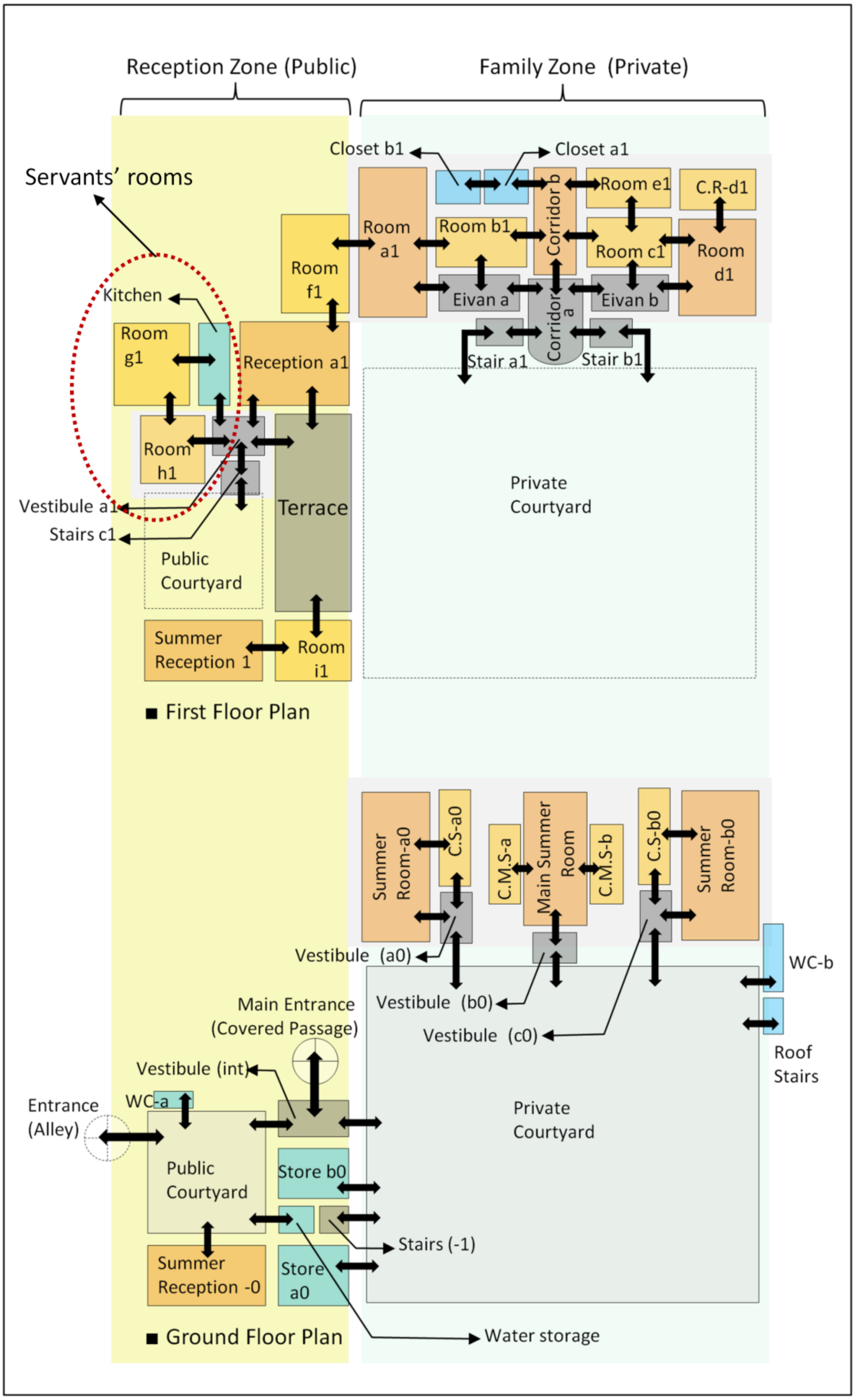


Figure 6-172: Break-up map of Jafar-Zade house

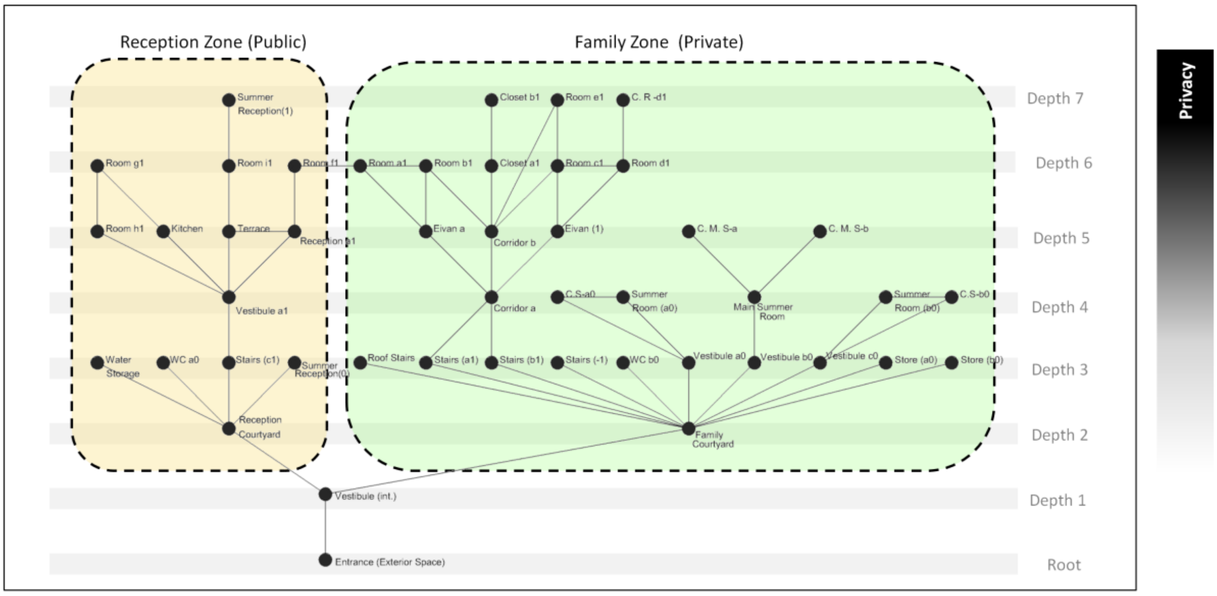


Figure 6-173: Justified graph of Jafar-Zade house

Ten loops in Jafar-Zade house could help to change the arrangement of the spaces (Figure 6-173) (Table 6-11).

Table 6-11: Distributedness of Jafar-Zade house

THE JAFAR-ZADE HOUSE			
Number of spaces	Mean Connectivity	Number of loops	Distributedness (Convex ringiness)
45	2.47	10	0.12

The courtyard and vestibules in the Jafar-Zade house act as an organizer of the spaces (Appendix A 9); the first twelve spaces are the circulation spaces, followed by the main rooms and finally the private rooms. (Figure 6-174)

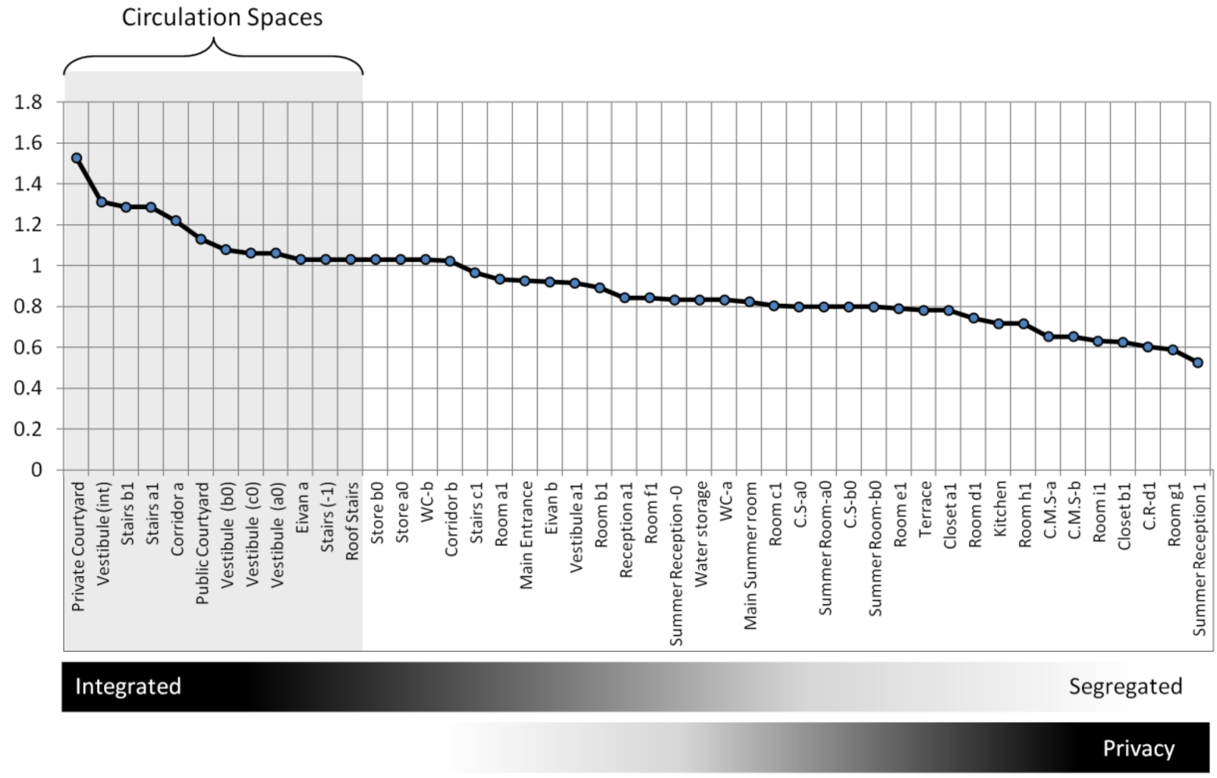


Figure 6-174: integration value of Jafar-Zade spaces

Figure 6-175 shows the schematic access hierarchy of Jafar-Zade house. The entrance vestibule works as a joint between public and private zones. Each zone has its own access hierarchy, too. This house is another typical example of the two-courtyard houses in this region.

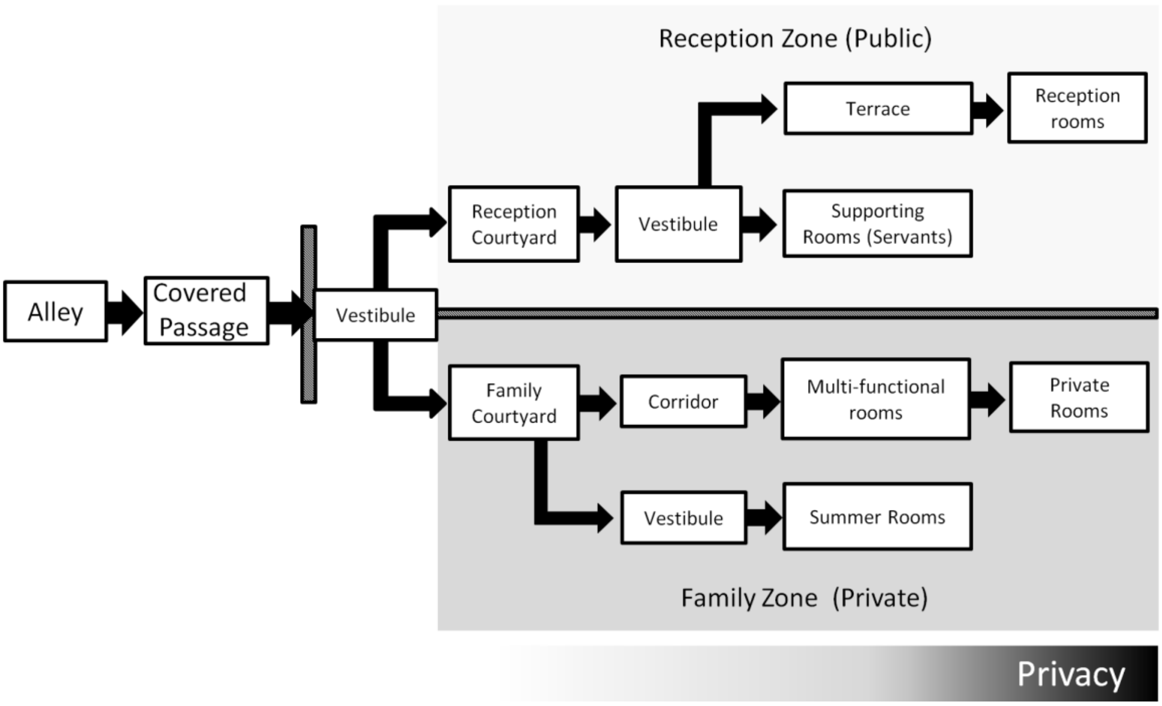
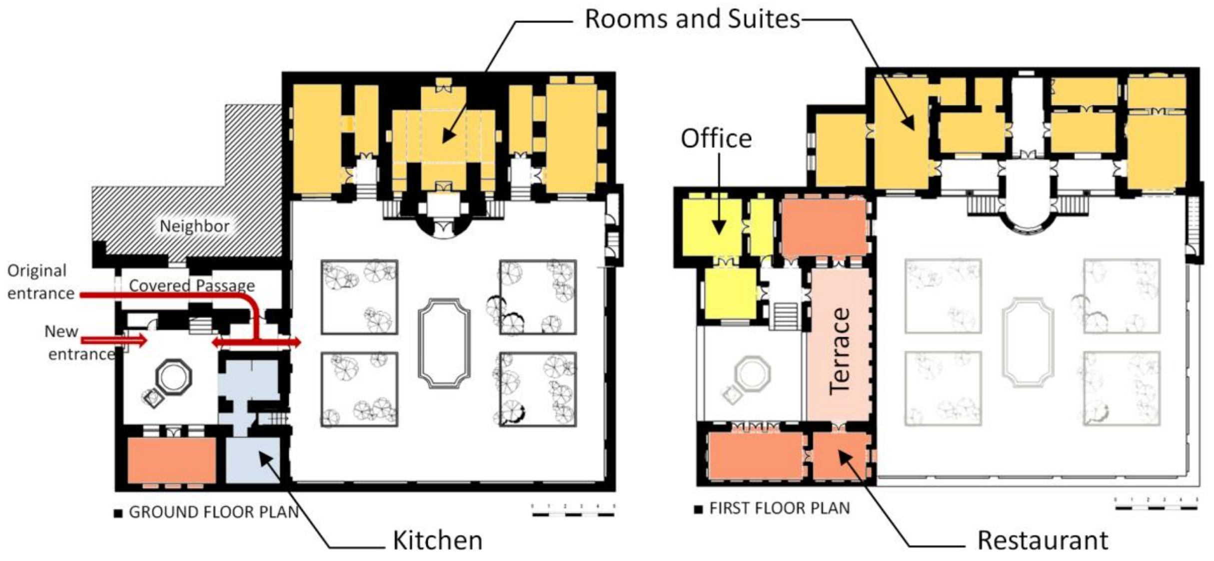


Figure 6-175: Schematic access hierarchy of Jafar-Zade house

6.7.6.2.3 Adaptation to a new function

The fixable spatial organization, the large numbers of entrances to rooms and three separate zones enable the house to be split up into small units. The biggest problem facing the building is not adaptation to the new lifestyle, but rather adaptation to new economic conditions. Given the historical and architectural value of the building, the new function should be selected so that to make the slightest change in the structure and even in the main concept of the building. The most logical new function for the Jafar-Zade house is a hotel. Servant's rooms can easily be changed into a reception and office spaces, the guest rooms in the public zone and the large terrace into indoor and outdoor restaurants and the private zone into rooms and suites. (Figure 6-176)

The new hotel would work best if it could integrate some small traditional houses that are in danger of being demolished and could not work as stand-alone hotels. The Achangi house, for example, which is located only 170 meters away from this house, could provide additional guest rooms.



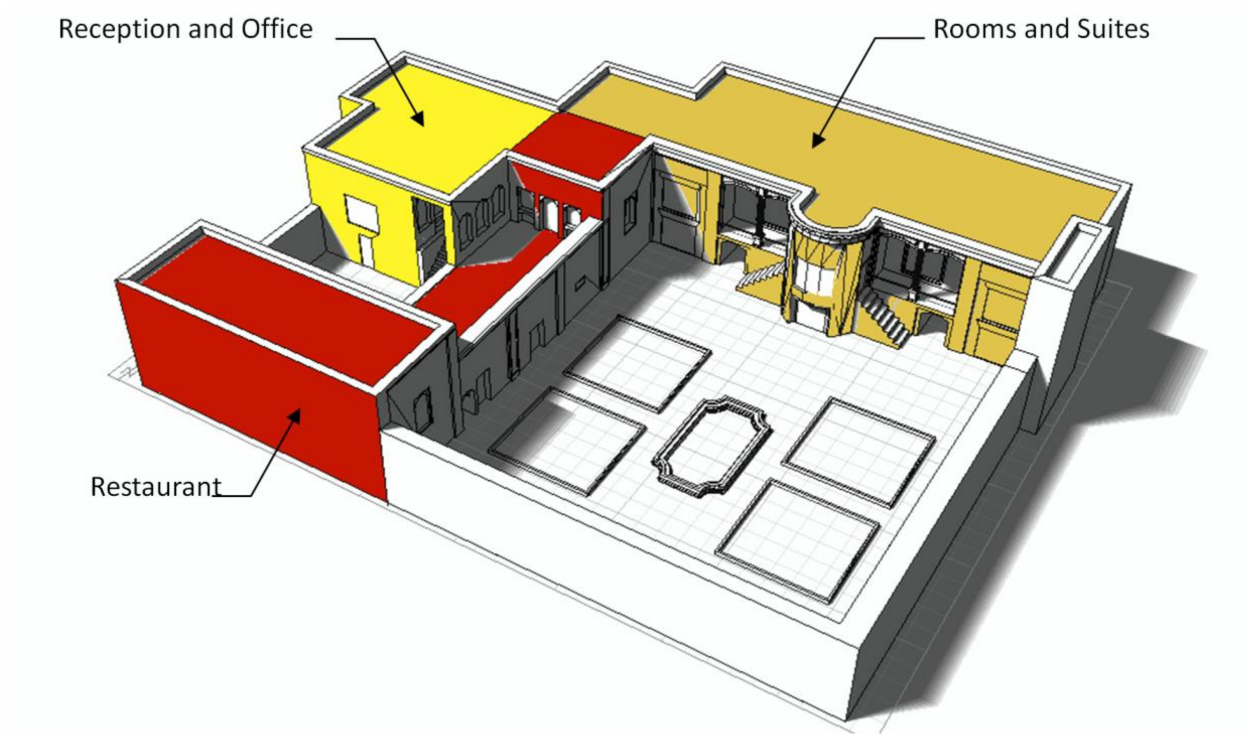


Figure 6-176: a proposal for changing the house into a boutique hotel

6.7.6.3 The Eslami (Haeeri) House

Figure 6-177: hand drawing of the Eslami house (Estaji, 2010), Drawn by Minoo Qasemi

Eslami house was constructed within the old Sabzevar city wall (Figure 6-178). The house is consists of two parts; the north part was the initial core of building that was built in the late Qajar, in the First Pahlavi period (1925–41) the south building was added to the old part (Towhidi-Manesh, 2001b).

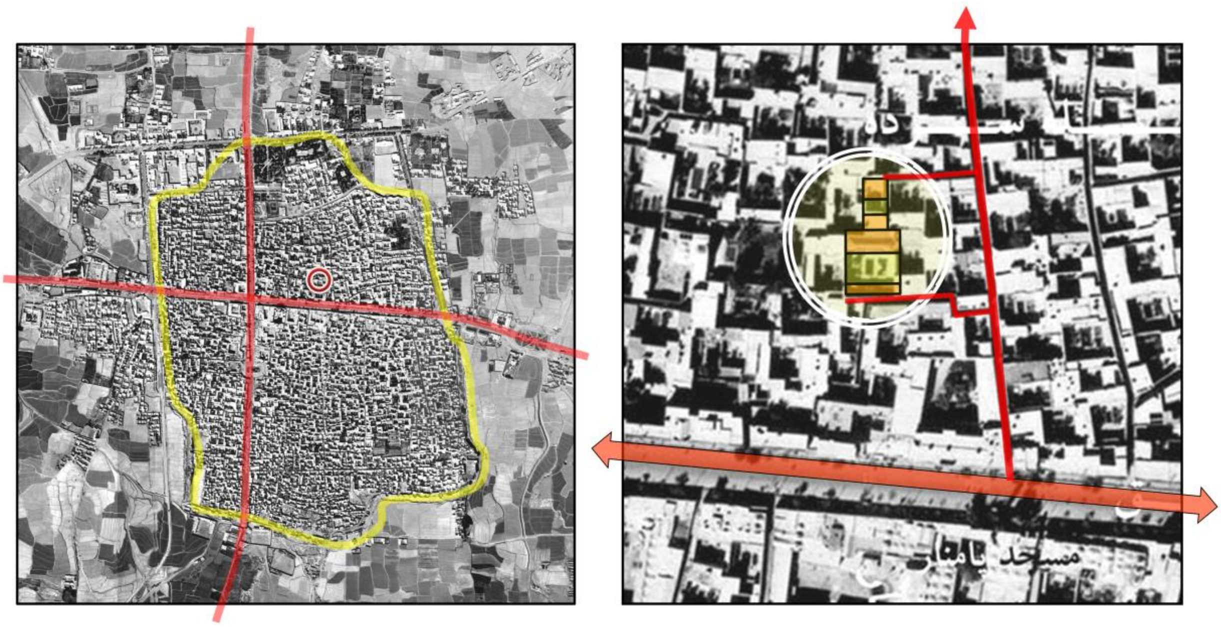


Figure 6-178: the position of the Eslami house in 1956, base photomosaic maps: (Zanganeh, 2003a)

The house belonged to the Haeeri family; in 1963 it was purchased by Mr. Eslami. The house was used as a private school for two years before 2000 after which it was used again as a residential building (Towhidi-Manesh, 2001b). In 2015, the Sabzevar Municipality rented it out and turned it into the ‘Sabzevarian Artists Forum’ (Sabzevar Municipality, 2015). (Figure 6-179)

Figure 6-179: opening ceremony of Sabzevarian Artists Forum in the Eslami house (Sabzevar Municipality, 2015)

Access to the building was through two separate entrances that opened into two different alleys. A vestibule connects the north zone to a dead-end alley, while another vestibule in the south of building connects the south courtyard to a further alley. (Figure 6-180)

Figure 6-180: access hierarchy from the street to closed spaces

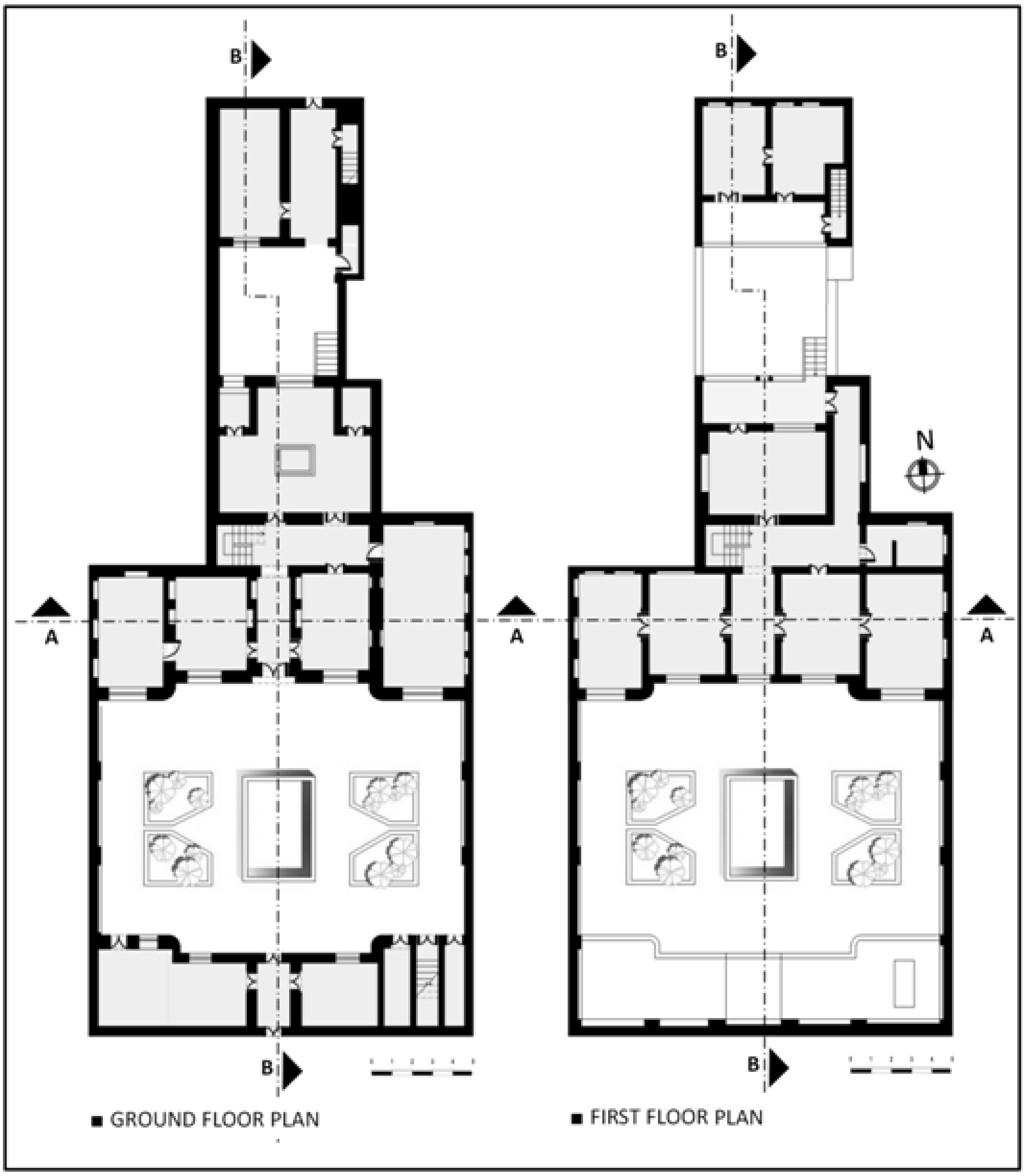


Figure 6-181: Plans of the Eslami house, source:(Estaji, 2010, Towhidi-Manesh, 2001b) and the local archives of ICHTO, with corrections

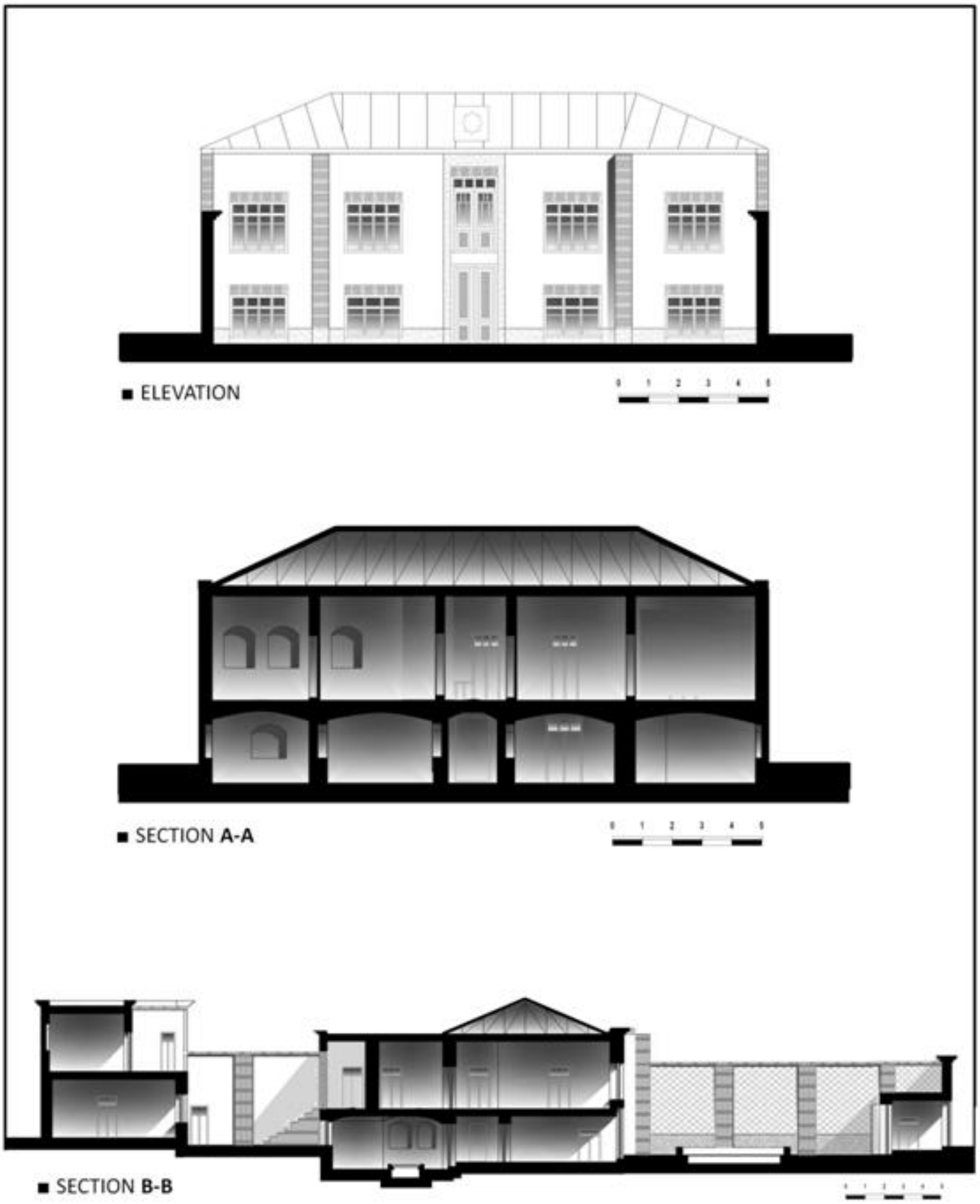


Figure 6-182: elevation and sections of the Eslami house, source:(Estaji, 2010, Towhidi-Manesh, 2001b) and the local archives of ICHTO, with corrections

■ South facing façade (south courtyard - Pahlavi period)

■ South entrance

■ North facing part (south courtyard - Pahlavi period)

Figure 6-183: photos of the south courtyard (Estaji, 2010)

■ North facing part (North courtyard – Qajar period)

■ South facing part (North courtyard – Qajar period)

■ Detail of pillared portico

Figure 6-184: photos of the north courtyard, top: photo collage of the main facade, base photos (Towhidi-Manesh, 2001b), edited by the author, source of bottom photos: the local archives of ICHTO

6.7.6.3.1 House Orientation and Sun Position

Eslami House faces the north-south with three degree of rotation to the west (Figure 6-185). The south-facing windows benefit from sunlight throughout the entire year, while the north facing spaces are completely in the shade.

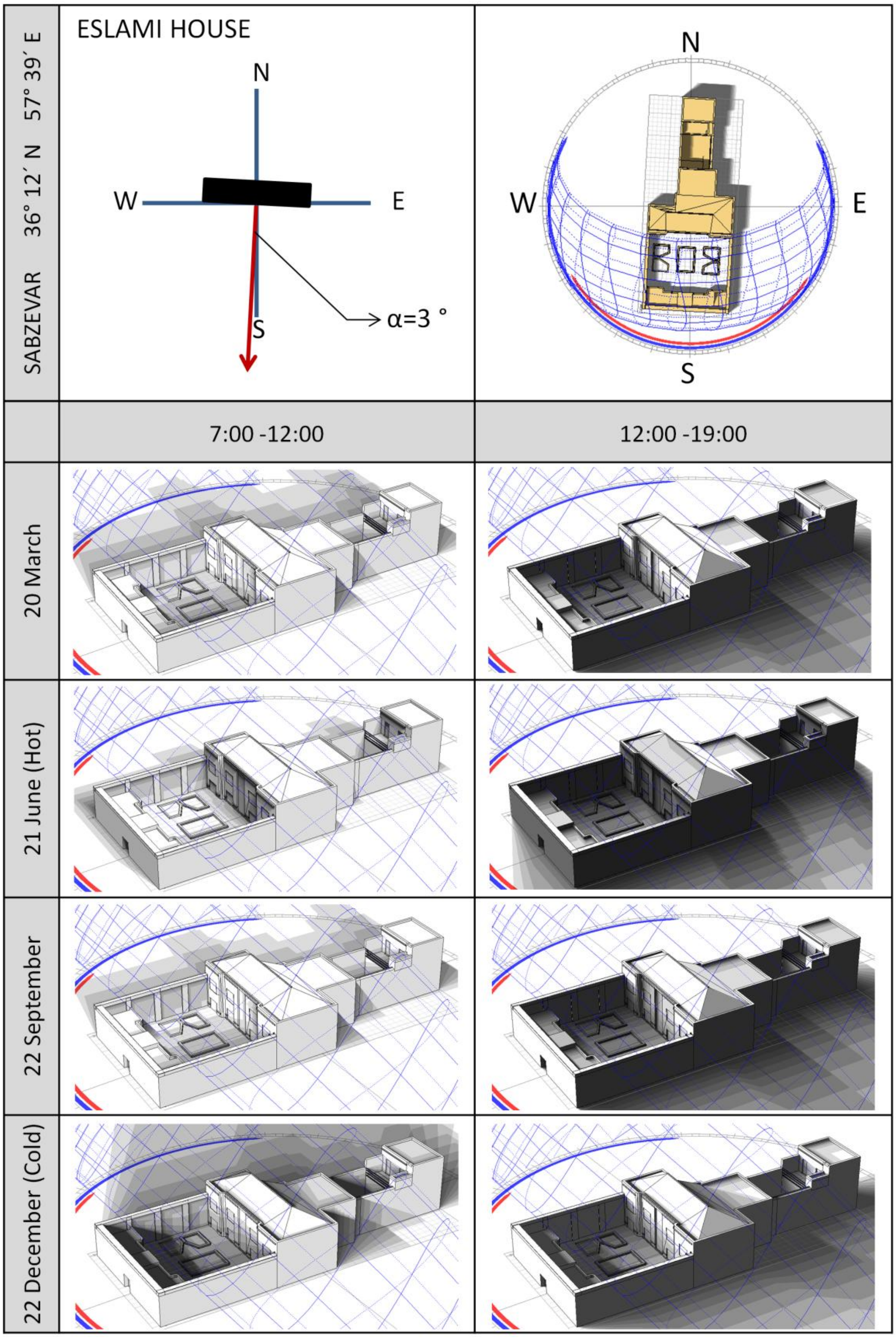


Figure 6-185: the position of shades in the morning and afternoon

The small north courtyard is very narrow, which means that the walls block the direct sunlight on the south-facing façade of the north wing. The ESC for the reception room on the ground floor is around 17 in winter and 30 in summer (Figure 6-186). The perimeter walls are very high, but due to the wide south courtyard the south-facing spaces are exposed to direct sunlight in winter and summer.

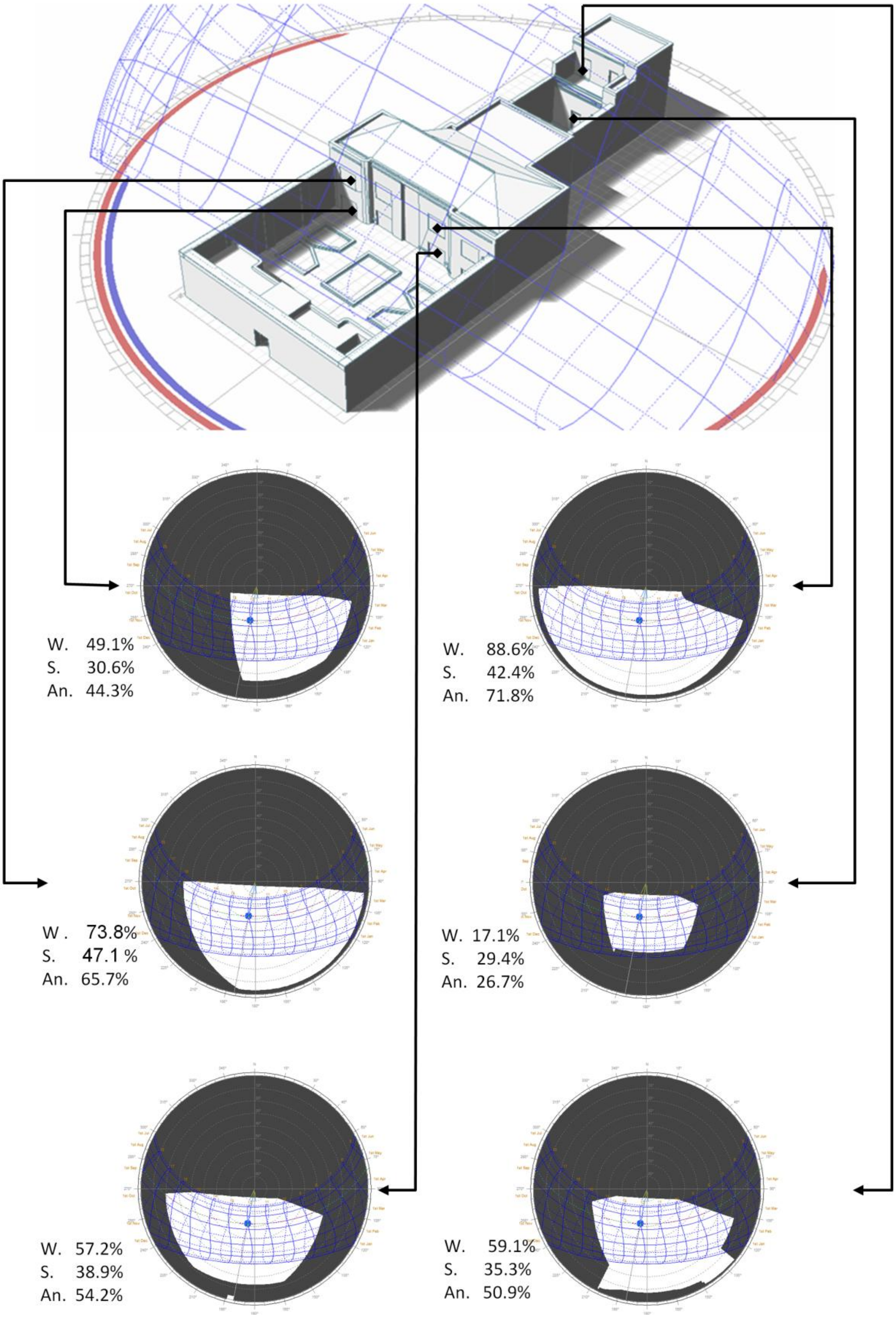


Figure 6-186: Shading Mask and Effective Shading Coefficients of south-facing openings

The north-facing spaces are completely in the shade all year round (Figure 6-187). For this reason, they can be used in the summer.

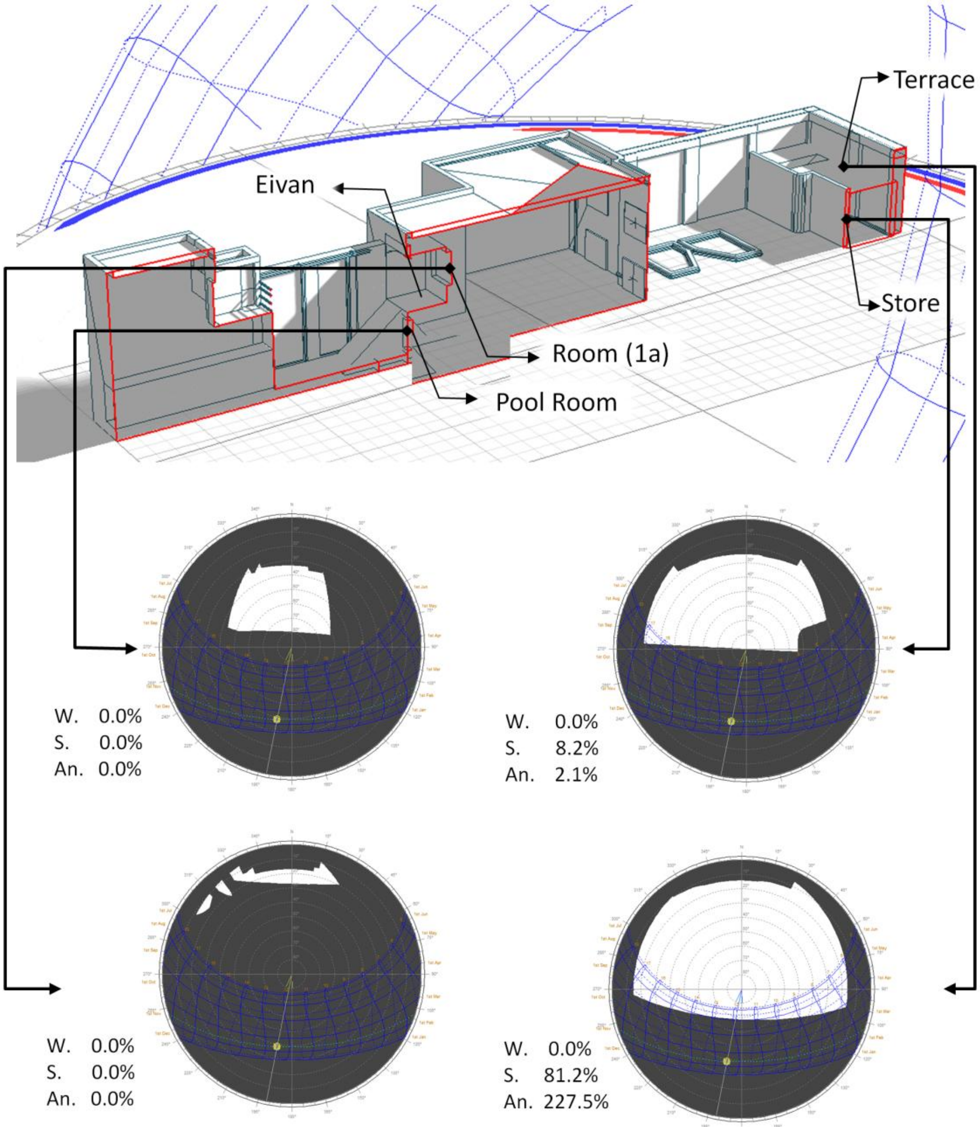


Figure 6-187: Shading mask and Effective Shading Coefficients (ESC) of north-facing openings and spaces

There is a terrace (Bahar-Khab) in the southern part of the building that is shaded and separated from the alley by a high wall. Since the terrace is in the shade in spring, autumn and winter, it can be used for afternoon family gatherings and sleeping at night in the mild seasons.

6.7.6.3.2 Spatial Configuration

The north courtyard of the Eslami house originally served as a reception zone. The north corridor directly connected the reception room on the first floor (north guest room) to the blind alley. The north stairs provide access to two independent rooms on the first floor (room (N1a) and (N1b)) that can be used as an independent unit for family or guests. There is a north facing pillared portico in this courtyard. The room behind it (Room 1a) and the pool room on the ground are suitable for summer use (Figure 6-188).

The south courtyard contains the main rooms that face the south and service areas like the kitchen and storerooms on the south side of the courtyard. The roof of these spaces is a long terrace that is connected to the courtyard by a staircase.

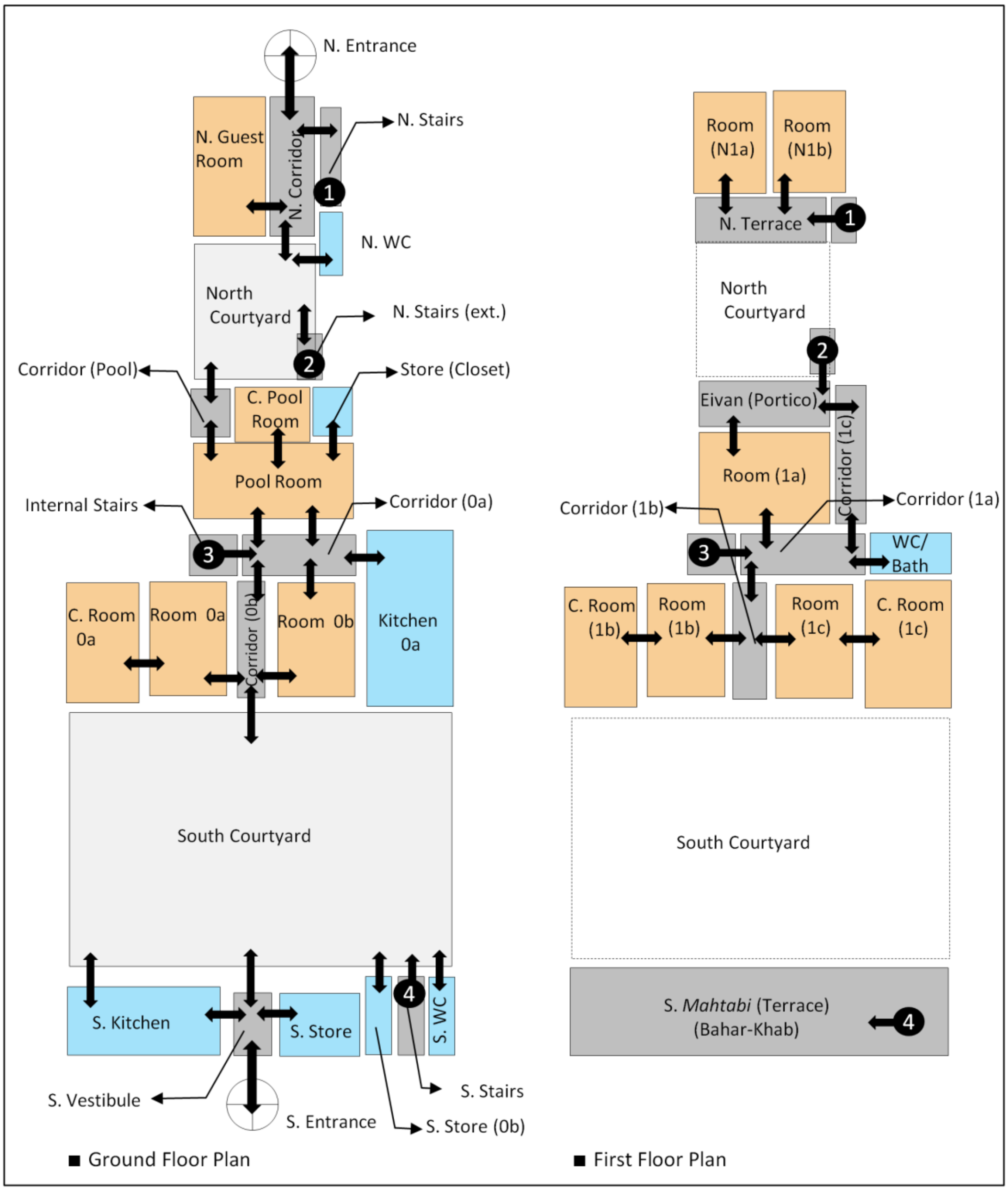


Figure 6-188: Break-up map of the Eslami house

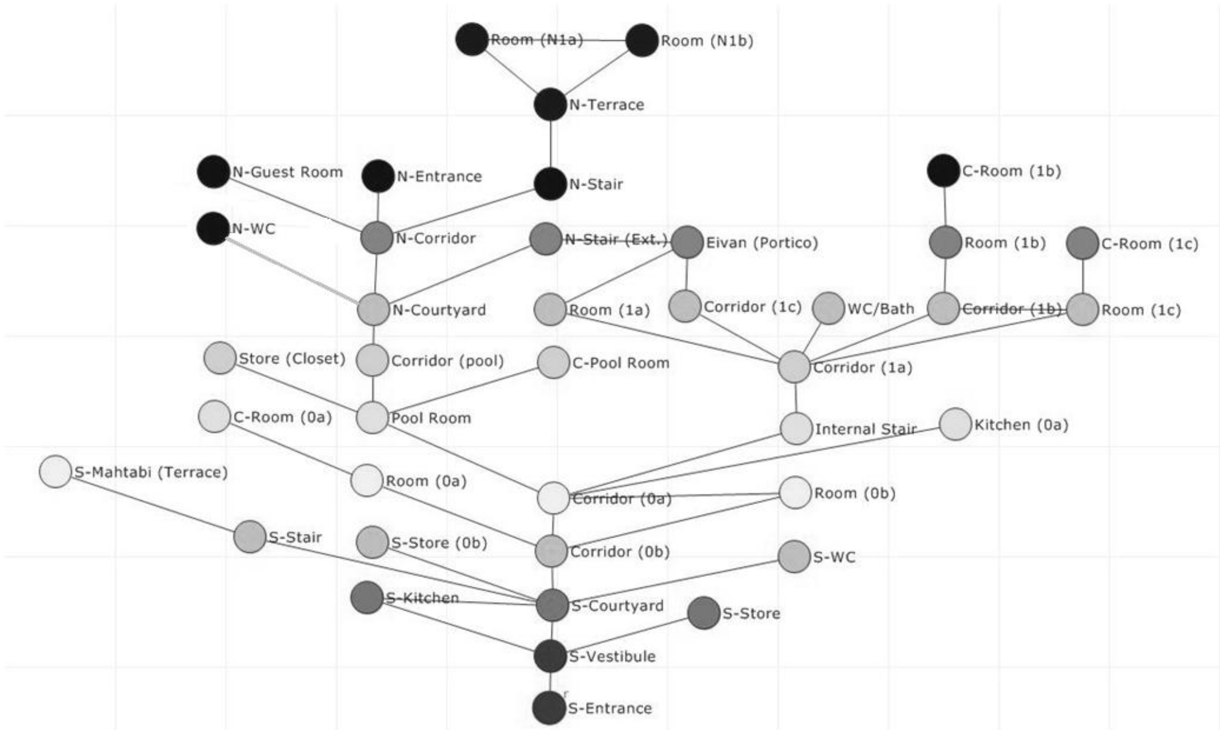


Figure 6-189: Justified graph of the Eslami house

In the south building from the Pahlavi period unlike the Qajar buildings in Sabzevar, the main circulation spaces are the internal corridors. The calculation of integration (Appendix A 10), as can be seen in the diagram (Figure 6-190), shows that the first six spaces are the corridors and internal staircase and that the pool room serves as a joint between two courtyards. The courtyards are located at eighth and ninth ranks.

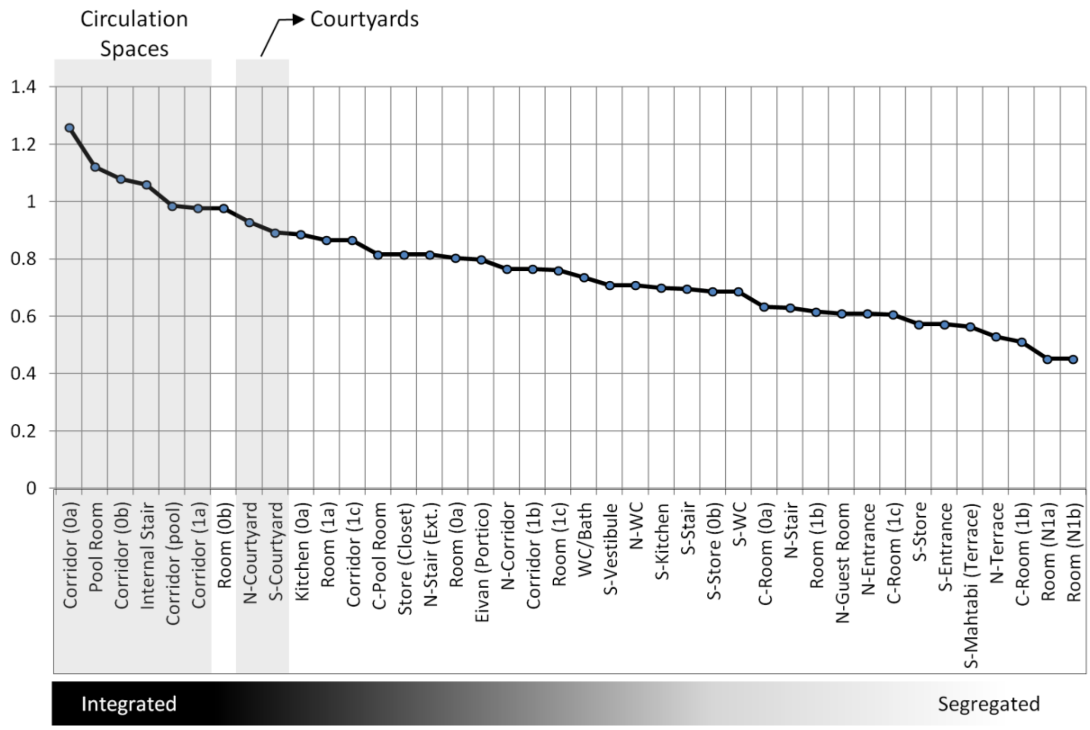


Figure 6-190: integration value of the Eslami spaces

In this house, unlike the Moslem and Jafar-Zade houses, the separation is achieved by two different entrances that located in two different alleys. (Figure 6-191)

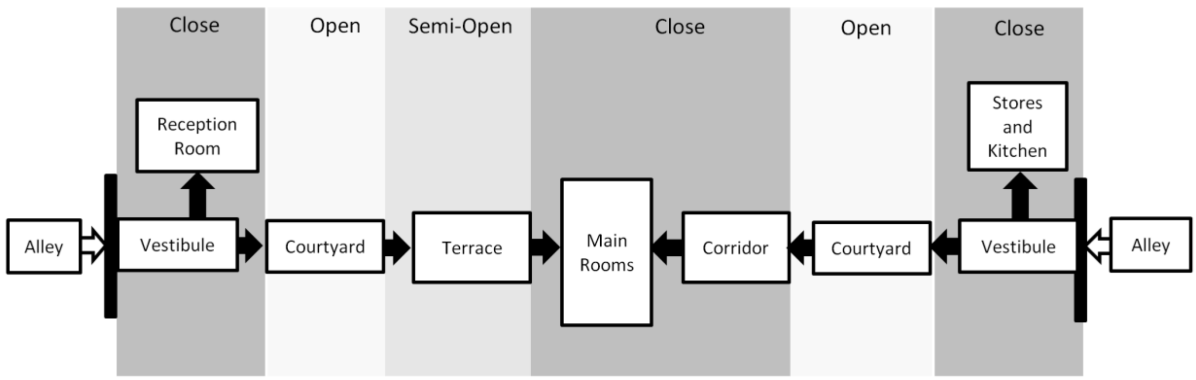


Figure 6-191: Schematic access hierarchy of the Eslami house

6.7.6.3.3 Adaptation to New Conditions

A large number of rooms with internal corridors enable the building to be used as an educational space, office and even as a hotel. From 2015 the house has been used as a cultural center (Sabzevarian Artists Forum). The flexible spatial configuration of the building lets it to be changed into a boutique hotel in future perspective with minor changes. But this change requires feasibility studies. In fact, this convertibility is only a potential that enable the building to be changed in a critical situation.

6.7.7 Chahar-Soffe (four platform) houses

The Chahar-Soffe house type is based on a roughly square plan divided into nine smaller squares with the central space providing access to the other spaces (Figure 6-192). This type of building is designed to have the least contact with the outside and meet the needs of users inside the building. In fact the central space acts as a small inner courtyard.

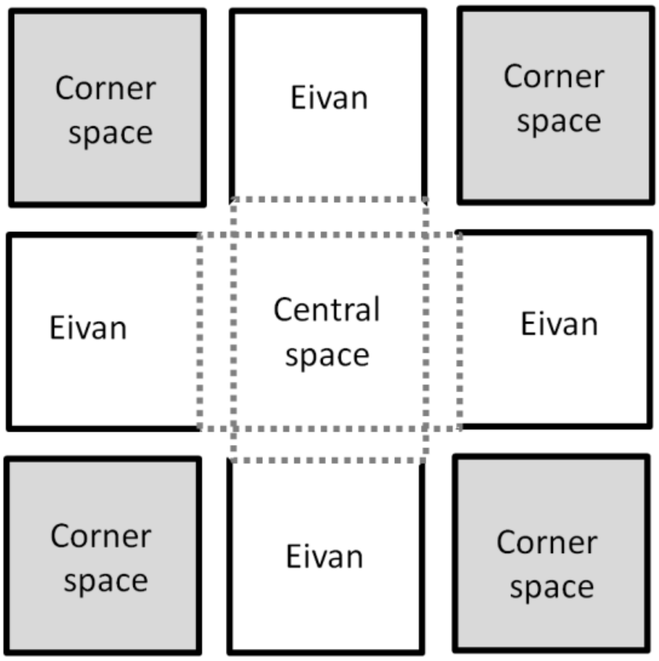
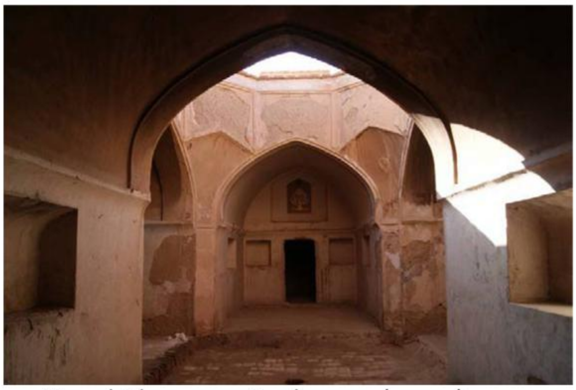


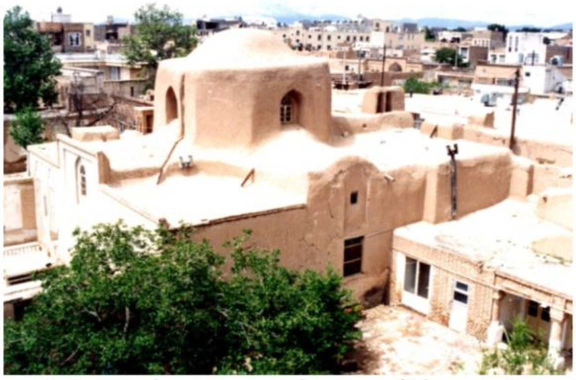
Figure 6-192: schematic concept of Chahar-Soffe building

The central space can be an open, semi-open or a closed space covered by a dome. The following picture shows the different shape of this ‘abstract yard’ in different historical cities of Iran (Figure 6-193). The corner spaces usually are closed spaces but in some cases they can be small yards too.



a - Panahi house – Boshroye (open)

b – Zavvare (Semi-open)



c - Azimian house – Sabzevar (Close –Dome)

d – Zavvare (Originally semi- open)

Figure 6-193: different types of central space of Chahar-Soffe houses, sources: a (Saeed-Pour, 2014), b and d (Deimary, 2012) and c the local archive of ICHTO in Sabzevar

6.7.7.1 The Azimian House

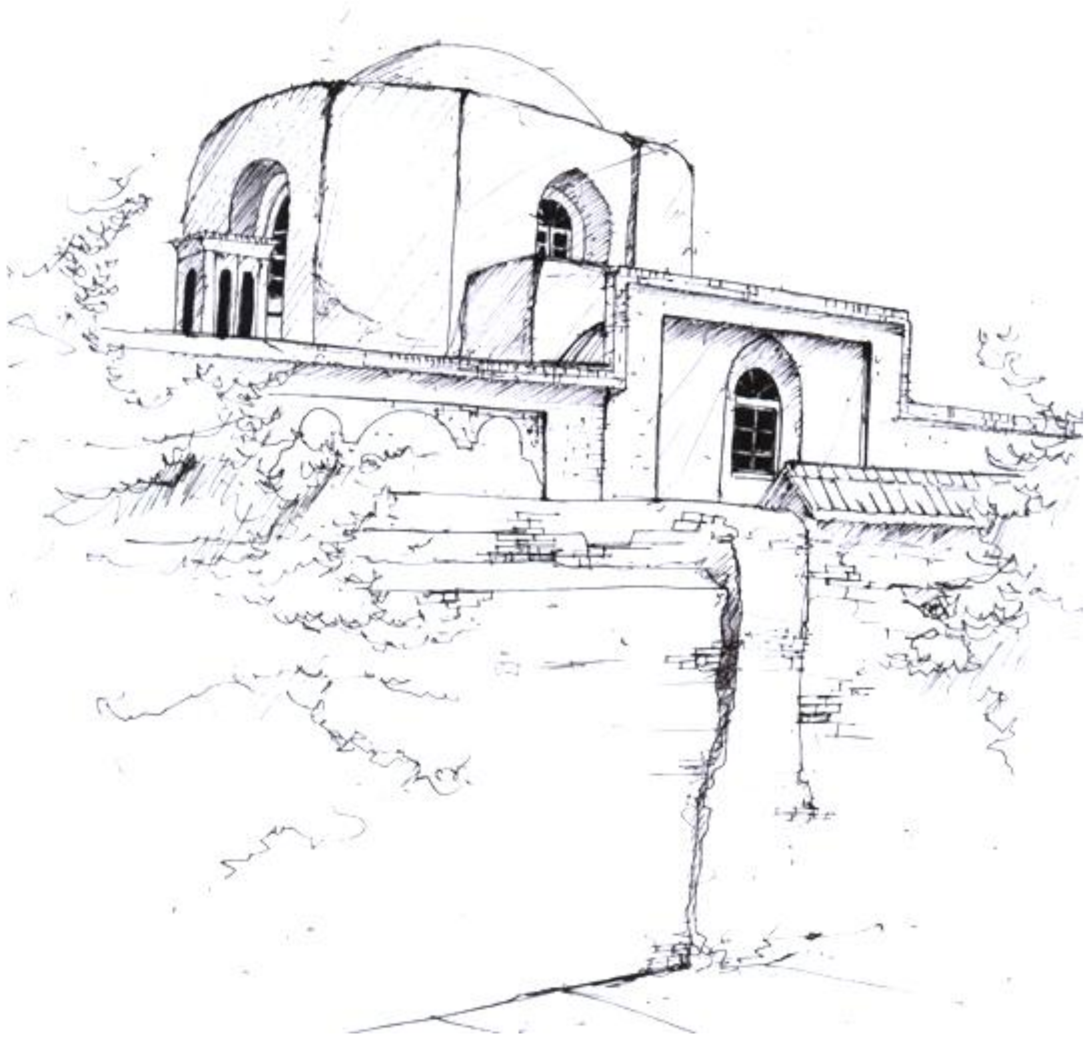


Figure 6-194: the Azimian house (Estaji, 2010), hand drawing by Minoo Qasemi

The Azimian house is the oldest remaining example of the Chahar-Soffe type in Sabzevar. According to the registration report of the house the construction of the building dates back to the Timurid period (1370-1506 AD). Some older pottery found in the yard suggests that it is probably even older (Towhidi-Manesh, 2002). It was constructed within the old Sabzevar city wall. Figure 6-195 shows the position of the house in regard to the old main routes and the old city wall in 1956 and the current location of the building in the city. Around 1965, the old city wall was demolished and turned into a street and in 1980 a main new street cut into the old urban fabric of Sabzevar. These changes altered the access hierarchy to the house and destroyed the south part of the house.

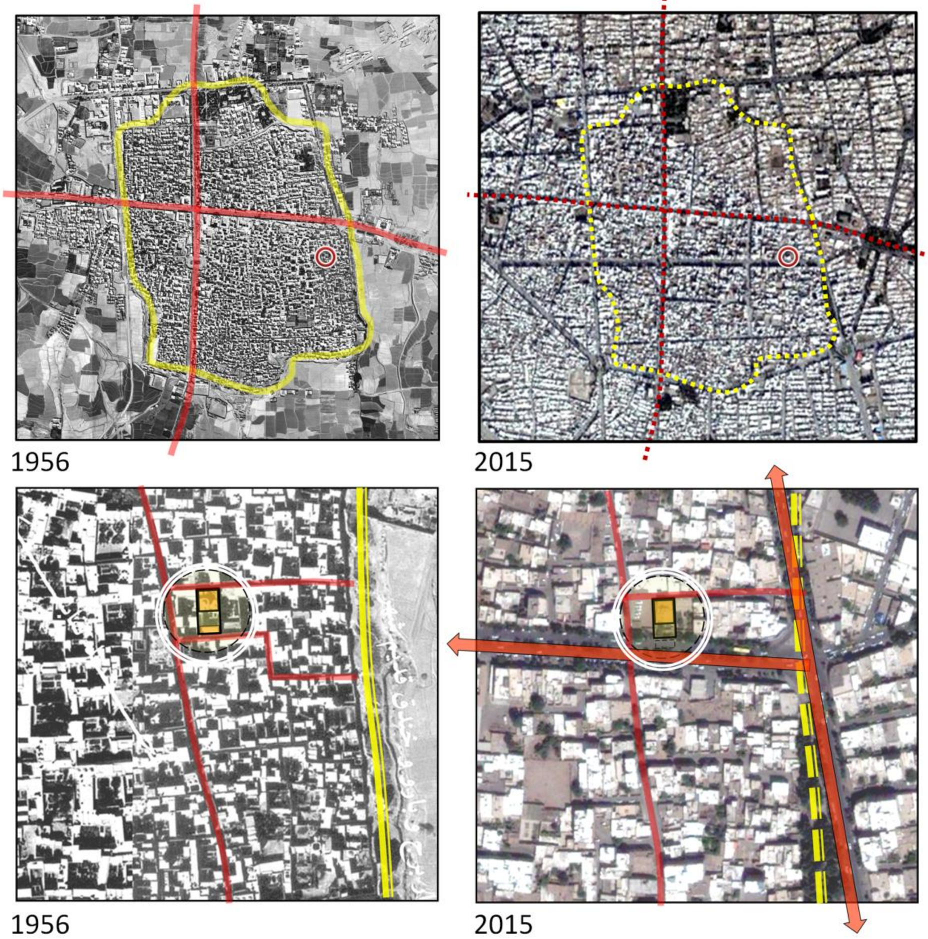


Figure 6-195: the location of the Azimian house in 1956 and 2015
base photomosaic maps of 1956:(Zanganeh, 2003a), 2015 aerial map: (Google Earth, 2015)

The house was situated between two subsidiary alleys. Access to the building was through two vestibules on the north and south sides of the building. The south entrance and part of the courtyard were demolished in 1980, after which the house was only connected to the new street by means of one door (Figure 6-196).

Figure 6-196: access hierarchy changes over time

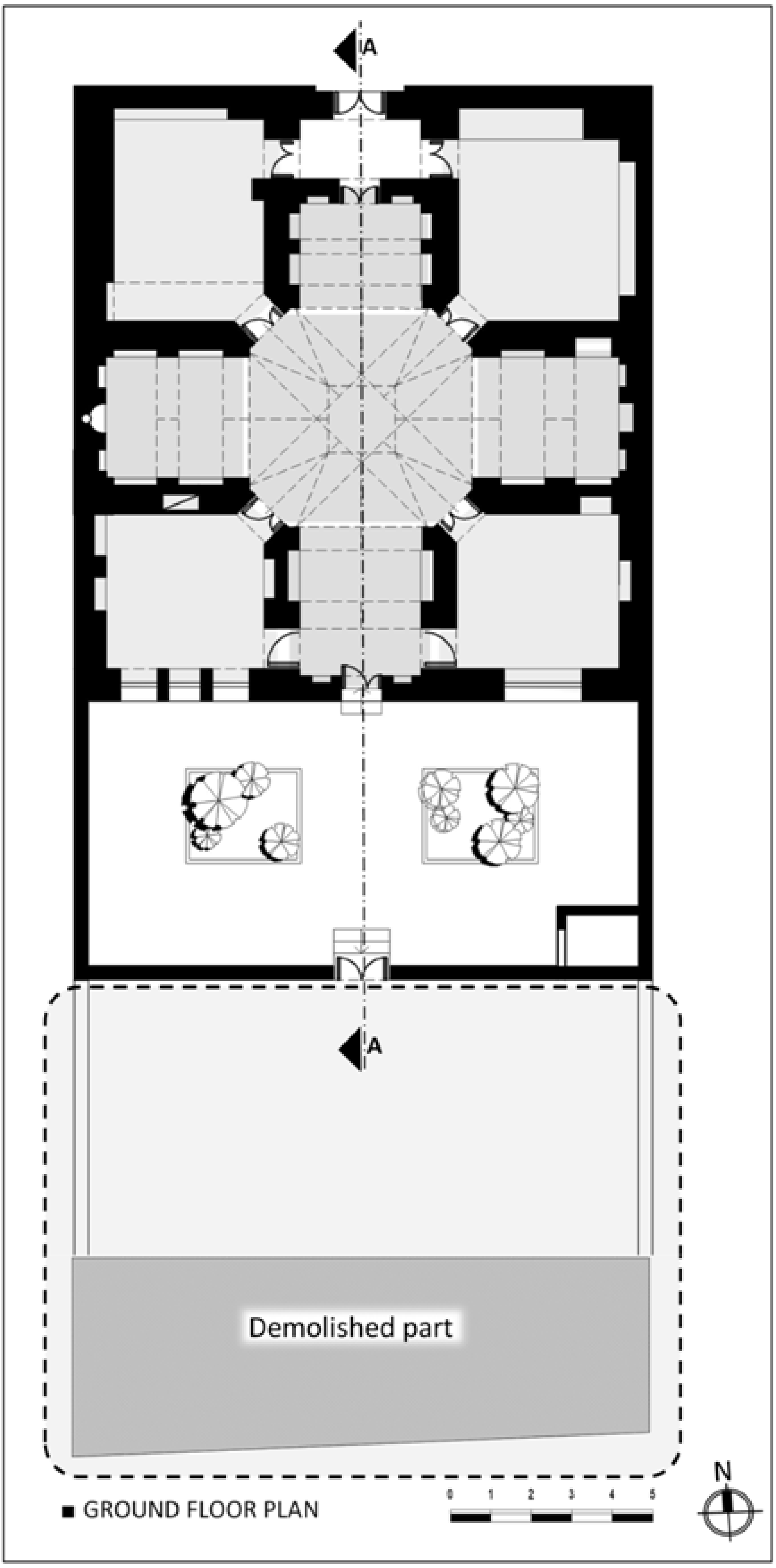


Figure 6-197: Plan of the Azimian house (Estaji, 2010, Towhidi-Manesh, 2002)

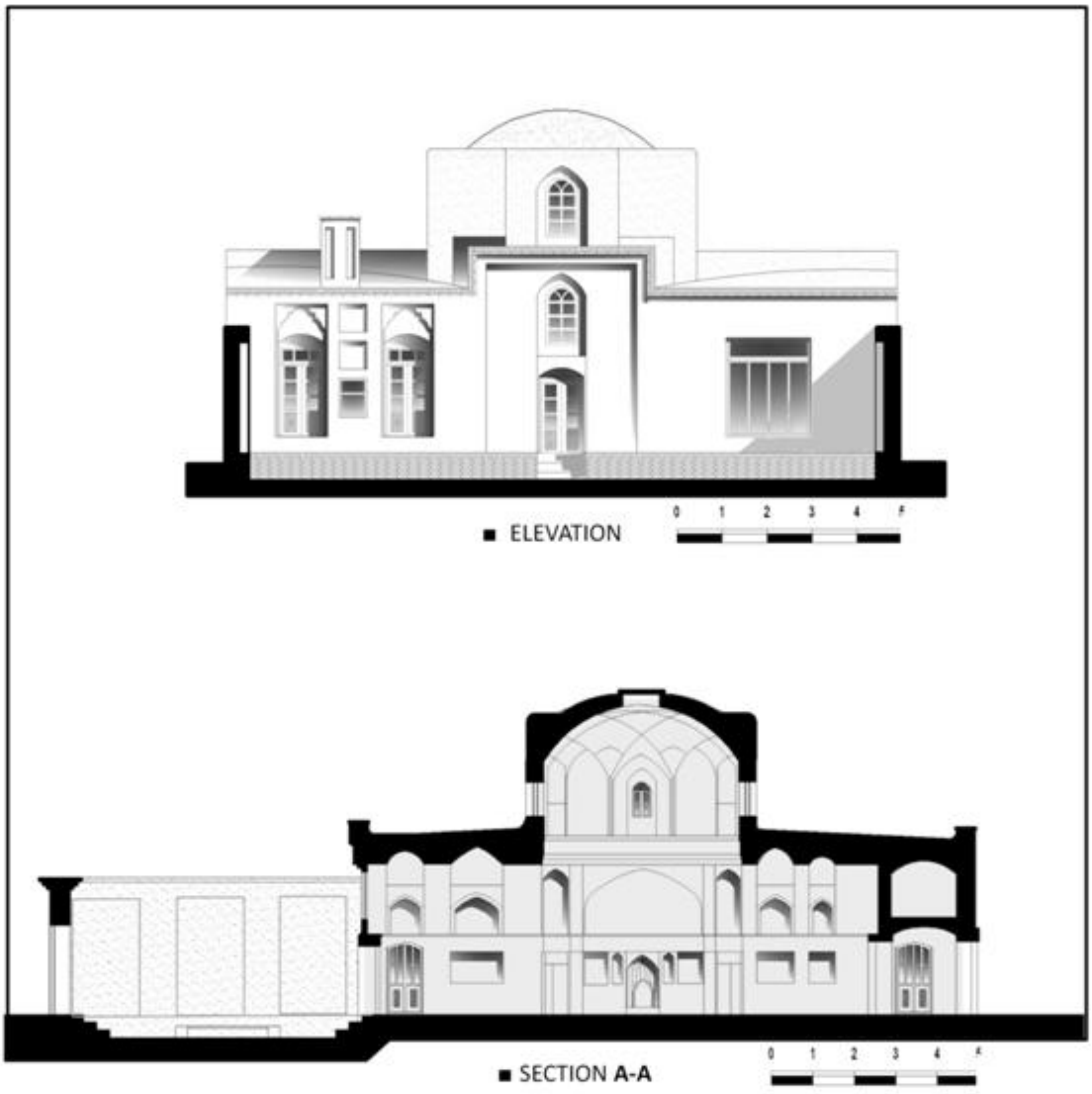
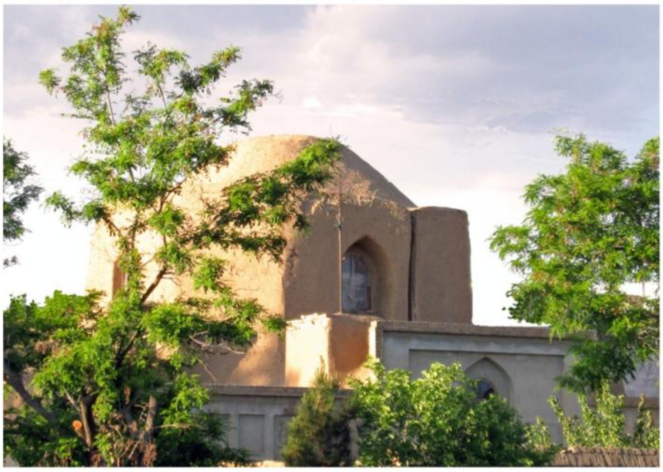


Figure 6-198: elevation and section of the Azimian house (Estaji, 2010, Towhidi-Manesh, 2002)



■ Central dome

■ Entrance from the courtyard

■ North inner Eivan*

■ South inner Eivan

■ West inner Eivan *

■ Corner of the central Space

Figure 6-199: photos of the Azimian house (Estaji, 2010), * Archives of the Sabzevar Cultural Heritage Organization

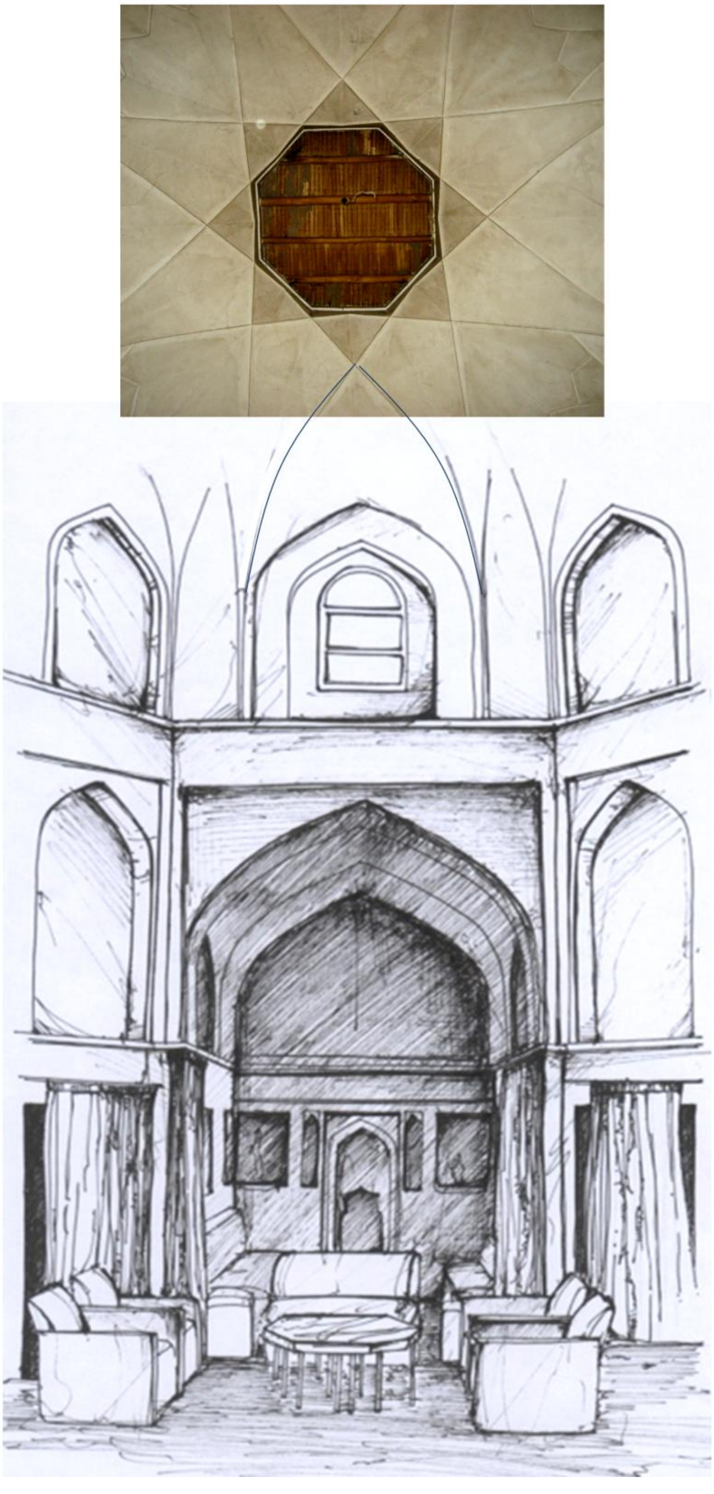


Figure 6-200: top: Under the central dome, bottom: hand drawing of west Eivan (Estaji, 2010), Drawn by Minoo Qasemi

6.7.7.1.1 House Orientation and Sun Position

The Azimian House is a south-oriented building with a two-degree orientation to the west (Figure 6-201). Only the south inner Eivan and two rooms facing the courtyard benefit from direct sunlight.

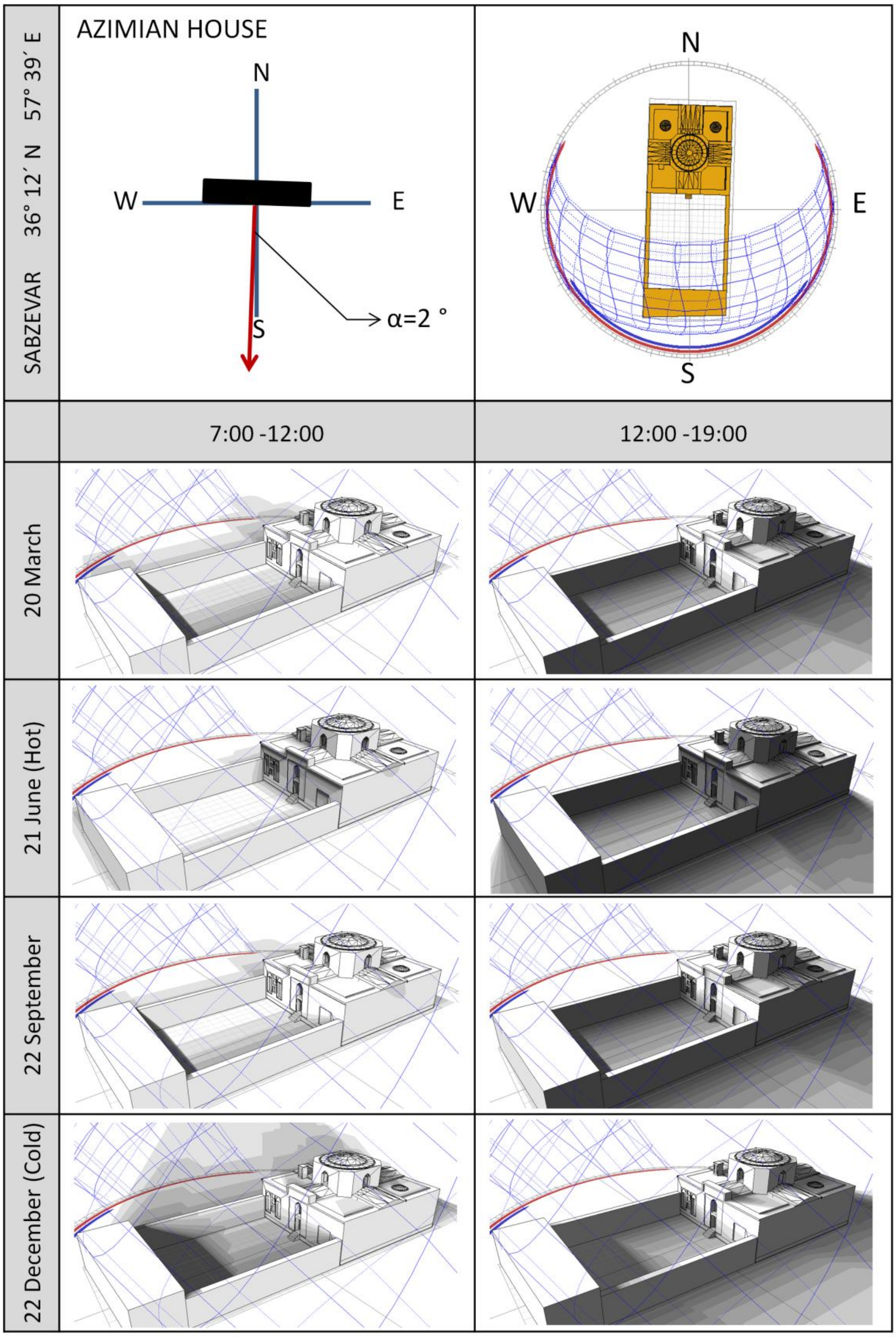


Figure 6-201: the position of shade in the morning and afternoon (original condition)

The small size of windows and the openings in the drum of the dome versus the large indoor spaces In practice minimize the impact of direct absorbed solar energy through the windows. In other words, the orientation does not have significant impact over the thermal performance of the Chahar-Soffe houses. The insolation analysis shows that there is not any significant difference between total absorbed radiation in the central dome and inner Eivans in winter and summer either. (Figure 6-202)

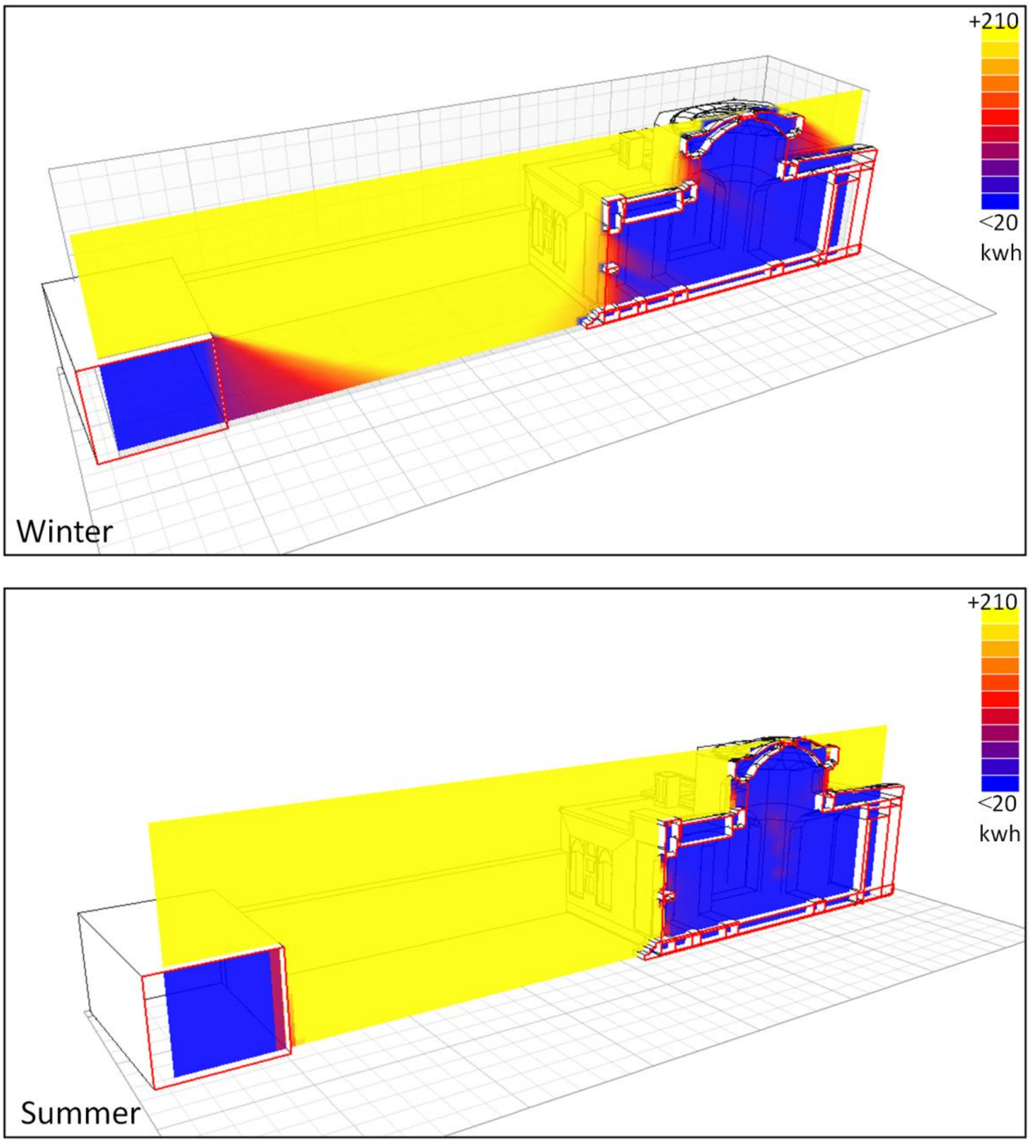


Figure 6-202: insolation analysis of total radiation in winter and summer

6.7.7.1.2 Spatial Configuration

In 1980, the south entrance and some service rooms like the stable and storerooms were demolished. The main remaining part contains the central space, four inner Eivans and four rooms. The central space is the core of the house that provides access to all other spaces. This main circulation space along with the west and east inner Eivans form a large room that can serve as a large living room. Two northern rooms are allocated for kitchen and storage and there are two private rooms on the south side. (Figure 6-203)

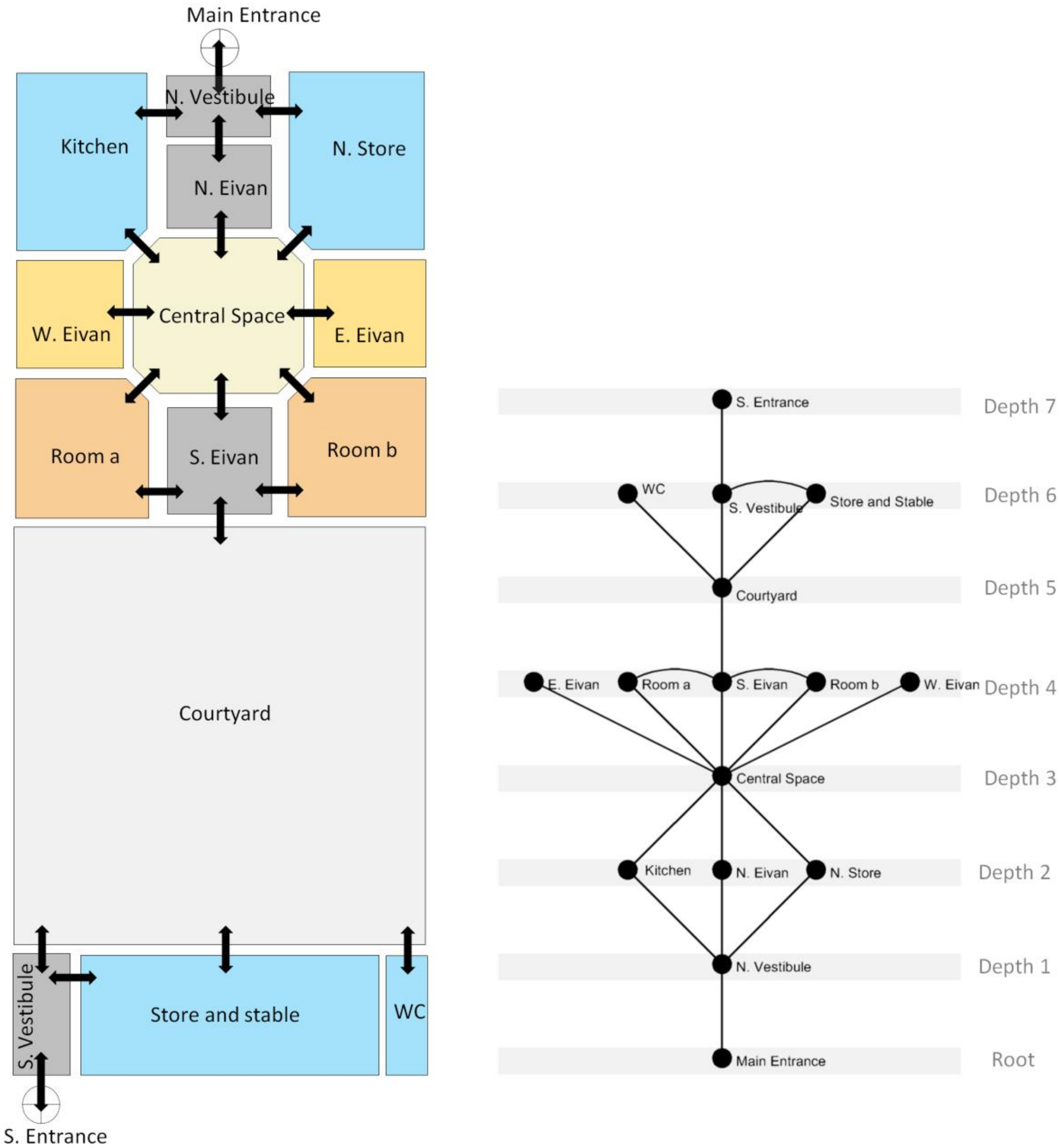


Figure 6-203: Breakup map and Justified graph of the Azimian house

The main characteristic of the house is the merging of circulation spaces and living space. The first integrated space is the central dome. The south Eivan is located in the second rank and the courtyard is in the third rank, followed by the main rooms and the private rooms (Appendix A 11). (Figure 6-204),

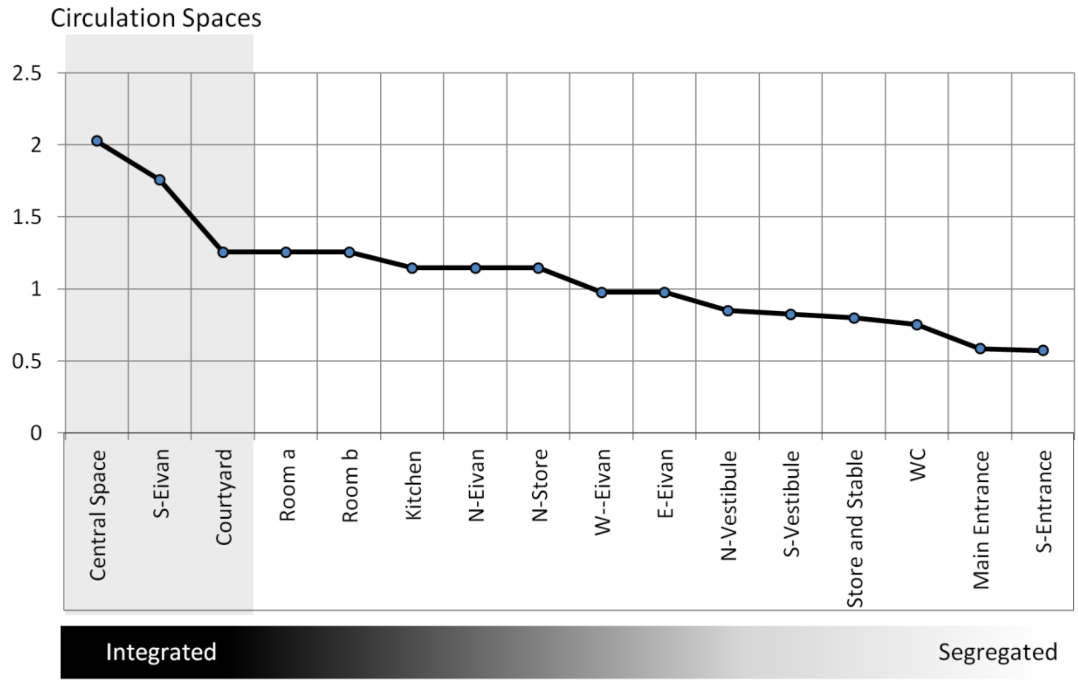


Figure 6-204: integration value of Azimian spaces

The north vestibule acts as a joint between the public space and the house; it blocks the direct view from the outside to the central spaces. The other living spaces are connected to the central space (Figure 6-205); it is a typical access hierarchy in the Chahar-Soffe houses.

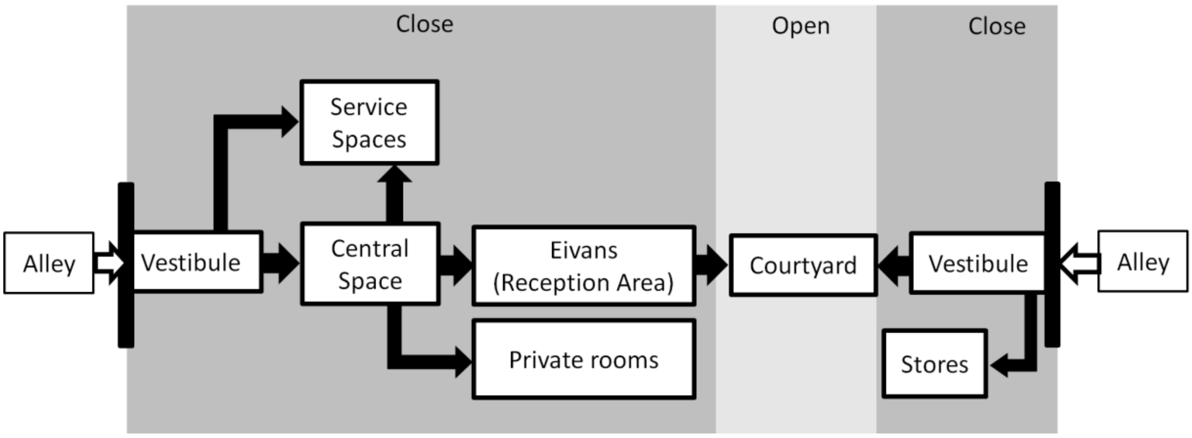


Figure 6-205: schematic access hierarchy of Azimian house

6.7.7.1.3 Adaptation to a new lifestyle

The engineer Davoudian who inherited the house from his family lives in the house. He added a bath and a toilet in the kitchen with a door from the north vestibule and the kitchen (Figure 6-206). The house is fully functional and in use. The Davoudian family is aware of the value of their house and maintains it very well. In 2012 the house was restored completely. The real value of this house is that after around six centuries it is still alive. As far as possible, the municipal authorities, the people of Sabzevar and NGOs should help the house to survive the times.

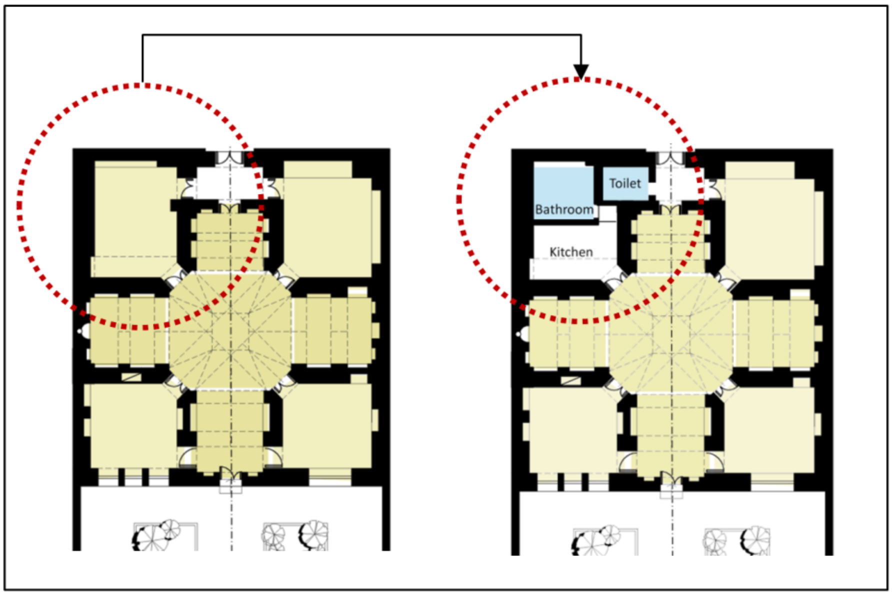


Figure 6-206: small modification to adapt the house with new lifestyle

6.7.7.2 The Dareini House

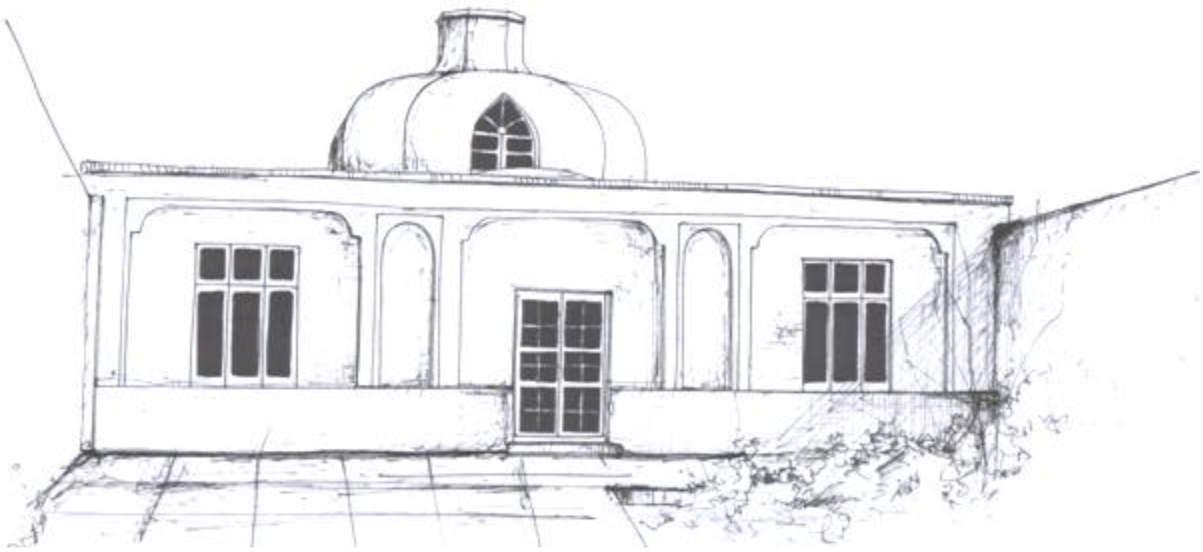


Figure 6-207: hand drawing of the Dareini house (Estaji, 2010), Drawn by Minoo Qasemi

Another house of the Chahar-Soffe type in Sabzevar was the Dareini house. It was demolished before 2005. The documents and archives contain little information about it. There are only two photos and a plan sketch in the archives of Sabzevar Cultural Heritage Organization. Based on these limited documents from SCHO the initial estimate of the construction time is Safavid era (1501–1722) but unfortunately before any serious research could be undertaken and the house registered it was destroyed. It was constructed in the oldest part of Sabzevar city near the Azimian house. Figure 6-208 shows the location of the house in 1956.

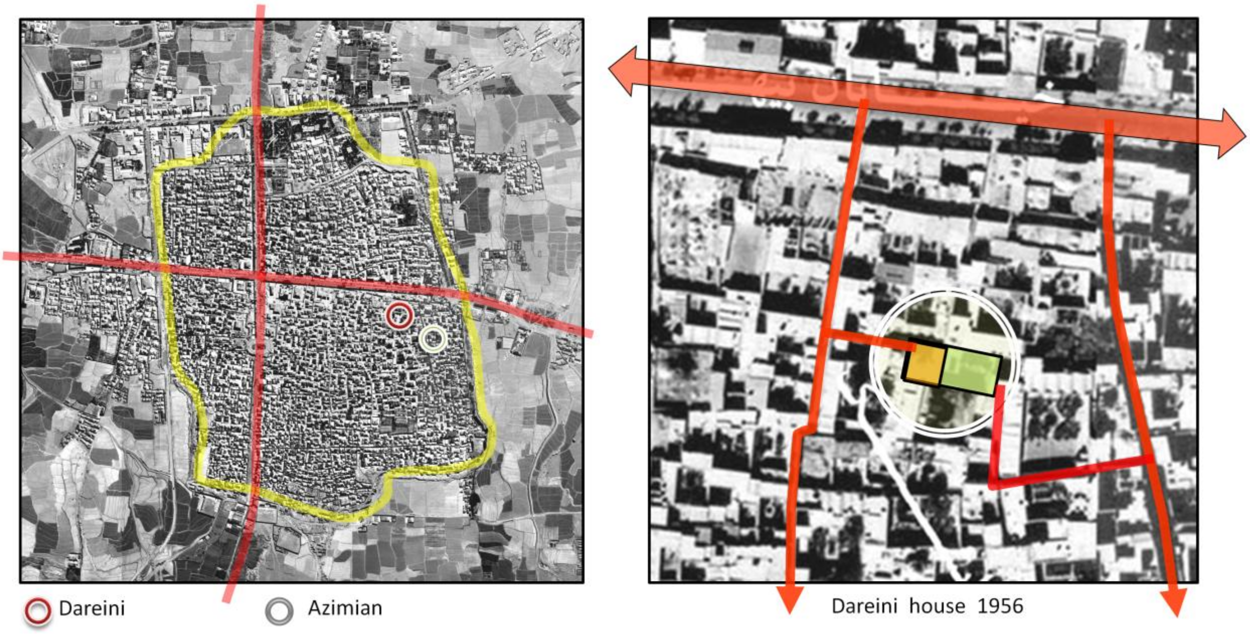


Figure 6-208: the position of Dareini house in 1956,base photomosaic map:(Zanganeh, 2003a)

The house was situated between two subcidary alleys. The access to the building was done trough two courtyards on the north-west and south-east of the building (Figure 6-209).The following maps and photos present plans and sections of the house as I tried to reconstruct them from the plan sketch and photos. (Figure 6-210, 6-208)

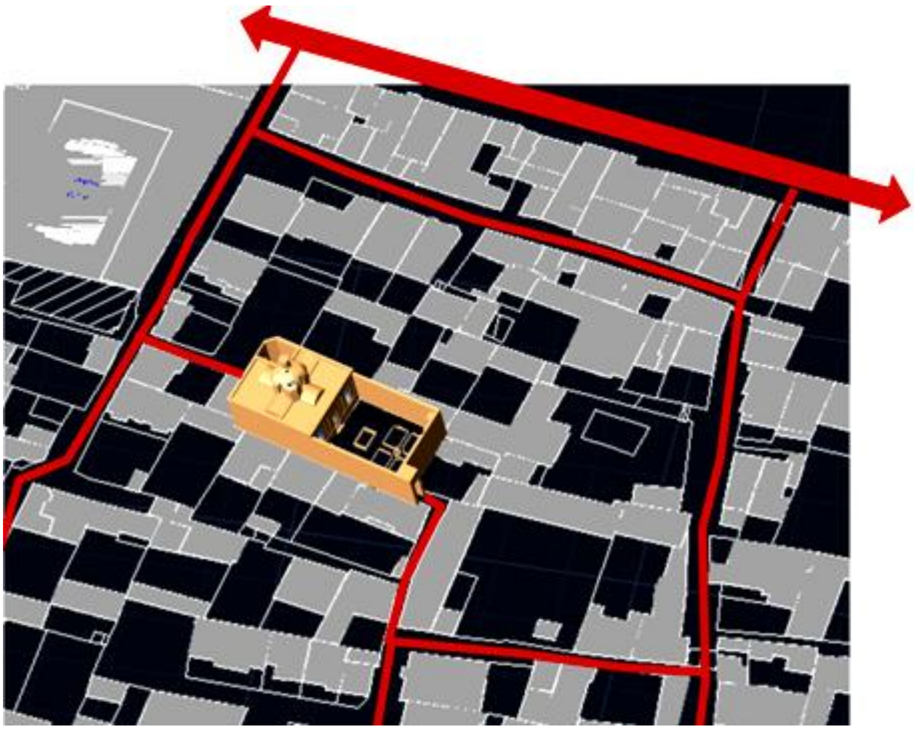


Figure 6-209: access hierarchy from alley to close spaces

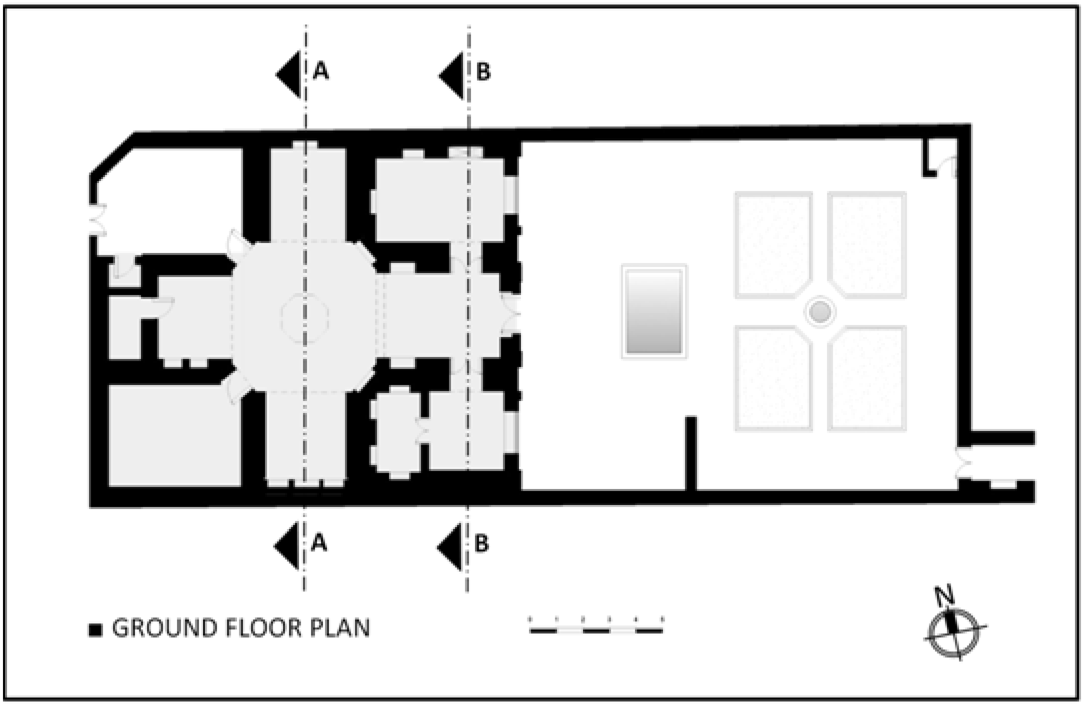


Figure 6-210: Plan of the Dareini house, source:(Estaji, 2010) and the local Archives of SCHO

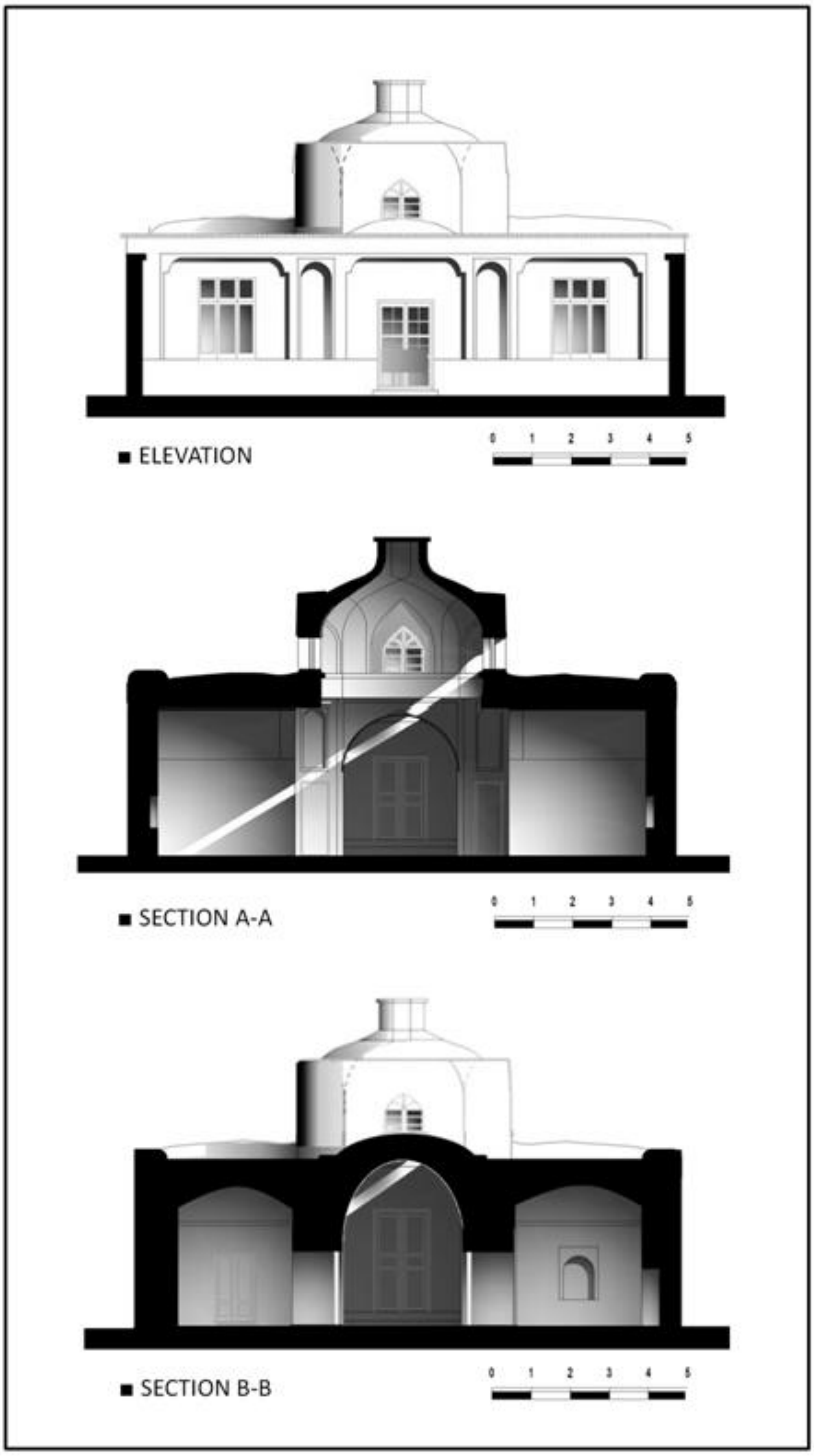


Figure 6-211: estimated elevation and sections of the Dareini house (Estaji, 2010) and the local Archives of SCHO

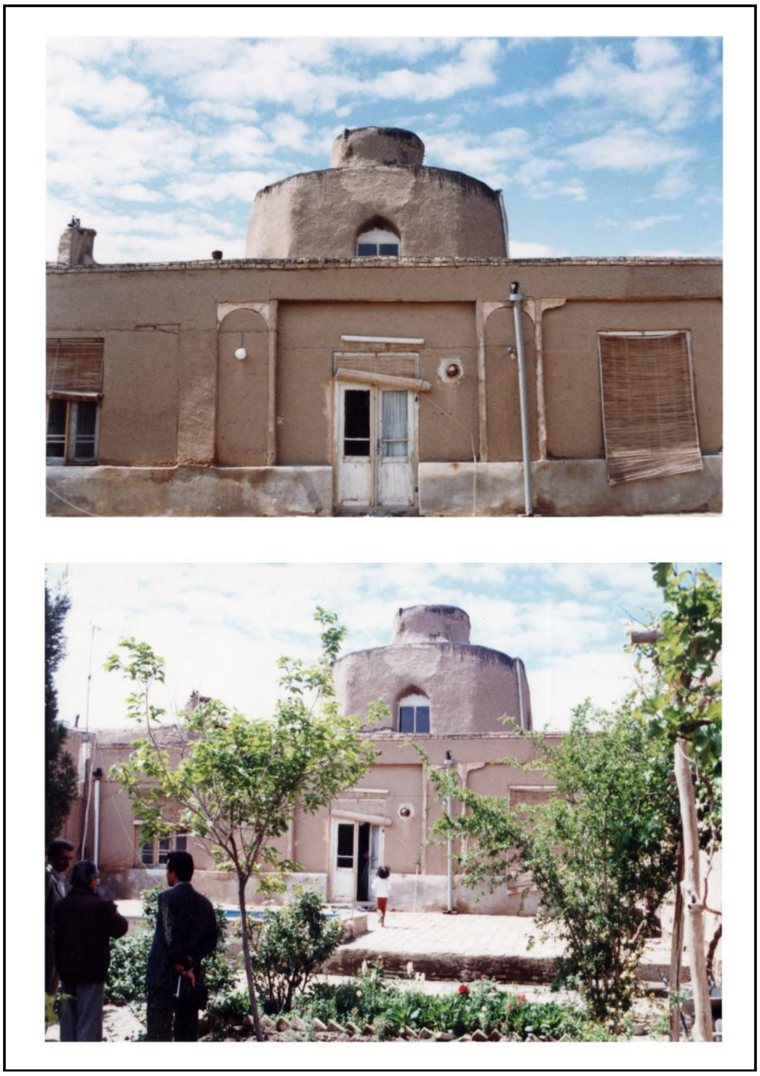


Figure 6-212: photos of the Dareini house, source: the local Archives of SCHO

6.7.7.2.1 House Orientation and Sun Position

The Dareini House was an east building with a fourteen-degree rotation to the south (Figure 6-213). There were only three small openings to the east that benefited from sunlight from morning till noon and were completely in the shade in the afternoon.

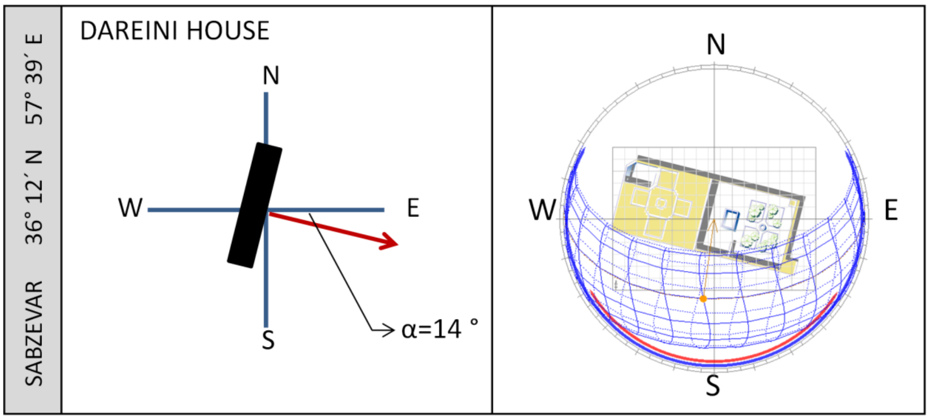


Figure 6-213: the Dareini house orientation

6.7.7.2.2 Spatial Configuration

The Dareini house consisted of a central space, four Eivans, three rooms and some ancillary spaces. (Figure 6-214). The spatial configuration of the house is very similar to the Azimian house, with the difference that an entrance courtyard has the task of connecting the indoor spaces to the alley.

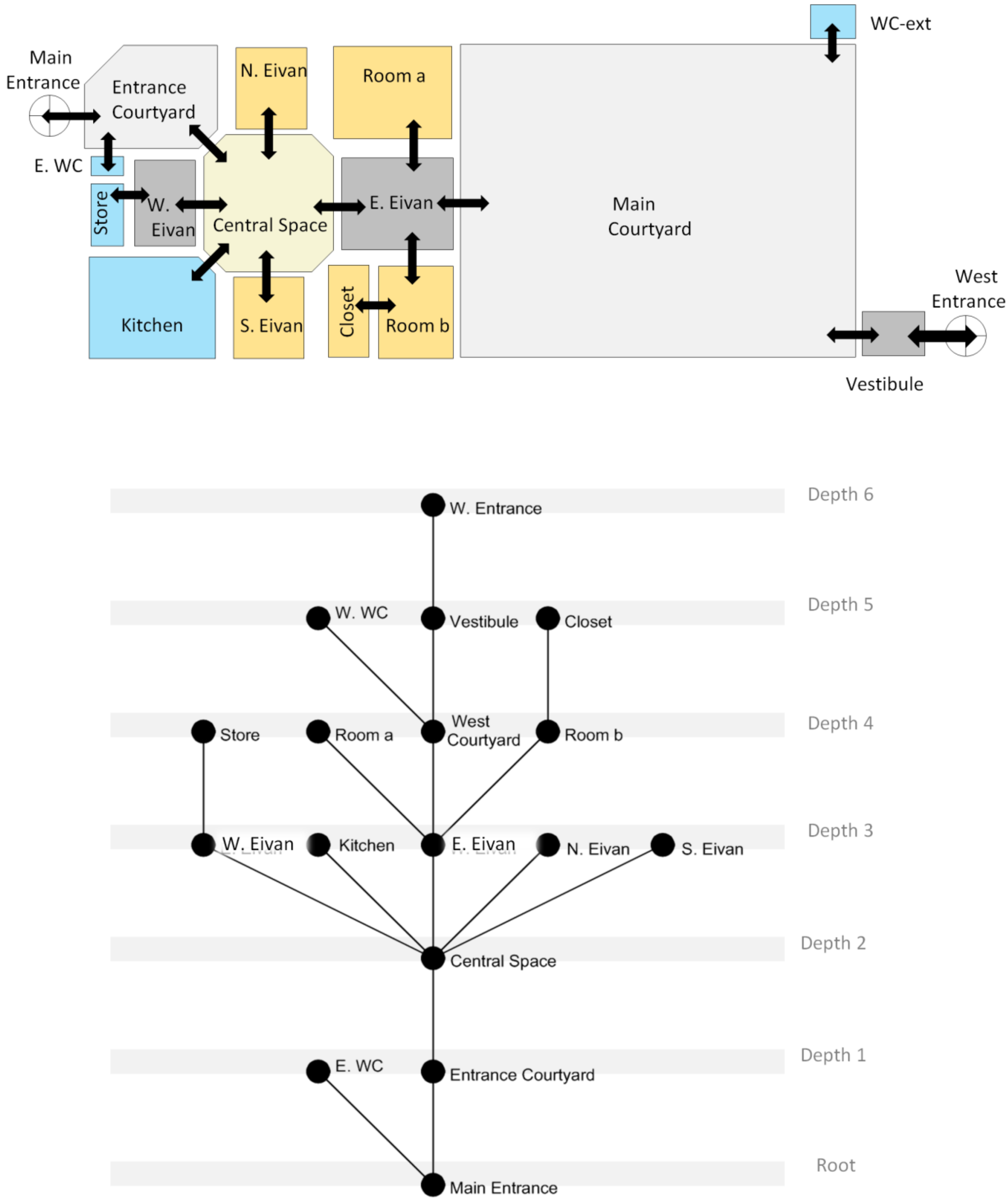


Figure 6-214: Break up and Justified graph maps of the Dareini house

The first five integrated spaces are the circulation spaces; the first integrated space accommodates the central dome, while the east Eivan is located in the second rank and the entrance courtyard is in the third rank, followed by the west Eivan and west courtyard. These circulation spaces are followed by the north and south Eivans as a living room and guest rooms and finally the private rooms (Appendix A 12). (Figure 6-215)

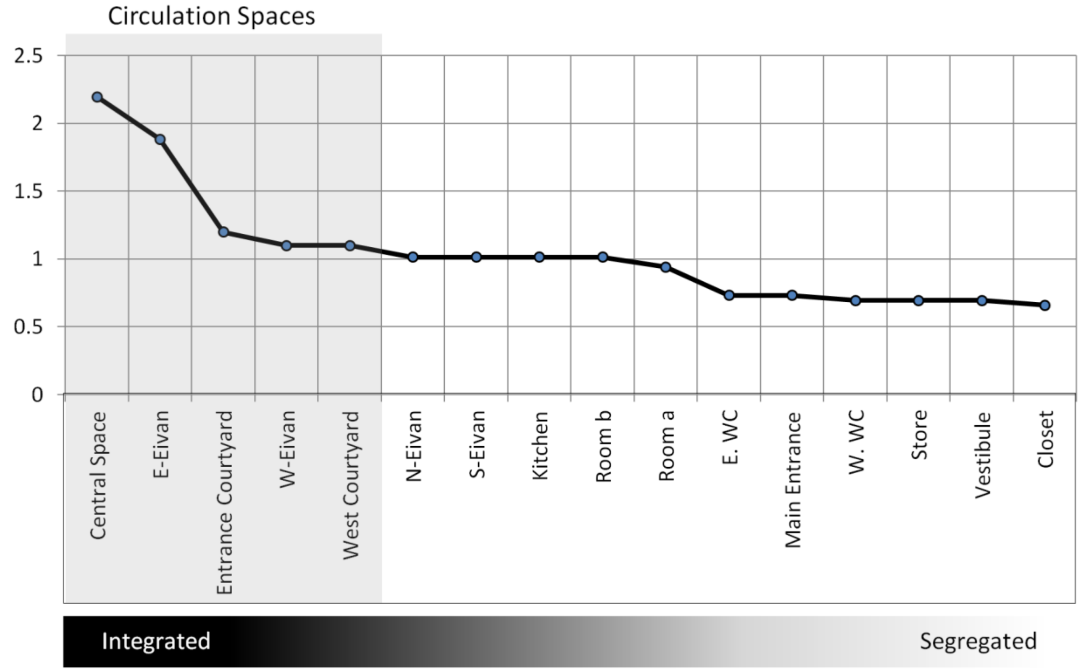


Figure 6-215: integration value of the Dareini spaces

Figure 6-216 shows the schematic access hierarchy of Dareini house. The north-west courtyard acts as a joint between the public space and the house. Unlike the Azimian house the private rooms in this house were not connected to the central space directly. Instead they were connected to one of Eivans.

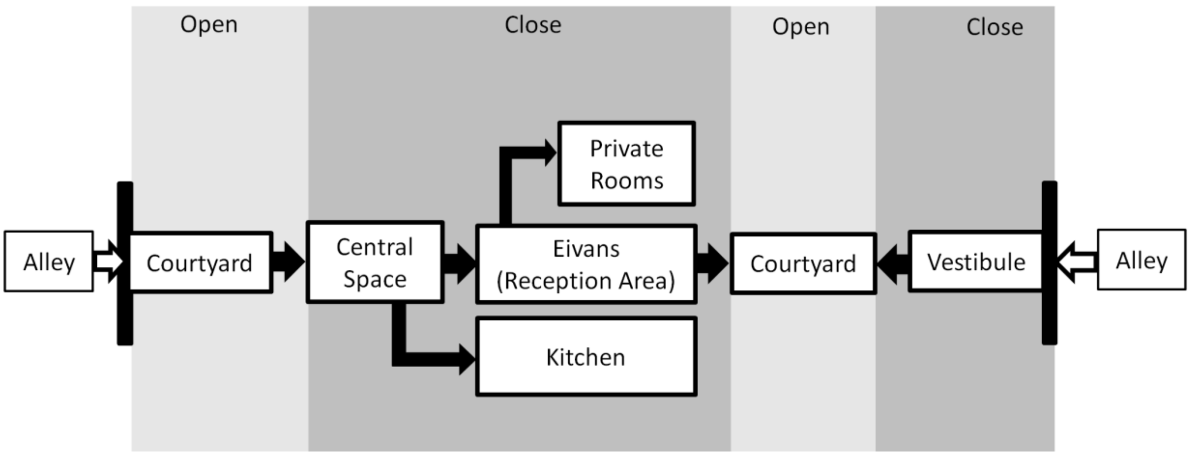


Figure 6-216: Schematic access hierarchy of Dareini house

6.7.8 Two Demolished Houses

During the period of this study (from 2010 on) not only the Moslem house that was studied in detail, but also two other houses were completely demolished. The Mohammadiyani and Cheshomi houses, located in the old Sabzevar city, were both from the end of the Qajar period. The following map shows their location in relation to the old main routes and the old city wall in 1956 (Figure 6-217).

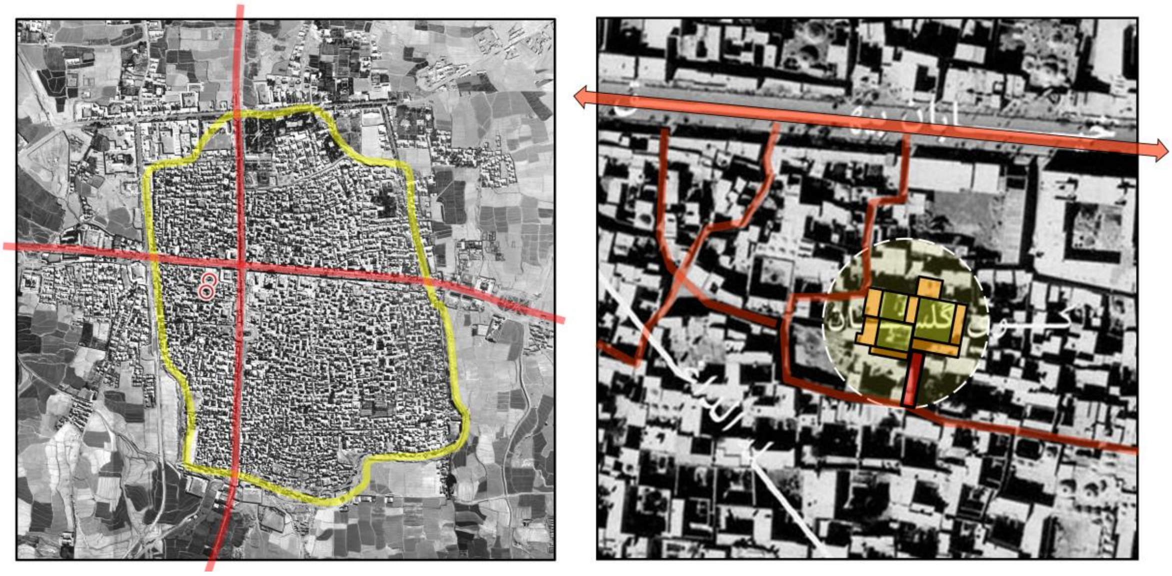


Figure 6-217: the position of the Mohammadiyani and Cheshomi houses in 1956, base photo-mosaic map:(Zanganeh, 2003a)

These houses stood next to each other .The Mohammadiyani house was a house with two courtyards with two separate entrances from two alleys and the Chatom house was a (L) shaped house with an entrance at the end of a blind alley. (Figure 6-218)

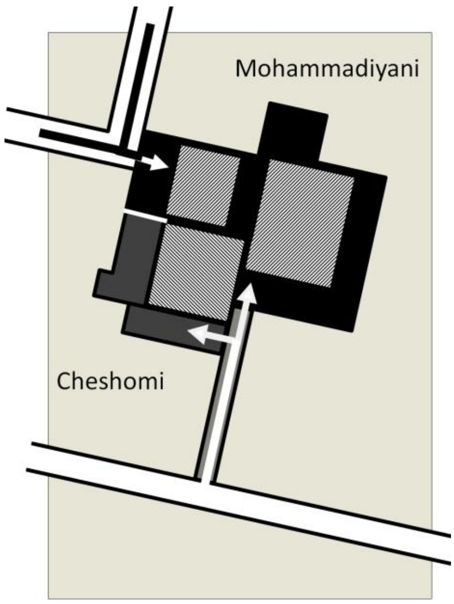


Figure 6-218: entrances of the Mohammadiyani and Cheshomi houses

6.7.8.1 The Mohammadiyani House

Figure 6-219: hand drawing of the Mohammadiyani house (Estaji, 2010), Drawn by Minoo Qasemi

The Mohammadiyani house consisted of four separate parts in two courtyards (Figure 6-220); this arrangement allowed the house to be split up into independent units and to be divided up among the heirs of the family. Unfortunately, none of them had any interest in restoring their units. This reluctance, economical problems, and a lack of unified management finally resulted in the house being completely destroyed in 2013.

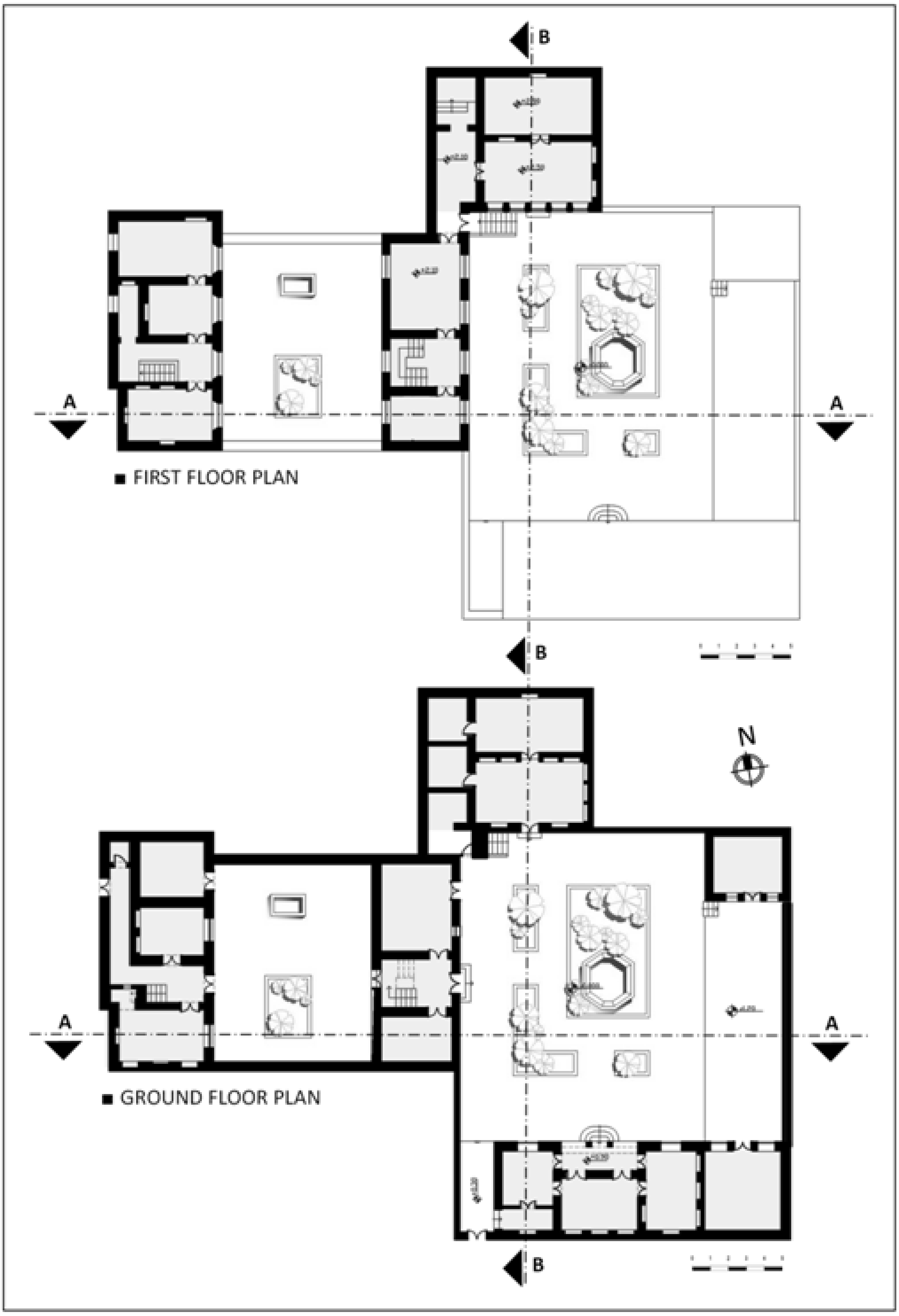


Figure 6-220: Plans of the Mohammadiyani house, source: (Estaji, 2010, Kermani-Moqaddam, 2005a) and the local archives of ICHTO with corrections

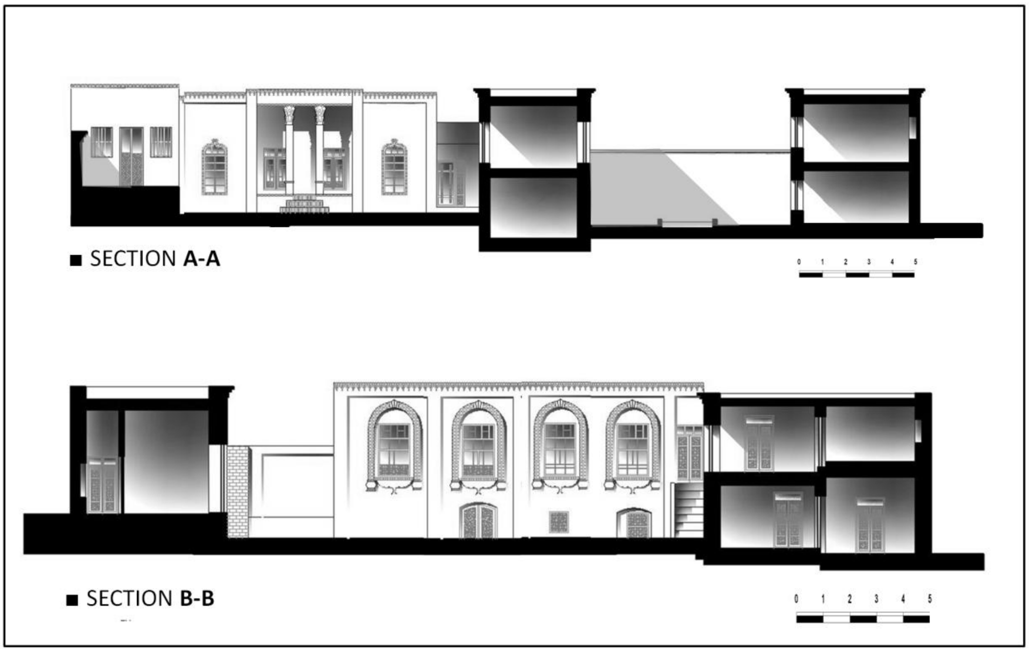
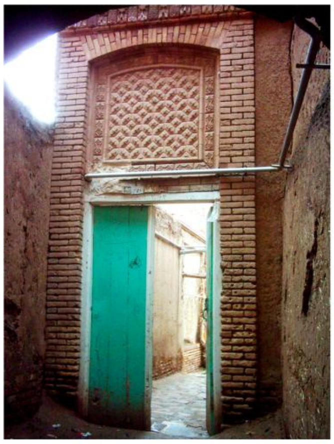


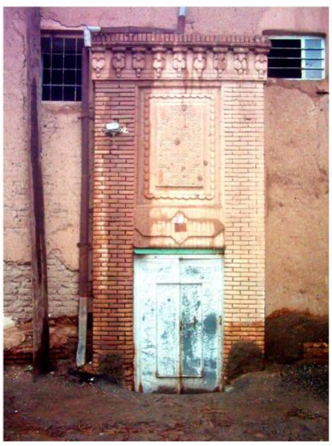
Figure 6-221: Sections of the Mohammadiyani house, source: (Estaji, 2010, Kermani-Moqaddam, 2005a) and the local archives of ICHTO with corrections

North facing part



South entrance

South facing part



West entrance

Figure 6-222: photos of the Mohammadiyani house (Kermani-Moqaddam, 2005a)

6.7.8.2 The Cheshomi House

Figure 6-223: the Cheshomi house (Estaji, 2010), hand drawing by Minoo Qasemi

The Cheshomi house consisted of two wings. i.e., a north-facing and an east-facing part (Figure 6-224). The house could be entered through a simple vestibule. There were two large rooms on the south side of the courtyard and the main living spaces were located on two floors on the west side. The ground floor contained a large summer room and storerooms. Two small Eivans provided access to the main multifunctional rooms on the first floor. Since the house owner was unable to paying the cost of maintenance and restoration, the house was abandoned around 2010. After the roofs collapsed in 2014, the house was destroyed. The following maps show the houses prior to demolition.

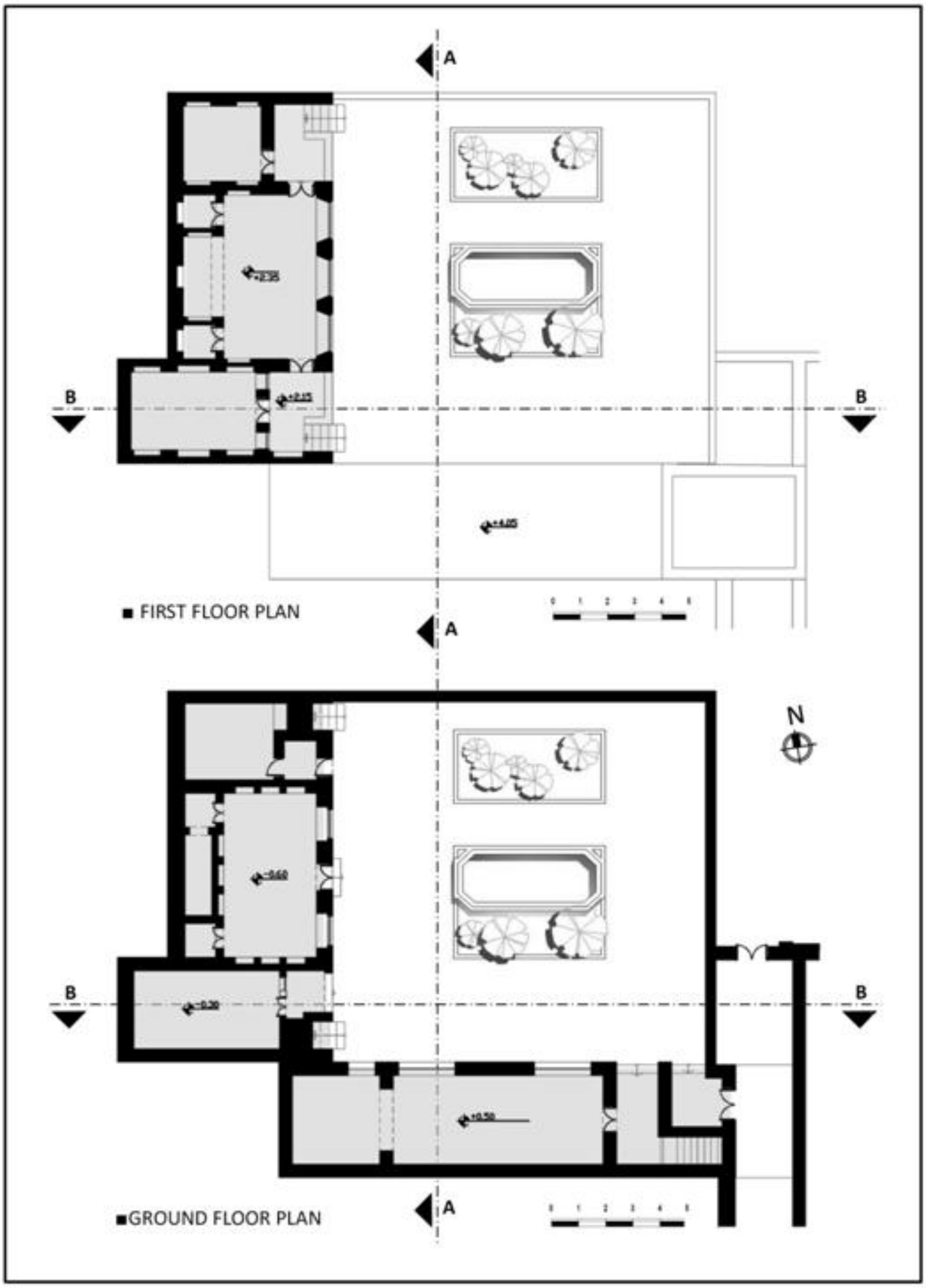


Figure 6-224: : Plans of the Cheshomi house, source: (Estaji, 2010, Kermani-Moqaddam, 2005b) and the local archives of ICHTO with corrections

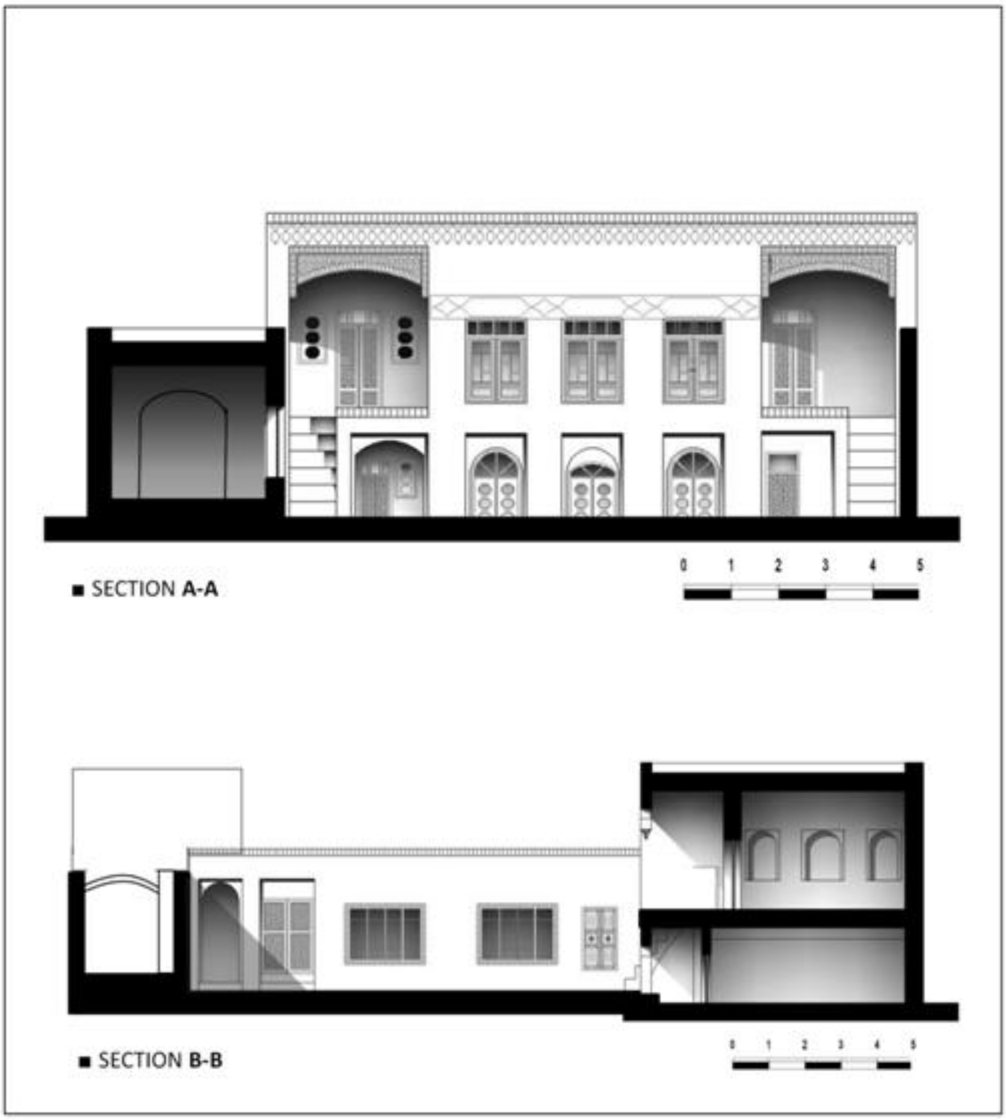
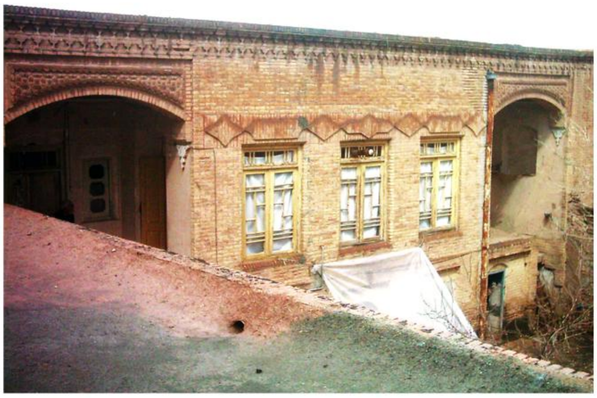
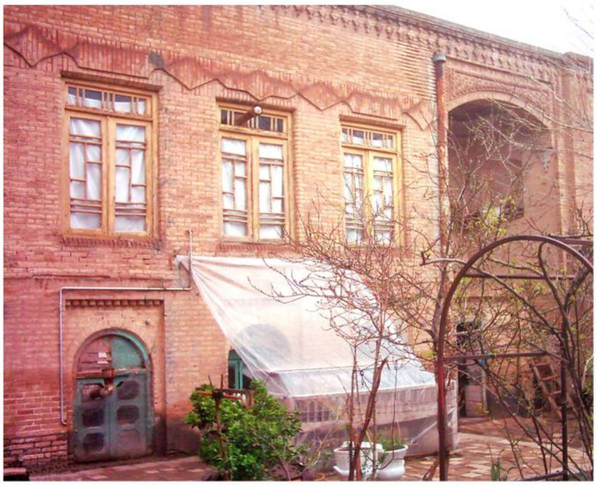
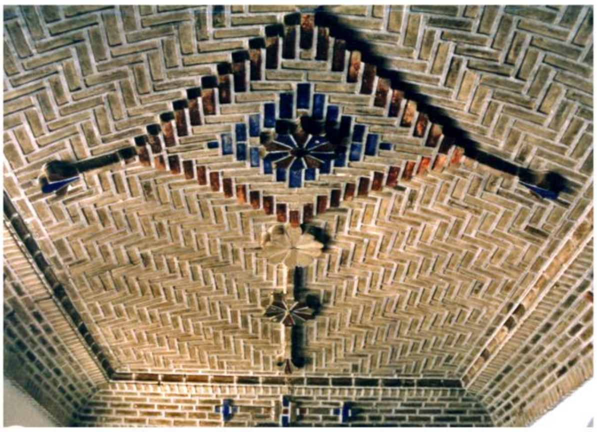


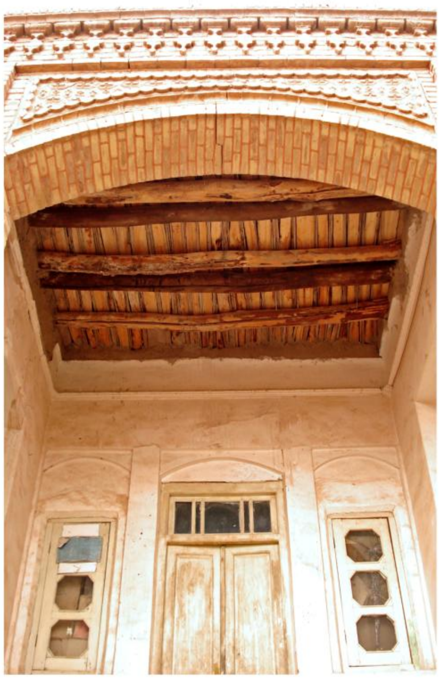
Figure 6-225: Sections of the Cheshomi house, source: (Estaji, 2010, Kermani-Moqaddam, 2005b) and the local archives of ICHTO with corrections







■Detail of the ground floor roof



■ Detail of the Eivan roof

Figure 6-226: photos of the Cheshomi house, source: the local archives of ICHTO in Sabzevar

Due to the high costs of maintenance and restoration, it was not cost-efficient to use these buildings for residential purposes. However, by merging these houses instead of tearing them down, they could be used as an educational or cultural building.

There are five private architecture universities in Sabzevar and most of them are housed in inappropriate buildings. Given their architectural and historical value, these two buildings could have been turned into a school of architecture. The following plan shows that by making only two openings between courtyards the houses could be united and used for a new purpose (Figure 6-227). Unfortunately, the buildings were completely destroyed, but this idea can help ensure the survival of similar buildings in Sabzevar or elsewhere.

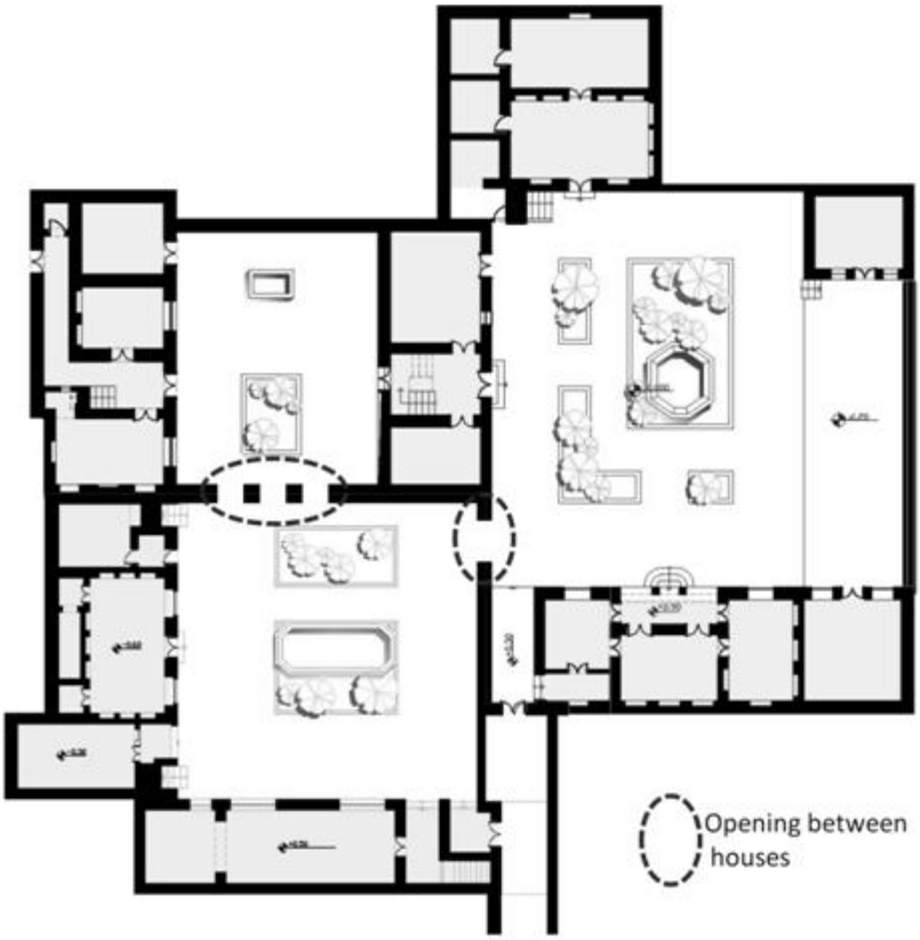


Figure 6-227: a proposal to merge the Mohammadiyani and the Cheshomi houses for use as a school of architecture

7 CONCLUSION

This chapter tries to answer the main research questions of my thesis. How were the buildings adapted to climatic conditions? Moreover, what strategies were applied to meet the needs of different residents during the lifecycle of the houses?
This chapter analyses the changes of individual houses that took place over time and also the evolution of the house types and regroups them according to different criteria.
My study analyses the buildings in terms of flexibility and adaptability and argues that the traditional houses were flexible and could be easily adapted to new conditions. However, there is a conflict. If they were flexible why did four houses disappear during this study? While investigating the demolished houses it became clear to me that a higher level of flexibility is needed to preserve traditional houses in Sabzevar and similar cities. I also make some suggestions that are directed to municipal authorities and the Cultural Heritage Organization to facilitate this rehabilitation process.

7.1 Adaptation to Climatic Conditions

Traditional houses of Sabzevar were adapted to the climatic conditions in the hot and arid region only by using some passive strategies; in the following these findings are listed:

7.1.1 House Orientation

Although calculations show that the best orientation in Sabzevar is to the south, the prevailing orientation of traditional houses in Sabzevar is to the east. In nine cases the living zones of the analysed houses face east, while in six cases they face south (Figure 7-1).
The studies on the shading masks of each window in the cases indicate that the deep verandas (Eivan) in the south and east-facing façades can block the direct sunshine on windows that are located behind them in hot seasons and let the façades benefit from the direct sun in winter, especially on south-facing façades. The Effective Shading Coefficients (ESC) of the façades behind the Eivans are between zero and twenty percent; the low value of the (ESC) emphasizes the effectiveness of the Eivan in controlling direct sunlight in this region.
Due to the agriculture-based lifestyle in the Qajar period, the residents worked outside the house in the warm seasons. This kind of lifestyle minimized the occupancy rate of rooms before noon. On the other hand, the east-facing zones are completely in the shade from midday on. The deep Eivans in this part of the building protected the rooms from direct sunlight before noon and provided a comfort zone for living purposes.
Four-season houses contain two separate zones for the hot and cold seasons. The north-facing wings are the best zone for summer days and the southfacing ones for cold days. This

type of traditional house needs a larger lot of land for construction, and also the costs of their maintenance are high, therefore these houses usually belonged to wealthy families.

Some of the traditional houses in Sabzevar (the cases) belonged to ordinary people. It can thus be safely assumed that there are only few spaces or areas used only in summer (mono-functional, north-facing space); there is only one house (Eslami) in which two wings face north. A wing of the Cheshomi house and a part of the Mohammadiyani, a room of the Moslem house and two rooms of the Jafar-Zadeh house also face north.

The houses analysed in this study clearly show that west sunlight was avoided. There are only three rooms in the Mohammadiyani house that face west.

From the end of the Qajar period on, with the arrival of new materials and the introduction of new active cooling and heating systems and the imitation of European architecture, the use of traditional patterns of house orientation that had emerged over the years gradually became less important.

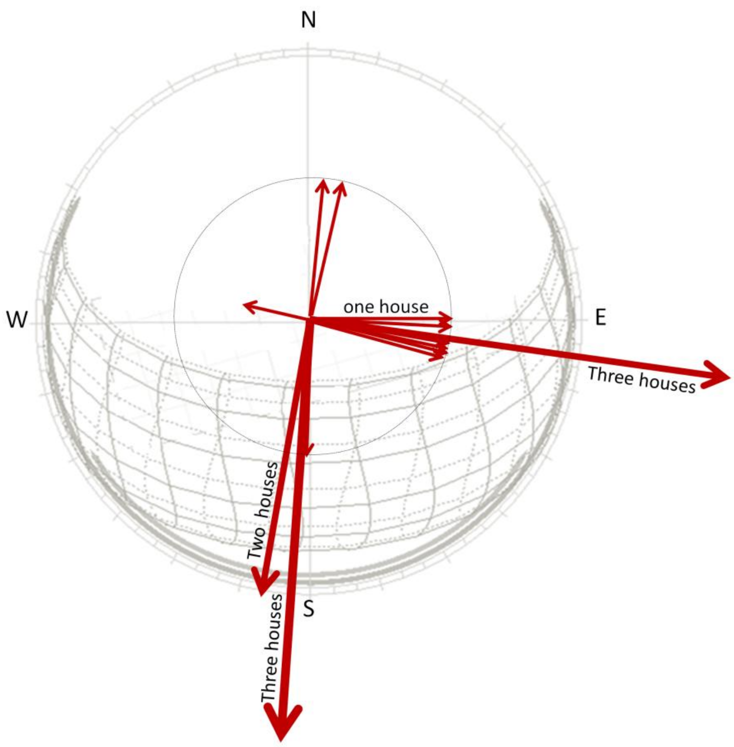


Figure 7-1: orientations of traditional houses in Sabzevar (cases in this study)

7.1.2 Vegetative Shading, Evaporative Cooling, and Natural Ventilation

Plants and trees work as smart shading devices in traditional houses. Deciduous trees block the direct sun in summer and allow the windows and façades to benefit from the sun during winter when the trees are without leaves.

The high average amount of evaporation in Sabzevar indicates the enormous potential of this region for the use of the passive evaporative cooling system on hot days. The combination of vegetative shading, evaporation cooling and natural ventilation in the traditional courtyard provides a cool and fresh micro-climate in summer.

Nowadays courtyard houses are not built anymore. The prevailing type of residential architecture is multi-storey apartment houses. If there are any courtyards, they do not serve multiple purposes like those in traditional houses did. Instead of being multifunctional spaces with various cultural and environmental tasks and meanings, they are now only used for access or as parking space.

The privacy of the courtyard in the traditional houses was under the control of residents; it was shared only with the family and certain people who were permitted into the courtyard. Now the courtyard is a space shared by unrelated families that receive visitors from the outside. In fact, it is a semi-public space with no control over who enters and who leaves. People are still interested in having a private yard, but because of the high land prices it is almost impossible.

Designing small private open spaces (such as roof gardens or loggias) on different levels in apartment buildings would be an option for regaining the qualities of the courtyard in contemporary housing design.

7.1.3 Earth Cooling

Earth-cooling is another forgotten strategy in contemporary housing design in this region. Going down to the ground level, the temperature decreases dramatically. For example, in Sabzevar the earth temperature at a depth of four meters below the surface is around 23 °C on hot days. The problem that buried buildings lose access to direct sunlight was solved in a brilliant way in traditional architecture. Small courtyards lowered into the ground provided light from one side, while the other sides of the underground spaces were still in direct contact with the earth mass. This space is called 'gowdal-baghche' in Persian, which means 'sunken garden'. This concept could be revived and used again in contemporary architecture.

7.1.4 Vertical and Horizontal Movements of Residents between Different Spaces

Movement of the residents between the various spaces with different temperature during the day and night or the cold and hot seasons was a passive strategy in this region – passive in the sense that no mechanic air conditioning system was required to provide acceptable indoor conditions. This strategy requires a large building with a large number of spaces. Nowadays this strategy of temperature management does not work anymore because of the changed family structure (small nuclear families instead of the large families of the past). Due to high property and real estate prices, costs of construction and maintenance fees, families can only afford small houses or flats. The strategy of leaving half of the house seasonally uninhabited is no longer feasible.

7.2 Evolution Process of the Traditional Houses in Sabzavar

In the sixth chapter, the houses are classified according to their positions on the plot. Following detailed analysis of the evolution process of the cases during the time, in Table 7-1 and Table 7-2, the houses are rearranged in chronological order with regard to the period of construction. This classification allows them to be regrouped according to different other criteria as well, such as circulation patterns and spatial configurations. Before addressing these changes, it is better to mention that the Azimian and Dareyni houses have not been classified as courtyard houses even though they have a yard. It is characteristic of the Chahar-Soffe house type that it has the least contact with the urban environment and the courtyard and that the circulation space is integrated within the building. Moreover, the Chahar-Soffe was not the only house type in this region before the Qajar period. Most likely other house types such as simple courtyard houses were also common in this area. However,due to the use of soil and raw clay in their construction, there are no traces of them now.

Table 7-1: chronological order of the cases (first part)

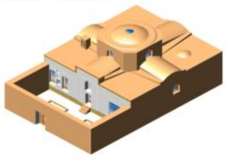
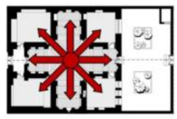
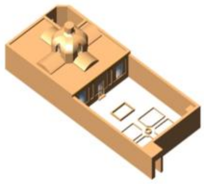
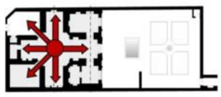
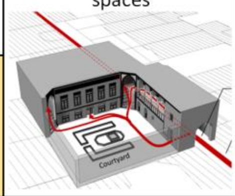
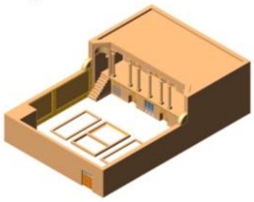
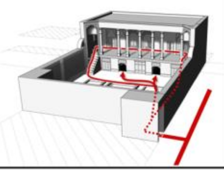
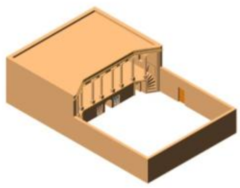
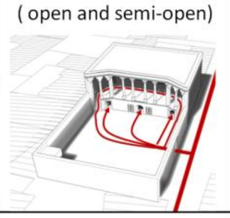
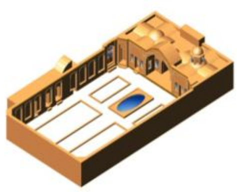
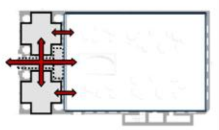
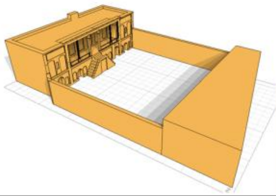
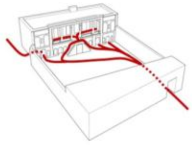
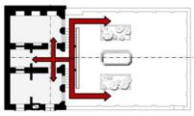
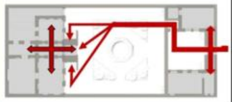
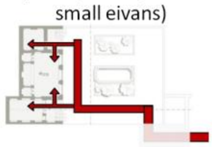
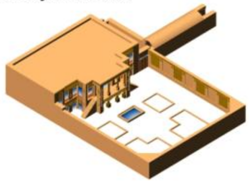
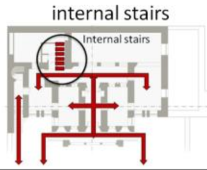
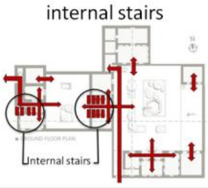
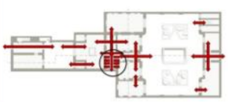
	Name of House	Date of construction/ Condition	Main Circulation spaces	Spatial diversity	Description(s)
Chahar-Soffe (Four Platform) Houses	**The Azimian House** 	Timurid period (1370-1506 AD) Currently in use -In good condition	Internal (closed space) 	**Low** (only closed spaces)	Minimum contact with the outside
	The Dareyni House 	Safavid period (1501–1722AD) demolished in 2005	Internal (closed space) 	**Low** (only closed spaces)	
Courtyard(s) Houses	**The Kian House** 	Qajar ~1900 in danger of demolition-needs an emergency renovation	Internal and external spaces 	**High** (open, semi-open, and closed spaces in different orientations)	Tend to use the semi-open spaces (vaulted and columned Eivans) as multifunctional spaces; living and circulation space and shading device in this region at the end of Qajar
	The Jafar-zadeh House 	Qajar ~1920 Under major renovation	External stairs with semi-open and closed corridor 	**Very High** different open, semi-open, and closed spaces in two zones and different orientations	
	The Baqani House 	Qajar ~1920 Currently in use – needs minor renovation	external spaces (open and semi-open) 	**Medium** the house contains different open, semi-open, and closed spaces but the living rooms are in the same situation.	
	The Amiri (Sadidi) House 	Qajar ~1920 Currently in use – needs minor renovation	external spaces (open and semi-open) 	**Medium** the house contains different open, semi-open, and closed spaces but the living rooms are in the same situation.	
	The Mashhadi House 	Qajar ~1925 Under minor renovation	Open and semi-open spaces (courtyard and semi-open corridor) 	**Medium** In spite of having all three types of spaces (open, semi-open and closed) but because of the small number of rooms the diversity of the spaces is not high.	

Table 7-2: chronological order of the cases (second part)

	Name of House	Date of construction/ Condition	Main Circulation spaces	Spatial diversity	Description(s)
Courtyard(s) Houses	**The Aldaqi House** 	Qajar ~1925 Under major renovation	external spaces (open and semi-open) 	**Medium** the house contains different open, semi-open, and closed spaces but all of the living rooms are facing to the east.	The use of the columned Eivan as living and circulation space and shading device
	The Afchangi House 	Qajar ~1925 Currently in use – needs minor renovation	External stairs with closed corridor 	**Low** The semi-open space of this house is used only as a circulation spaces. all of the living rooms are facing to the east in a wing.	The semi-open spaces (Eivan) lost their living function ;they turned into decorative elements and were only used as circulation spaces.
	The Moslem House 	Qajar ~1925 demolished in 2012	Open, semi-open and closed spaces (courtyard ,external stairs and closed corridor) 	**Very High** different open, semi-open, and closed spaces in two zones and different orientations	
	The Cheshomi House 	Qajar ~1925 demolished in 2014	Open and semi-open spaces (courtyard and small eivans) 	**High** the house contains different open, semi-open, and closed spaces in two wings	
	The Hejazi House 	early Pahlavi periods, around 1930 Currently in use – needs minor renovation	courtyard , closed corridors, external and internal stairs 	**High** the house contains different open, semi-open, and closed spaces in different size and orientation.	Start time of using the internal stairs to connect two floors
	The Mohammadiyani House 	First part Qajar ~1920- Second part Pahlavi ~ 1935 demolished in 2014	courtyard , closed corridors, external and internal stairs 	**Very High for the whole of the house but very low for the Pahlavi part** the houses contains different open, semi-open, and closed spaces in different size and orientation in two courtyards.	Using the courtyard and Eivan for circulation spaces in the Qajar part and using the internal stairs in the Pahlavi part confirms the evolution of the circulation spaces from outside to inside of houses in this region. -Elimination of semi-open spaces in the Pahlavi period
	The Eslami House 	First part Qajar ~1920- Second part Pahlavi ~ 1940 Currently in use – in good condition	courtyard , closed corridors, external and internal stairs 		

In the Qajar houses, access to the different rooms and spaces was mostly through the open air spaces; the courtyard and Eivan were the main circulation spaces. In the Qajar period, residents did not heat their rooms; they only provided heat for themselves by creating a micro-climate comfort zone in a room (Kursi) and wearing warm clothes. Little by little, by changing the way of heating at the end of the Qajar period the comfort conditions changed dramatically. Residents heated the entire rooms and stopped wearing warm clothes in the interior during the cold seasons. They disliked entering cold semi-open and open spaces when they moved between heated rooms. Around the Pahlavi period the semi-open spaces lost their role for circulation and were in some cases turned into a decorative elements (e.g. the Afchangi house) or were replaced by internal corridors (the Hejazi and the Pahlavi parts of the Mohammadiyani and Eslami houses).

The following plans (Figure 7-2) show how at the end of the Qajar period semi-open spaces were gradually eliminated and how this development affected the transition from the outside to the inside of buildings.

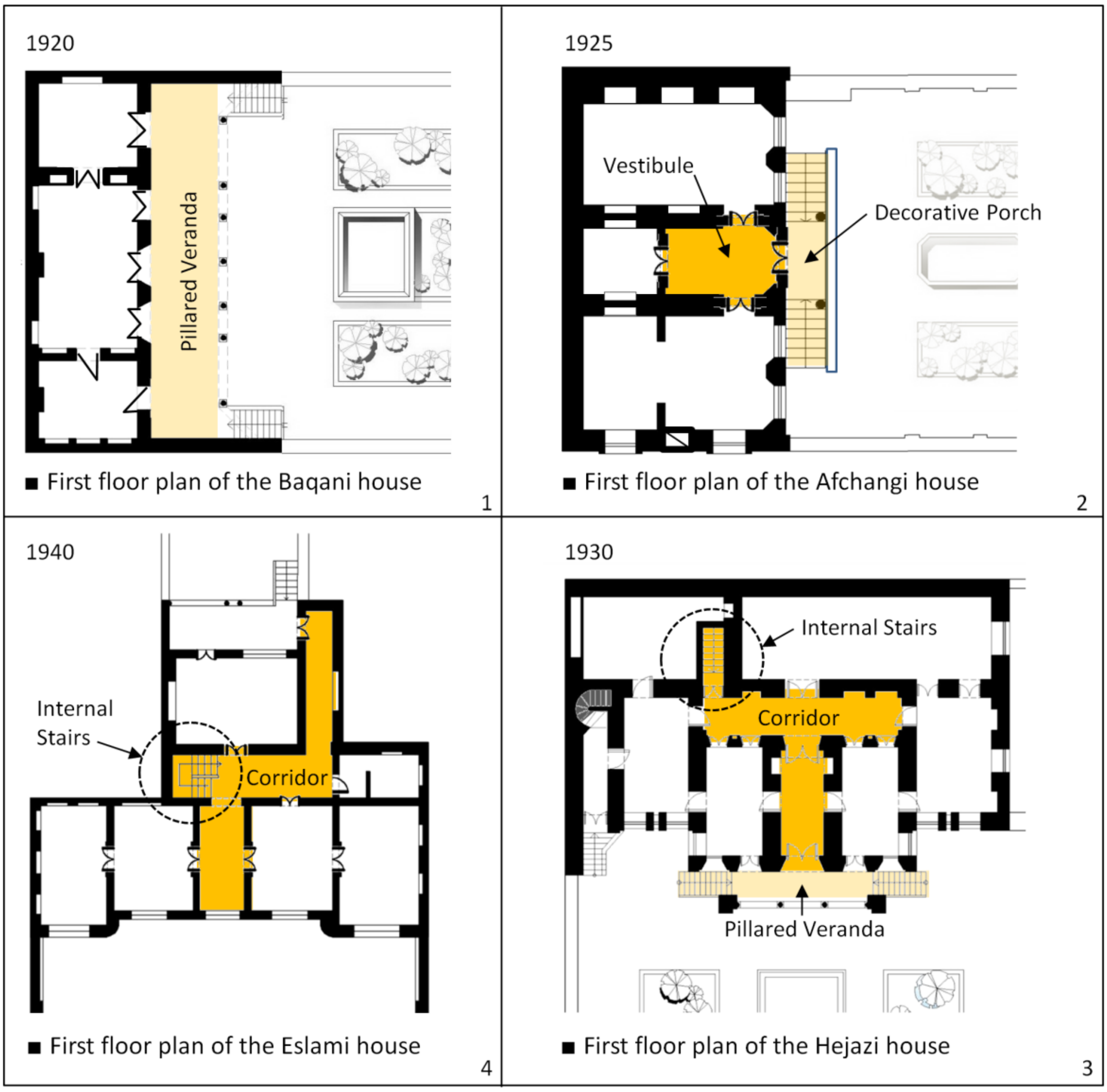


Figure 7-2: evolution of the circulation spaces from outside to inside of building

Due to the low price and abundant supply of oil in the Pahlavi period and the use of active heating and cooling systems, the complex passive strategies of traditional architecture fell into oblivion. Semi-open spaces used for shading gradually disappeared.

The elimination of semi-open spaces meant that building façades and windows were exposed to the direct sunlight. This change, along with the changes in size and proportions of windows under the influence of European architecture, changed the thermal performance of houses. In this superficial imitation of European architecture, the small windows were replaced by wide windows. The small walls which separate the traditional window-doors of the seh-dari and panj-dari (three and five door-rooms) acted as vertical shading devices, as a sort of brise-soleil, which was particularly effective to block solar radiation from the side and a low angle in the mornings and evenings. The loss of shade provided by verandas and a large amount of energy absorbed by glazed areas changed the thermal performance of the buildings for the worse. For this reason, the buildings from the end of Qajar and Pahlavi periods are warmer in summer and need active cooling systems for acceptable indoor temperature conditions.

The imitation of European architecture can be clearly seen in the Pahlavi part of the Eslami house. Even the roof of the house is galvanized iron notwithstanding the climatic conditions in Sabzevar. (Figure 7-3)

Mashhadi house (end of Qajar) | Afchangi house (end of Qajar) | Eslami house (first Pahlavi)

Figure 7-3: Changes in the size and proportions of windows under the influence of European architecture, source of photos: (Estaji, 2010)

The main changes of the courtyard houses in this region over time can be summarized as follows:

- location of the circulation spaces moved from open air to closed spaces
- change in the role of the courtyard
- transformation of the semi-open spaces from multifunctional and habitable spaces to decorative elements for circulation parts at the end of the Qajar period and complete elimination of semi-open spaces in the Pahlavi period
- moving from spatial diversity to simplicity; emphasis on closed spaces

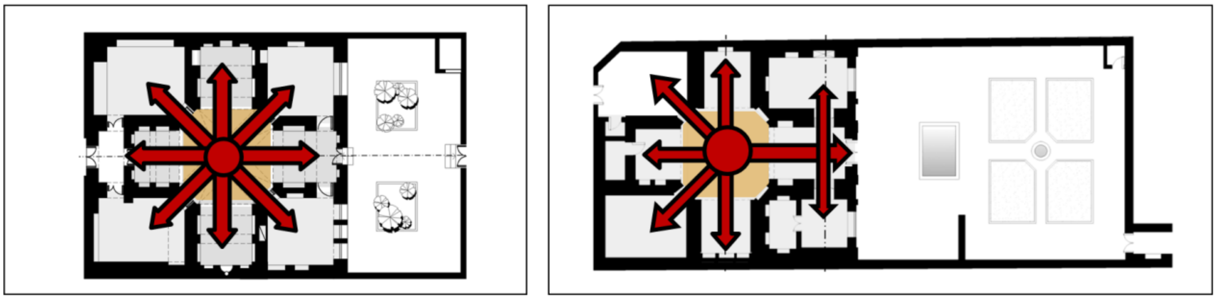
- the emergence of the internal staircase in the housing design from the beginning of Pahlavi period
- changes in the size and proportions of windows
- changes in the thermal performance of houses

7.2.1 Different House Types with regard to Circulation Patterns

Although most cases in this study are limited to a small geographical area (old part of Sabzevar) and a short time range (around the end of Qajar period) the circulation patterns of the analysed houses are very different. Access to the main living rooms is through different open, semi-open or closed spaces. The houses are classified according to the types and functions of circulation spaces below. In the Qajar period, the courtyard was the main circulation space that connected the building to the streets and provided access to the floors, storage rooms, toilets, and summer rooms on the ground floor. Later the courtyard gradually lost this important function. The following new classification of houses focuses on different patterns of access to main living rooms from the courtyard or entrance.

7.2.1.1 Internal Circulation

In this house type access to the main rooms is through a closed central space. The chahar-soffeh houses are the best example of this house type. The central domed rooms of the Azimian and Dareyni houses provide access to the inner Eivans and corner rooms. Access to the central room of the Azimian is through two Eivans from the outside; one of them connects the building to the alley and another one into the courtyard on the other side of building (Figure 7-4 left). In the Dareyni house, the building is accessed from the alley via a small corner yard, and an inner Eivan connects the domed room to the main courtyard (Figure 7-4 right).

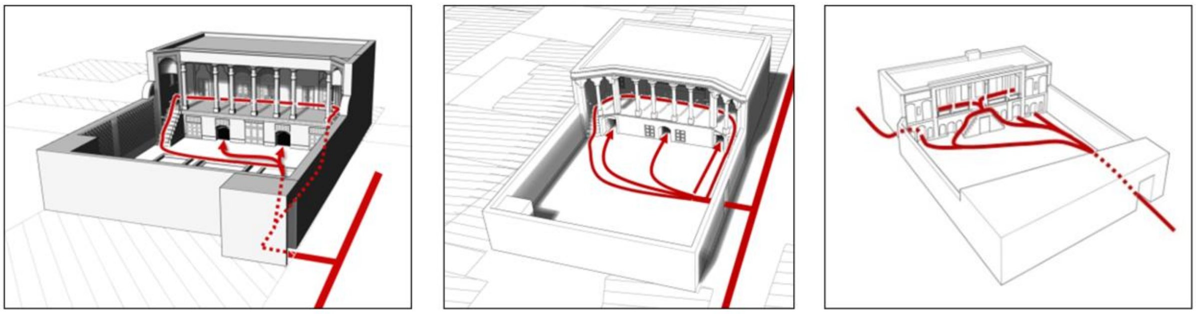


The Azimian House **The Dareyni House**

Figure 7-4: central domed room as main circulation space

7.2.1.2 Semi-open/ Multifunctional

In the Baqani, Amiri, and Aldaqi houses (Figure 7-5), of which all date from the 1920s (Qajar period), access to the main living rooms on the first floor is through a deep columned Eivan that is used as a living space in the hot and mild seasons. All of these Eivans face east, and they act as shading devices as well.

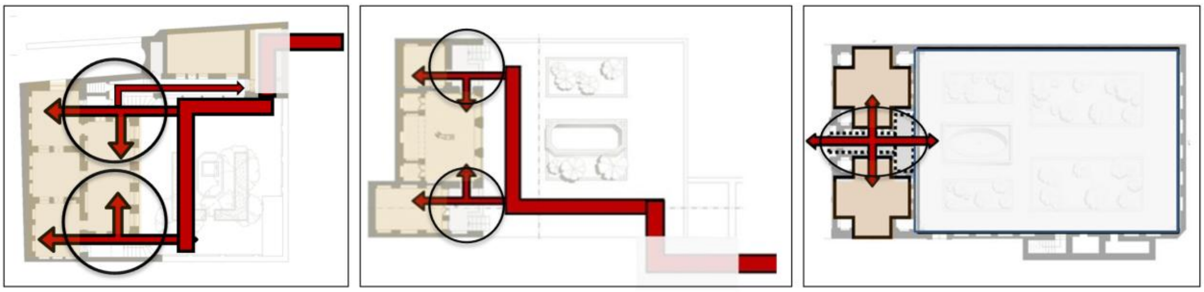


The Baqani House The Amiri (Sadidi) House The Aldaqi House

Figure 7-5: deep columned Eivans as circulation spaces

7.2.1.3 Semi-open/ Mono-functional

In this house type, small Eivans only provide access to the main rooms. Due to their small size they cannot be used as living spaces. Two symmetrical stairs under two decorated Eivans allow access to the Talar and rooms of the Kian and Cheshomi houses. In the Kian house, the north-vaulted Eivan is connected to another narrow pillared Eivan that is linked to some other rooms in the north wing (Figure 7-6). In the Mashhadi house, a small semi-open vestibule provides access to the main rooms from two sides.



The Kian House The Cheshomi House The Mashhadi House

Figure 7-6: small Eivans provide accesses to Talars and main rooms

7.2.1.4 Decorative Semi-Open Space along with Internal Corridor

In this house type, the Eivans lost their function as a temporary living room; they were turned into decorative elements and were only used as circulation spaces. An internal corridor connects the small Eivan to the main rooms. Figure 7-7 shows the connection of small Eivans and the internal corridor in the Afchangi and Moslem houses.

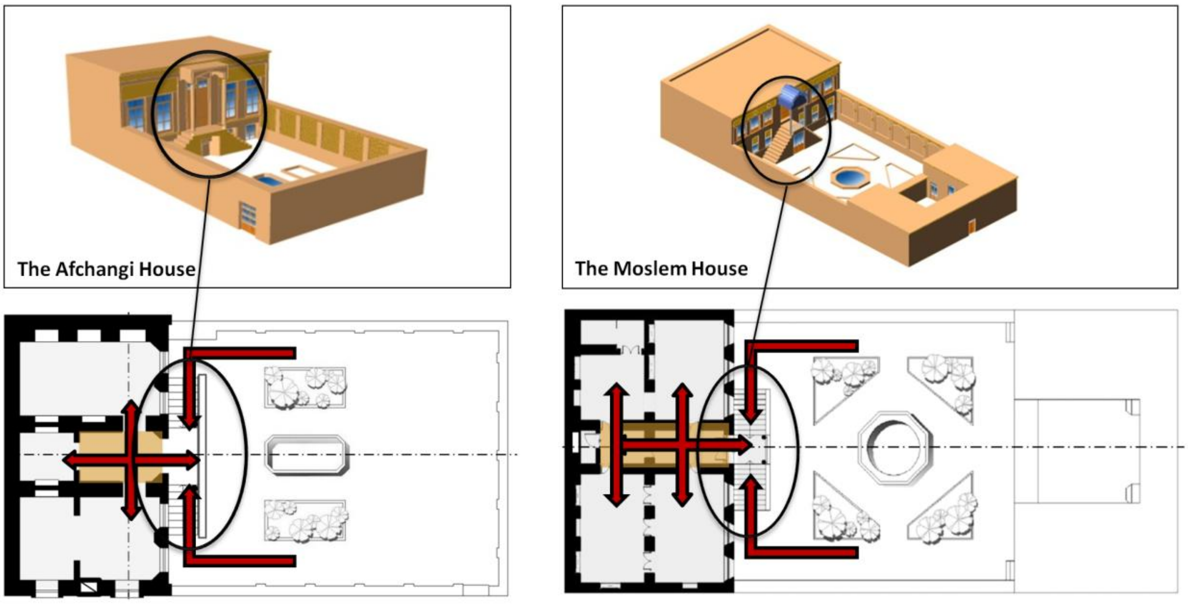


Figure 7-7: decorative Eivan and internal corridor of the Afchangi and Moslem houses

7.2.1.5 Internal Corridors

In this house type, horizontal access to the main rooms is given through internal corridors, with internal staircases facilitating the vertical connection between floors. In the Pahlavi parts of the Eslami and Mohammadiyani houses the internal corridors connect the rooms to the courtyards. The internal stairs provide access between floors and minimize contact with the open spaces. In this house type the main circulation spaces are limited to internal corridors; due to use of internal staircases semi-open spaces are no longer required as circulation spaces.

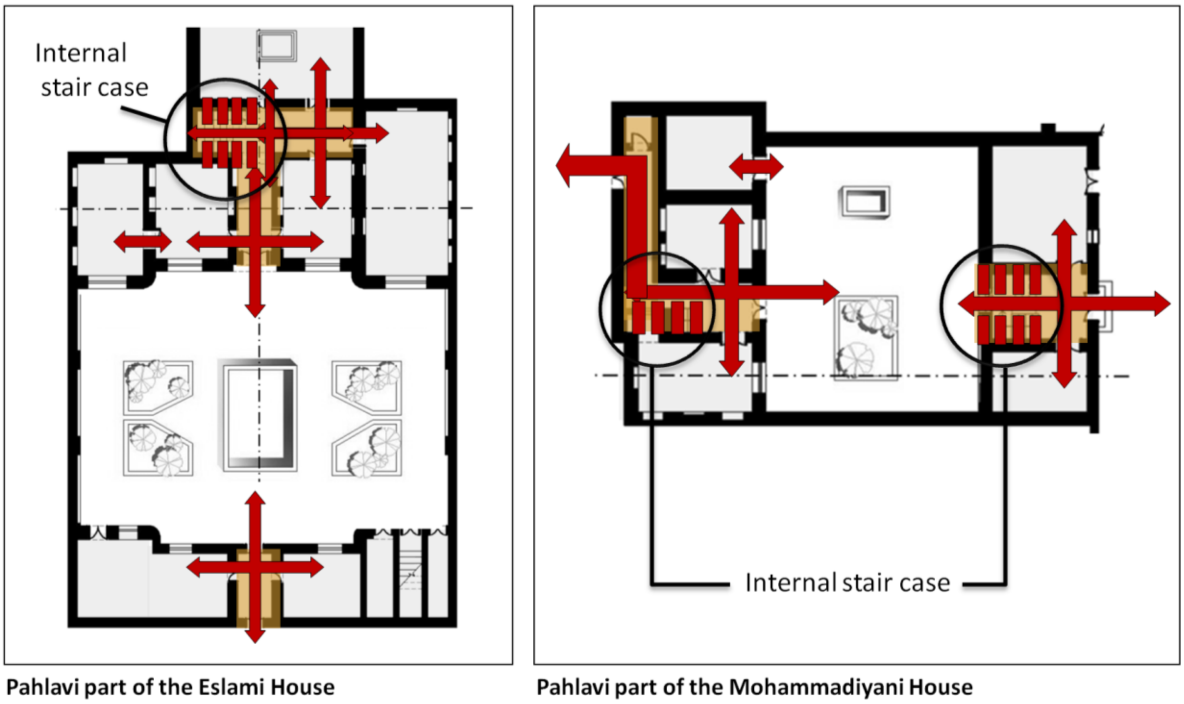


Figure 7-8: internal corridors and staircases of the Eslami and Mohammadiyani houses

7.2.1.6 Mixed Circulation Pattern

The vast and extended houses in the Qajar period applied different circulation patterns in different parts of the houses. The main circulation spaces of the Hejazi house consist of a two-story columned Eivan, T shaped internal corridors on the ground floor and first floor and an internal staircase (Figure 7-9 left). In fact, it is a collection of different circulation types. The other extended house is the Jafar-Zadeh house; the main circulation spaces include two columned Eivans, four semi-open vestibules, two exposed stairs, a terrace, and an internal corridor as a backbone for the main rooms (Figure 7-9 right).

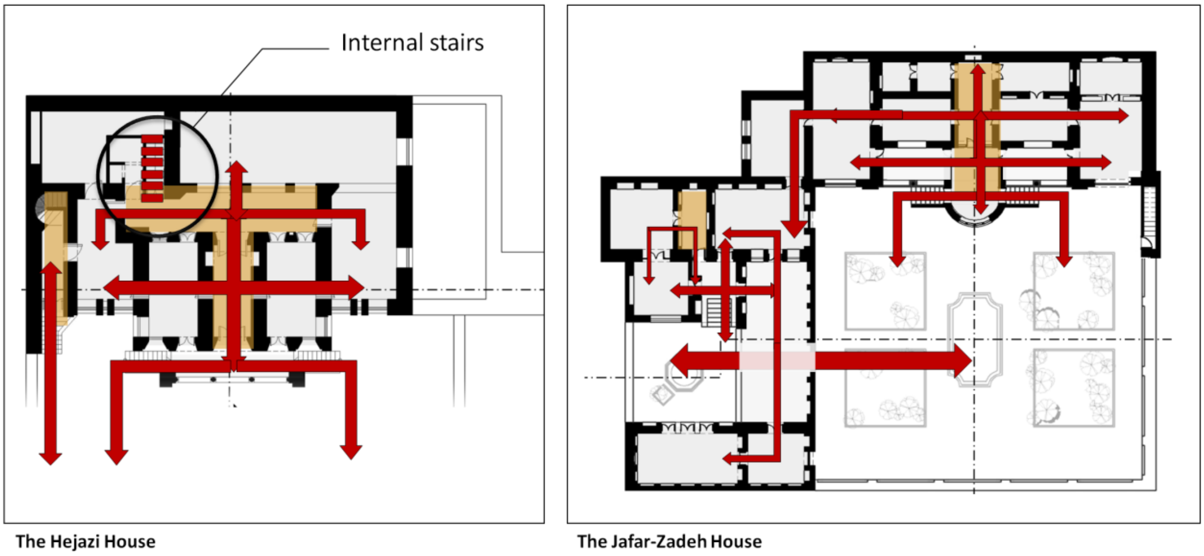


Figure 7-9: different circulation types in the Hejazi and Jafar-Zadeh houses

Although the circulation type of the Pahlavi parts of the Eslami and Mohammadiyani houses is internal circulation, all of the houses (including the Qajar part) have different types of circulation spaces. In these houses, in addition to the circulation spaces mentioned above; two terraces serve as outdoor circulation spaces. These terraces were used as living spaces in mild seasons too. These two extended houses are a collection of different open, semi-open and closed circulation spaces. Figure 7-10 shows the diversity of circulation spaces in them.

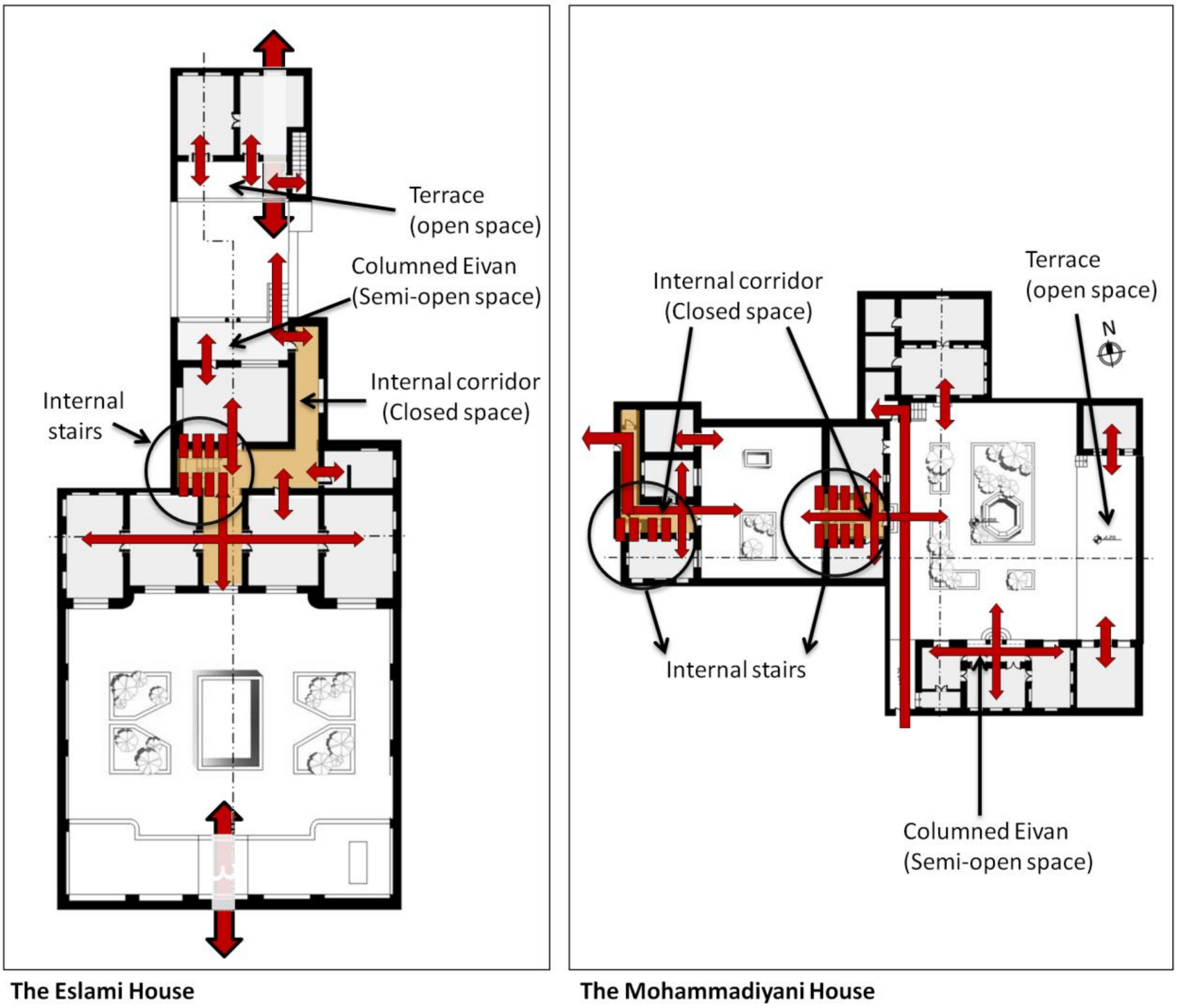


Figure 7-10: the diversity of circulation spaces in the Eslami and Mohammadiyani houses

7.2.2 Redefining the Semi-Open Space in Contemporary Housing Design

The main feature of the Qajar houses (before the late-Qajar period) was the existence of three types of open, roofed semi-open, and closed spaces side-by-side in a building. This feature can no longer be found in the contemporary houses in this area. People nowadays refuse to step into open spaces when they want to go to another room. For this reason, the semi-open spaces are not designed to be used as circulation spaces anymore. Semi-open spaces could also be used again in contemporary housing design with some changes for adaptation to the new situation and new needs of the residents.

To extend the use and improve the efficiency of roofed semi-open spaces which are used for shading in summer, they could be equipped with movable screens, shutters or glass panels that would transform them into closed spaces in winter. Some flexible and movable elements as described in chapter two (2.2.5 Flexible Façades) could serve this purpose. These flexible spaces would provide internal circulation spaces for winter time and shield them off from cold weather. They could also act as greenhouses in winter and help to warm up the building.

7.3 Evaluation of Houses in terms of Providing a Comfortable Indoor Climate by Passive Strategies

After the houses were ordered chronologically and classified according to the position of the building on the land plot and the type of circulation, the following question (based on the first research question of this study) arose: Which houses most efficiently provide a comfortable indoor climate by means of passive strategies? And which characteristics make them effective in this respect? An overall summary of the passive strategies used in each house helped to compare them and find the most efficient individual houses in cold and hot seasons.

The shape, the main orientation, and proportion of the building, relation to the ground, the position of open and semi-open spaces, window sizes and positions, materials, room height, ventilation and shading devices are the main characteristics determining the thermal behavior of buildings. According to the previous calculations in the fifth chapter the best orientation in Sabzevar is facing south and having an Eivan, east and north rank second and third, the least favorable orientation is to the west. The shape of the building is an important factor for thermal building performance with regard to the heat transferred from the surface of buildings. For this reason, minimizing the surface to volume ratio is a way to minimize energy losses. This factor represents compactness of buildings; the most compact building would be a sphere. Compact buildings minimize heat gain in summer and heat loss in winter. In this study it was impossible to precisely assess the surface to volume ratio of the buildings, because in many cases the original connection to the neighbouring houses no longer exists, that is to say, the extent and size of the exposed walls has changed. In general it can be said, that the characteristic traditional way of assembling houses in a high-density low-rise urban fabric reduces heat gains and losses.

The size of windows also affects the heat gain and loss: larger windows gain and lose more heat. Furthermore, the orientation of windows is a decisive factor for the amount of energy absorbed by them.

Another passive strategy used in traditional houses is building thick adobe and brick walls as thermal insulation and high thermal mass. Controlling the humidity (absorbing moisture and releasing humidity again) and moderating temperature peaks are other advantages of using earth walls in houses.

Control of direct sunshine by using roofed semi-open spaces such as the columned Eivan is a common strategy used in this region. Its effectiveness is analyzed in the sixth chapter by modeling the shading masks and calculating the effective shading coefficients (ESC) of façades behind the Eivans. In some cases, deciduous trees act as a variable shading device that provides shadow in summer, when it is needed, and allow the façades to benefit from the sunshine in winter. Additional methods used for passive cooling are earth cooling, evaporative cooling, stack ventilation, and high-ceiling effect.

Table 7-3 evaluates each of these characteristics one by one. All items are rated on five scales: very unfavorable, rather unfavorable, neutral, somewhat favorable, and very favorable. The table gives an overview over strengths and weaknesses of each house in providing a comfortable indoor climate for residents.

Table 7-3: main characteristics (passive strategies) that determine the thermal performances of houses

Name of House	Main orientation	Building proportion envelop to volume	Window sizes and positions	Thermal mass (wall thickness)	Shading (Semi-open spaces)	Vegetative shading	Earth Cooling	Evaporative Cooling	Stack ventilation	High-ceiling effect
Azimian	4	4	4	4	0	2	2	2	4	4
Dareyni	2	4	4	4	0	2	2	2	4	4
Kian	1	3	3	3	1	4	3	4	0	4
Jafar-zadeh	4	2	3	3	2	2	3	3	0	4
Baqani	1	1	3	3	4	3	3	3	0	4
Amiri (Sadidi)	1	1	3	3	4	3	3	3	0	4
Aldaqi	1	1	3	3	4	3	3	3	0	4
Mashhadi	4	0	4	4	2	2	2	3	4	4
Afchangi	1	2	2	3	0	2	3	3	0	4
Moslem	1	2	2	3	0	2	3	3	0	4
Cheshomi	1	2	3	3	0	3	3	3	0	4
Hejazi	4	3	3	3	4	3	3	3	0	3
Mohammadiyani (Qajar part)	3	1	3	3	2	2	2	2	0	3
Eslami (Qajar part)	3	1	3	3	2	2	4	4	0	3
Eslami (Pahlavi part)	4	2	1	2	0	2	2	3	0	3
Mohammadiyani (Pahlavi part)	0	1	1	2	0	2	2	3	0	3

0	1	2	3	4
Very Unfavorable	rather Unfavorable	Neutral	Somewhat Favorable	Very Favorable

The most compact houses with small windows and very thick walls are the Azimian and Dareini houses. These characteristics give them great potential to save heat in winter; thanks to the symmetrical shape of the houses and small size of the windows, the main orientation has little effect on the thermal performance of the Chahar-Soffeh house type. The compact massing and the use of small windows minimize heat gain in summer, and the thick walls and roof protect indoor spaces from the sun and act as thermal mass. The Tambour windows on four sides of the central dome facilitate natural ventilation (stack ventilation) in hot and mild seasons.

The main wing of the Kian house is a compact building facing east without any Eivan. The Kian house controls the direct sunlight by using trees and high walls as shading devices. The trees also increase the humidity of the yard; this humidity and evaporation of the water from the pool into the air provides an energy-efficient cooling system.

The main concept of the Baqani, Amiri, and Aldaqi houses are very similar; they are linear houses facing east with a deep columned Eivan. Their orientation and proportions are their weaknesses in cold seasons. The strengths of this house type are controlling the direct sunshine by using the deep semi-open space and benefiting from the earth-cooling phenomena on the semi-underground floor. This house type is successful in providing comfortable indoor climate by passive cooling strategies on hot days but not on cold days.

In the Mashhadi house proper orientation, small openings, and thick walls and roofs minimize energy losses in the winter but the unfavorable ratio of envelope to volume is a weakness of this house. The roofs of the main rooms are high: the effect of high ceilings and natural ventilation from the openings in the dome lantern, respectively, (stack ventilation) are two successful passive cooling strategies on hot days.

The Afchangi house and the main parts of the Moslem and Cheshomi houses are linear houses facing east with only small decorative Eivans. The main weakness of this house type is that there are no significant shading devices to protect the windows and façades from direct sunshine on hot days. In summe,r these houses benefit from the high ceiling effect and earth-cooling phenomena. The residents of Moslem house also moved seasonally between the summer and winter rooms.

The Hejazi house combines different passive strategies (except stack ventilation). The compact layout of rooms and an internal corridor and staircase allow it to effectively save energy on cold days. The use of columned Eivans on the first and second floors as shading devices is another strength of the house.

The Qajar parts of the Mohammadiyani and Eslami houses contain south and north facing wings. The rooms are located in two separate parts, which means that the ratio of envelope to volume is high. There is an Eivan in the south part of each house; due to their orientation to the north they do not serve as shading elements, but as shelters on rainy days.

There is a small pool on the underground floor of the Eslami house; the evaporation of water cools the air. The combination of evaporative cooling and earth cooling provides a comfortable indoor climate on hot days in this part of the house.

The thermal performance of the Pahlavi parts of the Eslami and Mohammadiyani houses is dramatically different from the older house parts. The exposed façades (without any shading devices), the large amount of heat gain and loss due to wide windows, the slender, linear shapes of the buildings, thinner walls and roofs, and lower ceilings make them warmer in summer and colder in winter compared to the Qajar houses.

The lack of attention given to experiences of previous generations is clearly evident in these Pahlavi houses. The simplest principle of traditional architecture in this area was avoiding the

west orientation. This is a point that was completely neglected in the Pahlavi part of the Mohammadiyani house.
The general conclusion we can draw is that the oldest houses are the most efficient in terms of providing a comfortable indoor climate by means of passive strategies.

7.4 Evaluation of Houses in terms of Flexibility and Adaptability

The future is unknown; architects and researchers cannot say definitively what kind of demands a building will face in the future. The only way to assess the flexibility of a system is to measure the total number of possible scenarios that may occur in the future.
As long as cultural concepts and ways of living developed at a slow pace, traditional houses were able to respond to these changes by modifying the relationship between spaces. A sudden increase in population, rapid economic growth, and change in family structures challenged this flexibility in responding to new needs. Rapid changes happened in two stages; around 1975, the municipalities commissioned a master plan for Sabzevar with the goal of widening the streets in the city and making them suitable for individual motor car traffic. The urban fabric was cut by new streets, some of the old buildings were demolished and the layout of existing neighborhoods was changed. The second phase began around 2000 when the common types of courtyard houses were replaced by multi-story apartment blocks. There are many traditional houses that require a higher level of flexibility to cope with, and adapt to, these rapid changes.
The studies of the relationship of different spaces in the individual buildings by means of the Space Syntax methods confirm that an important aspect of the houses in terms of flexibility is the maximum selective connectivity between rooms. The first indicator for evaluating the flexibility of a system is its size. A house with a large number of spaces, especially multifunctional rooms, can respond better to predictable and unpredictable changes. Figure 7-11 shows the number of spaces and the number of multifunctional rooms for each case. The Mohammadiyani and Jafar-zadeh houses with forty-five spaces including the main rooms, service rooms, yards and circulation spaces are the largest houses among the buildings investigated. They have nineteen and sixteen multifunctional rooms. And at the end of the list we find the Dariyni and Mashhadi houses with fourteen spaces. What is remarkable is that the Dareyni house has eight main rooms, while the Mashhadi house has only two rooms.

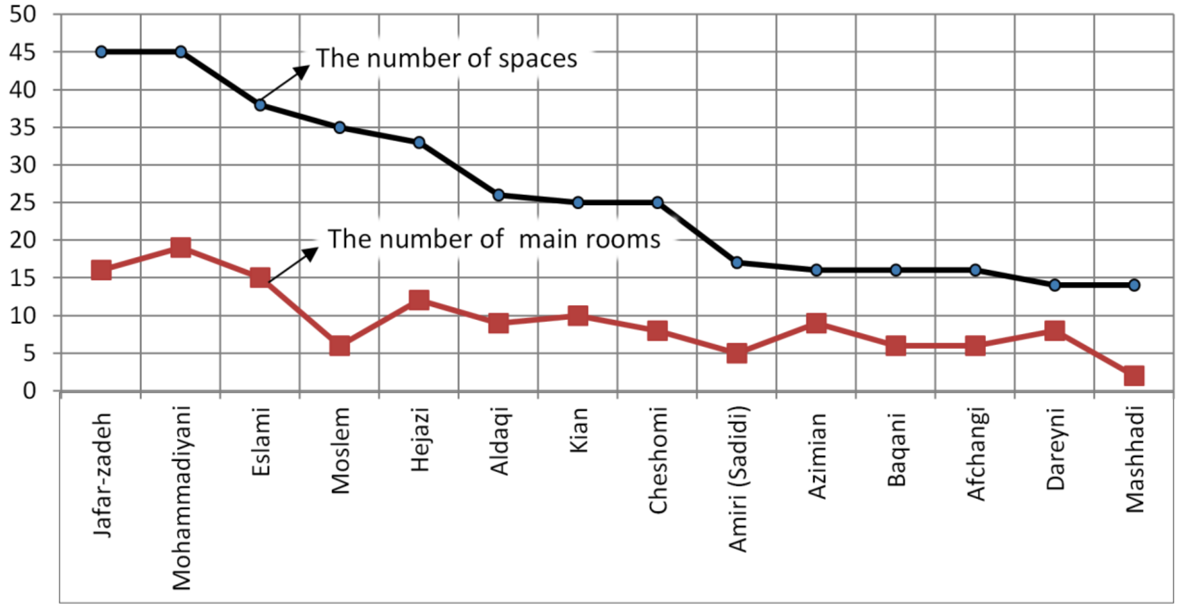


Figure 7-11: the size of houses according the number of spaces

The large numbers of service and circulation spaces and the different ways to access rooms certainly allow different arrangements of spaces and thus increase the flexibility of the system, while at the same time reducing the efficient use of spaces. Table 7-4 calculates the ratio of living spaces to the entire spaces for all of the studied houses. The percentages for the Dareyni and Azimian houses are 57 and 56, respectively, while this ratio for the Mashhadi house is only 14 percent.

Table 7-4: Spatial configuration of houses

Name of House	Number of spaces	number of main rooms	ratio of living spaces to the entire spaces	maximum connectivity/ Space	Mean Connectivity	Mean Connectivity of main rooms	Number of loops- Considering the potential openings	Distributedness (Convex ringiness) Considering the potential openings
Azimian	16	9	56%	Central Space (8)	2.5	2.75	7	0.26
Dareyni	14	8	57%	Central Space (6)	2	2.25	5	0.22
Kian	25	10	40%	courtyard (7)	2.36	3	9	0.2
Jafar-zadeh	45	16	36%	courtyard (11)	2.47	2.33	10	0.12
Baqani	16	6	38%	courtyard (6)	2.56	3	9	0.33
Amiri (Sadidi)	17	5	29%	courtyard (7)	2.41	3	8	0.28
Aldaqi	26	9	35%	courtyard (11)	2.41	2.42	8	0.17
Mashhadi	14	2	14%	courtyard (8)	2.5	5	4	0.17
Afchangi	16	6	38%	courtyard (5)	2.06	2.5	7	0.26
Moslem	35	6	17%	courtyard (8)	2.43	2.1	8	0.12
Cheshomi	25	8	32%	courtyard (8)	2.04	3	7	0.16
Hejazi	33	12	36%	courtyard (8)	2.82	3.5	19	0.31
Mohammadiyani	45	19	42%	courtyard (8)	2.18	1.63	8	0.09
Eslami	38	15	39%	courtyard (6)	2.31	1.57	8	0.11

The number of openings to the main living rooms is another indicator for evaluating the flexibility of a building. Thanks to a large number of openings (doors) to the rooms the residents are able to alter the arrangement of the spaces if the need arises. The most integrated spaces with maximum connectivity in all of the cases are the courtyard and the central domes of the Azimian and Dareyni houses. (Table 7-4)

The following chart (Figure 7-12) compares the mean connectivity of all spaces with the mean connectivity of main rooms. There is no significant difference between the mean connectivity of houses; they range from 2.82 (Hejazi) to 2 (Dareyni). However, there are remarkable differences inthe mean connectivity of the main rooms; they range from 5 (Mashhadi) to 1.57 (Eslami). Figure 7-12 classifies the houses according to the mean connectivity of main rooms.

There are only two main rooms in the Mashhadi house with five openings to each room. Three different ways provide access to the rooms; from the interior vestibule, the Eivan, and the courtyard. The Mashhad building is an exception among the houses, being a large building with only two living rooms. The Hejazi house ranks second; it is a large house with twelve rooms with an average of 3.5 doors to each room. The Baqani, Amiri, Kian, and Cheshomi houses with an average of three doors to each room rank third. Two houses from the Pahlavi period, Mohammadiyani and Eslami houses, with an average of 1.63 and 1.57 doors to each room rank lowest. It can be concluded that by changing the way of how families live together the spatial concepts of houses changed dramatically. the organization of rooms changed from nested spaces to independent rooms in the Pahlavi Period.

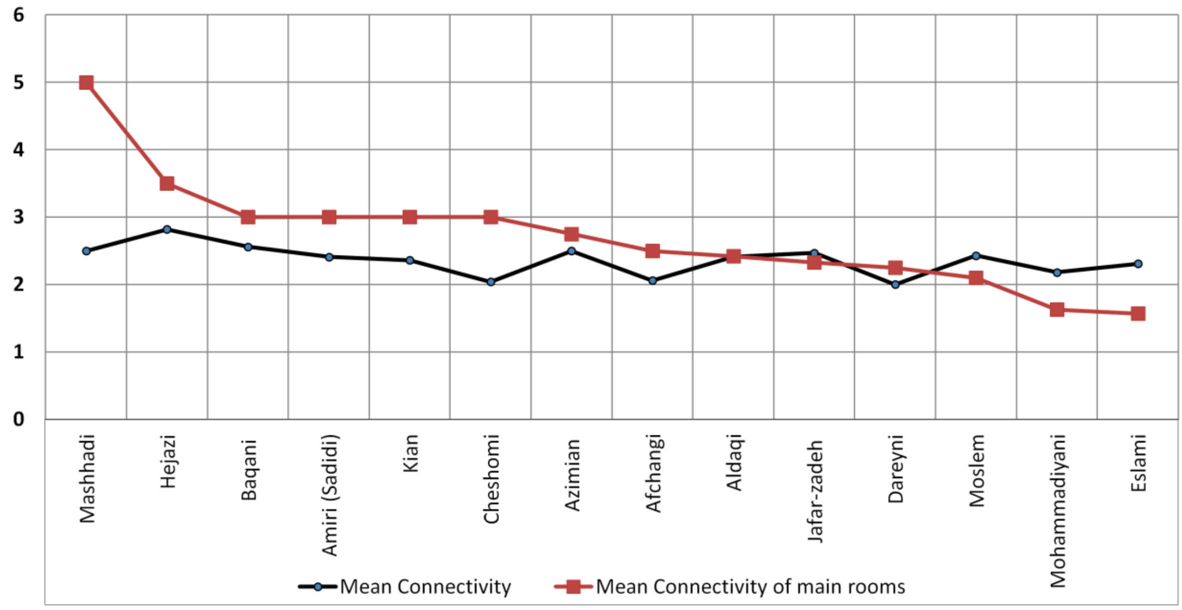


Figure 7-12: the average of doors (opening) to each space and room

A house with a large number of loops can better rearrange its configuration by locking some doors (loops) and provide access via another loop.

There are nine loops in the Baqani house that has only sixteen spaces, while two large Pahlavi houses, the Eslami and Mohammadiyani houses, with 45 and 38 spaces have only eight loops.

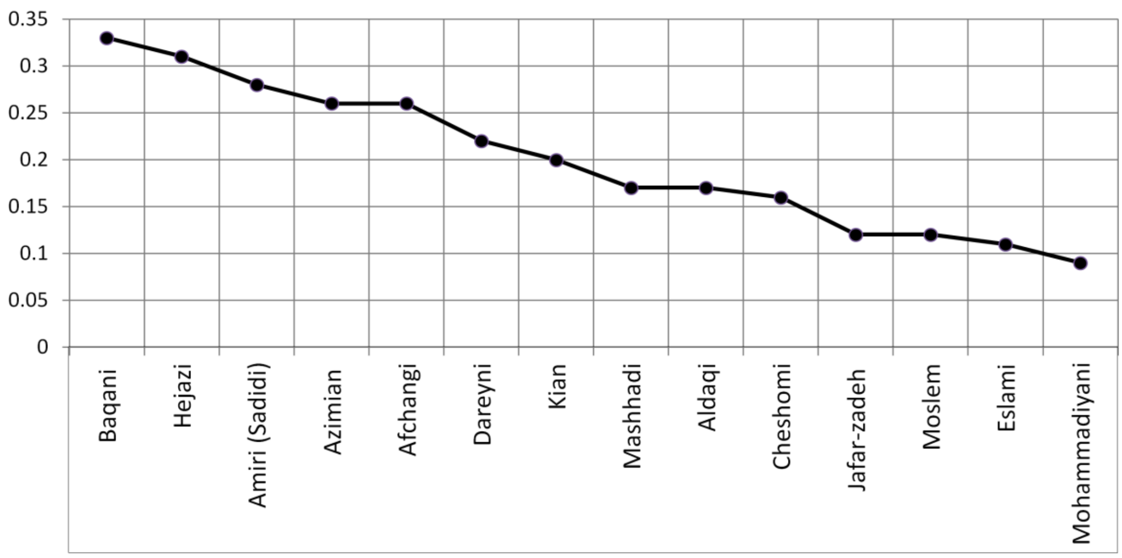


Figure 7-13: Distributedness (Convex ringiness) considering the potential openings

For better comparison of the cases, the size of houses, the mean connectivity of main rooms, the distributedness of the system (Convex ringiness), and the efficiency of space use (high ratio of main spaces to ancillary spaces) are normalized. It helps to group the houses according to these indicators. The following charts (Figure 7-14) present the different house types according to their spatial configurations. The first group is small houses with the maximum efficiency of space use and high distributedness. The Azimian and Dareini houses are included in this group (Figure 7-14, a). The Baqani, Amiri, and Afchangi houses (group b) are small houses with very high distributedness and acceptable connectivity and efficiency. Group c comprises three medium-sized houses where all indicators are located in average conditions. Two Pahlavi houses, the Mohammadiyani and Eslami houses, and the Jafar-zadeh house (from the late Qajar period) are the largest houses among these cases. In terms of space use they score highly, but their spatial configurations are not flexible at all. The houses scoring worst regarding the efficiency of space use are the Moslem and Mashhadi houses; there are a lot of circulation and service spaces for few living rooms. The Mashhadi house has the maximum connectivity among the analysed houses and acceptable distributedness, while the spatial configuration of the Moslem house is not flexible. The most flexible spatial configuration according to the above indicators can be found in the Hejazi house (group g); a medium-sized house with high connectivity and great distributedness.

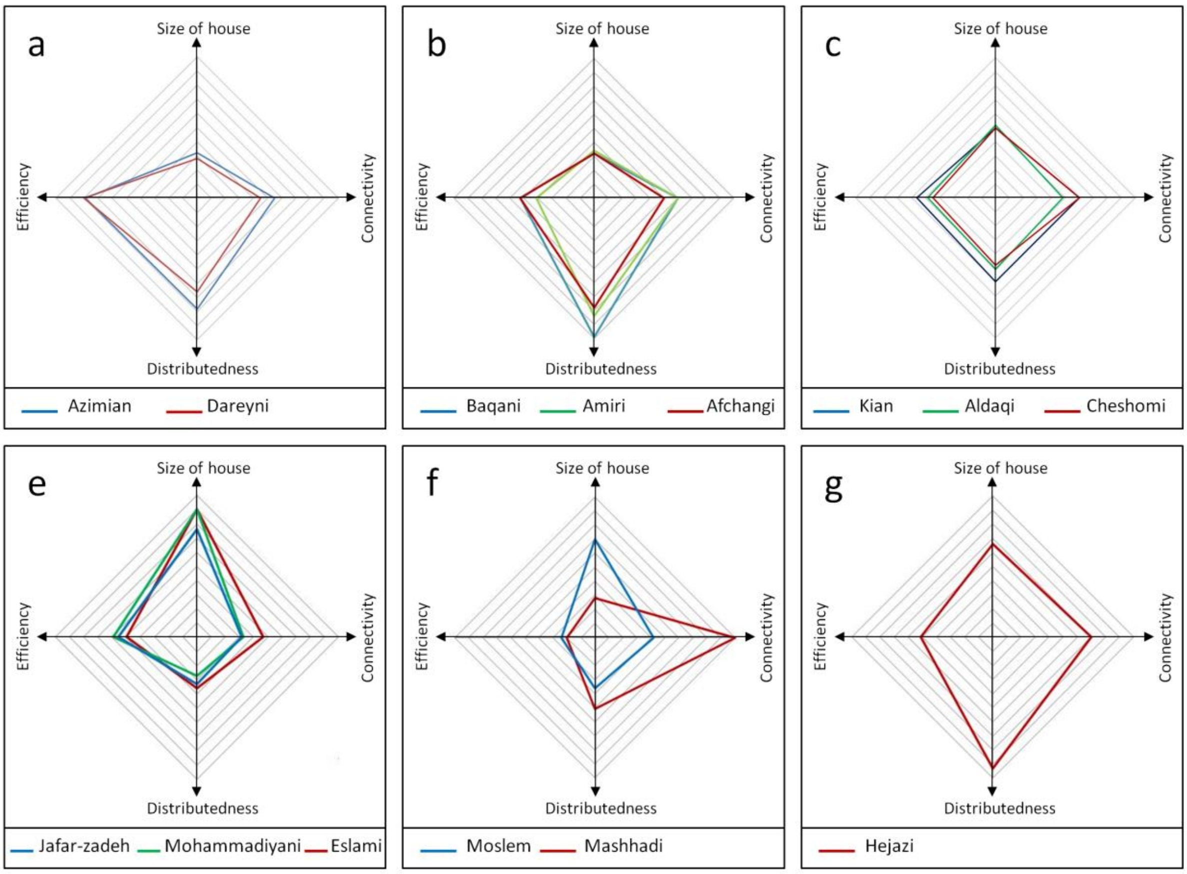


Figure 7-14: different house groups according to the spatial configurations

The multifunctionality of spaces (rooms) is a common characteristic of traditional houses in this region. Traditional Iranian houses are space-based as opposed to furniture- based; there was no fixed furniture in the rooms, so the residents could easily change the function of rooms as needed. It is important to mention that this strategy arose from the simple traditional lifestyle before the modern period. Nowadays, people tend to cook in fully equipped kitchens with fixed shelves, refrigerators, and cooking equipment or sleep in a bedroom with large beds. It means that the buildings studied here were flexible buildings in the past, but it cannot be expected that now with the new needs of residents this strategy is still viable.

The higher scale of multifunctionality allows changing the function of a part of a building or the entire building. Some of these houses have experienced these changes in their lifecycles. A wing of the Aldaqi house was converted from storage space into commercial premises. The Kian house was transformed into a bank office about a hundred years ago. The functions of the Mashhadi and Eslami houses were changed several times. The multifunctionality of the building scale is an important factor in extending the lifespan of buildings and saving them from demolition. In the next part (8.6 Demolition Process) this issue is discussed in detail.

Expandability and shrinkability are other indicators for assessing the flexibility of buildings. The Mohammadiyani and Eslami houses were expanded horizontally by connecting them with neighboring courtyard houses. The Aldaqi house was extended by adding one more story to the ground floor. Due to the weak structure of the old buildings another vertical expansion would require substantial structural reinforcements and is out of the question for financial reasons. Also, the historical value of the houses makes it impossible to make major changes in the structure and the main design of the building.

New lifestyles require new spaces; residents nowadays prefer closed spaces for moving between rooms and building floors and expect private toilets and bathrooms. It requires a great deal of proficiency, inventiveness and architectural sensitivity to integrate internal staircases and wet rooms into the old structures without destroying the proportions and beauty of the main spaces. Especially the service spaces lend themselves to accommodating these new facilities. In the best-case scenario, there is a vacant lot available where stairs and sanitary spaces can be built. This addition can also service another part of the building. (Figure 7-15)

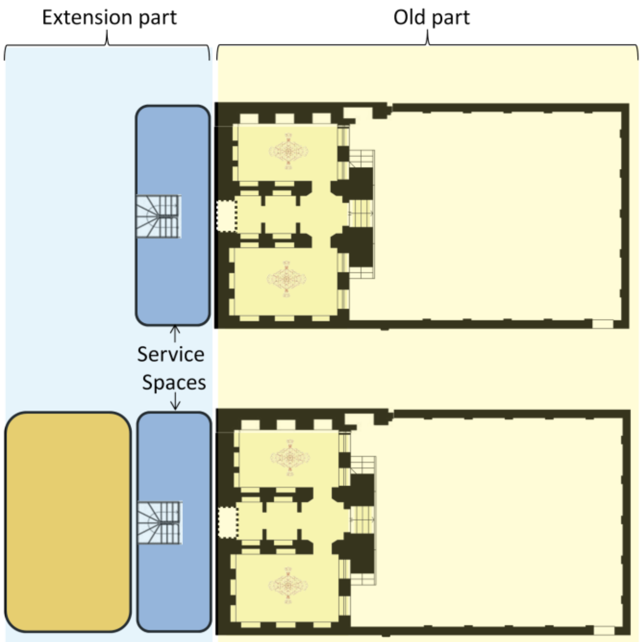


Figure 7-15: adding new service spaces to the old building

Shrinkability (divisibility) was one of the main features of flexibility in traditional houses. Until the Qajar period a household consisted of the extended family that comprised several generations; the grandparents, parents, married sons and their wives and children. They lived in a large house with shared kitchen, storages, and service rooms. Any changes in the size and structure of the family (such as marriage) required new spaces. The residents could divide the large houses into smaller units for new members of the extended family by locking some doors or blocking some openings by means of walls.

The divisibility of a house depends on the house size, the layout of spaces (spatial configuration), and the number of floors and wings. The main concept and spatial configuration of the Azimian and Dareyni houses make it impossible to split them into smaller units. The Mohammadyiani and Eslami houses consist of different separated parts (wings) in two courtyards; this layout of spaces enables the houses to be divided into separate parts easily. The Kian and Jafar-zadeh have different wings and can be split up with minor modifications. The Hejazi house is a compact house without wings but the large number of openings and the flexible spatial configuration facilitates division by blocking some doors.

When in the last decades the structure of households changed from extended to nuclear families and smaller flats were required, it seemed, at first glance, that the large houses could be easily subdivided into smaller units for unrelated families. Nevertheless, with the exception of one case (the Mohammadiyani house), this never happened. The Mohammadiyani house was divided between the heirs of the family for a few years. However, this change did not preserve the building. The young generation of the residents of Mohammadiyani house wanted to live completely separate from the older generation and did not want to share any spaces with them. The house was demolished in 2014 and was replaced by a new apartment block.

It can be concluded that the divisibility was a successful strategy in the past, but this strategy no longer works in the current situation for preserving old houses.

7.5 Demolition Process

The following charts (Figure 7-16) depict a general lifecycle scheme of buildings. Non-flexible houses reach their maximum performance shortly after construction. Then due to the increasing age of the building, as well as the changing needs of users a downward trend begins. This process continues until the building value falls below the price of the land plot. After this critical point, the house is in danger of being demolished because it is profitable to tear down the old building and replace it with a new one. Flexible buildings can be adapted to the new condition with minor changes. This changeability helps residents to use the buildings for a longer time.

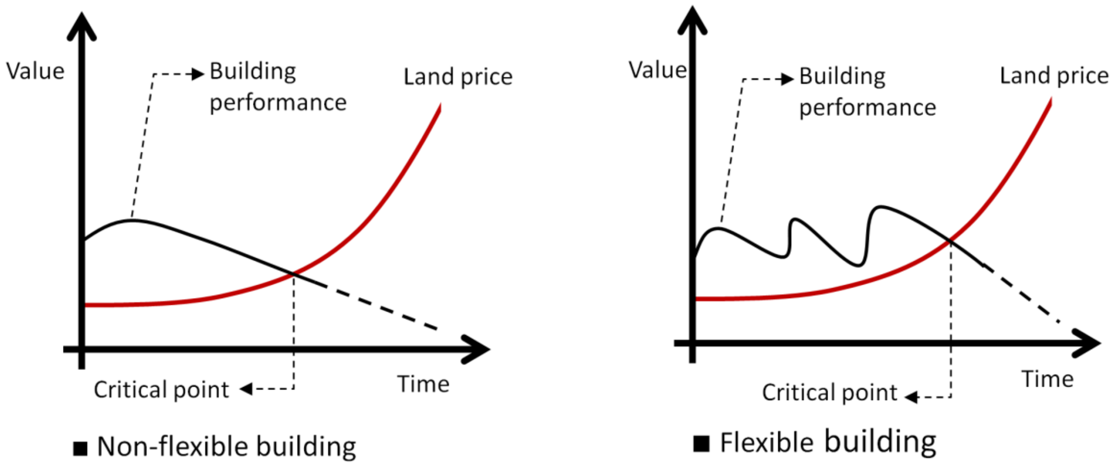


Figure 7-16: the life analysis of flexible and non-flexible buildings

The following diagrams (Figure 7-17) show what will happen to an old building when it no longer serves the needs of residents. There are two options then - either renovation or demolition.

The value of the renovated building must be more than the sum of the land price and renovation costs. Otherwise, the renovation is not cost-effective, and the landlords will consider demolition.

The costs of replacing an old building with a new one include the demolition costs, costs for building permits, and construction costs. As soon as the value of units that will be built exceeds the sum of the land price and other costs, demolition becomes a real option.

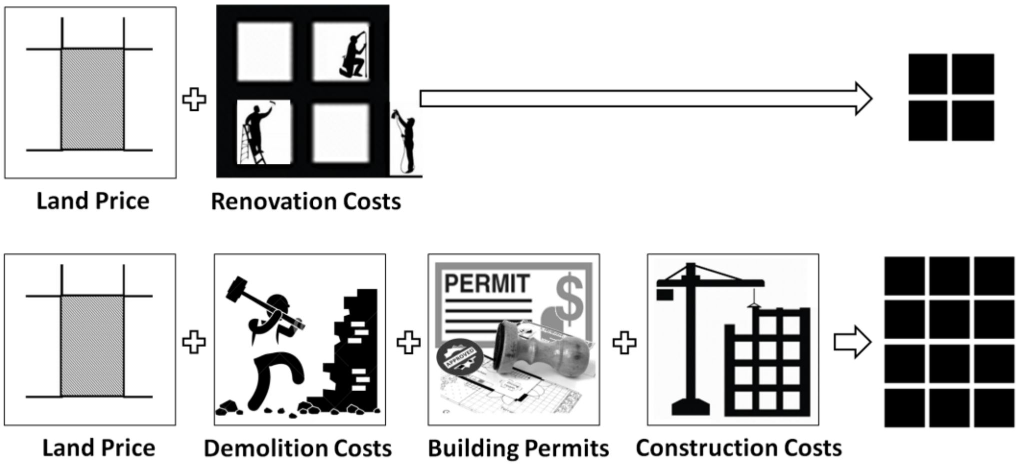


Figure 7-17: renovation or demolition

There is yet another alternative for adapting old buildings for contemporary use – house expansion. Instead of adding fundamental changes to the old structure, a new part is added. As in previous methods the value of the renovated and added building must be more than the sum of the price of the old plot and the added land, renovation costs, building permits, and construction costs. (Figure 7-18)

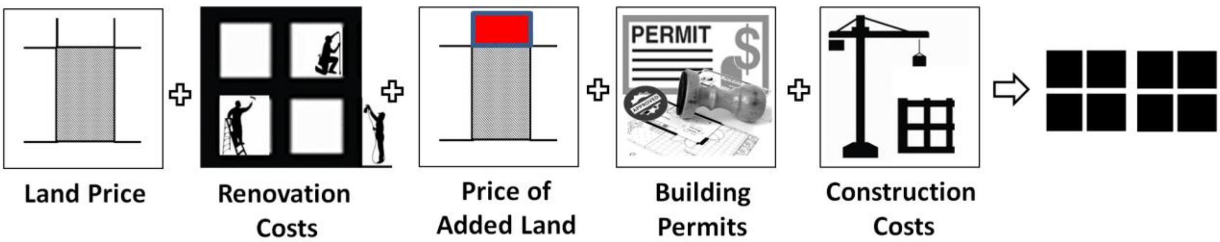


Figure 7-18: house expansion costs

The old houses need a higher level of flexibility to overcome the steep increase in land prices. In all of the above examples, the value of the renovated or added buildings is a main determining factor in preserving old buildings. One way to increase the value of a building is changing the function of it. The study on the traditional houses in Sabzevar confirms that multi-functional buildings can survive better than mono-functional ones. One effective strategy can be to change the function of the building from residential to commercial. This change increases the value of the building; such a move can also serve as a way to motivate the owners to maintain the buildings. (Figure 7-19)

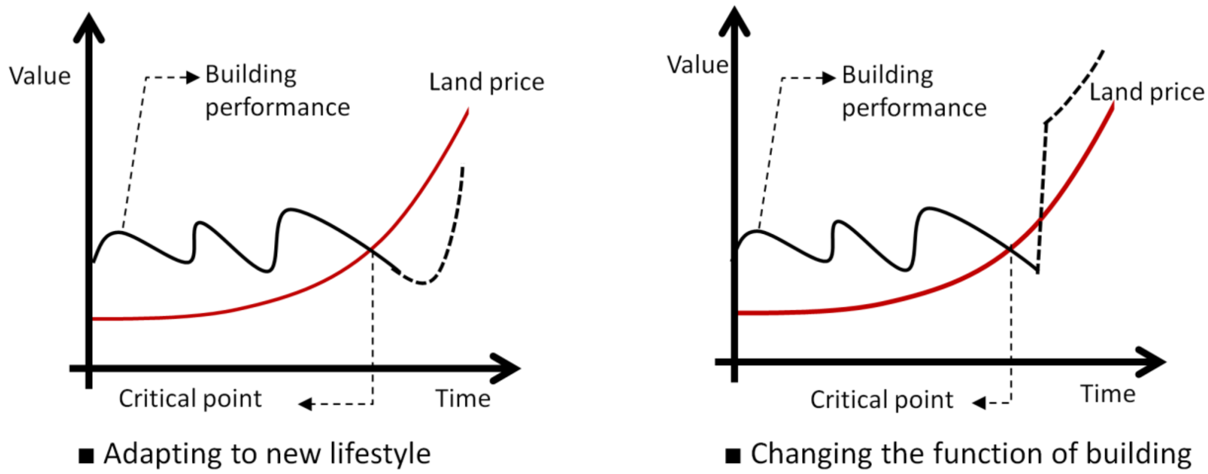


Figure 7-19: different levels of changes in flexible buildings

7.6 A Suggestion for Municipal Authorities and Cultural Heritage Organization

In all of the above calculations there is a missing factor, namely, the cultural, historical and social value of traditional building. The first duty of municipal authorities, Cultural Heritage Organization, NGOs and elite people is to make people aware of this valuable factor. The Azimian house is a successful example that shows how an old house can be preserved by a wealthy family with some cultural awareness. In addition to public awareness, public funding for restoration is a motivation for house owners.

The current laws do not allow house owners to modify the function of their houses, to make major changes or demolish the buildings that are registered in the list of Iranian cultural heritage.

The building height in central urban areas and the neighbors of the registered traditional houses is limited by the authorities in development plans; this facilitates the preservation of traditional architecture. But on the other hand, the house owner can ask the national court to remove the house from the list. In this case, the government must buy the house in six months or let the court to remove the house from the registered list. Unfortunately, due to limited financial resources, only a limited number of buildings are bought by the government.

In addition to asking the court to remove the building from the list, if they are not willing to maintain their buildings, they will find a way to circumvent the law. The usual procedure in these cases is to destroy the roof drainage and abandon the building, leaving the rain to complete the destruction process. Outside pressure to conserve the historic building is not a lasting solution to the problem. The best way is to change the function of houses from residential to commercial.

By removing administrative barriers and rigid legal rules and providing some financial incentives, local authorities can encourage the house owners to preserve and maintain their buildings. If people found that registration of a house on the cultural heritage list is beneficial to them, they would welcome it.

Some of the large traditional houses in Sabzevar such as the Aldaqi, Hejazi, Eslami and Jafar-Zade examples have the potential to be converted into stand-alone commercial units, but the use of small houses as commercial units is not so cost-effective for the house owner. All of the traditional houses in Sabzevar could be united under a single management. In this model each building supports the others, thus reducing operating costs and increasing the variety of functions.

Flexibility and multi-functionality were the main features of the buildings that have proven conducive to changes and protection from demolition. Once again, these two factors can be used for planning the new network of traditional houses.

Possible alternatives to residential use include uses as boutique hotel, restaurant, conference space, art gallery, small museum, educational and cultural center, workshop for production and supply of handicrafts and similar functions. Due to the fluctuations in the number of visitors in different seasons, the functions of the buildings must be flexible. For example, the spaces can be used for tourists in the high seasons and provide services, e.g., organizing local festivals, cultural exhibitions, and educational workshops to the local people in the low seasons. This strategy increases the flexibility of the system with respect to unknown and unpredictable changes in the future.

Feasibility studies based on statistical data of current and targeted visitors (tourists) and local users are required to elaborate a development plan for all of the houses. This plan will define the role of each house in the group.

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List of Figures

List of Tables

Appendix A

Appendix A 1: the Afchangi house

THE AFCHANGI HOUSE									
Space	Function	Type of Space	Seasonal Use	Privacy	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Courtyard	Courtyard	Open	All	Common	5	154	1.28	0.89	1.12
Vestibule (0)	Circulation	Close	All	Family	4	106	0.88	1.30	0.77
Vestibule (1)	Circulation	Close	All	Common	4	106	0.88	1.33	0.75
Eivan	Circulation	Semi-Open	All	Common	3	112	0.93	1.09	0.92
Stair (1b)	Circulation	Open	All	Common	2	57	0.47	0.99	1.01
Stair (1a)	Circulation	Open	All	Common	2	51	0.43	0.99	1.01
Stair (0)	Circulation	Semi-Open	All	Common	2	110	0.92	1.06	0.94
Store (0a)	Service	Close	All	Family	2	30	0.25	1.74	0.57
Main Room (1b)	Multi-function	Close	All	Common	2	30	0.25	1.78	0.56
Exterior	Circulation	Open	-	Public	1	0	0.00	1.40	0.71
WC	WC	Close	All	Common	1	0	0.00	1.40	0.71
S. Room (a)	Multi-function	Close	Sum.	Family	1	0	0.00	1.81	0.55
S. Room (b)	Multi-function	Close	Sum.	Family	1	0	0.00	1.81	0.55
Main Room (a)	Reception/ Multi-function	Close	All	Reception/Common	1	0	0.00	1.84	0.54
Kitchen	Service	Close	All	Family	1	0	0.00	1.84	0.54
Store (0b)	Service	Close	All	Family	1	0	0.00	2.25	0.44
Connected Room	Multi-function	Close	All	Family	1	0	0.00	2.29	0.44

Appendix A 2: the Mashhadi house (the original condition of building)

THE MASHHADI HOUSE									
Space	Function	Type of Space	Seasonal Use	Privacy	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Courtyard	Courtyard	Open	All	Common	8	113	1.24	0.30	3.36
Main Room (a)	Multi-function	Close	All	Common	5	52	0.57	0.47	2.14
main Room (b)	Multi-function	Close	All	Common	5	56	0.62	0.47	2.14
Vestibule	Circulation	Semi-Open	All	Common	4	29	0.32	0.64	1.57
Eivan	Multi-function	Semi-Open	Sum.	Common	4	28	0.31	0.42	2.35
closet (a1)	Service	Close	All	Family	1	0	0.00	1.02	0.98
Kitchen (Bread)	Service	Close	All	Family	1	0	0.00	0.85	1.18
closet (a2)	Service	Close	All	Family	1	0	0.00	1.02	0.98
closet (b1)	Service	Close	All	Family	1	0	0.00	1.02	0.98
closet (b2)	Service	Close	All	Family	1	0	0.00	1.02	0.98
kitchen	Service	Close	All	Family	1	0	0.00	0.85	1.18
stair case	Service	Close	All	Family	1	0	0.00	0.85	1.18
WC	Service	Close	All	Common	1	0	0.00	0.85	1.18
store	Service	Close	All	Family	1	0	0.00	0.85	1.18
Exterior	Circulation	Open	All	Public	1	0	0.00	1.19	0.84

Appendix A 3: the Hejazi house

THE HEJAZI HOUSE									
Space	Function	Type of Space	Seasonal use	Privacy	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
courtyard	Courtyard	Open	All	Common	8	572	1.02	0.64	1.57
Corridor (b1)	Circulation	Close	All	Common	7	180	0.32	1.06	0.95
Eivan (1)	Circulation	Semi-Open	All	Common	5	193	0.34	0.88	1.13
Basement (store)	Service	Close	All	Family	4	136	0.24	1.04	0.96

Room (c0)	Circulation	Open	Sum.	Common	4	88	0.16	1.20	0.84
Corridor (a0)	Circulation	Open	All	Common	4	77	0.14	1.09	0.92
Room (b0)	Multi-function	Close	Sum.	Common	4	130	0.23	1.20	0.84
Eivan 0	Circulation	Semi-Open	All	Common	4	256	0.46	0.96	1.04
Room (c1)	Multi-function	Close	All	Family	4	50	0.09	1.04	0.96
Corridor(a1)	Circulation	Close	All	Common	4	13	0.02	1.04	0.96
room (b1)	Multi-function	Close	All	Family	4	51	0.09	0.99	1.01
Room (a1)	Multi-function	Close	All	Family	4	185	0.33	0.98	1.02
Kitchen (0)	Service	Close	All	Family	3	158	0.28	0.89	1.12
room (d1)	Multi-function	Close	All	Family /common	3	13	0.02	1.23	0.81
Corridor (c1)	Circulation	Close	All	Family	3	183	0.33	0.90	1.11
Stair (b0)	Multi-function	Close	All	Family	2	49	0.09	1.02	0.98
Room (d0)	Multi-function	Close	All	Family	2	15	0.03	1.34	0.75
Exterior Space	Circulation	Open	All	public	2	76	0.14	0.90	1.11
Stair (0)	Circulation	Semi-Open	All	Common	2	277	0.49	0.81	1.24
Corridor (b0)	Circulation	Close	All	Family	2	71	0.13	0.86	1.16
Guest Room	Reseption	Close	All	Common	2	0	0.00	1.40	0.71
Stair (Ex.c)	Circulation	Open	All	Family	2	177	0.32	0.81	1.24
Stair (Ex.a)	Circulation	Open	All	Common	2	62	0.11	0.80	1.25
Stair (Ex.b)	Circulation	Open	All	Common	2	127	0.23	0.80	1.25
Kitchen (1)	Service	Close	All	Family	2	66	0.12	1.31	0.76
Stair (a1)	Circulation	Close	All	Family	2	100	0.18	1.07	0.94
Stair (a0)	Circulation	Close	All	Family	2	112	0.20	1.00	1.00
Cor. (c 0)	Circulation	Close	All	Family	2	97	0.17	1.02	0.98
C (c0)	service/store	Close	All	Family	1	0	0.00	1.55	0.64
C (b0)	service/store	Close	All	Family	1	0	0.00	1.55	0.64
Room (a0)	Multi-function	Close	Sum.	Family	1	0	0.00	1.55	0.64
C.K.(1)	service/store	Close	All	Family	1	0	0.00	1.67	0.60
WC	service/store	Close	All	Common	1	0	0.00	0.99	1.01
Store (0)	service/store	Close	All	Family	1	0	0.00	0.99	1.01
Roof Stair	Circulation	Close	All	Family	1	0	0.00	1.26	0.79

Appendix A 4: the Amiri (Sadidi) house

THE AMIRI HOUSE									
Space	Function	Type of Space	Seasonal use	Privacy	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Courtyard	Circulation /Multi-function	Open	All	Common	7	210	1.54	0.59	1.70
Eivan-B	Circulation /Multi-function	Semi-Open	All	Common	4	85	0.63	1.27	0.79
Eivan	Circulation	Semi-Open	All	Common	3	105	0.77	0.96	1.04
Main room	Multi-function	Close	All	Common	3	1	0.01	1.70	0.59
Kitchen	Service	Close	All	Family	2	23	0.17	1.33	0.75
Store (a0)	Service	Close	All	Family	2	3	0.02	1.70	0.59
Summer room	Multi-function	Close	Sum.	Common	2	8	0.06	1.33	0.75
Corridor	Circulation	Close	All	Common	2	32	0.24	1.39	0.72
Stair (c)	Circulation	Open	All	Common	2	60	0.44	0.96	1.04
Stair (b)	Circulation	Open	All	Common	2	33	0.24	0.96	1.04
Stair (a)	Circulation	Open	All	Common	2	48	0.35	0.96	1.04
Stair (d)	Circulation	Semi-Open	All	Common	2	46	0.34	0.77	1.29
Stair (e)	Circulation	Semi-Open	All	Common	2	64	0.47	0.77	1.29
Room (1a)	Multi-function	Close	All	Common	2	0	0.00	1.74	0.58
Room (1b)	Multi-function	Close	All	Common	2	0	0.00	1.74	0.58
WC	Service	Close	All	common	1	0	0.00	1.08	0.92
Store (b0)	Service	Close	All	Family	1	0	0.00	1.89	0.53
Entrance	Circulation	Open	All	Public	1	0	0.00	1.08	0.92

Appendix A 5: the Baqani house

THE BAQANI HOUSE									
Space	Function	Type of Space	Seasonal use	Privacy	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Courtyard	Courtyard	Open	All	Common	6	171	1.43	0.51	1.95
Eivan	Circulation	Semi-Open	All	Common	5	81	0.68	0.99	1.01
Summer Room	Multi-function	Close	Sum.	Common	4	38	0.32	1.02	0.98
Vestibule (a0)	Circulation	Semi-Open	All	Common	3	42	0.35	0.82	1.22
Vestibule (b0)	Circulation	Semi-Open	All	Common	3	74	0.62	0.72	1.39
Main Room	Multi-function	Close	All	Common	3	0	0.00	1.43	0.70

Room (a0)	Multi-function	Close	Sum.	Common	2	0	0.00	1.16	0.86
Kitchen (0)	Service	Close	All	Common	2	30	0.25	1.16	0.86
Vestibule (ext.)	Circulation	Semi-Open	All	Common	2	30	0.25	0.96	1.05
Stair (a0)	Circulation	Open	All	Common	2	61	0.51	0.75	1.33
Stair (b0)	Circulation	Open	All	Common	2	27	0.22	0.75	1.33
Room (b1)	Multi-function	Close	All	Family common	2	0	0.00	1.47	0.68
Room (a1)	Multi-function	Close	All	Family common	2	0	0.00	1.47	0.68
C.S.R	Multi-function	Close	Sum.	Common	1	0	0.00	1.54	0.65
C.K.(0)	Service	Close	All	Family	1	0	0.00	1.67	0.60
WC	Service	Close	All	Family common	1	0	0.00	1.02	0.98
Entrance (Exterior Space)	Circulation	Open	All	public	1	0	0.00	1.47	0.68

Appendix A 6: the Aldaqi house (the original condition of building)

THE ALDAQI HOUSE					
Space	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Courtyard	11	502	1.67	0.48	2.10
Eivan	5	206	0.69	1.05	0.95
Vestibule (S-W)	4	94	0.31	0.80	1.25
Room (1b)	3	0	0.00	1.43	0.70
Landing	3	228	0.76	0.82	1.22
Room (1c)	3	4	0.01	1.41	0.71
Room (1d)	3	48	0.16	1.41	0.71
Main Summer Room	3	94	0.31	1.12	0.89
Room (1a)	2	0	0.00	1.45	0.69
Stair (a)	2	59	0.20	0.65	1.55
Stair (b)	2	179	0.60	0.65	1.55
Kitchen	2	48	0.16	0.85	1.18
Vestibule (0a)	2	132	0.44	0.78	1.28
Room (0a)	2	0	0.00	0.83	1.20
Vestibule (N-E)	2	48	0.16	0.85	1.18
C.R. (1d)	1	0	0.00	1.82	0.55
C. Kitchen	1	0	0.00	1.26	0.79
C.M.S.R	1	0	0.00	1.53	0.65
Closet	1	0	0.00	1.53	0.65

Stable	1	0	0.00	1.21	0.83
Store (0a)	1	0	0.00	0.88	1.13
Store (0b)	1	0	0.00	0.88	1.13
Store (0c)	1	0	0.00	0.88	1.13
Store (0d)	1	0	0.00	0.88	1.13
Original Entrance	1	0	0.00	1.21	0.83
East Entrance	1	0	0.00	1.26	0.79

Appendix A 7 : the Kian house

THE KIAN HOUSE									
Space	Function	Type of Space	Seasonal use	Privacy	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Courtyard	Courtyard	Open	All	Common	7	426	1.42	0.48	2.10
Stairs (a0)	Circulation	Semi-Open	All	Common	4	267	0.89	0.58	1.73
Summer Room	Multi-function	Close	Sum.	Common	4	211	0.70	0.71	1.40
Stairs (b0)	Circulation	Semi-Open	All	Common	2	108	0.36	0.75	1.34
Vestibule (ent)	Circulation	Semi-Open	All	Common	3	58	0.19	0.82	1.22
Vestibule (a1)	Circulation	Close	All	Common	3	83	0.28	0.82	1.22
Store (d0)	Service	Close	All	Common	2	34	0.11	0.85	1.18
WC (0)	Service	Close	All	Common	1	0	0.00	0.88	1.13
WC/Bath	Service	Close	All	Common	1	0	0.00	0.88	1.13
Eivan (Portico)	Multi-function	Semi-Open	All	Common	4	138	0.46	0.88	1.13
Vestibule (b1)	Service	Semi-Open	All	Common	3	93	0.31	0.99	1.01
Roof Stairs	Circulation	Close	All	Family	1	0	0.00	0.99	1.01
Connected Room (a0)	Multi-function	Close	Sum.	Common	3	79	0.26	1.05	0.95
Vestibule (a0)	Circulation	Close	All	Family	2	13	0.04	1.09	0.92
Main Room (Hall)	Reception	Close	All	Family /common	3	34	0.11	1.09	0.92
Store (Closet)	Service	Close	All	Family	1	0	0.00	1.12	0.89
Room (a1)	Multi-function	Close	All	Family	2	5	0.02	1.16	0.86
Stable/	Service	Close	All	Family	2	3	0.01	1.19	0.84

Store									
Entrance	Circulation	Semi-Open	All	public	1	0	0.00	1.22	0.82
Store (a1)	Service	Close	All	Family	1	0	0.00	1.29	0.77
Kitchen (1)	Service	Close	All	Family	1	0	0.00	1.29	0.77
Room (c1)	Multi-function	Close	All	Family	1	0	0.00	1.29	0.77
Room (b1)	Multi-function	Close	All	Family	2	28	0.09	1.33	0.75
Store (a0)	Service	Close	All	Family	2	1	0.00	1.43	0.70
Connected Room (a1)	Multi-function	Close	All	Common	3	11	0.04	1.43	0.70
Store (b0)	Service	Close	All	Family	1	0	0.00	1.46	0.68

Appendix A 8: the Moslem house

THE MOSLEM HOUSE									
Space	Function	Type of Space	Seasonal use	Privacy	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Family Courtyard	Courtyard	Open	All	Family	8	847	1.42	0.74	1.35
Vestibule (a0)	Circulation	Semi-Open	All	Common	4	422	0.71	1.16	0.86
Reception Courtyard	Courtyard	Open	All	Common	4	570	0.96	0.95	1.05
Corridor (b0)	Circulation	Close	All	Family	4	124	0.21	1.02	0.98
Corridor (a1)	Circulation	Close	All	Family	4	400	0.67	1.28	0.78
Corridor (b1)	Circulation	Close	All	Family	4	182	0.31	1.55	0.65
Room-a0	Multi-function	Close	All	Family	3	6	0.01	1.33	0.75
Corridor (c0)	Circulation	Close	All	Family	3	9	0.02	1.32	0.76
Summer Room-b0	Multi-function	Close	Sum.	Family	3	60	0.10	1.04	0.96
Eivan	Circulation	Semi-Open	All	Family	3	433	0.73	1.07	0.93
Room–a1	Multi-function	Close	All	Family	3	73	0.12	1.86	0.54
Stair (a0)	Circulation	Semi-Open	All	reception	2	132	0.22	1.47	0.68
Stair (b0)	Circulation	Semi-Open	All	reception	2	132	0.22	1.47	0.68
Winter Reception	Service	Close	Winter	reception	2	68	0.11	1.80	0.56

Connection Vestibule	Circulation	Close	All	Family	2	509	0.86	0.85	1.18
Joint Room	Multi-function	Close	Sum.	reception	2	68	0.11	1.80	0.56
Summer Room-a0	Multi-function	Close	Sum.	Family	2	1	0.00	1.34	0.75
Corridor (a0)	Circulation	Close	All	Family	2	58	0.10	1.05	0.95
Room-b0	Multi-function	Close	All	Family	2	1	0.00	1.35	0.74
Stair (a1)	Circulation	Open	All	Family	2	249	0.42	0.91	1.10
Stair (b1)	Circulation	Open	All	Family	2	201	0.34	0.91	1.10
Main Room–a1	Multi-function	Close	All	Family	2	59	0.10	1.59	0.63
Room–b1	Multi-function	Close	All	Family	2	3	0.01	1.88	0.53
Main Room–b1	Multi-function	Close	All	Family	2	11	0.02	1.61	0.62
Stair (-1b)	Circulation	Close	All	Common	2	68	0.11	1.28	0.78
Stair (-1a)	Circulation	Close	All	Common	2	33	0.06	1.26	0.79
Pool Room (-1)	service/store	Close	All	Common	2	19	0.03	1.16	0.86
Stair (-1c)	Circulation	Close	All	Family	2	50	0.08	1.05	0.95
Stair (-1d)	Circulation	Close	All	Common	2	68	0.11	1.07	0.93
Closet (a0)	Service	Close	Winter	Common	1	0	0.00	2.15	0.47
Summer Reception	Multi-function	Close	Sum.	Family	1	0	0.00	2.15	0.47
Roof Stair	Circulation	Close	All	Family	1	0	0.00	1.90	0.53
WC/Bath	Service	Close	All	Family	1	0	0.00	2.21	0.45
WC(-1)	service	Close	All	Common	1	0	0.00	1.42	0.70
Store (-1)	service/store	Close	All	Family	1	0	0.00	1.63	0.61
Entrance	Circulation	Open	All	public	1	0	0.00	1.51	0.66

Appendix A 9: the Jafar-Zade house

THE JAFAR-ZADE HOUSE					
Space	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Private Courtyard	11	1279	1.29	0.65	1.53
Corridor a	5	631	0.64	0.82	1.22
Public Courtyard	5	621	0.63	0.88	1.13
Corridor b	5	354	0.36	0.98	1.02
Vestibule a1	5	479	0.48	1.09	0.91
Room c1	4	46	0.05	1.24	0.80
Vestibule (int)	3	641	0.65	0.76	1.31
Vestibule (c0)	3	172	0.17	0.94	1.06
Vestibule (a0)	3	172	0.17	0.94	1.06
Eivan a	3	181	0.18	0.97	1.03

Room a1	3	259	0.26	1.07	0.93
Eivan b	3	137	0.14	1.09	0.92
Room b1	3	135	0.14	1.12	0.89
Reception a1	3	227	0.23	1.19	0.84
Main Summer room	3	174	0.18	1.22	0.82
Terrace	3	172	0.17	1.28	0.78
Room d1	3	88	0.09	1.35	0.74
Stairs b1	2	318	0.32	0.78	1.29
Stairs a1	2	243	0.25	0.78	1.29
Vestibule (b0)	2	252	0.25	0.93	1.08
Stairs c1	2	394	0.40	1.04	0.97
Room f1	2	227	0.23	1.19	0.84
C.S-a0	2	0	0.00	1.25	0.80
Summer Room-a0	2	0	0.00	1.25	0.80
C.S-b0	2	0	0.00	1.25	0.80
Summer Room-b0	2	0	0.00	1.25	0.80
Room e1	2	0	0.00	1.27	0.79
Closet a1	2	88	0.09	1.28	0.78
Kitchen	2	62	0.06	1.40	0.72
Room h1	2	24	0.02	1.40	0.72
Room i1	2	88	0.09	1.58	0.63
Room g1	2	0	0.00	1.70	0.59
Store b0	1	0	0.00	0.97	1.03
Store a0	1	0	0.00	0.97	1.03
Stairs (-1)	1	0	0.00	0.97	1.03
Roof Stairs	1	0	0.00	0.97	1.03
WC-b	1	0	0.00	0.97	1.03
Main Entrance	1	0	0.00	1.08	0.93
Summer Reception -0	1	0	0.00	1.20	0.83
Water storage	1	0	0.00	1.20	0.83
WC-a	1	0	0.00	1.20	0.83
C.M.S-a	1	0	0.00	1.53	0.65
C.M.S-b	1	0	0.00	1.53	0.65
Closet b1	1	0	0.00	1.60	0.63
C.R-d1	1	0	0.00	1.66	0.60
Summer Reception 1	1	0	0.00	1.90	0.53

Appendix A 10: the Eslami house

THE ESLAMI HOUSE					
Space	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
S-Courtyard	6	538	0.73	1.12	0.89
Corridor (1a)	6	518	0.70	1.02	0.98
Corridor (0a)	5	820	1.11	0.79	1.26
N-Corridor	4	414	0.56	1.31	0.77
Pool Room	4	514	0.69	0.89	1.12
Corridor (0b)	4	652	0.88	0.93	1.08
S-Vestibule	4	150	0.20	1.41	0.71
N-Courtyard	4	560	0.76	1.08	0.93
N-Terrace	3	148	0.20	1.89	0.53
Eivan (Portico)	3	186	0.25	1.25	0.80
Room (1c)	3	76	0.10	1.32	0.76
Corridor (1b)	3	148	0.20	1.31	0.77
Corridor (pool)	2	384	0.52	1.02	0.99
Internal Stair	2	368	0.50	0.94	1.06
Room (0b)	2	0	0.00	1.02	0.98
Room (0a)	2	76	0.10	1.24	0.80
S-Kitchen	2	0	0.00	1.43	0.70
S-Stair	2	76	0.10	1.44	0.70
Room (N1a)	2	0	0.00	2.22	0.45
Room (N1b)	2	0	0.00	2.22	0.45
Room (1a)	2	118	0.16	1.16	0.86
Corridor (1c)	2	70	0.09	1.16	0.86
Room (1b)	2	76	0.10	1.62	0.62
N-Stair	2	216	0.29	1.59	0.63
N-Stair (Ext.)	2	192	0.26	1.23	0.82
N-Guest Room	1	0	0.00	1.64	0.61
C-Pool Room	1	0	0.00	1.23	0.82
Store (Closet)	1	0	0.00	1.23	0.82
Kitchen (0a)	1	0	0.00	1.13	0.89
C-Room (0a)	1	0	0.00	1.58	0.63
S-Store	1	0	0.00	1.75	0.57
S-Store (0b)	1	0	0.00	1.46	0.69
S-WC	1	0	0.00	1.46	0.69
WC/Bath	1	0	0.00	1.36	0.74
C-Room (1c)	1	0	0.00	1.65	0.61
C-Room (1b)	1	0	0.00	1.96	0.51
S-Mahtabi (Terrace)	1	0	0.00	1.77	0.56
N-Entrance	1	0	0.00	1.64	0.61
S-Entrance	1	0	0.00	1.75	0.57
N-WC	1	0	0.00	1.41	0.71

Appendix A 11: the Azimian house

THE AZIMIAN HOUSE					
Space	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Central Space	8	139	1.32	0.49	2.03
N-Vestibule	4	30	0.29	1.18	0.85
S-Eivan	4	101	0.96	0.57	1.76
Courtyard	4	94	0.90	0.80	1.26
S-Vestibule	3	28	0.27	1.21	0.82
Kitchen	2	28	0.27	0.87	1.15
N-Eivan	2	10	0.10	0.87	1.15
N-Store	2	6	0.06	0.87	1.15
Room a	2	0	0.00	0.80	1.26
Room b	2	0	0.00	0.80	1.26
Store and Stable	2	0	0.00	1.25	0.80
W--Eivan	1	0	0.00	1.02	0.98
E-Eivan	1	0	0.00	1.02	0.98
WC	1	0	0.00	1.33	0.75
Main Entrance	1	0	0.00	1.71	0.59
S-Entrance	1	0	0.00	1.75	0.57

Appendix A 12: the Dareini house

THE DAREINI HOUSE					
Space	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Central Space	6	160	1.52	0.46	2.20
W-Eivan	4	130	1.24	0.53	1.88
West Courtyard	3	54	0.51	0.91	1.10
Entrance Courtyard	3	54	0.51	0.83	1.20
E-Eivan	2	28	0.27	0.91	1.10
Room b	2	28	0.27	0.99	1.01
N-Eivan	1	0	0.00	0.99	1.01
Room a	1	0	0.00	1.06	0.94
S-Eivan	1	0	0.00	0.99	1.01
Kitchen	1	0	0.00	0.99	1.01
Closet	1	0	0.00	1.52	0.66
W. WC	1	0	0.00	1.44	0.69
Store	1	0	0.00	1.44	0.69
E. WC	1	0	0.00	1.37	0.73
Vestibule	1	0	0.00	1.44	0.69
Main Entrance	1	0	0.00	1.37	0.73

Appendix A 13: the Mohammadiyani house

THE MOHAMMADIYANI HOUSE					
Space	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
E-Courtyard	8	1262	1.33	0.69	1.45
Cnt. Corridor (0)	5	1055	1.12	0.70	1.43
Hall(W0)	5	918	0.97	0.92	1.09
Eivan (Portico)	4	236	0.25	0.96	1.04
Hall (W1)	4	330	0.35	1.43	0.70
W-Courtyard	3	898	0.95	0.79	1.26
Basement Room	3	250	0.26	0.97	1.04
S-Corridor (Int.)	3	162	0.17	0.97	1.03
Mahtabi (Terrace)	3	170	0.18	0.98	1.02
Corridor (Nib)	3	359	0.38	1.11	0.90
Cnt. Hall (1)	3	135	0.14	1.14	0.87
Room (S0a)	3	7	0.01	1.24	0.81
Room (S0b)	3	3	0.00	1.26	0.80
N-Corridor	3	250	0.26	1.39	0.72
W-Corridor (Int.)	3	170	0.18	1.49	0.67
Room (0e)	2	0	0.00	0.85	1.17
Ext. Stair	2	383	0.40	0.91	1.10
Cnt. stair	2	177	0.19	0.94	1.07
Stair (W-Int)	2	390	0.41	1.17	0.86
C-Corridor (w0)	2	246	0.26	1.20	0.84
Room (W0a)	2	86	0.09	1.23	0.82
S-Corridor (0b)	2	5	0.01	1.25	0.80
Room (1e)	2	34	0.04	1.26	0.80
Room (S0c)	2	0	0.00	1.27	0.79
C-Basement Room	2	86	0.09	1.27	0.79
Main room (N1)	2	86	0.09	1.69	0.59
Room (W1b)	2	86	0.09	1.73	0.58
N-WC	1	0	0.00	1.01	0.99
Room (0d)	1	0	0.00	1.02	0.98
Room (W0c)	1	0	0.00	1.11	0.90
Room (W0b)	1	0	0.00	1.24	0.81
Closet (N0b)	1	0	0.00	1.28	0.78
S-Entrance	1	0	0.00	1.29	0.77
NE-Room	1	0	0.00	1.30	0.77
Summer Room	1	0	0.00	1.30	0.77
Room (1d)	1	0	0.00	1.46	0.68
Closet (W0a)	1	0	0.00	1.54	0.65
Closet (N0a)	1	0	0.00	1.59	0.63
Closet (N1)	1	0	0.00	1.71	0.59
Closet (W1)	1	0	0.00	1.75	0.57
Room (W1a)	1	0	0.00	1.75	0.57
W-Entrance	1	0	0.00	1.80	0.55

W-WC	1	0	0.00	1.80	0.55
C-Main room (N1)	1	0	0.00	2.01	0.50
C-Room (W1b)	1	0	0.00	2.05	0.49

Appendix A 14: the Cheshomi house

THE CHESHOMI HOUSE					
Space	Connectivity	Choice	Choice [Norm]	RRA	Integration [HH]
Courtyard	8	485	1.62	0.69	2.10
M-Room (1)	5	151	0.50	0.52	0.95
M-Room (0)	3	136	0.45	0.58	1.28
Corridor (a0)	3	136	0.45	0.58	1.28
Eivan (b1)	3	160	0.53	0.55	1.18
Eivan (a1)	3	85	0.28	0.55	1.18
Stair (b1)	2	167	0.56	0.56	1.47
Stair (a1)	2	92	0.31	0.56	1.47
Vestibule (ent)	2	48	0.16	0.55	1.18
Corridor (c0)	2	48	0.16	0.55	1.18
Corridor (b0)	2	48	0.16	0.55	1.18
Closet (b0)	2	48	0.16	0.47	0.86
Guest Room	2	48	0.16	0.47	0.86
WC	1	0	0.00	0.53	1.13
Closet (a0)	1	0	0.00	0.46	0.84
Stair (roof)	1	0	0.00	0.46	0.84
Entrance	1	0	0.00	0.43	0.79
Store (a0)	1	0	0.00	0.43	0.79
Kitchen (0)	1	0	0.00	0.43	0.79
Room (b1)	1	0	0.00	0.43	0.79
Room (a1)	1	0	0.00	0.43	0.79
Closet (a1)	1	0	0.00	0.41	0.68
C-M-Room (1)	1	0	0.00	0.41	0.68
Closet (b1)	1	0	0.00	0.41	0.68
C-Closet (a0)	1	0	0.00	0.37	0.64
C-Guest Room	1	0	0.00	0.37	0.64