The Study of the Relation between Spatial Organization and Climate in Traditional Iranian Architecture by the Use of Graph Theory

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Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Doctor of Philosophy
in
Architecture

Eastern Mediterranean University
August 2014
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

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ABSTRACT

This research will analyze the traditional Iranian buildings according to the climatic factors by the use of graph theory. By this way, the hypothesis that climate factor has a major effect on the organization of the spaces in traditional Iranian buildings will be tested.

Access graphs have been used to clarify the connectivity and depth of a building's spaces from the socio-cultural point of view. However, it cannot be applied to climate studies. Thus, this study developed and justifies the existing technique to define building layouts in terms of climate and thermal comfort. The thermal comfort was graphically evaluated by the two main factors like solar gain and wind effect, with the use of a simple multi-attribute rating technique. All the analysis had been done in the interval of zero (the worst condition) to three (the best condition). The proposed justified graph method proved that the thermal comfort factors of the buildings under study match the seasonal movements of their inhabitants. Consequently, the developed justified graph method can be used to study space organization in traditional Iranian building in terms of solar gain and wind effect.

Keywords: graph theory; justified graph method; thermal comfort; Iranian traditional architecture; seasonal movement.

ÖZ

Bu çalışmada, grafik teorisi kullanarak iklim faktörünün İran'daki beş farklı iklim bölgesinde analizleri yapılmıştır. Sosyo- kültürel bakış açısıyla, erişim grafikleri kullanılarak, binalardaki mekanların bağlantı ve derinlikleri açıklanmıştır. Fakat, erişim grafikleri mevcut haliyle iklim çalışmalarına uygulanmamaktadır çünkü mevcut bağlantı anlayışı iklim çalışmalarında uygun sonuçlar vermez. Bu nedenledir ki, bu çalışmada mevcut teknikler revize edilmiştir. Yazar, termal konfor faktörleri açısından yapı düzenlerini tanımlamak için doğrulanmış grafik yöntemi geliştirmiştir.

Bu çalışmada, termal konfor faktörleri grafiksel olarak multi-özellik değerlendirme tekniği ile uyumlu olarak değerlendirilmiştir. Bu çalışmada da grafiksel olarak değerlendirilen iki ana faktör, güneş kazanımı ve havalandırma, termal konfor koşulları olarak analiz edilmesi mümkündür. Bütün analizler, bir, iki ve üç sıfır aralığı miktarında yapılmıştır. Giriş grafik mantığına benzer olarak yüksek derinlik değeri daha fazla gizlilik anlamına gelir. Bu doğrulanmış methodda üç aralığı en iyi termal konfor durumunu ve sıfır en kötü termal konfor aralığıdır. Son olarak, bu çalışmada doğrulanmış grafik yöntemi, çalışmanın binaların termal konfor faktörlerini yaşayanların mevsimsel hareketleri adı altında kanıtlıyor.

Anahtar Kelimeler: Grafik teorisi; doğrulanmış grafik method; termal konfor; geleneksel İran mimarisi; mevsimsel hareketler.

To My Family

&

My Love, Arian

ACKNOWLEDGMENT

My deepest gratitude is to my co-supervisor, Prof. Dr. Mesut Özdeniz and my supervisor Asst. Prof. Dr. Polat Hancer who helped me in different steps of my dissertation which without their support and patience I could not picture my success in PhD. They assisted me with their appreciated supervision and I am so thankful that I was lucky enough to being with them in this scientific journey.

My heartfelt thanks to my love Arian since without his everlasting love and patience, none of this would have been imaginable. He supports me by his tolerance in all these years and he tries to keep me calm to overcome hardships throughout my life.

Finally, I would like to thank my adored family, my father who always supports me in up and down of my life by his effort. I hope by dedicating my thesis to him I could be a bit thankful for all his work. And also my beautiful and kind mother that without her love and generosity I could not stand on that place that I am today. At the end I am so thankful to my lovely sister and my kind brother who encouraged me all the time in my life. Although I am far away from them but there is no distance from our hearts.

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Talar Balcony

Eyvan Semi-open space, which has a roof and it, is closed from three side and just open from one side.

LIST OF SYMBOLS/ABBREVIATIONS

NW	North wall
EW	East wall
WW	West wall
SW	South wall
SF	Solar gain on floor
Sn	Solar gain value
PW	Prevailing wind
Mj	Mega joule
SPF	Sunshine periods on a façade
AVG	Average
S1	Semi-open and open space 1
S2	Semi-open and open space 2
S3	Semi-open and open space 3
S4	Semi-open and open space 4
Jn	Justified number

Chapter 1

INTRODUCTION

1.1 Thesis Description

Since the early 1970s, scholars have used an approach called space syntax to investigate the human environment of houses in large cities. “Space syntax is a set of techniques for representation and quantification of spatial patterns. The steps towards quantification can be achieved by considering the spatial pattern of a two-dimensional convex structure (Orhun, Hillier, & Hanson, 1995)”.It has been nearly 20 years since the establishment of space syntax. However, this method became popular in the architectural field only a decade ago.

Space syntax is a mathematical theory that takes into consideration the spatial organization in buildings (Dawes & Ostwald, 2013).In general, space syntax explores the relationship between the spaces in an adjacent set. Understanding spatial relations has a direct effect on the social interactions between them. Recognizing the social interactivity of spaces requires an understanding of the occupants’ activities within and among the spaces. Hence, the activity within and relations between spaces are more significant than the shape and form of the spaces, and thus, by using space syntax, it is conceivable to understand and analyze the social interactivity of spaces.

In addition, some researchers (e.g., Mustafa, Hasan, & Bape, 2010) have analyzed the factors that have a role in creating privacy in domestic interior spaces. In his research they attempted to find out the extent to which the creation of privacy affected the arrangement of domestic spaces. Another purpose of their research was to recognize the morphology and layout of buildings as a reflection of the residents' privacy. To the end, they used space syntax theory to analyze the traditional and modern building in Erbil from a spatial morphological perspective, and their main purpose for using space syntax was to determine the degree of privacy in spatial organizations. Furthermore, their research demonstrated that traditional buildings in Iraq proposed better organizational patterns in relation to privacy than modern buildings do.

One of the most common types of traditional Iranian architecture is the introverted house, which could be defined as the kind of building that has a central courtyard. This building type is very common in hot-dry climates and hot-dry with cold winter climates because the central courtyard creates a comfortable environment under those climate conditions. More precisely, in traditional introverted Iranian houses, all the rooms open onto the central courtyard for protection from dust storms, and the courtyard traditionally includes plants, trees, and a fountain with a pool to increase the house's thermal comfort (Pourvahidi & Ozdeniz, 2013).

The socio-cultural factors in this traditional spatial arrangement are also a significant issue. Nazidizaji and Safari (2013) used space syntax to investigate traditional introverted buildings in Iran, attempting to determine their genotype as a reflection of their complex socio-spatial modeling. They used Depthmap software to construct a convex map of case studies in Kashan, Yazd, and Shiraz, and they used SPSS software to present their numerical results. The outcome of their research demonstrated that controlled spaces and core integration are parallel to each other and that the depths of spaces with common functions are almost the same.

All these recent research signify that, most of the researchers applied space syntax method for analyzing the degree of privacy and social interactions. However, the purpose of this study is different than all the recent researches till now. Since, this study attempt to use space syntax for climatic aspect.

1.2 Problem Statement

There are different kinds of tools to evaluate climatic aspects of a building. However, these programs in the first step for evaluation need many climatic data so architects should have a lot of knowledge about cooling and heat transferring, convection and a lot of other climatic issues which architects must consider them for designing the building according to the climatic. So there is prerequisite to have simple and graphical method in the field of architecture, which could assist the architect to organize the spaces by considering thermal comfort issue in the faster and easiest way.

The purpose of this research is to study the effect of climate on space organization. For reaching to this purpose, author attempts to find a simpler, faster, and easier graphing method, the method that does not require complicated software. Access graph that is the tools of space syntax method could well defined as a graphical method. However access graph just verified the degree of circulation for each space. Furthermore, although space syntax is the simple method and it could translate a complicated plan into a simple graph but it could just reflect the movement of occupants by considering the social and cultural interactions. It means that this method does not address all the factors that determine the movement of inhabitants through the spaces. One of the main factors, which directly correlate with inhabitants' movements in Iranian traditional building, is climate.

Climate in organizing the spaces in Iranian traditional building has played a significant role. Therefore, simple and graphical, access graph that is the main tools of space syntax method could be developed and justify in the manner to be applicable for evaluating climatic issue on organizing spaces in Iranian building. Nobody has considered space syntax for climate issues (except Memarian, 2011), so this research feels that the existing method is insufficient to analyze the climate-consciousness of traditional Iranian building. Thus, this lack of consideration makes the space syntax method overly simplistic and only one dimensional in considering the movement of inhabitants. Hence, this research desires to justify this method to study the effect of climate for organizing spaces in traditional Iranian building.

1.3 Aims and Objectives

In this research, the author aim to find a simple method to evaluate a building in terms of thermal comfort factors. Although there are different kinds of software for this, but the author evaluates thermal comfort issues graphically in this research. To that end, this research has chosen the space syntax method, which plays a significant role in the graphical representation of architecture. However, as mentioned in the previous section, the space syntax method has deficiencies related to climate issues, and this study proposes a justified graph method in this research to account for climate conditions. Therefore, this study main purpose is to use access graph tools to adjust the space syntax method for climate issues because climate in seasonal movements of inhabitants in traditional Iranian architecture play an important role in rather than the socio-cultural background. Consequently, this research has developed the access graph method to organize those spaces in terms of thermal comfort conditions, and author graphically illustrated all the probable thermal comfort conditions. In sum, the two main thermal comfort factors are solar gain and wind effect would be demonstrated graphically and would be evaluated mathematically in this research.

Traditional Iranian buildings are the best representations of spaces organized in consideration of climate conditions. For instance, central courtyard create comfort ability for the inhabitants in the introverted buildings where are located in hot-dry with cold winter climatic region. Hence, this research by justifying a graph method to attempts to find a proper mathematical outcome for climate issues. These evolutions would be done on traditional buildings in the five different climate regions of Iran. These five regions are hot-dry, hot-dry with a cold winter, hot-humid, cool, and temperate-humid. Then, comparing these results with existing research, the author concluded that the developed and justified graph method used in this research is appropriate for the study of the effect of climate in space organization.

1.4 The Research Design & Method Section

In this research, the author pursues a quantitative and qualitative research method, using data gathered from the existing literature in the field, archival documents, and case studies. This methodology can be classified in five stages:

- Theoretical framework through literature review
- Methodology development
- Methodology testing through case studies
- Comparison of the case study results with existing research
- Conclusions

Having defined the study problem, aims, and limitations of this research in this chapter, the author reviews the climate factors that affect spatial organization in the next chapter. Additionally, in Chapter 2 this research, study thermal comfort factors and their effect on the building envelope, which causes occupants' seasonal movements, concentrating on previous research related to space syntax and access graph theory. In that chapter, the author also present the data gathered from theoretical and documentary information. Furthermore, the deskwork research had been done according to the literature surveys. Ultimately, having gathered the data on climate factors and the specifications of space syntax, author develops the existing access graph into a justified graph method that accounts for climate issues.

In Chapter 3, this research also analyzed traditional Iranian buildings with the justified graph method for climate issues. Author has chosen case studies among traditional Iranian buildings by using previous research to classify them in five climate regions (Pourvahidi & Ozdeniz, 2013), and this study did this because the analysis of Iran's five climate regions offer a wide range of results for applications to similar environments elsewhere. Thus, the purpose of this study is to develop access graph tools into a justified graph method to understand the effect of thermal comfort conditions in spaces organization in variety of climate conditions.

In addition, this study used the simple multi-attribute rating technique (SMART) to evaluate spaces in terms of thermal comfort factors. Edwards (1977) developed SMART, a technique later revised by Edwards and Newman (1982). SMART is an easy approach to weighted evaluation techniques, mostly applied in engineering (Hancer, 2005). Three represents the maximum performance and zero represents the minimum performance in this case of thermal comfort conditions in each space under investigation.

In the discussion section of Chapter 3, this research compare the outcome of the justified graph method for thermal comfort conditions with the existing data, demonstrating that the proposed method is applicable for each climatic region and could assist designers in organizing spaces that meet thermal comfort conditions in different climate regions.

Finally, in Chapter 4, this study offers the general conclusions for this research.

1.5 Limitations

The SMART approach used in this study evaluates criteria on a scale of zero to three. It is the same logic as the existing access graph method, which the highest level demonstrated as more privacy and conversely the lowest level illustrated as less privacy. In this research also the highest grade (3) indicates the best thermal comfort conditions and the lowest grade (0) indicates the worst thermal comfort conditions. The author has applied this justified graph method to thermal comfort conditions in residential buildings and their rooms (closed spaces) and semi-open and open spaces. Hence, this research did not consider the other spaces of a residence, such as kitchens or storage, or other building types. Furthermore, the author studied traditional buildings in Iran because of the various climate conditions there.

During the author work toward a master’s degree, surveyed that the existing climate classifications of Iran, retrieving climate data from 68 Iranian meteorological stations and using that data to construction a new bioclimatic chart for Iran and new climate classifications for architectural purposes there. As a result, Pourvahidi (2010) identified five climates for Iran (Pourvahidi, 2010) like temperate-humid, hot-humid, hot-dry, hot-dry with cold winter climate and cool climate. Hence, in this research, the author concentrates on the climate issues for traditional Iranian buildings in these five different climatic zones. Furthermore, this research, limits the evaluation to traditional buildings in Iran because of their popularity in designing according to the climatic issue. Those buildings have become symbolic of climate-conscious design in Iran. In addition, this study did not considered the texture of the city during the evaluation and it just focused on the space organization of a building from the aspect of the catching solar gain and wind effect. Moreover, although some of the climatic region of Iran such as hot-dry with cold winter and hot and humid has wind catcher, but the evaluation of this research had been done from the climatic perspective with the view of not considering the additional tools related to cooling and heating system of a building and just consider the building envelope as it is. Since, choosing the case studies was according to the one that does not have wind catcher. In addition, during the evaluation of solar gain analysis, this research focused just on the amount of solar gain on vertical and horizontal facades of a building hence, author limit the study and did not consider the window’s effect on amount of solar gain through the spaces.

Chapter 2

DEVELOPING JUSTIFY GRAPH METHOD IN TERMS OF THERMAL COMOFRT FACTORS

2. 1 Climatic Design in Traditional Building

Human settled close to the nature from the beginning of their life. They had balanced interaction and harmony because of friendly and sympathetic relationship. Unfortunately, after they developed knowledge, their approach changed to their surroundings, learning to keep themselves from stormy weather and enemies. Proud, sightless by feeling of dominance and power and without knowing they became nature's enemy. As humans shifted further and further away from their derivations they constructed living spaces foreign to their earlier survival (Senosiain, 2003). And then the relation between human and nature becomes negative.

Human were affected by climate from the starting point of the time. The first idea of them was to create a shelter in the manner to protect them from harshness of the weather. They constructed a shelter for protecting themselves. Thus it is recognized that "we must at the outset take note of the countries and climate in which buildings are built (Oktay, 2006)".

Therefore it is clear that variation in natural environment, which is called climate conditions, could be cause to have different building approaches in vernacular architecture. In vernacular architecture in all the regions there are some elements that are showing the effect of climate.

There are basics features, which are demonstrating the effect of climate on vernacular architecture in all the regions. For instance in hot and dry climate, the significance of the thickness of the wall assists the inhabitant to keep the hot weather inside of the building. In addition, in such a hot-dry climate, there are some other climatically elements inside of the building like wind catcher. The role of the wind catcher in such a climate is that to bring the wind inside of the building followed by having the thickness of the walls the wind become cool until it get out of the wind catcher (Zandi, 2006).

Furthermore, there are some examples from temperate humid climate where are located on north part of Iran. For instance, because of the humidity inhabitant construct their building with empty spaces underneath. Otherwise, mainly, humidity could have a chance to get inside of the building. Moreover, because of the rainy weather most of the buildings have sloppy roof, which this slope is approximately between 50-60 percent hence, rain water cannot get inside from the roof (Ghobadian, 2006).

Moreover, there is some other feature that is directly related to the climatic issue that is called as seasonal movement. Seasonal movement happened by occupants through different seasons, which in the following part, the author demonstrated the reason of this movement.

2.2 Seasonal Movement

Climate has had a great impact on the spatial arrangement in Iranian traditional building. As well as, influencing the overall form of the house, it can also generate seasonal movement between different parts of the house (Beazly & Harverson, 1982). Seasonal movement in a house is one of the features of domestic life in Iran and some neighboring Arab countries (Memarian & Brown, 2006). As an effective factor of inner relations, it has both a socio-cultural and climatic basis.

People in Iran have adapted their demands to the environmental properties and in correlation with the entire religious belief being applied by them to form their houses. Iranian life environment correlation has been noticed by Nasr who proved this fact by making note of people's survival, actions and behavior when passing through the inconsistent climate (Nasr, 2003) and seasonal movement is one of those adoptions.

As a climatic response during history, the inhabitants of a house might exploit air circulation and solar radiation in the hot and cold seasons, respectively. In more primitive accommodations used by nomads, seasonal movement take place as a result of long distance change in location from hot region to a cold region or vice versa. Seasonal movements vary widely according to the type of house. For example, in some types of block houses, seasonal movements take place vertically. When the ground floor is given over to storage, however, they are more likely to occur horizontally. In the courtyard house, seasonal movement takes place around the perimeter of the courtyard, though occupants may move to the basement or the first and second floor in the heat of the day to take advantage of cool winds or lower temperatures. In winter the inhabitants would stay mostly in rooms with few openings (Memarian & Brown, 2006)

The frequency of applying and particular space may therefore be determined by the time of the year, not simply by the overall pattern of access and circulation. Furthermore, it is not easy to display seasonal movements on graph. Seasonal movement that happens in the summer is a fact that has been completely ignored in some studies that deal with climatic conditions very close to those of Iran such as traditional Turkish houses (Orhun, Hillier, & Hanson, 1995). In the Turkish dwellings the seasonal movement happens among rooms, the south facing quarter in cold seasons and the north facing quarter in hot seasons like a courtyard house type (Kucukerman, 1988).

These examples from different part of Iran, which have diverse kind of climate condition illustrates that each climate have appropriate approach to convey from harsh climatic sense. Consequently, climate could be acknowledged as an initial term in vernacular architecture.

According to all above explanation, this research finds out the signification role of climate in designing a building and also on the movement of inhabitant through the spaces. Hence, for continuing the research on the climatic issue, considering the thermal comfort factors is needed. In the following section, the author concentrates on different thermal comfort issues, which according to above explanation have direct effect on organization of spaces.

2.3 Thermal Comfort

Condition that human body by spending minimum amount of energy could adjust itself into the environment is well-defined as thermal comfort. Thermal comfort factors could be divided into two aspects such as objective and subjective. The factors like air temperature, air velocity, radiation and relative humidity could be included as objectives factor. Metabolic rate, thermal insulation of clothing, activity level, and diet, shape of the body, sex and adaptation can be considered as subjective factors (Hancer, 2005). In this research the objective factors, which could be signify them graphically would be determined.

Olgyay revealed that it is so hard to describe the effects of the meteorological condition individually. Hence, there is prerequisite of having an appropriate architectural evaluation for each climatic condition. And this assessment should be clarifying the effect of different meteorological condition on building and also should be demonstrated the comfortable condition of each of them separately. In this manner Olgyay for attainment to this aim, try to discuss about the basic climatic elements such as air temperature, solar radiation and wind and besides try to find the relationship of them. Furthermore, Givoni also improve Olgyay's basic climatically elements and he add humidity, consideration and precipitation such as rain, snow and also Givoni attempt to scrutinizes the relationship between all of these climatic elements. (Olgyay, 1963) (Givoni, 1976).

Consistent with the McMullan (McMullan, 1998), climatic element can have difference according to the time of a day and different season. But some of them like sun can have predictable time. However, wind and cloud are the climatically elements that have less predictable situation in the short period of time. Subsequently a different data are realized by assembling the data of these kinds of climatic elements. Hence, he illustrated these data as follow:

- Maximum or minimum values
- Average values
- Probabilities of frequencies

Mc Mullan also demonstrated that developed climatic data could be used for design requirement. For instance, maximum or minimum peak values are required for deigning wind loads (McMullan, 1998).

The purpose of construction, each artificial climatic is just in the manner to provides the thermal comfort condition for inhabitants. ASHARE standards 55-66 described the thermal comfort condition for human as "that states of mind which expresses satisfaction with the thermal environment (Ashrae, 2011)". However, from another point of view, Fanger mentioned that in a same room with the group of people never satisfying of all of them would be same cause that each of the human has different physical variance. Fanger in his research illustrated that, heating and air condition is the first purpose of the industry in the manner to create the comfortable condition for inhabitant. This attitude in building industry provides different kind of construction sector and different choice of material. Furthermore, the main function of the building should be design in a correct position in the way to create comfortable condition of residents, which all of these is depend on thermal resistance of the building. Unfortunately today most of the building tries to create comfortable condition only with use of artificial climatic elements. Therefore, architects should have awareness of the condition that could prepare the thermal comfort. According to Fanger ideas, these features can be defined as:

- Activity level of occupants
- Thermal resistance of the clothing
- Air temperature
- Mean radiant temperature
- Relative air velocity (Fanger P. O., 1970).

Roulet (Roulet, 2001)asserted that a well comfortable building should be designed in the way to protect the residence form extreme outdoor condition and also create the indoor comfortable condition. Furthermore, Roulet describes his idea in figure 1 that the best-adopted building has shown by curve A. The design of this building is in the way to protect the indoor spaces from solar radiation in summer and from another point try to conduct the solar radiation inside of the building during the winter time. Hence, this building has good thermal insulation from solar gain and ventilation in all the season. In the following, curve B demonstrated the poor situation from efficiency design for solar energy and ventilation. The reason of that is this kind of building is designed without using any other energy sources than the sun. For instance, the energy that is usable for heating is decreased. Hence if the internal heat load is within a reasonable boundary for cooling is not obligatory. Roulet in his research mentioned that, the building that have same situation as curve B is the result of having low temperature during winter and too high temperature during summer in indoor spaces. And this could be a reason that they should have extra mechanical equipment in the manner to create thermal comfort condition inside the building.

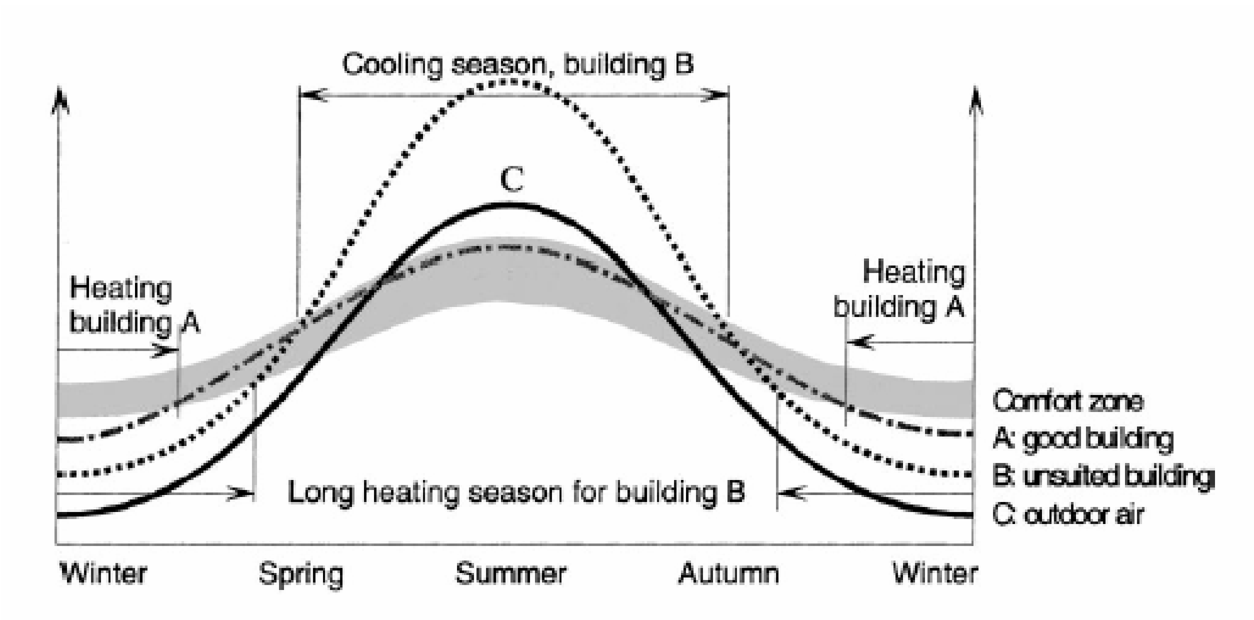


Figure 1: Development of temperatures in a free variable building and its environment during the year, Northern hemisphere (Roulet, 2001)

Moreover, in the following section the author concentrate on them separately for better understanding the thermal comfort factors and their effect on building envelope.

2.3.1 Air Temperature

Olgyay 1969 and Givoni 1976 mentioned that air temperature depends on the cleaners or cloudiness of the sky as the most important climatic elements. However, this situation changes according to the seasons. Clear days in summer are warmer, but clear days in winter are cooler. This condition can be explains the reason of this situation related to the solar radiation. Since, more solar energy could be received in a clear day in summer time. However, long night period causes heat loss easily through clear atmosphere in a clear day in winter. Therefore, as Givoni 1976 demonstrated, a solar radiation has an indirect effect on air temperature. Subsequently, annual and daily patterns of air temperature depends on the variation of surface temperature, architectural design process can definitely use local seasonal, daily and annual metrological data to get enough information about air temperature (Olgyay, 1963).

Givoni 1976 argues that wind characteristic of a region also significant variable, which affects the air temperature. Those characteristics are affected by global distribution of air pressure, the rotation of earth, the daily variations in heating and cooling of land and sea and the topography of the given area (Givoni, 1976).

2.3.2 SolarRadiation

Givoni 1976 describes solar radiations as an electromagnetic radiation emitted from the sun. According to Olgyay 1969 some part of the solar radiation is absorbed and some part of is reflected by the surface. Most of the energy of solar radiation is absorbed by the surfaces and illustrates itself as a heat within the surfaces. The temperature of the air also changes according to the amount of the absorbed radiation.

Solar radiation rate also changes according to different seasons. Heat exchange and radiation rates differ from winter to summer. Summer values of mean daily temperature are much higher than winter values. A part from atmospheric diffusion of solar radiation, radiant heat transfer also affects buildings. Olgyay 1969 determines the ways of this effect as below (Givoni, 1976) (Olgyay, 1963):

- Direct short-wave radiation from the sun
- Diffuse short wave radiation from the sky vault
- Short wave radiation reflected form the surrounding terrain
- Long wave radiation from the heated ground and nearby objects
- Outgoing long wave radiation exchange from building to sky.

The sun is the brightest star in the Earth’s solar system. Not only does sun give us light, but is also a valuable source of heat energy. The sun can be considered the ‘life giver’ of all living things on Earth. Without the sun, many living organisms would cease to exist. But, the sun also creates some problems for human as well. For example, extreme heat is undesirable as it may cause a sudden increase in bodily temperature. Hence, people have always sought ways to harness the sun’s power and at the same time reduce the detrimental effects of it (Lee Jin You, 2003).

One of the most effective factors for climatic design of a building is sun. During the winter time, solar radiation enters from the opening, which gives desired heat. However during summer time, this much of heat causes uncomfortable condition for inhabitants. Hence, controlling the solar gain during winter and summer time is one of the significant issues for architectural design (Szokolay, 2007).

2.3.3 Humidity

Humidity is another climatic element. McMullan (1998) (McMullan, 1998) defines humidity as the amount of moisture in the atmosphere. In other words, Givoni (1976) (Givoni, 1976) defines humidity as the water vapor content of the atmosphere, and uses several terms such as absolute humidity (vapor amount rate by g/m3), specific humidity (vapor amount rate by g/kg), vapor pressure (vapor amount rate by mm Hg), and relative humidity (vapor amount rate by 100 % of the absolute saturation humidity). Saturation is a key term in the problem of humidity, and McMullan (1998) describes saturation point of the air as the point when the maximum amount of water vapor is contained at given temperature.

Givoni (1976) illustrated about different sources of water vapor and rate of water vapor. According to him, water vapor comes into the air from different sources such as oceans, vegetation, and water bodies in varying sizes by evaporation, which is carried and also distributed by the winds. The rate of the water vapor in the air depends on different factors. The main factor is air temperature. Vapor distribution is highest in warm climates and lowest in cold climates.

McMullan (1998) states that natural humidity of a particular place depends on weather conditions of that place. He underlines that; the thermal conditions and the use type of that building also affect interior humidity of a building. According to Goulding, Lewis and Steemers, humidity of the air can be regulated by the presence of water and vegetation. Pools, fountains, water jets, and vegetation next to buildings bring about humidification of the air. These tools have also evaporative cooling effect on the air (Goulding, 1994).

2.3.4 Condensation and Precipitation

Givoni explained condensation in the open air is as a dew-point dependent event (Givoni, 1976).He defines dew point as the temperature at which air becomes saturated. But, dew point is not a constant value; any cooling below the dew point causes the condensation of the water vapor in excess of the air capacity at the new lower dew point. Since being a dew-point dependent event, condensation is also in a direct relation with cooling levels. The author also points out that the cooling level of air is affected by several factors such as contact with cooler surfaces, mixing with cooler air and expansion associated with raising air currents.

McMullan (McMullan, 1998) discussed to focus on the problematic side of condensation in buildings. In buildings, condensation results in dampness caused by water vapor in the air. He points out that, misting of windows, beads of water on non-absorbent surfaces, dampness of absorbent materials, and mold growth are some of the effects of condensation. The author claims that condensation is not a problematic situation for every kind of space in the building. For instance, it does not create a problem for bathrooms or indoor swimming pools. On the other hand, unwanted condensation creates problems because of causing unhealthy living conditions or damaging to structural or decoration materials. Therefore, problems that are caused by condensation should definitely be considered in the design process of buildings; also in terms of designing heating, cooling or ventilation functions of the building.

McMullan (1998) also states that, condensation in buildings generally shows itself in two ways such as surface condensation and interstitial condensation. Surface condensation is revealed on the walls, windows, ceilings, and floors. Surface condensation may be displayed even on absorbent surfaces when condensation occurs continuously.

Interstitial condensation occurs inside the structure when the air that containing moisture cools while passing through the structure. This process may cause serious damage to structural materials such as corrosion of iron parts.

Generally, condensation happens when most air and cold surface comes together. There are also other factors that cause condensation in buildings. McMullan (1998) defines those factors as several indoor moisture sources (indoor plants, number of living people, etc.), air temperatures, structural temperature, ventilation, and use of buildings. Also, Givoni (1976) considers indoor vapor pressure level and absorptivity level of the internal surfaces as important condensation factors. McMullan (1998) proposed a proper combination of ventilation, heating, and insulation techniques in order to prevent condensation in buildings. Suitable material choice is also another way of preventing condensation.

2.3.5 Wind

Olgyay (1969) asserted that wind effect on housing have to be considered both outside and inside of the building. Both positive and negative effects of the wind on thermal comfort conditions have to be considered. In this research same as Olgyay's idea, wind is evaluated both from positive and negative point of view during summer and winter. Furthermore, according to Olgyay (1969), architectural designers should use effect of the wind properly; strong and negative wind effects should be blocked during coldest periods. But, designer should utilize wind effect at overheated times; because wind is an essential cooling tool for buildings.

Both wind velocities and air flow forms affected by close surroundings near low buildings. This frees strict orientation necessities for the building in some measure. The elements for designing landscape including, trees, fences, walls, shrubs and plants materials can generate low and high pressure zones nearby the house. The arrangement throughout the overheated times do not remove desired cooking winds so the building should be planned in order to accelerated and direct useful movements of the air toward the building (Olgyay, 1963).

Buildings' natural ventilation can produce by two categories of forces one of them is change in air caused by temperature differences. The second one is movement of the air, which produced by differences in pressure. Depend on the design of the building and condition of the atmosphere; wind forces may act combined with or in the opponent to the other or even alone (Olgyay, 1963).Natural ventilation of a building depends on the speed of the wind, which blows around the building. Related to the speed of the wind, length, height, width and also the direction of street are the most significant issue (Firouz, 1994). It means that in the country side which has little dense of a single story building, the speed of the wind will be different rather than the urban city which has compact selectmen pattern of high rise buildings. Moreover, trees and shrubs have a direct effect on the wind blow as well.

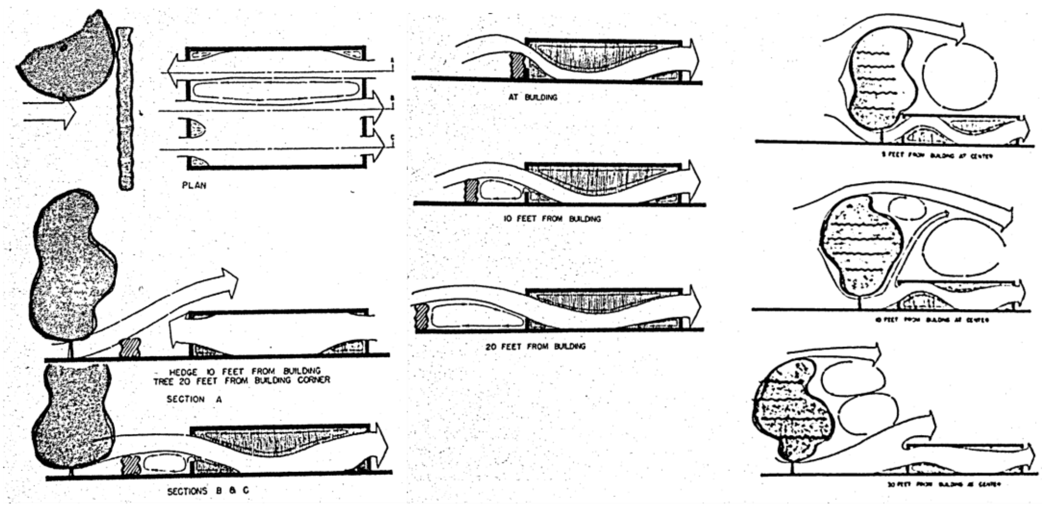
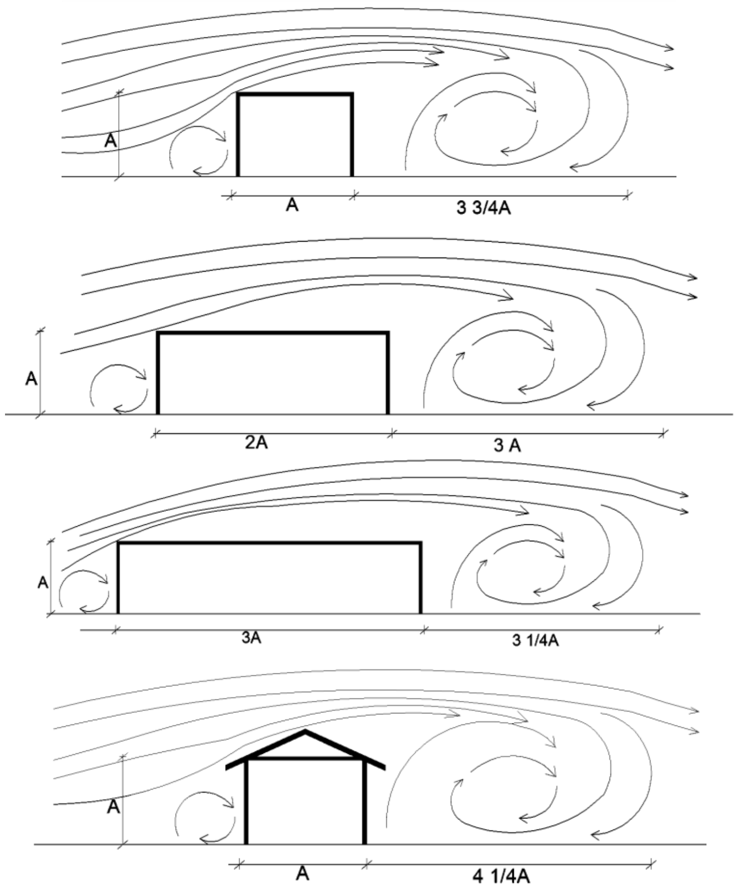


Figure 2: Adjustment of airflow pattern in relation with landscape (Olgyay, 1963)

Olgyay (1963) illustrated that the house, which placed in air stream, plies up and slows down the air moving at its side of windward and causing relatively high-pressure area. On the other hand relatively low-pressure wind produces on the sides next to wind shadow by the flow cinctured the building. The wind shadow slowly will be accumulating with the air of surrounding and the air will be at rest approximately at twice of the building's height. It means that both in away from the building and reverse toward it, the wind carry on its original velocity approximate around seven times the height of the building. The airflows around the house are independent of the air speed and determined by building's geometry. A vertical wind sections are shown in below (Dekay & Brown, 2014). The differences of pressure on leeward and windward sides can provide airflow inside of the building.



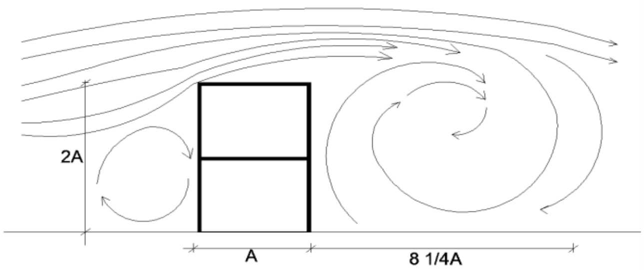


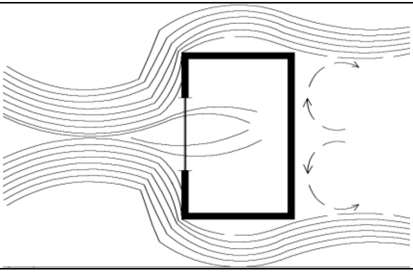
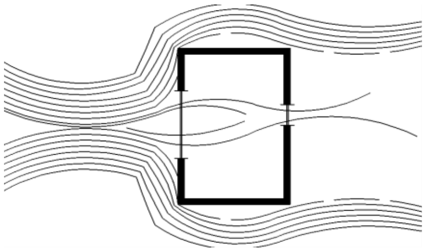
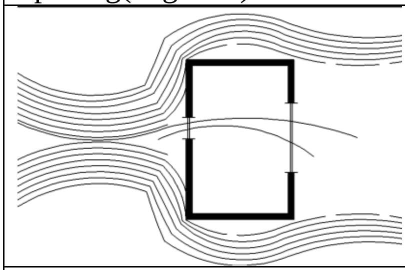
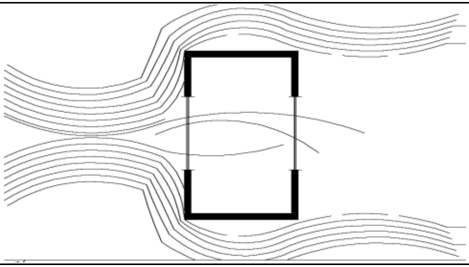
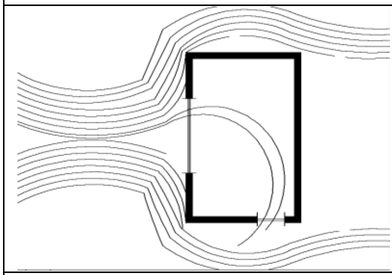
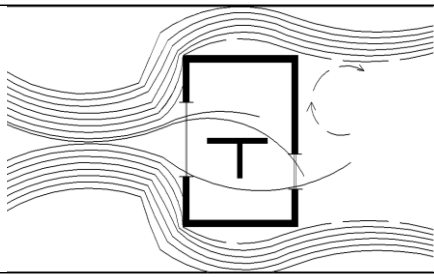
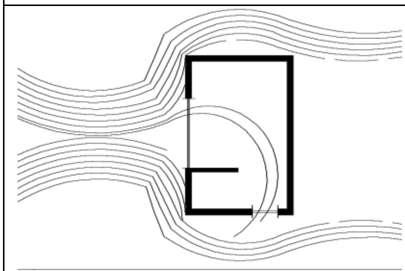
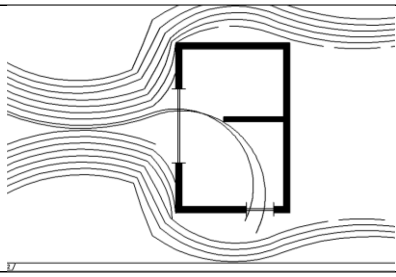
Figure 3: Relation of the wind shadow with width, height and length of a building beside the shape of the roof (Dekay & Brown, 2014)

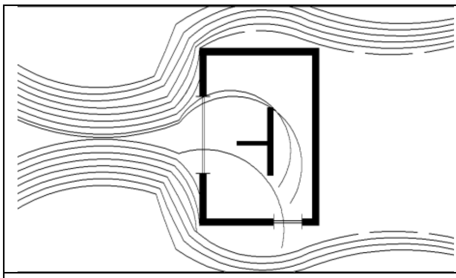
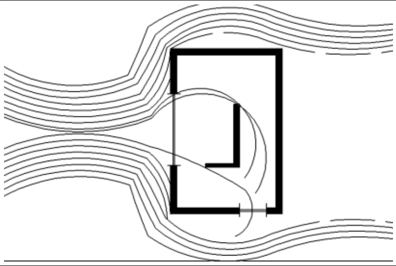
Furthermore, the most important thing related to wind blowing in urban city is related to the height of the building and more significantly the location of the building where are located next to each other (Kasmaee M. , 2009). For instance in hot-humid climatic region, for preventing the inappropriate condition of wind blow, the high rise buildings should not be located toward the direction of the wind. Since, the high-rise buildings are blocking the wind and causes decreasing of the airflow surrounding of the building environment.

There was a research in United States that scientist started to test the model that was made by Plexiglas with the two-dimensional wind tunnel. This test was evaluated by the teamwork of David. Hazen from department of Aeronautical engineering. Complete studies settled in the arena by Texas Engineering Experiment Station with the cooperate work of William W.Caudill, Bob H.Reed and Ben H. Evan (Caudill, Crites, & Smith, Some General Consideration in Natural Ventilation of Buildings, 1951) (Smith, Reed, & Hodges, 1951) (Smith E. G., The feasibility of using models for predetermining natural ventilation, 1951) (McCutchan & Caudill, 1952) (Caudill & Reed, 1952). The result demonstrated the effect of wind both on plan and section according to the direction and size of the opening.

Table 1: Effect of wind flow inside the space by Olgyay (Olgyay, 1963)

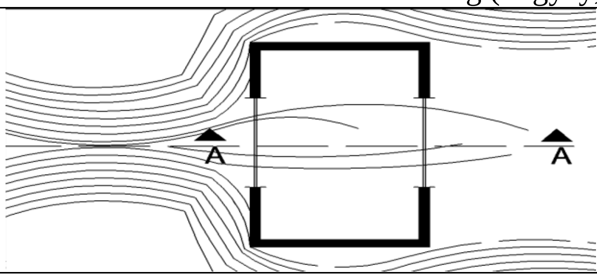
Effect of wind flow inside the space by Olgyay (1963)

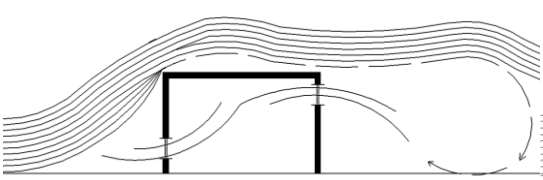
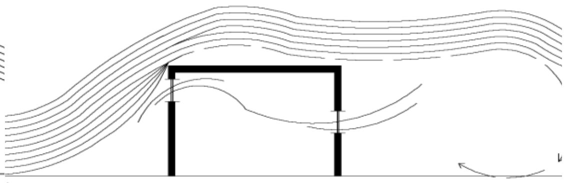
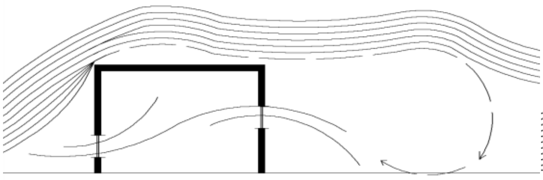
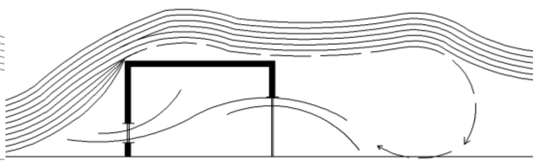
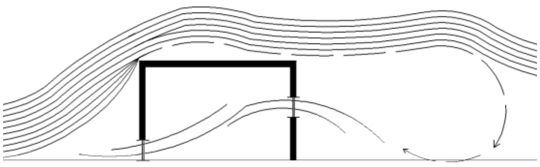
	
There is no outlet in this building, hence air flow could not happen inside. Since having air flow inside the building need both inlet opening (positive) and outlet opening(negative).	High velocities happen outside of the building, which causes the less cooling, effect when building has Large inlet with small outlet.
	
Cooling air flow occurs inside the building If building has small inlet with a large outlet. Therefore it causes highest speed in the building.	large openings with same size could occur the maximum air flow if there are located contrary to each other. Also the speed of air flow inside is alittle bit higher than outside area.
	
A house with no partition wall cause that air flow with an oblique angle occurs inside the building. Since, the position of inlet and outlet makes the air flow to have smooth curve.	Partition wall is parallel to air flow and it makes it breaches, but then outcome is satisfactory high speed.
	
A partition wall dose not restrict the direction of wind flow as a result the main air stream occurs approximately eight times as stronger by turning.	Partition wall cut off the air flow pointedly therefore air flow would be slows down as a result lower room accept only insufficient flow and upper room receive no wind.

	
Partition wall is perpendicular to the air flow alert patterns as a result the back side room is inadequately received the cooling wind.	Air flow is stopped by partitions wall hence it will be block and its cause that cooling effect turn into inadequate.

Moreover, when the inlet faces a high, location of opening is most operative; the outlets lease a low-pressure area. By pressure changes and by effectiveness of the unprotected openings, the air change is overseen. The high outlet to inlet size ratio secures fastest airflow and so most cooking area in the building. Outlet location is irrelevant to income flow pattern and if energy is inspired by directional changes, speeds will be slow. Instead, the flow pattern directs upward to the ceiling, slightly toward or downward the floor, if the position of outlet held constant while inlet placed at low, middle or high positions. The stream has to be heading to the living space, uncertainty the air flow is to be effective and create a cooling effect for the inhabitants. The inlet placement governs the pattern of flow in the structure and can be controlled by positioning, type and arrangement of inlet (Olgyay, 1963).

Table 2: The effect of wind flow on section of a building (Olgyay, 1963)


Plan
Effect of wind flow on section of a building

 Section A-A	 Section A-A
Outlet located near to the ceiling and inlet places down which causes to have satisfying air flow.	Inlet position high near to the ceiling, oulet located in the middle. Inlet and outlet have unequal size as well. As a result of inlet and outlet position air flow will lost the cooling effect.
 Section A-A	 Section A-A
Outlet situated in the middle but inlet place down hence the air flow is downward and it is pleasant.	Outlet located down, close to the floor and inlet places down as well hence, pleasant air flow goes through the space,
 Section A-A	
Inlet located down but outlet place in the middle the result of this situation is having the air flow down toward the floor .	

By having all these data related to wind effect both on plan and section of a building, this study attempts to develop the justified graph method which could consider the effect of wind both on two dimensional and three dimensional perspectives. After considering different factors of thermal comfort conditions, this study try to use a modest method that could demonstrate the thermal comfort condition graphically. So, this research chose space syntax method, which is simple and easy method to use.

2.4 Space Syntax

The meaning of the syntax in literature is the word order in one sentence. From another point of view syntax means the relation of each space with the other spaces. From another point of view, it describes as understanding the role of one word in one sentence. Steadman, Bill Hillier and Julian Hanson, has started space syntax from 70th century in England. This is the kind of new subject in architecture, which there is just one Iranian article about it. The inventor of this method attempts to survive on architecture field from social-cultural point of view that has ability to analyze the building with different tools. The aims of these researchers were to comprehend the social relation between the spaces such as understanding the degree of privacy and public between them. For reaching to this purpose they use Graph.

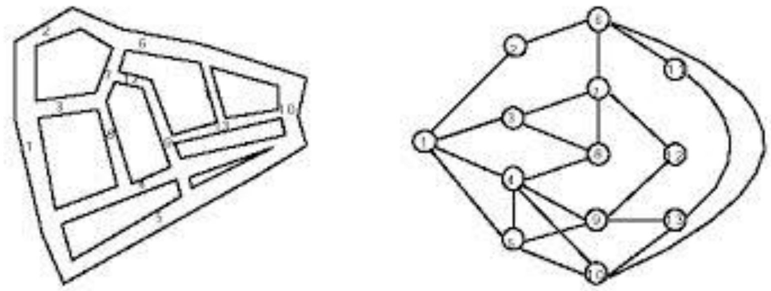


Figure 4: Access graph is a tool of space syntax method (Hillier B. , 2007)

The significant theoretical idea of space syntax is a social reason that is understandable if it is assumed as being defined by two relationships. These relations could be distinct between the inhabitants (private) and other people (public). This kind of impression is not distinctive to Hiller and Hanson's formulation of space syntax. For instance, Urry (Urry, 1987) illustrated that there is a significant disagreement between those who are local such as the people like us and those who are non-local such as the outsider.

In addition, there are two terminologies of genotype and phenotype in space syntax method. Phenotype is the one, which could be different among the time and place.

However genotype is the one that is always same. For instance, army camp composed of different functions such as kitchen, storage, soldier's tent, head of the camp and etc. if these army camp has been located on the jungle or on the desert the organization of the function would be same and just the location would be different. The relation of the function with each other called as terminology of genotype that is immutable. The location that the camp should be locates on it called as terminology of phenotype, which is immovable. The relation between these function always will be the same such as situating the head of the camp as a head of this army on the protected area whit some defending function round of it and so on (Memarian G. , 2012).

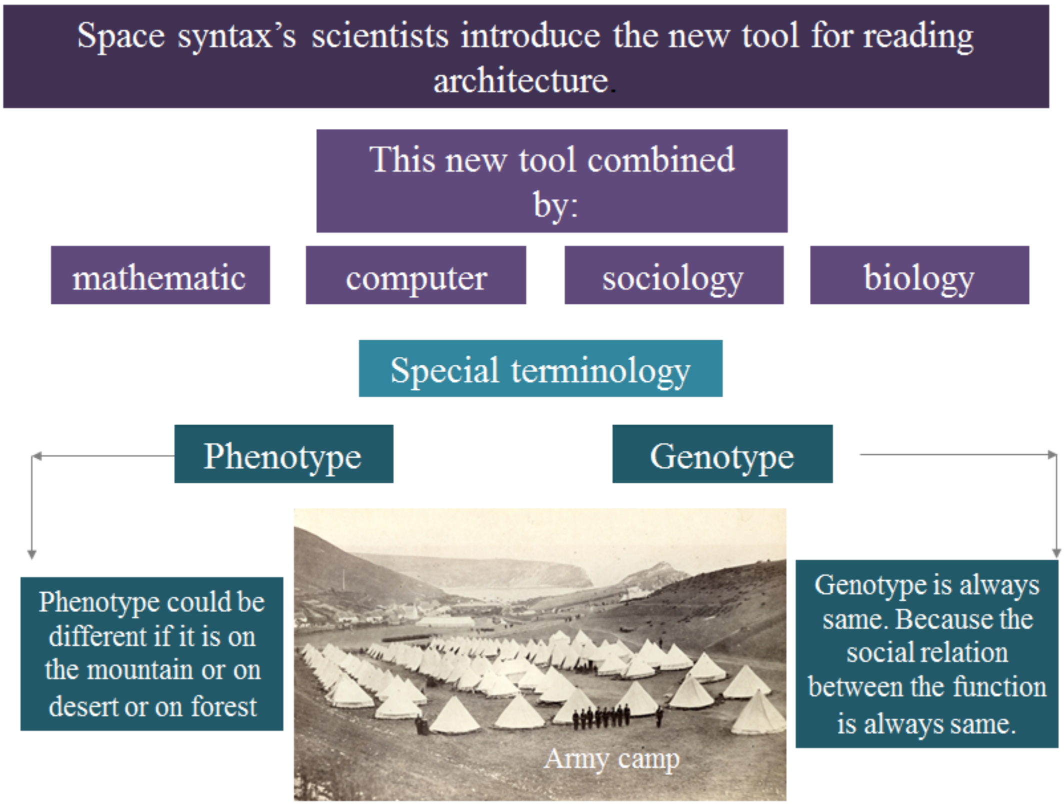


Figure 5: Terminologies of space syntax

Steadman in his book with the simple language compared the geometrical form of the spaces in one building in the manner to find out the possible combination between them. For instance, he considered the combination of one corridor with one room. Then he illustrated the combination which has more functional logic among the others option. However, Hillier and Hanson developed this idea from the other aspect. They started to work on the hidden factors such as the genotype, which cause different combination of spaces (Memarian G. , 2012).

The spatial organization analysis of the built environment has also developed from space syntax analysis that was perceived by Hillier and Hanson (Hillier & Hanson, 1997) (Hiller & Hanson, 1984). Space syntax analyzed the built environment theories in the manner to find out how this construction of space can be distinct by using standardized visual conventions. It becomes probable to evaluate the social relationships characteristic in spaces through the identical forms of visual representation and explanation. Afterwards, in 80^{th} century, Hillier and Hanson for reaching to this purpose developed the method by getting use of access graph. Access graph make it possible to do different simulation of space organization.

2.5 Access Graph

At first it should be mentioned that there are different kinds of tools to evaluate climatic aspects of a building. These include TAS (building plants and systems design and simulation, energy consumption, building simulation, CO2 emissions, dynamic thermal insulation, HAVC simulation, day lighting, thermal analysis, energy simulation, energy cost, design day simulation, solar shading, comfort studies, natural ventilation,), HEED (application for simulating home energy efficient design), ZEBO (Zero Energy Building), BEAVER (it is applicable for simulating thermal analysis and energy), AVReporter (simulation program for energy management), BuildingSim (applicable for simulating thermostat and energy cost), Building Advice (energy simulation of whole building, sustainability buildings and renewable energy), BV2 (this is a kind of durational diagram for simulating annual energy use), BUS** (it is applicable for simulating indoor air quality, ventilation, air flow, energy performance and noise level), DOE-2 (this simulation is applied in residential and commercial buildings, research, design, energy performance, retrofit), Efficiency SMART (it is applicable for operational energy efficiency measures, building performance, schedule, reports peak demand, alerts, energy data visibility, energy savings, management, adjustment, meter data, interval data and energy performance) and ESP-r (this simulation is applicable for energy simulation and environmental performance in commercial buildings, residential buildings and visualization complex) (US department of energy, 2014). All of these software tools are used to do complicated evaluation criteria for estimate a building's performance in terms of thermal comfort factors. However, most of these software programs disregard a building’s energy performance because these programs only estimate the potential energy preservation in a building rather than the actual amount preserved in a building's energy performance. Furthermore, these software programs never address the comfort of the inhabitants in the energy-efficient architecture designed to meet the energy-preservation estimates they generate. However, the access graph is a useful tool to analyze spatial relations.

The first step of access graph is related to the history of Königsberg. Nowadays the name of the city is Kaliningrad and it is one of the main cities for industrial and commercial trades in western Russia Königsberg is a city where Pregel River by passing through it, divided the city into four districts. The city is located in western Russia. During the eighteenth century, there were constructed seven bridges that connect the four different regions to each other. However, the resident of the city were wondering that for going to one of the region they should pass from one of the bridge twice or it is possible to just pass once from each of the bridge. Leonhard Euler who is a Swiss mathematician researcher invented the solution from the new chapter of mathematics that is named graph theory (Van Dooren, 2009).

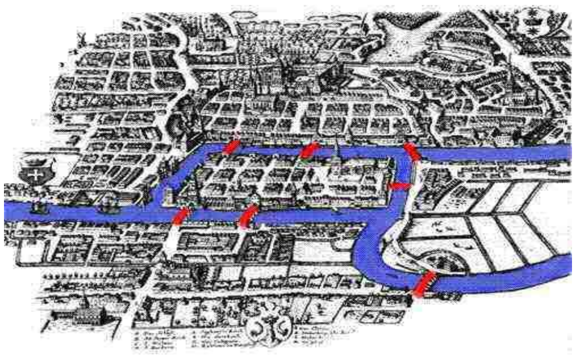


Figure 6: Königsberg city where is divided by the river into four regions (Van Dooren, 2009)

Four regions are displayed by vertex and seven edges are connected them as follow:

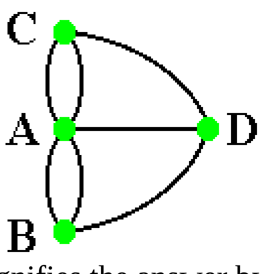


Figure 7: Leonhard Euler signifies the answer by graph (Van Dooren, 2009).

The conversion of the buildings into the graph analysis is simpler rather than the settlement pattern. For the reason that, each spaces in a building could be consider as a cell and some link can be represent the relationship between them. Also there is some kind of spaces such as carrier where are located outside and it is signified as a point.

A step being can be identifying as a movement from one space to another. For instance, every space in the building is allocated a depth value. This depth value is consistent with the minimum number of steps that inhabitant must be taken to reach at that space from the starting carrier. For drawing the graph, each space could be illustrated by the circle and connection by lines. At the same time, all the spaces depth are organized horizontally on top of the carrier and all the space are connected with lines which could illustrated the direct permeability (Hiller & Hanson, 1984). For instance figure 8 exemplified the different permeability graph which are allocated to the three building plan with the same adjacent. This differentiation will demonstrate the degree of each spaces where are integrated or segregated from the whole complex.

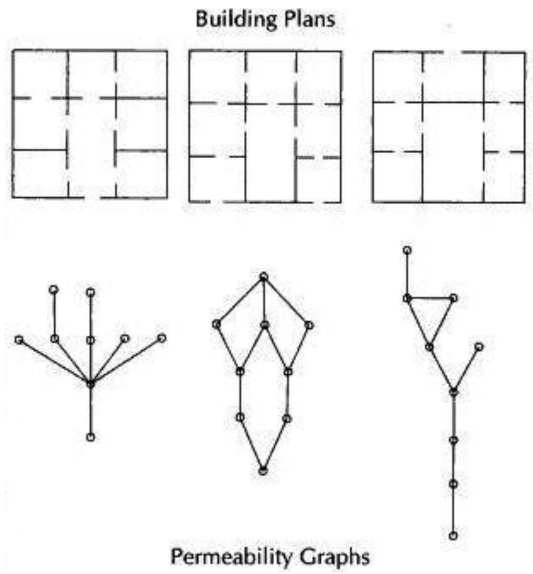


Figure 8: Example of three buildings with identical room adjacency but different permeability graphs (Hiller & Hanson, 1984).

2.6 Basic Concepts of Graph Theory

The basic concept of graph theory concludes of vector and edges. These factors could be illustrated as spaces and the edges expressed the connection between them (Beineke & Wilson, 2005).

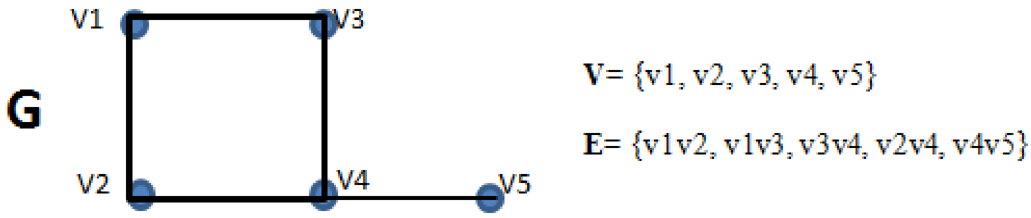


Figure 9: Bullets demonstrated the vector and line illustrated the edges (Marcus, 2008).

Furthermore, there are two different types of graph like direct and digraph. Directed graph or digraph is a kind of graph which edges are directed. From another point of view, edges have a specific direction. Furthermore, a path that is joined in two vertices X and Y of a digraph is a structure of separated vertices and directed edges. Sometimes there is some kind of path that is starting from one vertex and ending to that point then this kind of path is called loop (Marcus, 2008).

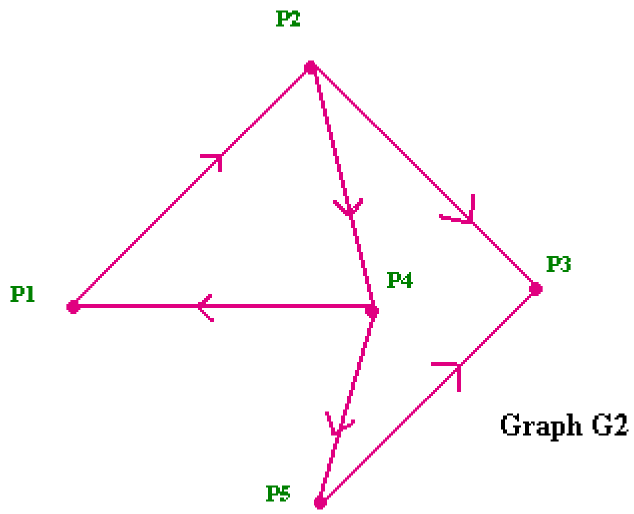


Figure 10: In this graph there is a loop in P1, P5, P2, and P4 (Marcus, 2008)

There is another kind of graph such as connected and disconnected graph. Connected graph is a kind of graph that there is a path connecting between any vertexes and by reveres if there is not any connection between vertexes it is called disconnected graphs (Marcus, 2008).

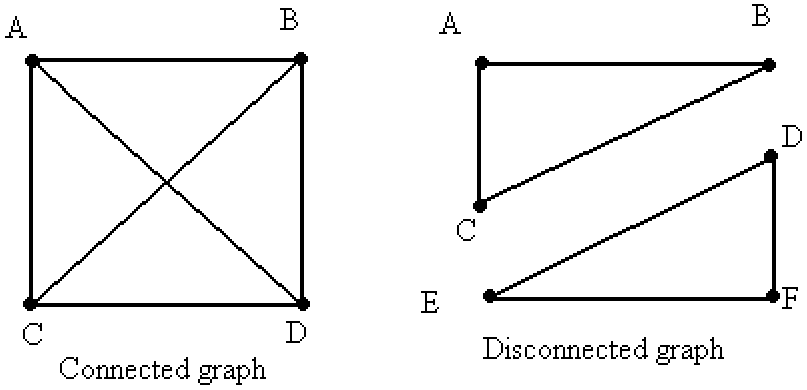


Figure 11: Connected and discounted graph (Marcus, 2008) (Beineke & Wilson, 2005)

Moreover, graph theory represented these vectors and edges into the matrix analysis. The sum of the matrixes can demonstrate the rate of connectivity for each of the vectors (figure 12).

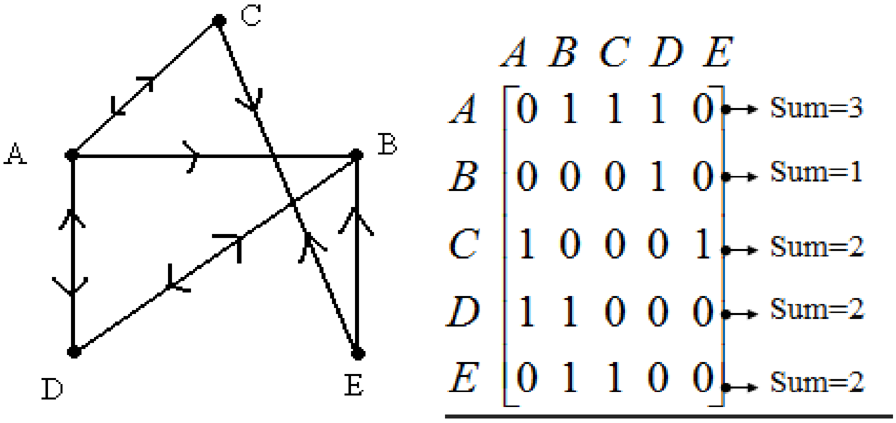


Figure 12: Graph theory and matrix analysis (Marcus, 2008)

In this entire graph bullet A took highest grade that means it has more connectivity with other spaces. But bullet B took the lowest grade and it is demonstrated that the connectivity of B is less than the other bullet. In addition bullet C, D and E have same condition of connectivity with other bullet. This research will use the same logic of graph theory and in terms of matrix analysis will analyze the value of each space by considering thermal comfort factors. It means that if the spaces in a building, same as bullet in this graph took more grade, could had the best comfortable condition and by reverse if they took the lowest grade means their condition for thermal comfort is on lower level. In the following section, this study concentrates on matrix for continuing the analysis in terms of matrix analysis.

2.7 Type of Matrix

A 0-matrix is a kind of matrix that each entry is 0. For instance, the calculation for matrix A and 0 of the same size is A+0=0+A=A. All 1-matrix is a matrix in which each entry is 1.

There is a matrix such as upper triangular matrix. This kind of matrix is a square matrix in which every entry below and to the left of the diagonal is 0. A lower triangular matrix is distinct similarly. A block matrix is another type of matrix that it is organized in sub matrix Bij (Beineke & Wilson, 2005).

$$\begin{pmatrix} B11 & B12 & .... B1x \\ B21 & B22 & .... B2x \\ \multicolumn{3}{c}{\dots\dots\dots\dots\dots\dots} \\ Br1 & Br2 & .... Brx \end{pmatrix}$$

Figure 13: Block matrix (Beineke & Wilson, 2005)

Sometimes working with graph is so complicated hence matrix will be very useful tool in the manner to study graph. Meanwhile they turn the picture into numbers, and then one can use techniques from linear algebra. For instance in the following diagram exemplifies the route map of a delivery company that is displays like below:

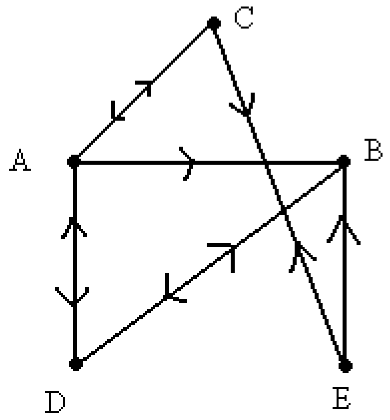


Figure 14: Diagram show the route map of a delivery (Cameron, 1999) (Dixon & Mortimer, 1996) (Lipschuts, 1974) (West, 2001) (Wilson, 1996)

Where A, B, C, D, E are the cities served by the company. The adjacency matrix *M* of the above graph is:

$$\begin{array}{c} \\ A \\ B \\ C \\ D \\ E \end{array} \begin{array}{c} \begin{array}{ccccc} A & B & C & D & E \end{array} \\ \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \end{bmatrix} \end{array}$$

Figure 15: Adjacency matrix M (Cameron, 1999) (Dixon & Mortimer, 1996) (Lipschuts, 1974) (West, 2001) (Wilson, 1996)

The matrix analysis displays the number of graph like A to A and A to E. Since, there is no connectivity between them. In addition, A to B, C, E and D has just one direction connectivity so demonstrated as 1. This formula continues for each bullet according to the connectivity between them.

There is another kind of graph that is called dominance -directed graph. A digraph *G* is named a dominance directed graph. For the reason that in this kind of graph there is a pair of distinct vertices *u* and *v* of *G*, either $u \to v$ or $v \to u$. For instance, $u \to v$ represent that there is an edge from *u* to *v*. in the following, this research demonstrate some example of dominance-directed graph.

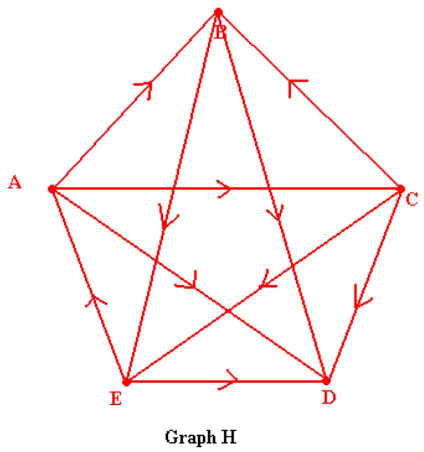


Figure 16: Dominance-directed graph (Cameron, 1999) (Dixon & Mortimer, 1996) (Lipschuts, 1974) (West, 2001) (Wilson, 1996)

Graph H demonstrate that vertices A, C and E have different kind of properties. For instance, from each of the vertices there is either a 1-step or a 2-step connection to any other. In a sports tournament these vertices would relate to the most influential teams in the manner that these teams beat any given team or beat some other team that beat the given team.

Researchers define the power of a vertex in a dominance-directed graph as being the entire number of 1-step and 2-step connections to other vertices. By using the adjacency matrix *M* of the graph, one can find the power of a vertex P_i as follows. For instance the sum of the items in the i^{th} row of *M* is the total number of 1-step connections from P_i to other vertices, and the sum of the entries in the i^{th} row of M^2 is the total number of 2-step connections from P_i to other vertices. Therefore, the sum of the entries in the i^{th} row of the matrix A=M+ M^2 is the total number of 1-step and 2-step connections from P_i to other vertices.

In a dominance-directed graph, one would like to locate the vertices with the largest power. To do that, we compute the matrix A=M+ M^2 , and then a row of A with the largest sum of entries corresponds to such a vertex. The below example can clarify the outcome of a baseball tournament of five teams such as A, B, C, D and E that are given by the dominance-directed graph H above. The result of adjacency matrix M of H is following like this

.

$$\begin{array}{c} \\ A \\ B \\ C \\ D \\ E \end{array} \begin{array}{c} \begin{array}{ccccc} A & B & C & D & E \end{array} \\ \begin{bmatrix} 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix} \end{array}$$

Figure 17: Matrix M

So, the matrix M^2 is

$$\begin{array}{c} \\ A \\ B \\ C \\ D \\ E \end{array} \begin{array}{c} \begin{array}{ccccc} A & B & C & D & E \end{array} \\ \begin{bmatrix} 0 & 1 & 0 & 3 & 2 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 2 & 1 \\ 0 & 1 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array}$$

Figure 18: Matrix M^2

Consequently, according to all these investigation, they found that since the first row has the largest sum so the vertex *A* must have a 1-step or 2-step connection to any other vertex. Hence, the ranking of the teams consistent with the powers of the conforming vertices would be like this: Team A (first), Team C (second), Teams B and D (third) and Team E (last) (Cameron, 1999) (Dixon & Mortimer, 1996) (Lipschuts, 1974) (West, 2001) (Wilson, 1996): the matrix $A=M+M^2$ is

$$\begin{array}{c} \\ A \\ B \\ C \\ D \\ E \end{array} \begin{array}{c} \begin{array}{ccccc} A & B & C & D & E \end{array} \\ \begin{bmatrix} 0 & 2 & 1 & 3 & 3 \\ 1 & 0 & 0 & 2 & 1 \\ 1 & 1 & 0 & 3 & 2 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 \end{bmatrix} \end{array} \begin{array}{l} \\ \to sum = 9 \\ \to sum = 4 \\ \to sum = 7 \\ \to sum = 4 \\ \to sum = 2 \end{array}$$

Figure 19: Matrix $A=M+M^2$

According to all of above description, this research will be going to study access graph in terms of matrix analysis in order to understand the thermal value of each spaces. However, access graph has some deficiency that in the following section the author focuses on these issues.

2.8 Discussion: Criticizing the Access graph

The space syntax method can translate a complicated plan into a simple language just by drawing an access graph (Brown, 1990; Frank, 1996). This research listed several problems with access graphs in general. Table 3 shows the advantage and disadvantage of the access graph method according to the literature surveyed in this research.

Table 3: Advantages and disadvantages of the access graph method.

Access Graph Method	
Advantage	**Disadvantage**
Access graphs are part of a long tradition of graphical or diagrammatic architectural analysis, and Lynch (1960) substantially influenced this tradition with his phenomenal city description.	The most applicable use of access graphs is limited to urban design.
Access graphs easily and clearly demonstrates the integration and segregation of spaces (Memarian, 2011).	The definition and drawing of access graph can be illustrated in two different ways. However, this differentiation cannot translate the two kinds of social interactions in a building (Memarian, 2011).
Access graphs can represent complicated plans in a simple language with bullet and line.	Spatial relations are insignificant because the same type of bullet represents a big room and a small storage closet.
Access graphs can present socio-structural issues (Hillier & Hanson, 1984; Hiller, 1986).	Access graphs are not applicable for the analysis of thermal comfort factors.
Access graphs determine and minimize the number of necessary nodes that is the important units that shaped the graph (Peponis, Wineman, Rashid, Kim, & Bafna, 1997).	Sometimes defining the nodes from two entrances will yield the wrong results in terms of spatial depth.
Access graphs for making a complicated plan simple for reading illustrate the closed spaces of buildings as full circles and the connecting spaces, such as stairwells and corridors, as empty circles.	Defining space as empty and full circles does not offer a realistic view of spatial functions and cannot even reveal the shape of the spaces.
Access graphs demonstrate the relations between spaces (Memarian, 2011).	The relations between spaces are only understandable from the point of entry.
Compared with different analytical methods in architecture, access graphs can yield interesting result. Since, by considering just connectivity could evaluate the privacy of each space.	Access graphs are problematic when used with buildings that have multiple entrances.

Access graphs illustrate the closed spaces of buildings as full circles and the connecting spaces, such as stairwells and corridors, as empty circles. In addition, the lines between them demonstrate the connection between spaces (Memarian, 2011). However, showing space in terms of empty and full circles does not present a realistic view of the spaces' functions and cannot even reveal the shape of the spaces. Sometimes the different shapes of spaces can inspire the movement of inhabitants differently. Furthermore, in access graph, the different areas of spaces are insignificant because the same type of circle will indicate a large room and a small storage closet, which cannot be meaningful for the most empathetic use of the spaces inside buildings. For example, in a traditional Iranian building, the size and shape of a space guides the space's function.

Another significant issue for understanding the privacy of each space with this method is the relation of spaces; the architect can comprehend the relation of spaces only from the entrance point. However, understanding spatial relations from the entrance point cannot give a meaningful answer to the relations of all spaces within a building. Likewise, access graphs are problematic when a building has more than one entrance. Furthermore, the definition and drawing of access graphs can be illustrated in two different ways since of having two entrances. Thus, according to these criticisms, author created a justified graph method, solving some of the issues with the access graph method to analyze traditional Iranian buildings in terms of thermal comfort factors.

For traditional Iranian buildings, Memarian (2011) studied the architecture from the cultural and climatic context of that by using the space syntax method. In his investigation of climate, Memarian analyzed two sections according to seasonal movement, and he proposed justified access graphs, one being general and two being winter and summer access graphs. However, there are some deficiencies in his research. For instance, he did not differentiate between buildings that have only one entrance and those that have multiple entrances. Moreover, Memarian did not consider open and semi-open spaces, which are the most comfortable spaces for the inhabitants of traditional Iranian buildings in the evening and overnight during the summer. Thus, Memarian's limited investigation of traditional Iranian architecture in terms of environmental issues does not give a thorough picture of that climate context.

Hence, this study endeavors to develop and justify the access graph method in order to analyze the effect of climate on organization of the spaces in Iranian traditional building in terms of solar gain and wind effect and call the developed method as justified graph method.

Moreover, access graph, justified access graph of Memarian and Sadoughi (2011) and justified graph method of this research has some similarities and differentiation with each other. In all the method, authors use the circle for illustrating the spaces such as the full one that shows the close spaces like room and the empty circles which demonstrating the connecting spaces like stair cases and corridors. In justified graph method of this research, circular shape reveals the close, semi-open and open spaces. The line between the circles in access graph and justified access graph exposed the connectivity between them. However, the line in justified graph method illustrated the specific direction of spaces according to north-south direction. Final appearance of access graph cited the degree of privacy and public of each space from the entrance point. Justified access graph specified the connectivity between the space and also demonstrated the winter and summer movement of inhabitants without considering the semi-open and open spaces. Consequently, justified graph method would be developed and justify the access graph in the manner to find out the effect of solar gain and wind effect on organization of close, semi-open and open spaces (figure 20).

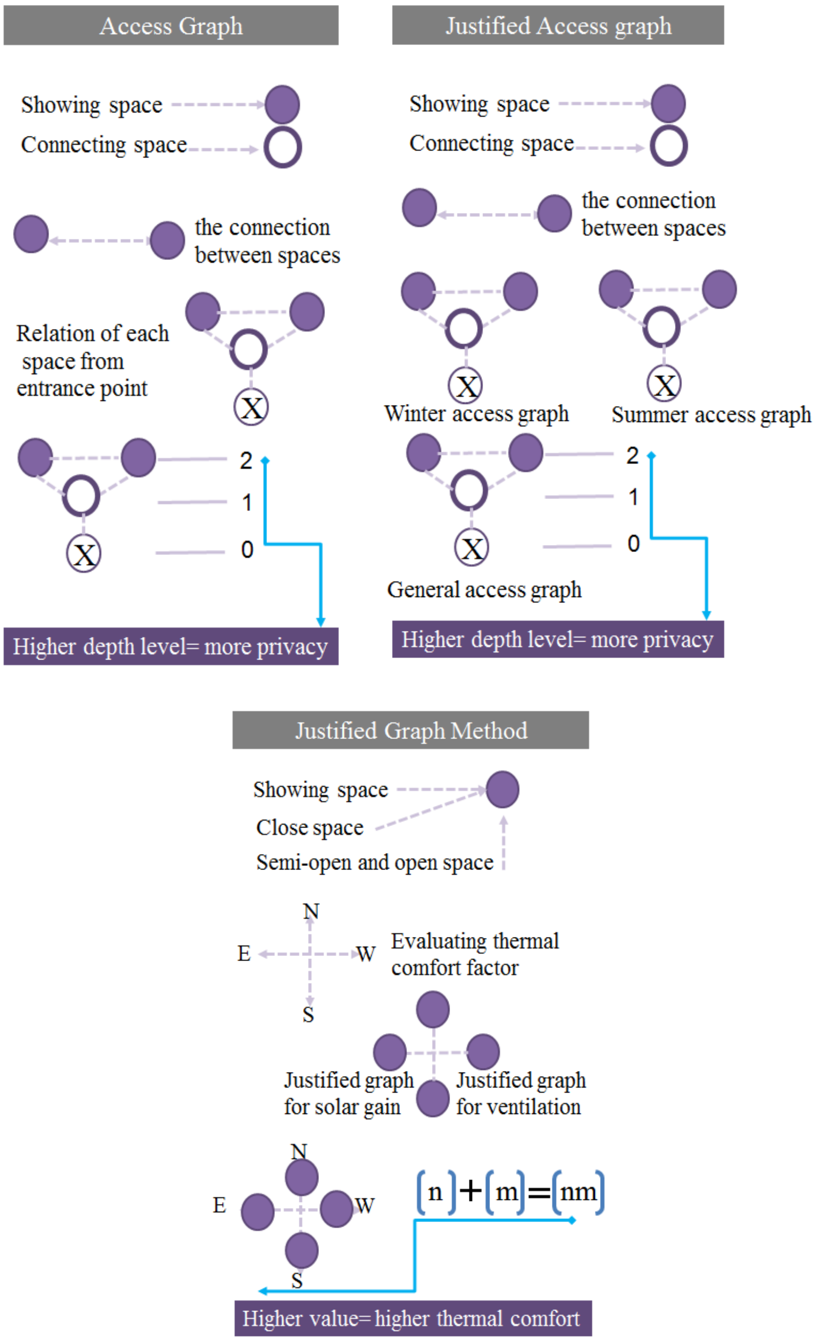


Figure 20: The differences and similarities between access graph, justified access graph and justified graph of this research

In the next section, this research will demonstrate that how justified graph method developed to resolve the climatic issue.

2.9 Developing and Justifying a Graph Method in Terms of Thermal Comfort Factors

In this study the authors used access graphs to show the effects of climate on a building's organization. This research also tested the location of some spaces that are climatically advantageous. The existing access graph method is developed to evaluate thermal comfort factors for comparison with inhabitants' seasonal movements.

Thermal comfort has various factors, such as solar gain, ventilation, humidity, air temperature, air velocity, and radiant temperature. Access graphs cannot evaluate any of these factors graphically. For the purposes of this study, these factors were divided into two main categories: solar gain and wind effect. Solar gain includes air temperature and radiant temperature; wind effect includes humidity and air velocity. However, it should be noted that the inhabitants' subjective comfort factors, such as clothing and activity were not included because these factors are not consistent enough for graphical representation.

This study used simple multi attribute rating techniques (SMART) to evaluate spaces in terms of thermal comfort factors. Edwards (1977) developed SMART, and later revised by Edwards and Newman (1982). SMART is an easy approach to weighted evaluation techniques, mostly applied in engineering (Hancer, 2005). Hence, according to SMART technique, this study defined the highest justified number three as the best thermal comfort condition and the lowest justified number zero as the worst thermal comfort condition. Figure 21 displayed the steps why the author pursuing this study, why this research is interested in use of access graph method, and what factors are used in this research's justified graph method.

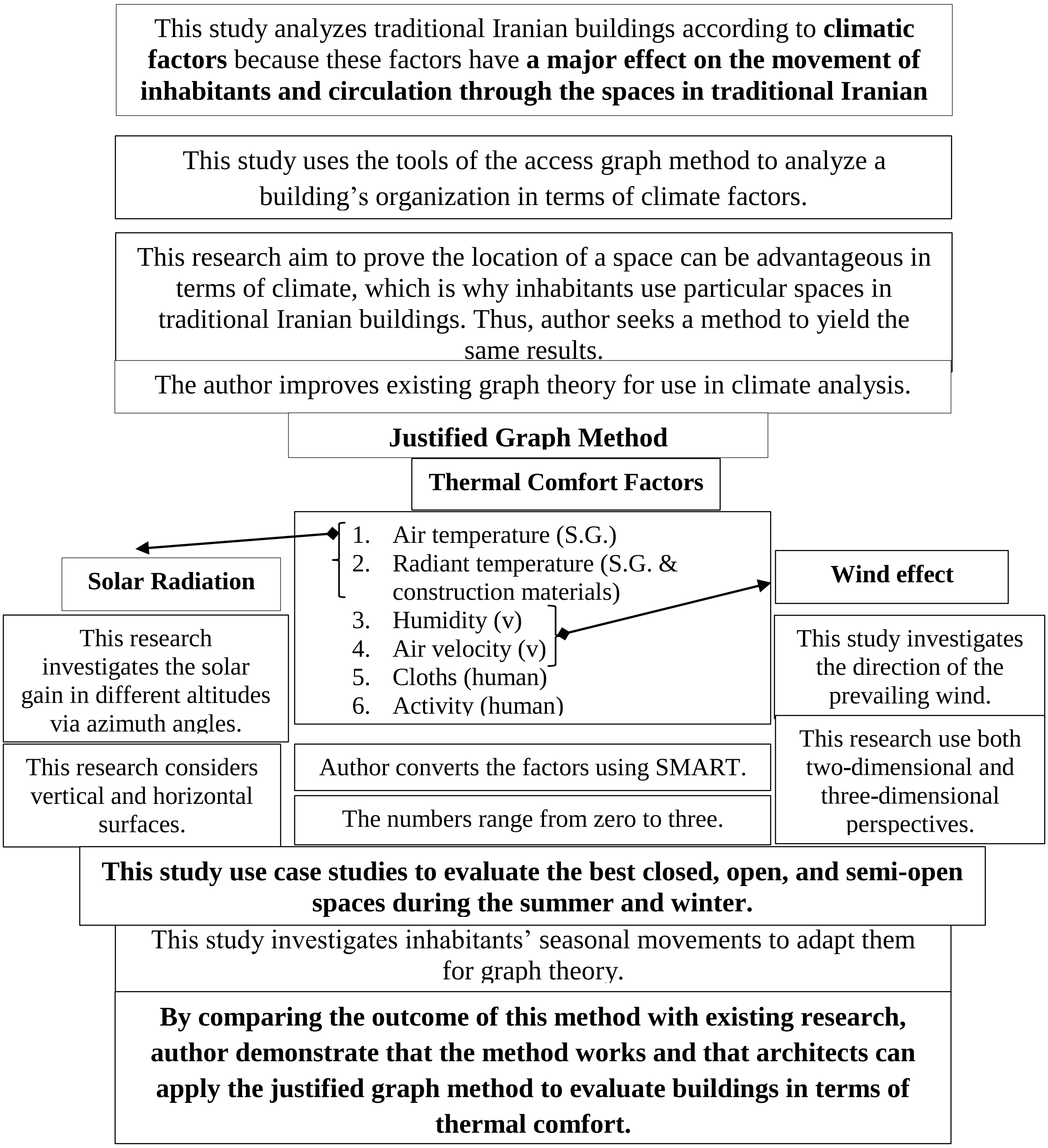


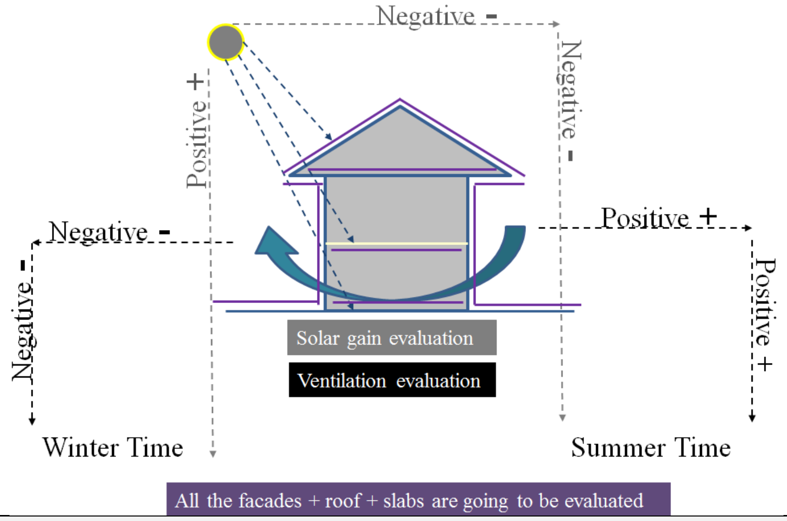
Figure 21: The steps in the adaptation of the access graph into a justified graph method

2.9.1 Developing andJustifyingGraph Method for Solar Gain

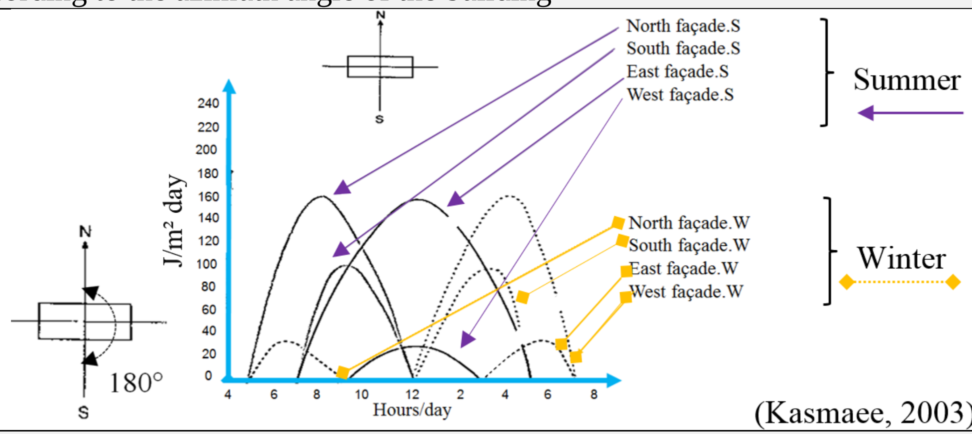
As a thermal comfort factor, solar gain is a positive factor during the winter and a negative factor during the summer. Table 4 demonstrated the solar gain graph, which by getting used of sub factors has been developed in different steps.

Table 4: Justifying the graph method for solar gain

Step 1: Considering solar radiation as positive factor during winter and negative factor during summer time.



Step 2: Finding the solar radiation and sunshine period data from Kasmee's chart according to the azimuth angle of the building



(Kasmaee, 2003)

Step 3: Identifying the intervals of amount of solar radiation (MJ/m² day) and sunshine period on building envelope (hours/day) for defining the justified number

Defining the intervals of amount of solar radiation (MJ/m² day) :

Winter time: 0 0.06 0.12 0.18 0.24 → 0 1 2 3

Summer time: 0 0.06 0.12 0.18 0.24 → 3 2 1 0

Defining the interval of sunshine period (hours/day):

Winter time 0-3 4-5 6-7 8-10 → 0 1 2 3

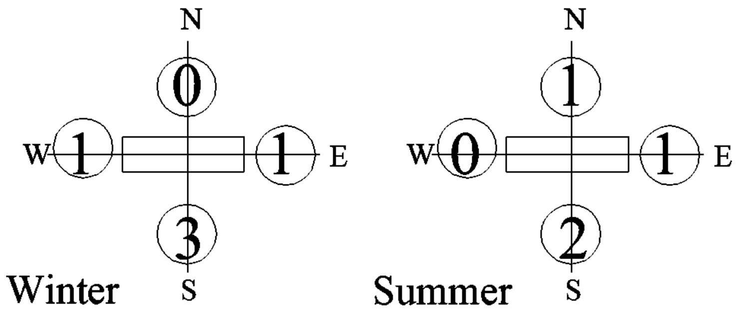
Summer time: 0-3 4-7 8-11 12-14 → 3 2 1 0

Step 4: Preparing the chart for finding the average amount of solar radiation and sunshine period on vertical surfaces at hot-humid climatic region (29 N degree latitude), during summer and winter

29° N degree latitude	180° azimuth angle	Hours/day	MJ/m² day	Justified numbers for sunshine period (hours/day)	Justified numbers for total amount of solar radiation (MJ/m2 day)	Average
Winter time	South wall	10h	0.20-0.22	3	3	3

	North wall	0	0	0	0	0
	East wall	4	0.10	1	1	1
	West wall	5	0.12-0.14	1	2	1
29° N degree latitude	180° azimuth angle	Hours/day	MJ/m² day	Justified numbers for sunshine period (hours/day)	Justified numbers for total amount of solar radiation (MJ/m2 day)	Average
Summer time	South wall	6h	0.6	2	3	2
	North wall	8h	0.2-0.8	1	2-3	1
	East wall	4h	0.1	2	1	1
	West wall	5	0.12-0.14	1	0	0

Step 5: Solar gain justified graph has been defined by finding the averages amount of solar radiation and sunshine period.



Sub-factors such as sunshine periods on a façade of a building (hours/day) and the total amount of solar radiation (MJ/m^2 day) on a building's envelope can be used in terms of solar gain, in the justified graph method. For better comprehension of the solar gain factors in different climatic regions of Iran, data from Kasmaee (2003) was used. He computed the solar effect by averaging the total incident solar radiation over the entire building envelope area during winter and summer time. These data were divided into four categories between zero to three. Justified number three demonstrates the maximum need and zero shows the minimum need of solar radiation and shading during winter and vice versa during the summer time. In Iran during winter the availability of the solar radiation on the horizontal plan being approximate half of the summer time. Hence during winter, the lowest justified number 0 is defined for the interval of 0 to 0.03 MJ/m² day. Furthermore, the interval range of 0.15 to 0.23 MJ/m² day is considered as a highest justified number 3. However, during the summer time, the total amount of solar radiation of 0 to 0.06 MJ/m² day defined for the justified number 3 and interval of 0.18 to 0.25 MJ/m² day is given to justified number 0.

In Iran, depending upon latitudes, direct solar radiation might be incident on an unobstructed roof for approximately 14 hours in summer and 10 hours in winter. The interval of sunshine period will be identified in four ranges of hours. During the winter time the facade that gets sunshine period between 0 to 2 hours will get the lowest justified number zero. But for the façade with the sunshine period of 9 to 10 hours will get highest justified number three. The justified numbers will be reverse during the summer time. The façade with sunshine period of 0 to 3 hours will get the justified number three and the façade with sunshine period of 12 to 14 hours will get the justified number zero. In the following, table 5 illustrates the justified numbers according to the total amount of solar radiation intervals. Table 6 displays the justified numbers according to the sunshine period.

Table 5: The total amount of solar radiation interval (MJ/m² day) during winter and summer

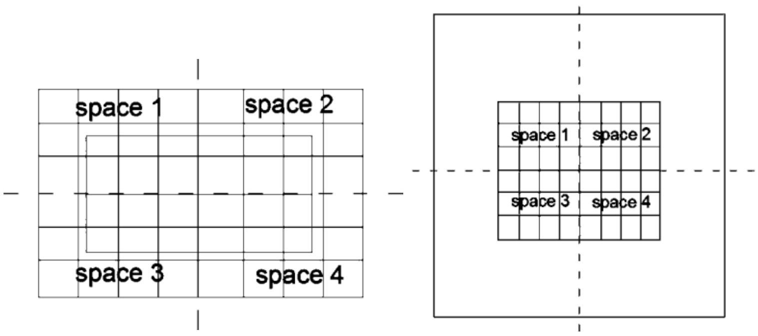
	Total amount of solar radiation interval (MJ/m² day) (Kasmaee, 2003)	Justified number		Total amount of solar radiation interval (MJ/m² day) (Kasmaee, 2003)	Justified number
Winter	0.00-0.03	0	Summer	0.00-0.06	3
	0.03-0.09	1		0.06-0.12	2
	0.09-0.15	2		0.12-0.18	1
	0.15-0.23	3		0.18-0.25	0

Table 6: Justified numbers according to the sunshine periods (day/hour) during winter and summer

	Sunshine period effect on building envelope, (hours/day) (Kasmaee, 2003)	Justified number		Sunshine period effect on building envelope, (hours/day) (Kasmaee, 2003)	Justified number
Winter	0-2	0	Summer	0-3	3
	3-5	1		4-7	2
	6-8	2		8-11	1
	9-10	3		12-14	0

Sketch Up software was used to evaluate open and semi-open spaces because this software can find the shaded areas at different hours of the day. Thus the best and worst conditions for open and semi-open spaces in the hottest and coldest months of the year were evaluated.

The plans of central courtyards of traditional Iranian buildings were divided into four different spaces. These spaces consist of three horizontal and four vertical lines, thus each space has twelve sub squares (Fig.22). During winter, the maximum number of squares (12) under solar radiation represents the highest justified number (three). The number of squares with the least amount of shade has justified number (zero)(Table 7).



Block building **Central courtyard building**

Figure 22: The division of semi-open and open spaces for defining the justified numbers according to the shading area

Table 7: Justified numbers according to the shading area of semi-open and open spaces during winter and summer

	Number of squares under shade	Justified number		Number of squares under shade	Justified number
Winter	0-3	3	**Summer**	0-3	0
	3-6	2		3-6	1
	6-9	1		6-9	2
	9-12	0		9-12	3

The second step in this investigation is to sum up the justified numbers using matrix analysis. Presenting the results through matrix analysis means that the justified graphs for solar gain are well defined. In other words, the matrix analysis results illustrate the characteristics of each closed, open, and semi-open space.

2.8.1.1 Evaluating Solar Gain on Floors and Roofs

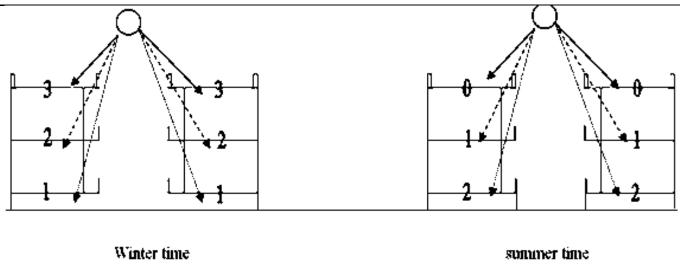
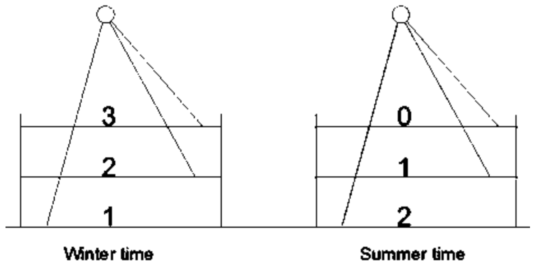
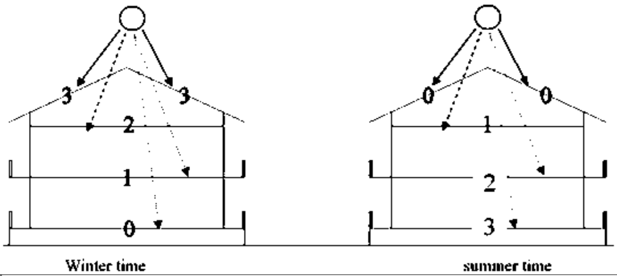
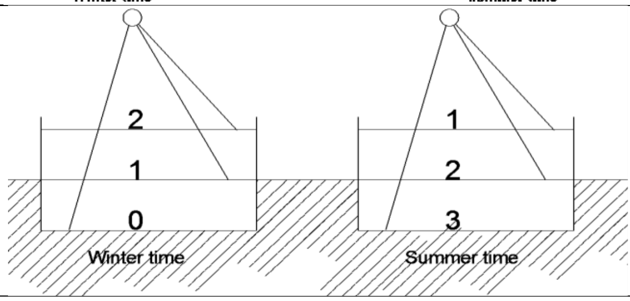
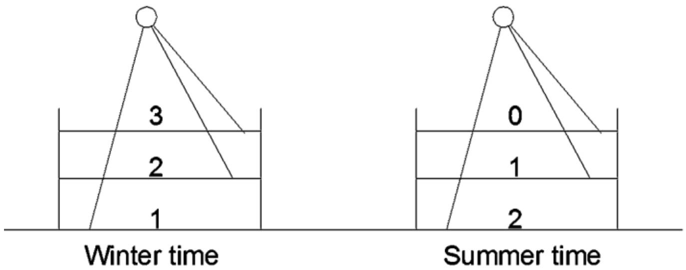
The solar gain of floors and roofs are also important in evaluations using the justified graph method. During the coldest month of the year in hot-humid climate in Iran, a flat roof may have the highest justified number (three) since; among all the surfaces of a building it has the most interactions with solar energy. First-floor slabs get a justified number of two and the ground floor, which absorbs less solar energy, has a justified number of one. The justified numbers of each floor and roof will be the reverse during the summer. Thus, light materials with low thermal capacity and with thermal insulation should be used.

In hot-dry with cold winter climate in Iran (33°N latitude), the circumstances are different since most of the traditional buildings have a ground floor and a basement. Thus, during summer, the highest justified number three applies to the basement floor, because this floor does not have any interact with solar energy. Consequently, the ground floor has a justified number of two, and the roof's level has a justified number of one. In this climate, heavy materials should be used for walls, floors, and roofs.

Intemperate-humid climate in Iran (37° N latitude), during winter, since of having sloppy roof highest justified number three are belonging to that level. Because sloppy roof receive have more interaction with solar gain during winter time. The second-floor slab should be two, the first-floor slab one and the ground floor slab zero. The materials for the traditional building envelope are the same as those, which are used, in hot-humid climate. The uses of light materials with a low thermal capacity are recommended. In addition, roofs in this climate should have thermal insulation and thermal capacity.

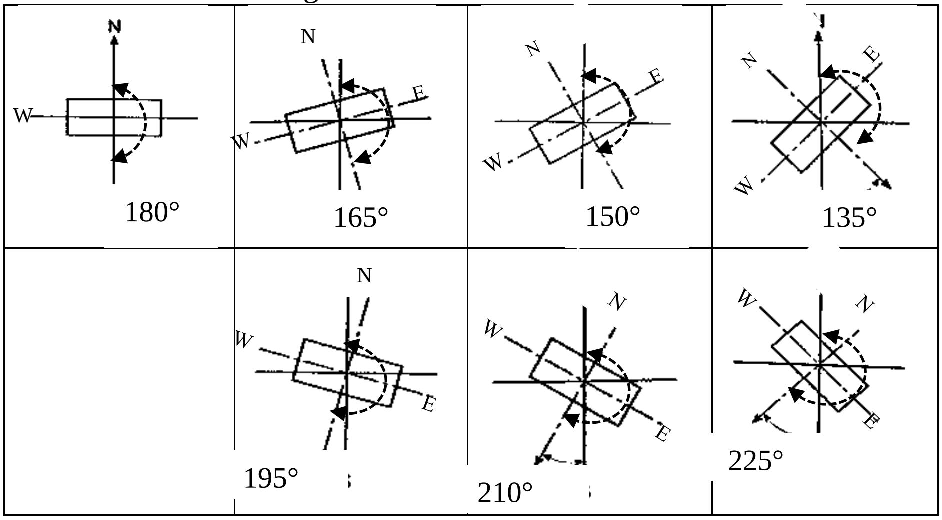
In cool climate in Iran (roughly 37°N latitude), the conditions are totally different. Traditional buildings mostly have flat roofs. Since the flat roof has more interaction with solar energy, it can have the highest justified number three during the winter; the first floor can have justified number two, and the ground floor can have a justified number one. During summer, the highest justified number three belongs to the ground floor, which has the least interaction with solar energy, and the justified numbers decrease in the opposite direction from the first floor (two) to the roof (one). Heavy materials with high thermal capacity are the best for this climate. In addition, proper insulation should be applied to the exterior of the external walls.

Table 8: Justified numbers of roof and floors according to the solar gain in winter and summer time.

	Justified numbers of roof and floors
Hot-humid climate	
Hot-dry climate	
Temperate-humid climate	
Hot-dry with cold winter climate	
Cool climate	

According to all the above explanations, justified graphs for solar gain for five different climatic regions of Iran were developed in different azimuth angels (Table 9).

Table 9: Different azimuth angles of the facades



2.9.1.2 Solar Radiation on Vertical Surfaces in hot and humid climatic region at 29° N Latitude

This subsection includes data from Kasmaee (2003) related to SPF and the amount of solar gain intensity (MJ/m² day), and this study converted that data to a justified graph method using SMART. Tables10 and 11 divide the data into four different facades, verifying the justified numbers as subsets of SPF and MJ to demonstrate the average (AVG) solar gain. The outcomes of the justified numbers were subjected to matrix analysis for the AVG section.

Table 10: Justified Numbers According to SPF and MJ at 29° N Latitude in the winter.

Winter	South wall			North wall			East wall			West wall		
Azimuth angle	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG
180°	3	3	3	0	0	0	1	2	1	1	2	1
150°	3	3	3	0	0	0	1	1	1	2	3	2
165°	3	3	3	0	0	0	1	3	2	2	2	2
135°	3	3	3	0	0	0	1	1	1	2	3	2
210°	3	3	3	0	0	0	2	3	2	0	1	0
225°	2	3	2	0	0	0	1	3	2	1	0-1	0
195°	3	3	3	0	0	0	1	3	2	1	2	1

Table 11: Justified Numbers According to SPF and MJ at 29° N Latitude in the summer.

Summer	South wall			North wall			East wall			West wall		
Azimuth angle	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG
180°	2	3	2	1	3-2	1	2	1	1	1	0	0
150°	1	3	2	1	3-2	1	2	1	1	1	0	0
165°	2	3	2	2	0-1	1	2	0	1	1	0	0
135°	1	3	2	1	1	1	2	0	1	1	0	0
210°	2	2	2	2	1	1	2	1	1	1	0	0
225°	2	2	2	2	1	1	2	1	1	1	0	0
195°	2	3	2	1	2	1	2	1	1	1	0-1	0

Having achieved the average of the justified numbers found on tables 11 and 12 this research represented the results of the matrix analysis as a justified graph. In the justified graph, bullets indicate the four facades of a building in different directions. Thus, the facades of a building in four different directions have specific justified numbers that signify the effect of solar gain during the summer and winter. This study then drew the justified graphs to be consistent with the north and south axes at different azimuth angles (Figs.23–29).

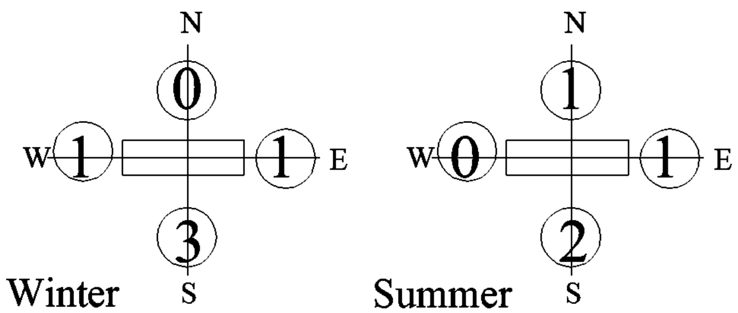


Figure 23: Justified graphs at 29° N latitude for 180° azimuth angle in winter and summer

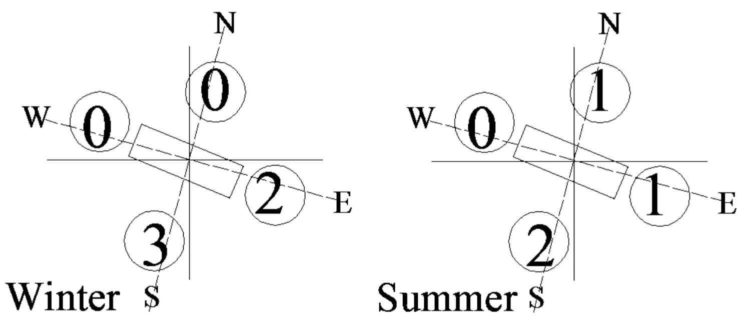


Figure 24: Justified graphs at 29° N latitude for 210° azimuth angle in winter and summer

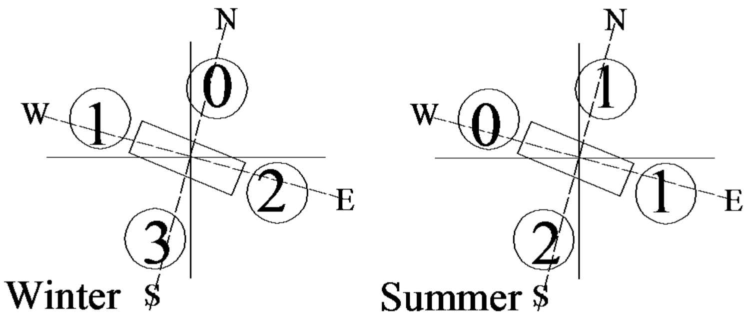


Figure 25: Justified graphs at 29° N latitude for 195° azimuth angle in winter and summer

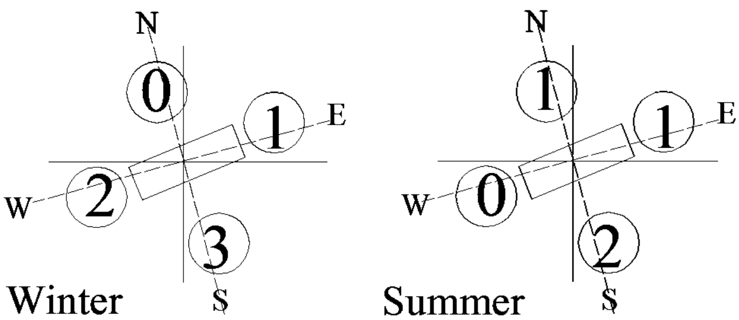


Figure 26: Justified graphs at 29° N latitude for 135° azimuth angle in winter and summer

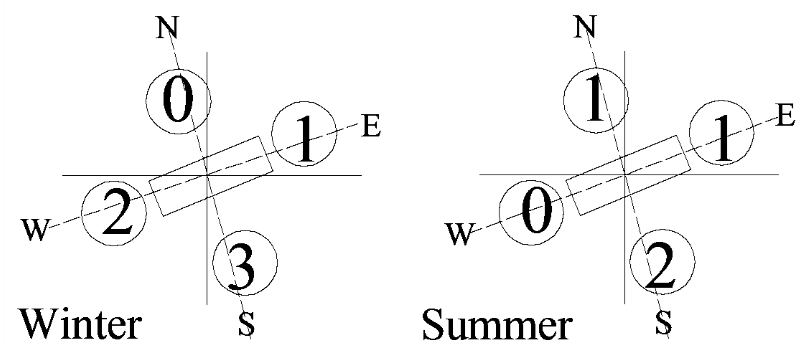


Figure 27: Justified graphs at 29° N latitude for 150° azimuth angle in winter and summer

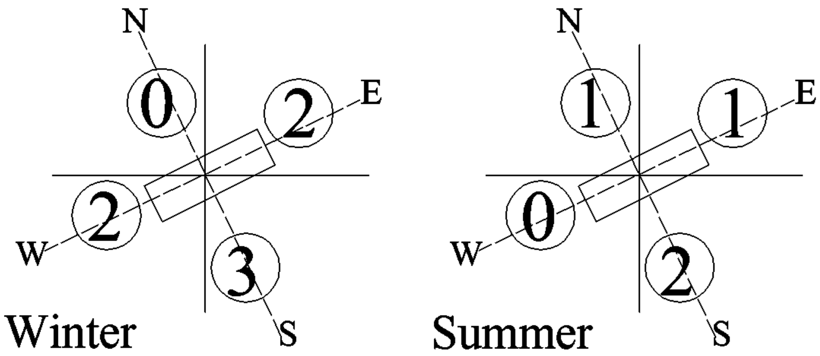


Figure 28: Justified graphs at 29° N latitude for 165° azimuth angle in winter and summer

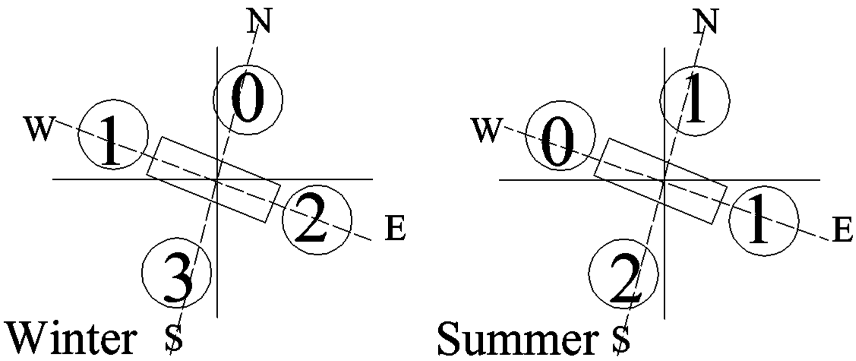


Figure 29: Justified graphs at 29° N latitude for 195° azimuth angle in winter and summer

The outcome exposed the different criteria consistent with various azimuth angles in such a hot-humid climate condition.

2.9.1.3 Solar Radiation on Vertical Surfaces in hot and humid climatic region at 33° N Latitude

For this subsection, author performed an analysis of the climate conditions on traditional Iranian architecture at 33° N latitude comparable to the analysis this study performed in the previous subsection. This research also converted the data consistent with SMART into the justified graph method for each different direction, acquiring the AVG via matrix analysis (Tables12 and13).

Table 12: Justified Numbers According to SPF and MJ at 33° N Latitude in the winter.

Winter	South wall			North wall			East wall			West wall		
Azimuth angle	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG
180°	3	3	3	0	0	0	1	2	1	1	2	1
150º	3	3	3	0	0	0	0	1	0	2	3	2
195º	3	3	3	0	0	0	1	1	1	1	2	1
165º	3	3	3	0	0	0	2	1	1	1	1	1
135º	2	3	2	0	0	0	2	0	1	1	1	1
210º	2	3	2	0	0	0	2	3	2	0	3	1
225º	3	3	3	0	0	0	3	3	3	0	1	0

Table 13: Justified Numbers According to SPF and MJ at 33° N Latitude in the summer.

Summer	South wall			North wall			East wall			West wall		
Azimuth angle	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG
180º	3	3	3	1	2	1	1	1	1	1	0	0
150º	1	3	2	1	1	1	1	1	1	1	0	0
195º	1	3	2	1	3-2	1	1	1	1	1	0	0
165º	1	3	2	1	2	1	1	1	1	1	0	0
135º	0	1	0	1	1	1	1	1	1	0	1	0
210º	2	2	2	2	1	1	1	1	1	1	0	0
225º	2	2	2	1	1	1	1	1	1	1	0	0

In accordance with the solar gain evaluation in the previous subsection, the author transferred all the averaged justified numbers into justified graphs for 33° N latitude. These justified graphs illustrate the solar gain’s justified numbers for each façade during the winter and summer (Figs. 30–36).

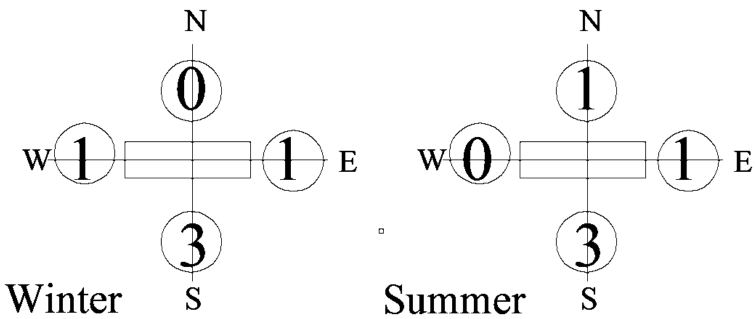


Figure 30: Justified graphs at 33° N latitude for 180° azimuth angle in winter and summer

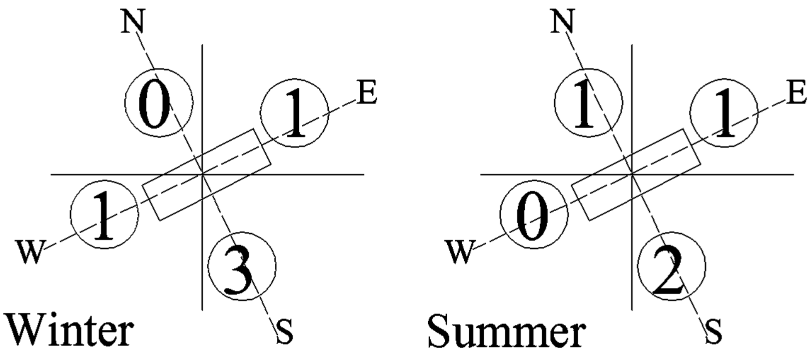


Figure 31: Justified graphs at 33° N latitude for 165° azimuth angle in winter and summer

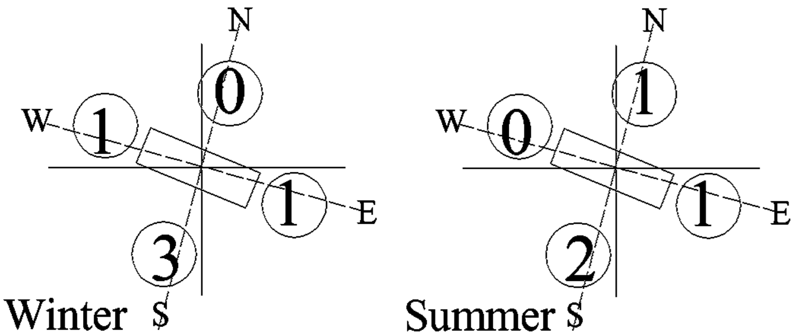


Figure 32: Justified graphs at 33° N latitude for 195° azimuth angle in winter and summer

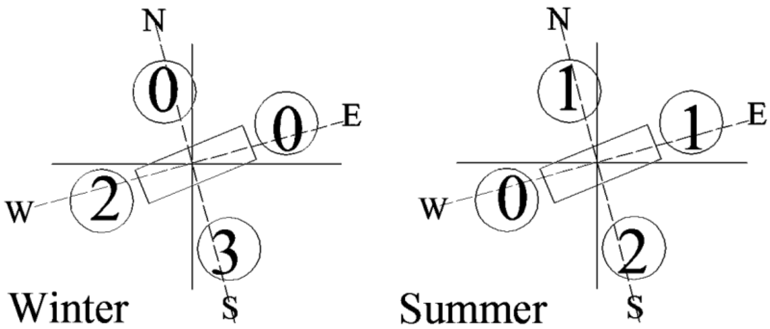


Figure 33: Justified graphs at 33° N latitude for 150° azimuth angle in winter and summer

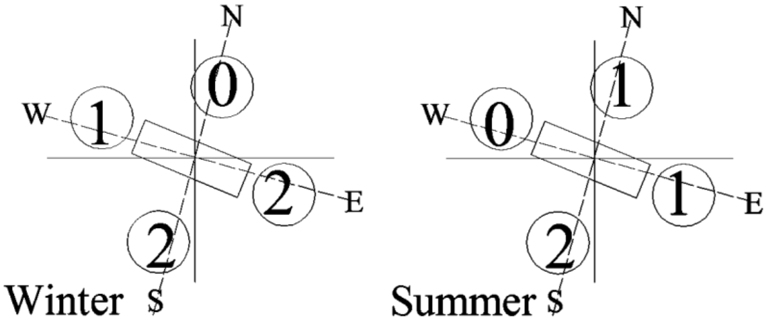


Figure 34: Justified graphs at 33° N latitude for 210° azimuth angle in winter and summer

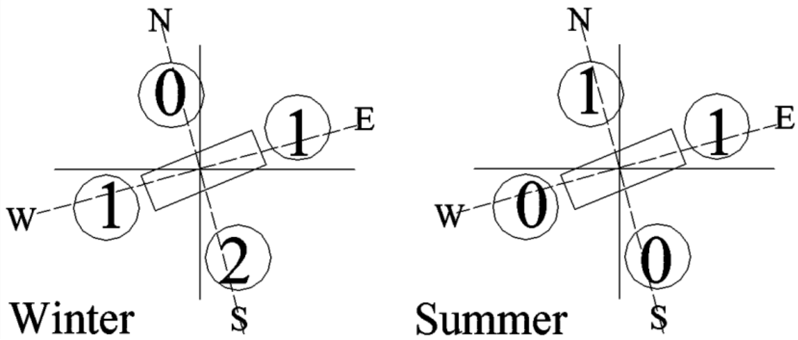


Figure 35: Justified graphs at 33° N latitude for 135° azimuth angle in winter and summer

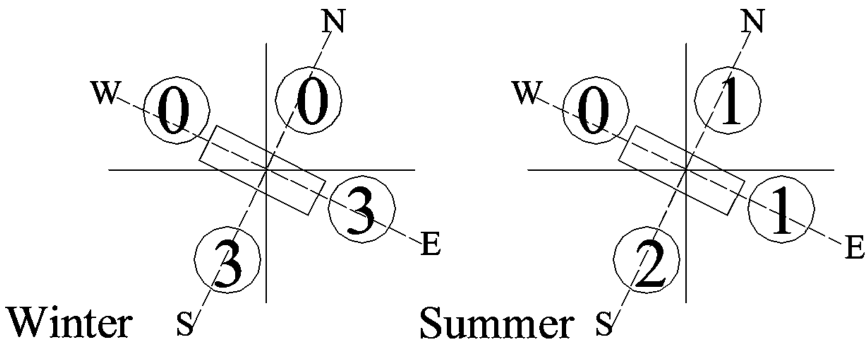


Figure 36: Justified graphs at 33° N latitude for 225° azimuth angle in winter and summer

2.9.1.4 Solar Radiation on Vertical Surfaces in temperate-humid and cool climatic region at 37° N Latitude

The analysis in this latitude matches the strategy in the previous subsections. Thus, this research converted the data collected in this section to justified numbers (Tables 14 and 15).

Table 14: Justified Numbers According to SPF and MJ at 37° N Latitude in the Winter.

Winter	South wall			North wall			East wall			West wall		
Azimuth angle	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG
180º	3	3	3	0	0	0	1	2	1	1	2	1
195º	3	3	3	0	3	1	1	1	1	1	0	0
165º	2	3	2	0	0	0	1	2	1	1	1	1
210º	3	3	3	0	0	0	2	3	2	0	1	0
225º	3	3	3	0	0	0	2	3	2	0	0	0
135º	3	3	3	0	3	1	1	2	1	0	1	0

Table 15: Justified Numbers According to SPF and MJ at 37° N Latitude in the Summer.

Summer	South wall			North wall			East wall			West wall		
Azimuth angle	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG	SPF	MJ	AVG
180º	1	3	2	1	1	1	1	1	1	1	0	0
195º	1	3	2	2	1	1	1	1	1	1	0	0
165º	1	3	2	1	2	1	1	1	1	1	0	0
210º	1	3	2	1	1	1	1	1	1	2	0	0
225º	1	3	2	2	1	1	1	1	1	2	0	0
135º	1	3	2	1	1	1	1	1	1	1	0	0

Consequently, the author identified the justified graphs of 37°N latitude at various azimuth angles during the summer and winter (Figs.37–42).

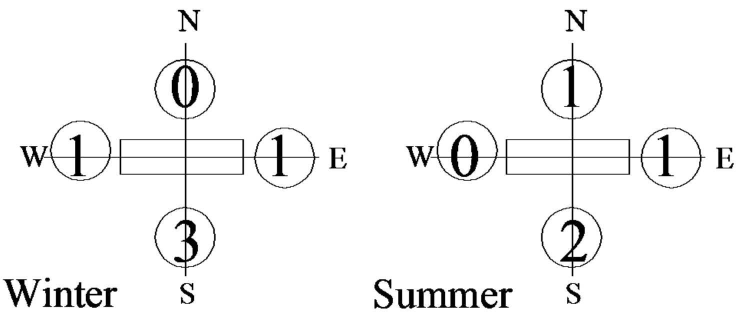


Figure 37: Justified graphs at 37° N latitude for 180° azimuth angle in winter and summer

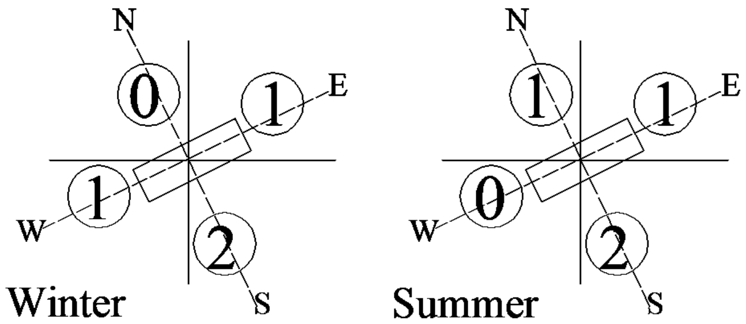


Figure 38: Justified graphs at 37° N latitude for 165° azimuth angle in winter and summer

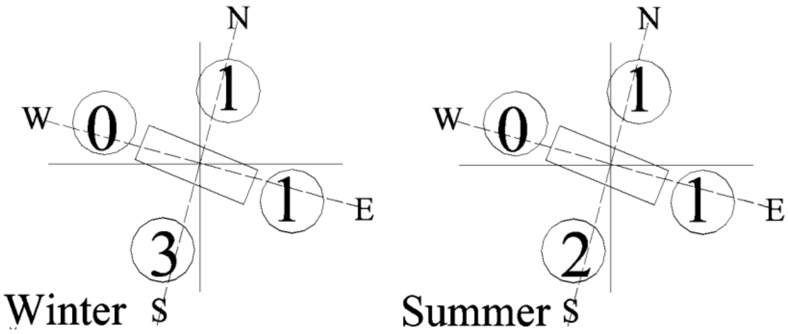


Figure 39: Justified graphs at 37° N latitude for 195° azimuth angle in winter and summer

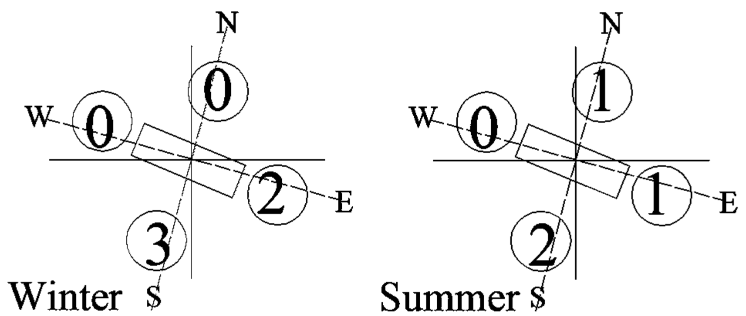


Figure 40: Justified graphs at 37° N latitude for 210° azimuth angle in winter and summer

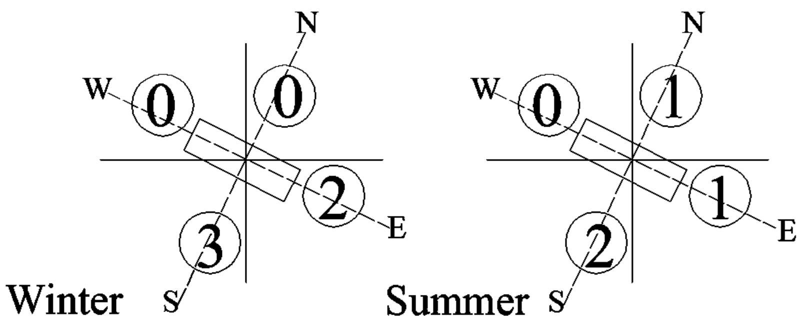


Figure 41: Justified graphs at 37° N latitude for 225° azimuth angle in winter and summer

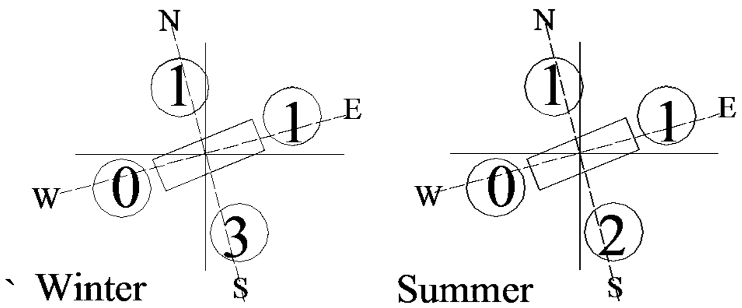


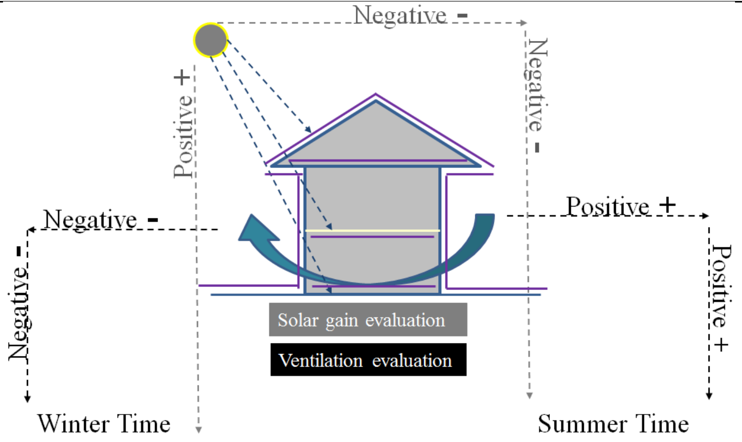
Figure 42: Justified graphs at 37° N latitude for 135° azimuth angle in winter and summer

After evaluating the solar gain, the next step has been continues by developing the method for wind effect analysis.

2.9.2 Developing a Justify Graph Method for wind effect

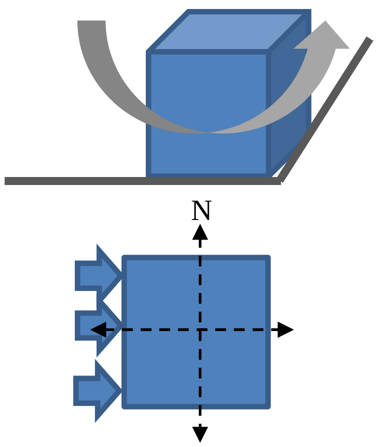
The effect of wind as a thermal comfort factor in summer and winter were evaluated. The justified numbers for each space were defined according to the direction of the prevailing wind and position of the opening (Table 16).

Table 16: Justifying the graph method for wind effect

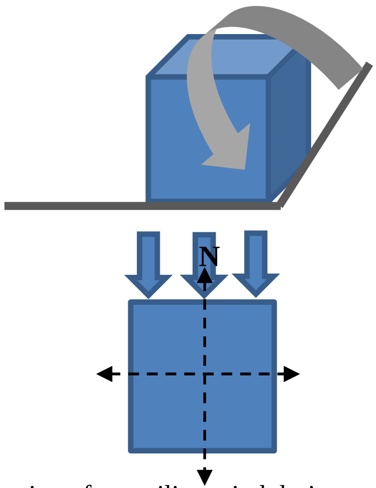
Step 1: Considering wind effect as positive factor during summer and negative factor during winter time.

Step 2: Finding the direction of the prevailing wind during summer and winter

Perspective

Plan

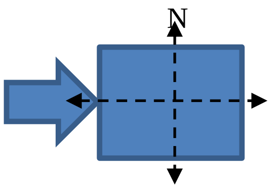


Direction of prevailing wind during winter

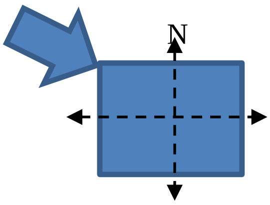


Direction of prevailing wind during summer

Step 3: Identifying the justified number according to the direction of prevailing wind

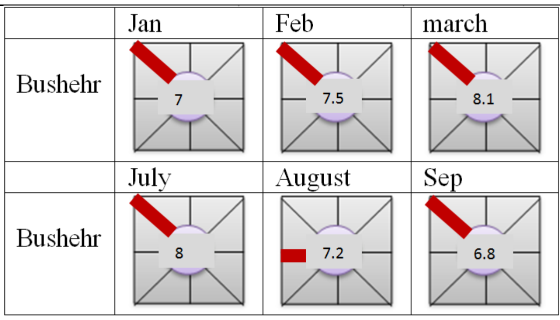


Direct wind highest justified number of the part where is under the wind direction during summer and lowest justified number during winter



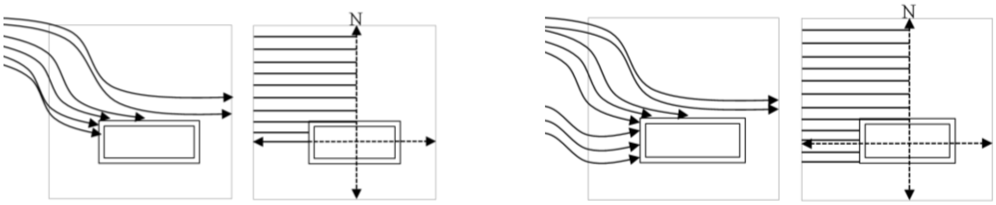
Indirect wind justified number 1 for the parts where have indirect wind during winter and justified number 2 during summer since it is not direct.

Step 4: Drawing the prevailing wind direction on the schematic plan of a building in Bushehr city and hatching the part, which are under the wind direction.



29ºN(Bushehr city)

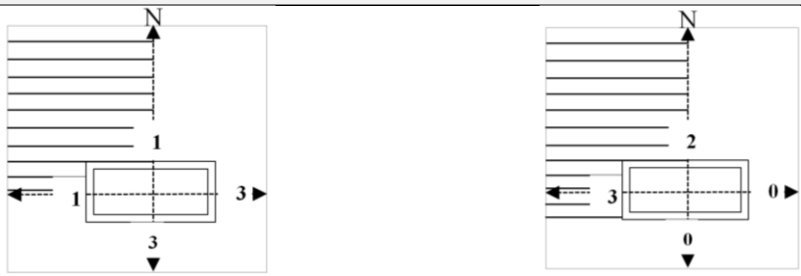
Direction of the prevailing wind in Bushehr city during winter and summer (Kasmaee, 2003)



Winter plan summer

Note* demonstrating the direction of prevailing wind on free standing building on the site

Step 5: Identifying the justified number according to the direction of prevailing wind

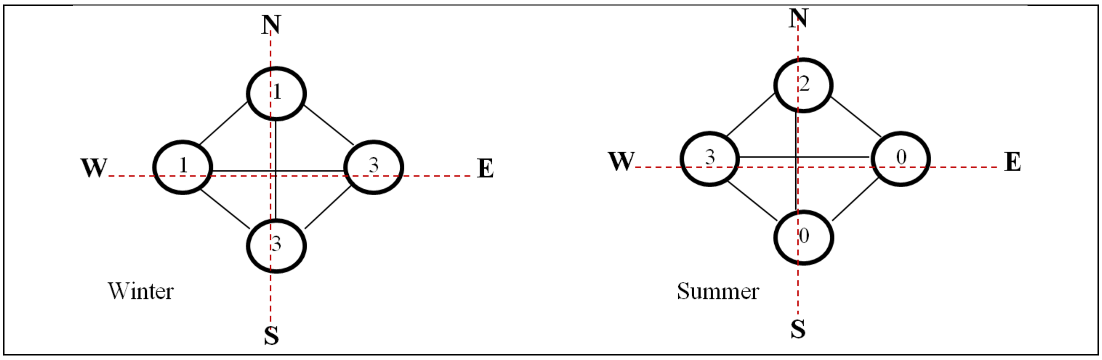


Plan

Since, during winter time the temperature is not go below zero so the facades which are under the wind direction has been defined by justified number (1) instead of (0). Furthermore, the facades that are not receiving any wind, have been defined by justified number (3).

Since, of hot and humid climatic condition of this region, the facades which are under the wind direction will get highest justified number like (3), and also the façades which are not receiving direct wind will het justified number (2) and the other facade which

Step 6: Justifying the wind effect's graph by finding the justfied number on the schematic plan accroding the direction of the prevailing wind during summer and winter time.



In a normal time the body temperature is 37 C° and 32 C° degree is a temperature of the skin. It means than human body start to absorb the heat by locating on the area hotter than skin temperature. Conversely, human body will lose the heat if it is located on the area cooler than the skin temperature. Consequently, this research is evaluating the wind as negative during winter time and positive during summer time according to the air temperature. If the air temperature is higher than the body temperature wind is negative, if it is lower than wind is positive during summer time. Conversely during winter time, if the air temperature is lower than the skin temperature, wind considered as negative and if it is higher than skin temperature, wind is positive (table 17). Furthermore, this research find out the climatic data from Iranian metrological center in the manner to evaluate the wind as positive and negative for each five different cities of Iran like, Bushehr, Kashan, Rasht, Dezful and Urumye during winter and summer time. During this evaluation, author considered 1st of July as hottest month and 1st of January as a coldest month of a year.

Table 17: Considering wind as positive and negative during summer and winter time

Winter time		Summer time	
Air temperature higher than the boy temperature 37 C°	Positive +	Air temperature higher than the body temperature 37 C°	Negative -
Air temperature lower than the body temperature 37 C°	Negative -	Air temperature lower than the body temperature 37 C°	Positive +

Generally, when evaluating wind as a thermal comfort factor, the direction of prevailing wind, placement of the opening on the facade, and the ratio of it are the evaluation criteria for wind effect’s justified graph method.

Differentiation of the air pressure on the external faced of a building cause air movement through the space of a building. Pressure difference is the consequence of air temperature difference inside and outside of a building and also the wind flow. Generally, pressure different, as the outcome of air temperate changes is very rare. Mostly, wind flow has a direct effect for causing pressure difference inside the building. It means that when the wind encounters the building facade, the direct wind flow stream above and around the building. Hence, the air pressure on the façade where are located on the exact direction of the wind is high and air pressure of the facades where are located at the backside of the wind are low (Kasmaee M. , 2003). Therefore, there is air pressure difference all around the building. From another point of view, during summer time, author defined the highest justified number 3 for the façade of a building which air flow encounter with it vertically, because this facade has positive pressure. Also, this research defined the lowest justified number 0 for the facade where are located at the backside of the wind and it has negative pressure. Furthermore, author highest justified number 3 for the facades, which has positive pressure because the wind encounter with an angle to them. In addition, the lowest justified number 0 stated to the facades at the backside of the wind where negative pressure have (figure

43). All these definition of justified number for the facades of a building will be opposite during the winter time (figure 44).In this research, the author determined the justified number for wind effect at five Iranian cities, each in a different climate region.

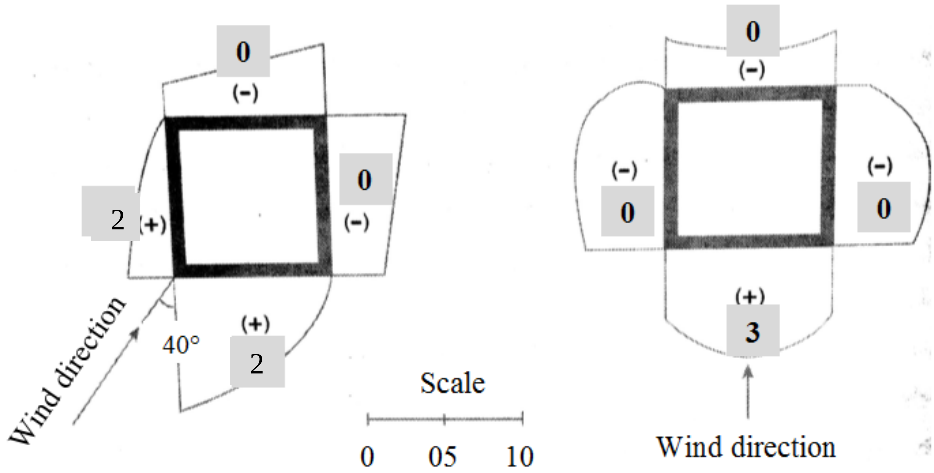


Figure 43: defining the justified number accoridng to the direction of the wind during summer time

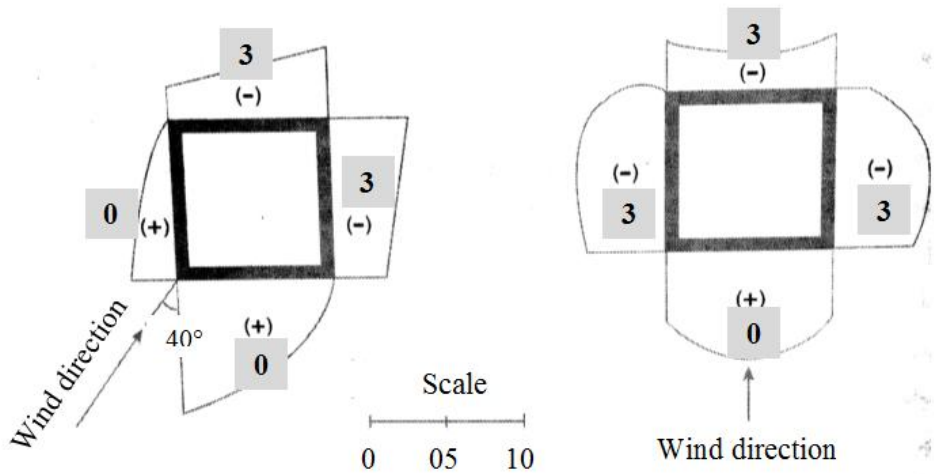
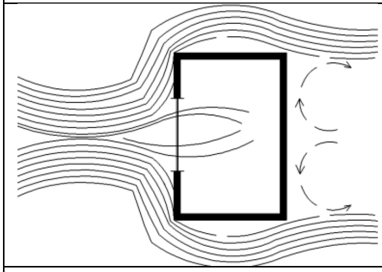
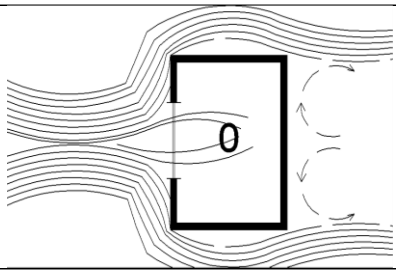


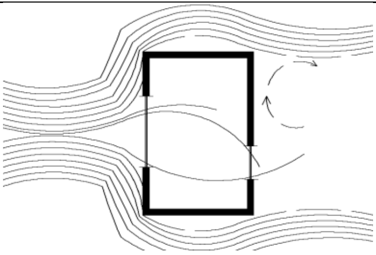
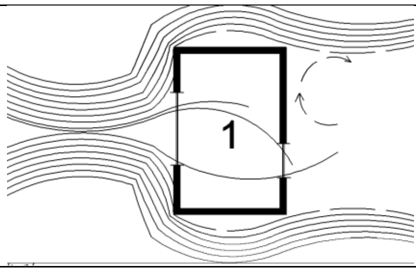
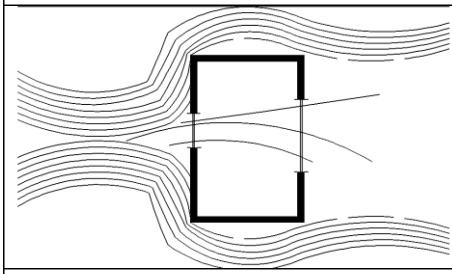
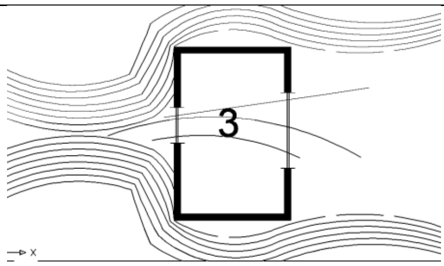
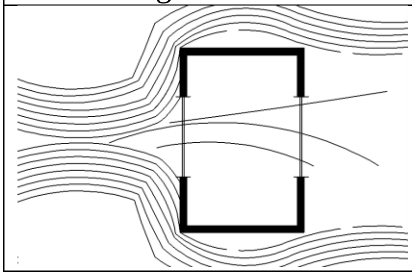
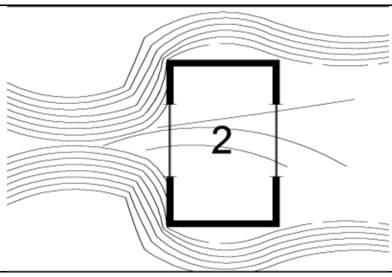
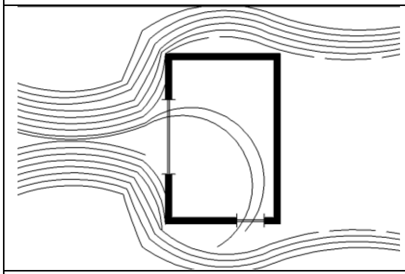
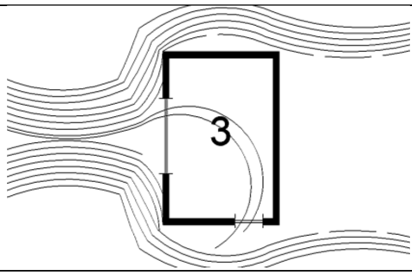
Figure 44: defining the justified number accoridng to the direction of the wind during winter time

In addition, this research defined the justified number for the spaces of the building according to the result that has been evaluated by the Texas Engineering Experiment station (Caudill, Crites, & Smith, 1951) (Smith, Reed, & Hodges, 1951) (Smith E. G., 1951) (McCutchan & Caudill, 1952) (Caudill & Reed, 1952).

The Texas engineering station cited that small inlet with large outlet increase the velocity inside the space by comparing to the outside. Hence, this study defined justified number 3 for the space, which has small inlet with large outlet size. Conversely, if the space has large inlet with small outlet, high speed of the wind occurs outside of a building so justified number 1 considered for this space. Equal size of the opening on the façade parallel to each other because internal pressure inside the space so justified number 2 considered for this kind of spaces. At the end the spaces, which has opening on different façade, that lead the air flow to have oblique angle inside the space cause to have air stream eight time powerful thus justified number 3 deliberated for this space.

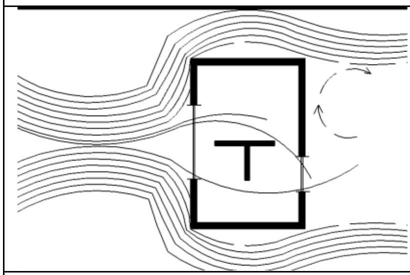
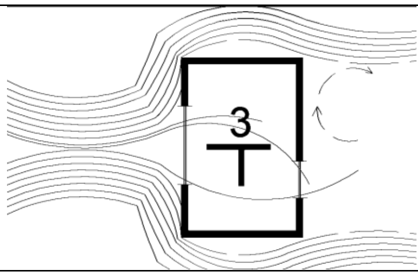
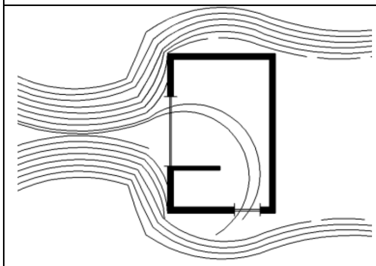
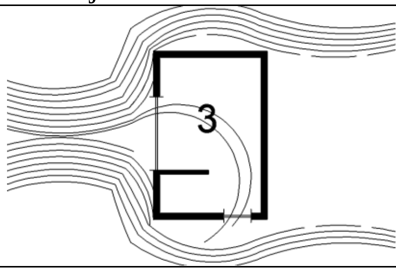
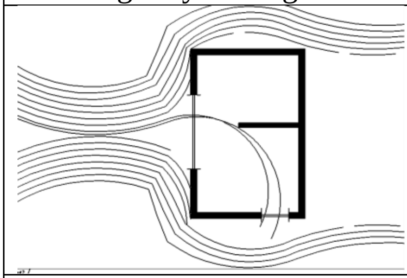
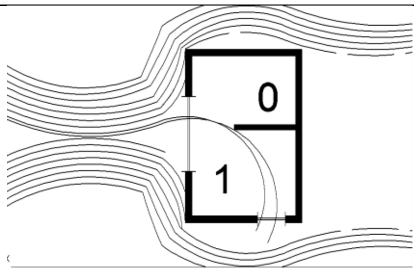
Table 18: Defning justified number accoridng to the wind effect inside the building without partition wall

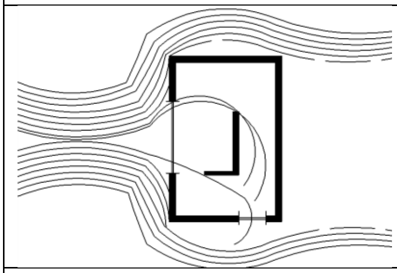
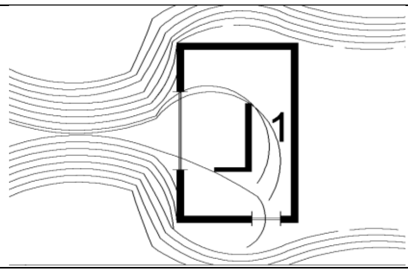
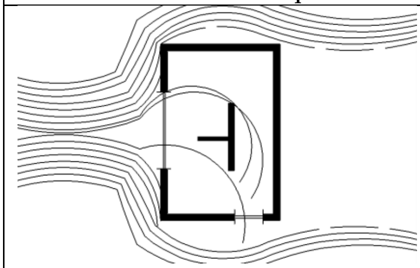
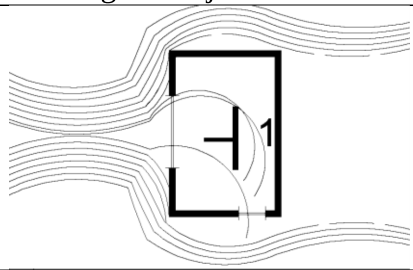
Wind effect inside the building without partition wall	
Effect of wind flow inside the space (Olgyay, 1963)	Defining Justified number for inside spaces according to the wind flow.
	
There is no outlet in this building, hence air flow could not happen inside. Since having air flow inside the building need both inlet opening (positive) and outlet opening(negative).	Lowest justified number like zero since of having no air flow inside the building.

	
High velocities happen outside of the building which causes the less cooling effect when building has Large inlet with small outlet.	Justified number 1 considered for this building because air flow lost its cooling effect.
	
Cooling air flow occurs inside the building If building has small inlet with a large outlet. Therefore it causes highest speed in the building.	Highest justified number 3 because of occurring high velocity inside the building rather than the outside.
	
large openings with same size could occur the maximum air flow if there are located contrary to each other. Also the speed of air flow inside is alittle bit higher than outside area.	External pressure of the wind is same as the internal pressure so justified number 2 considered for this building since of occurring air flow through the space.
	
A house with no partition wall cause that air flow with an oblique angle occurs inside the building. Since, the position of inlet and outlet makes the air flow to have smooth curve.	Air flow enter with angle so it makes the air stream 8 times powerful so this research considered the highest justified number 3 for this building.

Defining justified number for the spaces with partition wall is different. As Olgyay (1963) mentioned that if the partition wall is placed outside the airflow or located parallel with wind then the effect of the wind will be same so the space will get justified number 3. But if the partition wall is placed in the same pattern of airflow will cause the lowest speed of airflow hence the wind effect will be insufficient.

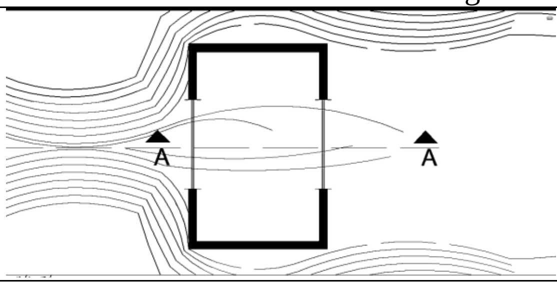
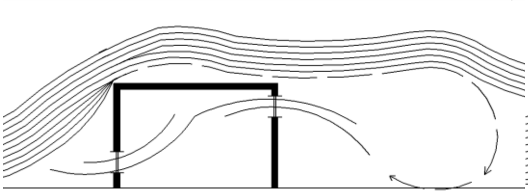
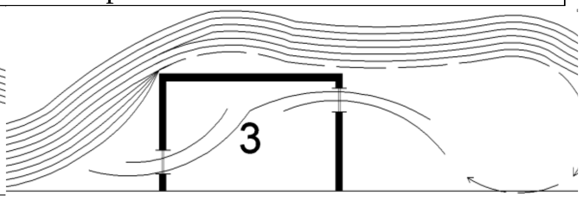
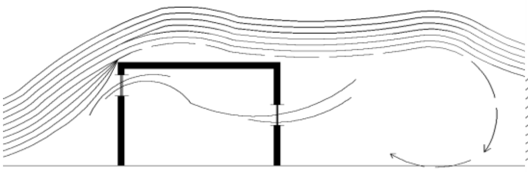
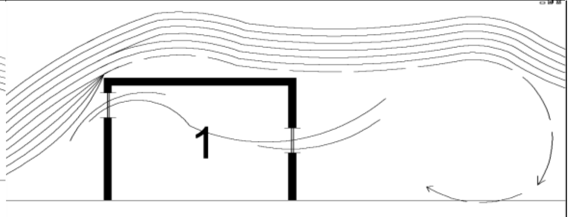
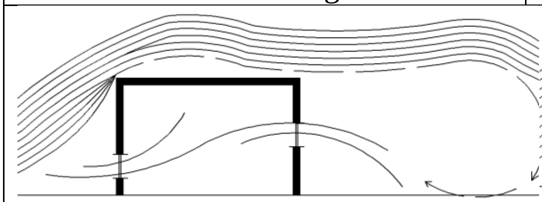
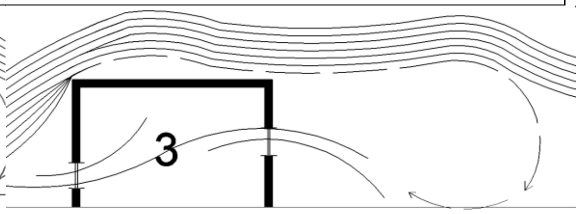
Table 19: Defining justified number according to the wind effect inside the building with partition wall

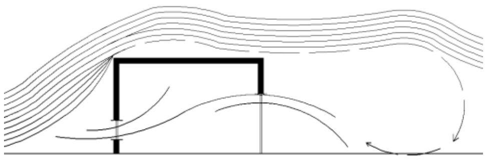
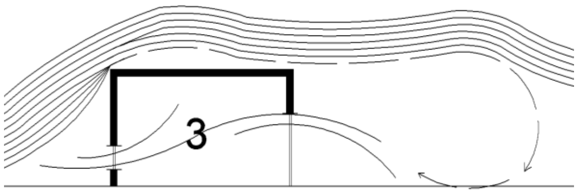
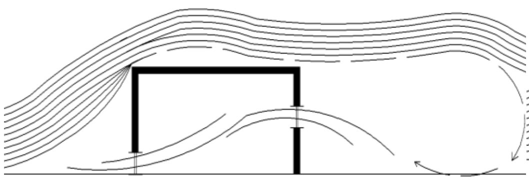
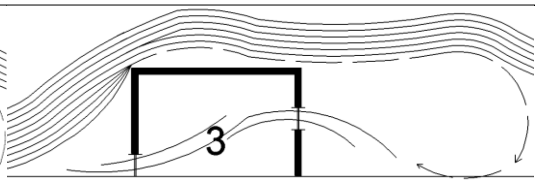
Wind effect inside the building with partition wall	
Effect of wind flow inside the space by (Olgyay, 1963)	Defining Justified number for inside spaces according to the wind flow.
	
Partition wall is parallel to air flow and it makes it breaches, but then outcome is satisfactory high speed.	Air flow and partition wall are parallel to each other so there is enough high speed of air flow inside the building hence justified number 3.
	
A partition wall dose not restrict the direction of wind flow as a result the main air stream occurs approximately eight times as stronger by turning.	Partition wall in this is not interfere to air flow therefore, air stream occurs 8 times powerful.
	
Partition wall cut off the air flow pointedly therefore air flow would be slows down as a	Partition wall interfere to the air flow therefore, upper room receiving no air so justified number 0 considered for the

result lower room accept only insufficient flow and upper room receive no wind.	upper room. Lower room receive less air flow therefore justified number 1.
	
Air flow is stopped by partitions wall hence it will be block and its cause that cooling effect turn into inadequate.	Partition wall cut off the air flow so there is less cooling effect inside the building hence justified number 1.
	
Partition wall is perpendicular to the air flow alert patterns as a result the back side room is inadequately received the cooling wind.	Partition wall is intercept the air flow since it is perpendicular toward it so space at back receive less wind flow hence justified number 1.

Olgyay (1963) stated that largest ratio of outlet to inlet because entering most cooling airflow through the space. Location of outlet is immaterial to have effect on speed of the airflow. However, the location of inlet has direct relation with entering air flow through space. It means that if inlet placed at high cause the airflow entered upward to the ceiling. Positioning the inlet in middle lead to have slightly downward air flow. Also the low position of inlet enters the airflow toward the floor. Consequently, the placement of airflow directs the flow pattern within the spaces of a building. The airflow will be happen within the space if the position, type and arrangement of the inlet chosen appropriate. Thus according to all explanation, this research defines the highest justified number 3 for the section of a building that has lowest inlet with outlet that is place middle or up to the ceiling. For the reason that in this position, airflow will have pleasant cooling effect. Justified number 1 defined for the section, which has high inlet with middle outlet since the airflow will lose the cooling effect, by passing through them.

Table 20: Defining Justified number for section of a building according to the wind flow and position of inlet and outlet and by considering the Olgyay estimation.

Wind effect inside the building	
	
Plan	
Effect of wind flow on section of a building (Olgyay, 1963)	Defining Justified number for section of a building according to the wind flow and position of inlet and outlet.
	
Section A-A Outlet located near to the ceiling and inlet places down which causes to have satisfying air flow.	Section A-A Highest justified number like 3 since the inlet place down.
	
Section A-A Inlet position high near to the ceiling, oulet located in the middle. Inlet and outlet have unequal size as well. As a result of inlet and outlet position air flow will lost the cooling effect.	Section A-A Outlet place in the middle and inlet located high near to the ceiling so the air flow would lose the cooling influence hence justified number 1.
	
Section A-A	Section A-A

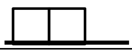
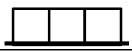
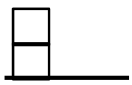
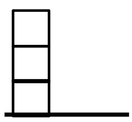
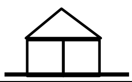
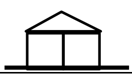
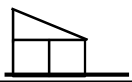
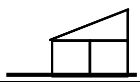
Outlet situated in the middle but inlet place down hence the air flow is downward and it is pleasant.	Inlet place low and outlet located in the middle as result there is pleasant wind flow hence justified number 3.
	
Section A-A Outlet located down, close to the floor and inlet places down as well hence, pleasant air flow goes through the space,	Section A-A Low inlet with outlet cause pleasant air flow so justified number 3.
	
Section A-A Inlet located down but outlet place in the middle the result of this situation is having the air flow down toward the floor .	Section A-A Low inlet and high outlet make the air flow goes through the space as pleasant.

This study also illustrated the wind effect on sections during the summer and winter to determine the effect of the prevailing wind on semi-open, open spaces. For adjusting the justified number for the semi-open and open spaces in three-dimensional perspective, author considered the length of the wind shadow.

The length of the wind shadow is depending on the geometrical shape of the building. Generally it depends on the slope of a roof, width, length, and height and most importantly the direction of a wind. For instance, if building has flat roof with equal dimension of width and height then the length of the wind shadow will be approximate 3.75 of the height of the building. If the width of a building is two or three times of the height then the wind shadow would be 3 or 3.25 of the height of a building (Dekay & Brown, 2014).

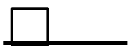
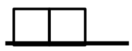
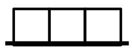
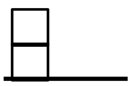
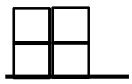
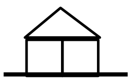
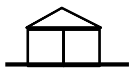
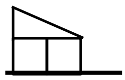
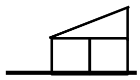
Donald and Kenet (1983) demonstrated the length of the wind shadow for a flat and sloppy roof consistent with the dimension of width, height and length of a building (table 21). The general rule related to the wind shadow is that if the building dimensions specifically height of the building has a main role for changing the direction and speeding of the wind.

Table 21: Length of the wind shadow according to height, width and length of the building (Donald & Kenet, 1983)

Width (W)	Height (H)	Sloppy roof	Length of the wind shadow according to the multiple of height					
			2A	4A	8A	16A	24A	Wind direction →
A	A	0°	2 1/4	3 3/4	5 1/4	8	8 3/4	
2A	A	0°	2	2 3/4	3 3/4	6	7	
3A	A	0°	2 1/4	3 1/4	4 1/2	5 3/4	5 1/2	
A	2A	0°	5 1/4	8 1/4	11 3/4	16 1/4	18	
A	3A	0°	6 3/4	11 1/2	16 1/2	18 3/4	20 3/4	
2A	2A	45°	2 3/4	5 1/4	9 1/4	13 1/4	15	
2A	1.6A	30°	3	4	6 3/4	10	13	
2A	1.5A	15°	3	5 1/4	8 1/4	11 1/2	14 3/4	
2A	1.5A	15°	2 1/4	4 1/2	6 1/2	11	13 3/4	

This research consistent with type of traditional buildings in Iran divided the table in different climatic region. As a specifically example the first three rows could be considered for hot-dry with cold winter climatic region since of having just one store height of a building. The fourth and fifth row could be considered for the cool, hot-dry and hot-humid climatic region because the most typically type of traditional building in these regions has two stories flat. In addition the last three rows since of having sloppy roof are going to be considered for temperate-humid climatic region.

Table 22: Different type of the buildings in five different climatic region

Hot-dry with cold winter climate (1story building)			
			
Hot-humid, hot-dry & cool climate (2 story building)			
			
Temperate-Humid climate (1 and 2 story building)			
			

According to all above explanation about wind shadow and its effect surrounding of a building, this research defined the justified number on three-dimensional perspective for each cities in different climatic region consistent with the geometrical shape (width, length and height) of the traditional building and also according to the wind direction and position of the opening (Appendix). For instance during summer time in hot-dry with cold winter climatic region, if the height of a building measured as “a” then the wind shadow will be continue till 3 ¾ a, so the highest justified number 3 defined for semi-open and open spaces where are located on that distance. Also the highest justified number distinct for close space which has two opening toward the wind direction however, the other close space where are located after wind shadow receive less wind thus, justified number two could be deliberated for this space although it has two opening. Hence, the justified number after wind shadow (3 ¾ a) gradually will be decrease (figure 45). Furthermore, traditional building in hot-humid climatic region has upper window as well. The upper window conducts the warm air, which has low weight to outside, and also lower window invite the cooler air through the spaces of a building. Therefore, the highest justified number three defined by this research for the rooms, which has opening on both facades. The space that has just opening on one façade also took justified number three. In addition, by considering the width of a building as "a" and the height of a building as "2a" (most of traditional building in this region has 2stories block) so wind shadow will be occurred on "8 ¼ a", hence the courtyard where are located on 8 ¼ a will get highest justified number 3 (figure 46).

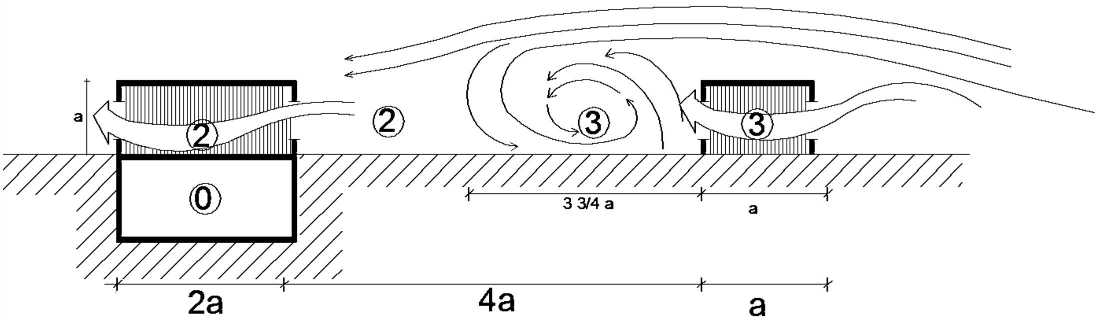


Figure 45: Justified number defined on section of traditional building in hot-dry with cold winter climate according to the wind shadow in summer.

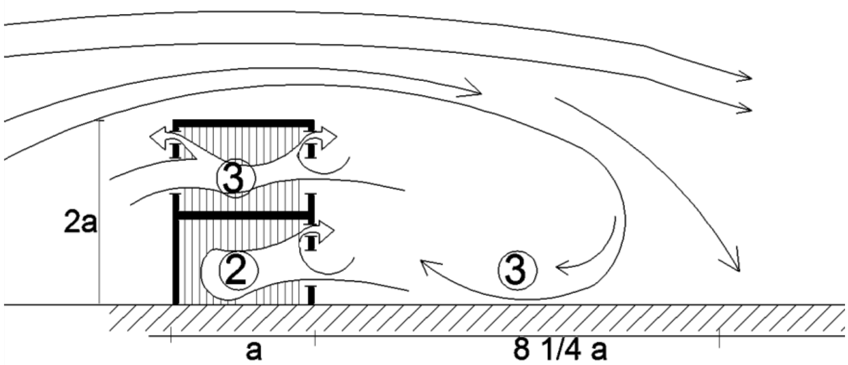


Figure 46: Justified number defined on section of traditional building in hot and humid climate according to the wind shadow in summer.

In the last stage of the wind effect analysis, the author determined the ratio of the openings. Specifically, this study used four different categories to express the ratio of opening to façade: 10–20%, 20–30%, 30–40%, and 40–80%, and this research distributed the justified numbers (0–3) among these categories. For example, the best percentage of the opening in temperate-humid climatic region is 40-80% that is defined with justified number three. In this climate there is lots of humidity during summer time so it needs cross ventilation for decreasing the humidity. Thus the best opening percentage is 40-80%. However, hot-humid climatic region since of having a lot of humidity during summer time, defining the large ratio percentage such as 40-80% is not suitable for this hot climatic region. Since, the openings ratio of 40-80% invite sun heat beside the wind flow. Therefore the best ratio percentage in this climate is 10-20% with shading devices that is this research considered it with justified number three. Furthermore, the situation of hot-dry with cold winter and hot-dry climate is similar to each other since of having hot and dry summer the best ratio of opening could be defined as 20-30%. This amount of opening's ratio causes wind flow beside of entering less sun heat through the space. Moreover, in cool climatic region the appropriate condition should be in the manner to have less wind flow and entering more sun heat inside the spaces. Thus the best justified number three is belonging to 30-40% ratio percentage of opening in this cool climatic region.

In sum, table 23 presents the best opening-to-façade ratio for each of the five climate regions in Iran as a consideration of solar gain and the direction of the prevailing wind.

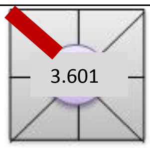
Table 23: The best ratios of the opening in five different climatic regions of Iran

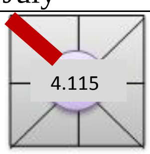
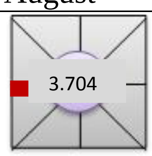
40-80%(3)	30-40%(3)	20-30%(3)	10-20%(3)
Temperate-humid climate	Cool climate	Hot-dry climate, Hot-dry with cold winter climate	Hot-humid climate

2.9.2.1 Wind effect Analysis at 29° N Latitude (Hot-Humid Climate): Bushehr

In this hot-humid climate region, the significant issue for spatial organization is conducting the wind through a building to decrease the humidity. According to Table 24, wind flow is typically from the North West, except in August. In addition, air temperature at 1st of January in Bushehr city is illustrated that it is lower than the body temperature so author considered the wind effect as negative during winter time. During 1st of July, air temperature is lower than the body temperature except noon and afternoon time hence this research is considered the wind effect as positive in evening and night time.

Table 24: Direction and Speed (m/s) of the prevailing wind during the winter and summer in Bushehr (Kasmaee M. , 2003).

	Jan	Feb	march
Bushehr			

	July	August	Sep
Bushehr			

TUE 01ST JAN, 2013								
Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	19 °c	18 °c	18 °c	19 °c	21 °c	22 °c	21 °c	20 °c
Feels	19 °c	18 °c	18 °c	20 °c	22 °c	24 °c	21 °c	20 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	0%	0%	0%	0%	0%	0%	0%	0%
Wind	4.02 m/s	4.47 m/s	4.47 m/s	4.02 m/s	4.91 m/s	5.36 m/s	4.02 m/s	3.12 m/s
	N	NNW	NNW	NNW	NNW	NW	NNW	NNW
Gust	16 mph	19 mph	19 mph	12 mph	13 mph	13 mph	12 mph	11 mph
Humidity	7.15 m/s	8.49 m/s	8.49 m/s	5.36m/s	5.81 m/s	5.81 m/s	5.36m/s	4.91m/s
Pressure	1019 mb	1018 mb	1018 mb	1020 mb	1019 mb	1019 mb	1020 mb	1021 mb

Figure 47: Climatic data of Bushehr city at 1st of January (World weather online, 2014)

MON 01ST JUL, 2013								
Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	35 °c	34 °c	34 °c	37 °c	40 °c	39 °c	37 °c	35 °c
Feels	37 °c	36 °c	37 °c	41 °c	44 °c	43 °c	39 °c	36 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	0%	0%	0%	0%	0%	0%	0%	0%
Wind	3 mph	2 mph	4 mph	6 mph	11 mph	14 mph	9 mph	5 mph
	1.34 m/s	0.89 m/s	1.78 m/s	2.68 m/s	4.91 m/s	6.25 m/s	4.02 m/s	2.23 m/s
Gust	5 mph	4 mph	5 mph	7 mph	13 mph	16 mph	13 mph	10 mph
Humidity	2.23 m/s	1.78 m/s	2.23 m/s	3.12m/s	5.81 m/s	7.15 m/s	5.81m/s	4.47m/s
Pressure	997 mb	997 mb	998 mb	998 mb	998 mb	996 mb	996 mb	996 mb

Figure 48: Climatic data of Bushehr city at 1st of July (World weather online, 2014)

This research also represented the justified number on the façade of a building according to the direction of the wind flow on schematic plan. Figure 49 shows the wind direction with indicated justified number. During winter time, the air temperature does not go below zero since of hot-humid climatic condition in this city so author defined justified number 1 instead of justified number zero for the facade where are under the wind flow. Furthermore, during summer time, the façade where are located on the stream direction of wind flow will adjusted with the highest justified 3 and the façade where are received the stream of wind with and oblique angle could get justified number 2. Moreover, according to the air temperature during summer time, the entering the wind flow inside the spaces just recommended evening and night time.

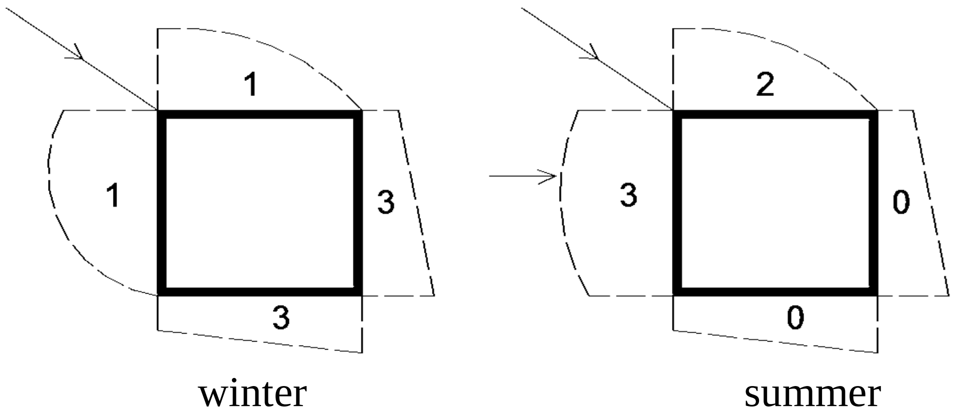


Figure 49: Dotted line demonstrated the ventilated spaces in Bushehr city during the winter and summer

In sum, figure 50 depicts all the justified numbers translated into the wind effect justified graph.

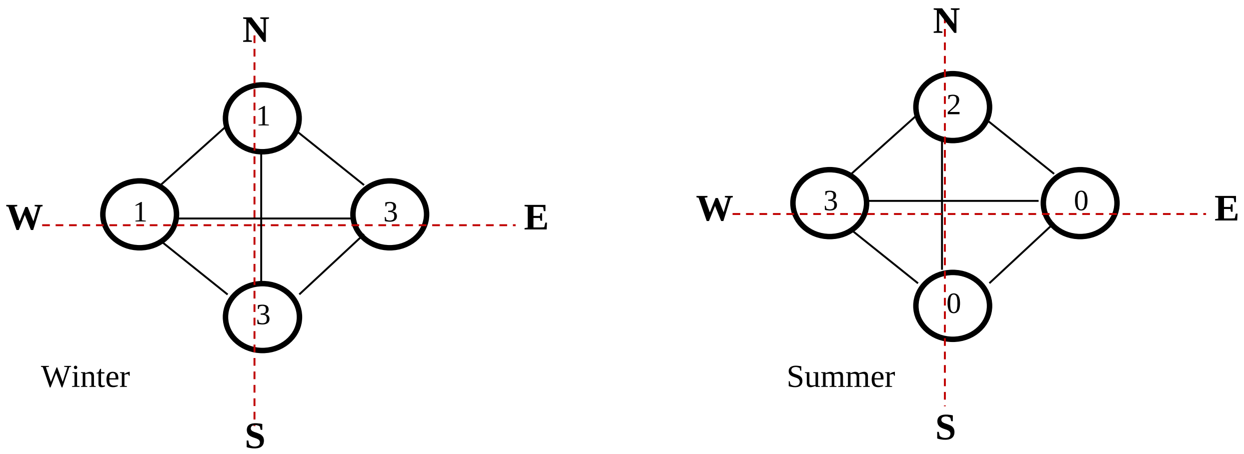


Figure 50: Justified graphs for wind effect in Bushehr during the winter and summer

All prior analyses of wind effect at Bushehr have been two-dimensional and in accordance with the plan's organization, hence author studied a three-dimensional SMART analysis by considering the wind shadow for demonstrating the wind effect on semi-open and open spaces and also inside the building. This study has analyzed elevations in terms of the prevailing wind direction and the number of openings on each wall. Thus, in Appendix A, the author presented justified number on sections in accordance with the wind flow received.

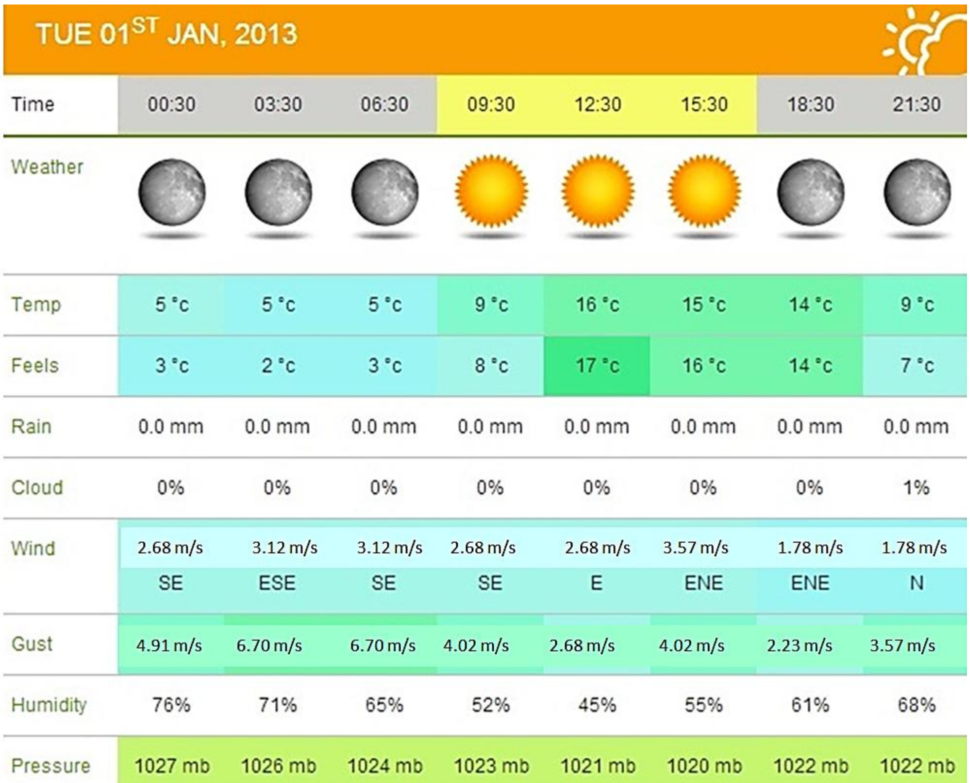
2.9.2.2 Wind Effect Analysis at 37° N Latitude (Temperate-Humid climate): Rasht

In the temperate-humid climate region, much like the hot-humid region in the previous subsection, the primary concern for spatial organization is the creation of cross ventilation through buildings by placing openings at appropriate locations. This research chose Rasht as a case study in the temperate-humid region of Iran, and table25 illustrates the prevailing wind flow of Rasht, which is from the west in the winter and summer. Moreover, the air temperature at 1st of January is lower than the body temperature so this research reflects the wind as negative during winter time. Also at 1st of July the air temperature is lower than the body temperature so it is considered as positive during summer time. Thus, architects in Rasht city should direct building's openings to face the wind from the west to ventilate the spaces during the summer.

Table 25: Direction and speed (m/s) of the prevailing wind during the winter and summer in Rasht (Kasmaee M. , 2003).

	Jan	Feb	march
Rasht	2.778	2.778	2.469

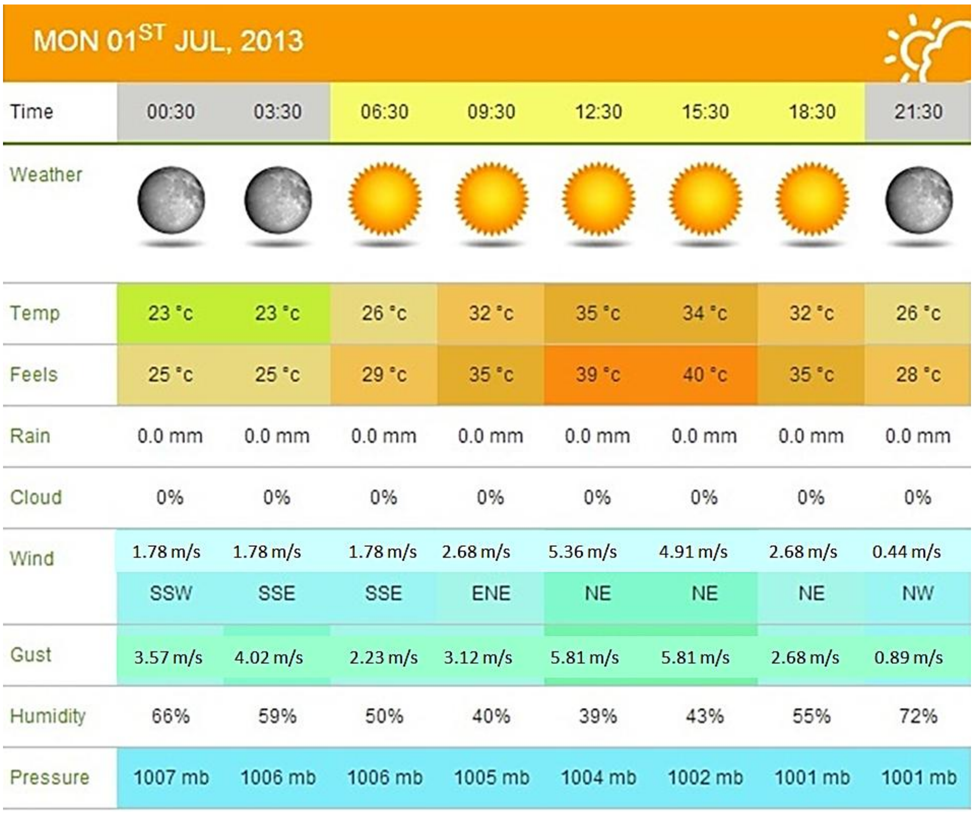
	July	August	Sep
Rasht	1.337	1.491	2.057



TUE 01ST JAN, 2013

Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	5 °c	5 °c	5 °c	9 °c	16 °c	15 °c	14 °c	9 °c
Feels	3 °c	2 °c	3 °c	8 °c	17 °c	16 °c	14 °c	7 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	0%	0%	0%	0%	0%	0%	0%	1%
Wind	2.68 m/s SE	3.12 m/s ESE	3.12 m/s SE	2.68 m/s SE	2.68 m/s E	3.57 m/s ENE	1.78 m/s ENE	1.78 m/s N
Gust	4.91 m/s	6.70 m/s	6.70 m/s	4.02 m/s	2.68 m/s	4.02 m/s	2.23 m/s	3.57 m/s
Humidity	76%	71%	65%	52%	45%	55%	61%	68%
Pressure	1027 mb	1026 mb	1024 mb	1023 mb	1021 mb	1020 mb	1022 mb	1022 mb

Figure 51: Climatic data of Rasht city at 1st of January (World weather online, 2014)



MON 01ST JUL, 2013

Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	23 °c	23 °c	26 °c	32 °c	35 °c	34 °c	32 °c	26 °c
Feels	25 °c	25 °c	29 °c	35 °c	39 °c	40 °c	35 °c	28 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	0%	0%	0%	0%	0%	0%	0%	0%
Wind	1.78 m/s SSW	1.78 m/s SSE	1.78 m/s SSE	2.68 m/s ENE	5.36 m/s NE	4.91 m/s NE	2.68 m/s NE	0.44 m/s NW
Gust	3.57 m/s	4.02 m/s	2.23 m/s	3.12 m/s	5.81 m/s	5.81 m/s	2.68 m/s	0.89 m/s
Humidity	66%	59%	50%	40%	39%	43%	55%	72%
Pressure	1007 mb	1006 mb	1006 mb	1005 mb	1004 mb	1002 mb	1001 mb	1001 mb

Figure 52: Climatic data of Rasht city at 1st of July (World weather online, 2014)

As with the process detailed in the previous subsection, this study drew the schematic plan for a traditional building in Rasht. Then, using the justified graph method, author illustrated the effect of wind on the façade of a building from plan (Fig. 54). Furthermore, in that schematic plan, this study defined justified number for the facades where are place on the wind flow. Furthermore, because the climate is mild in Rasht during the winter, the author stated lowest justified number as 1 instead of zero.

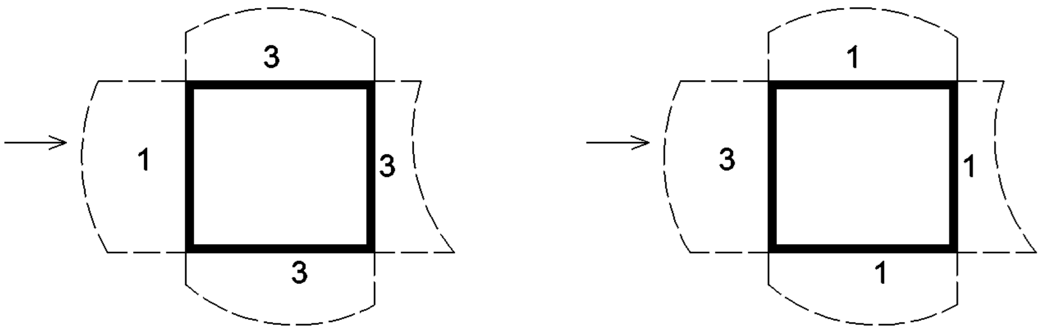


Figure 53: Dotted line demonstrated the ventilated spaces in Rasht city during the winter and summer

This study then translated the justified numbers into the wind effect justified graph. This graph (Fig.54) demonstrates the best direction for wind exposure during the hottest months of the year. In addition, the justified graph for wind effect displays the best spaces to minimize wind exposure during the coldest months of the year.

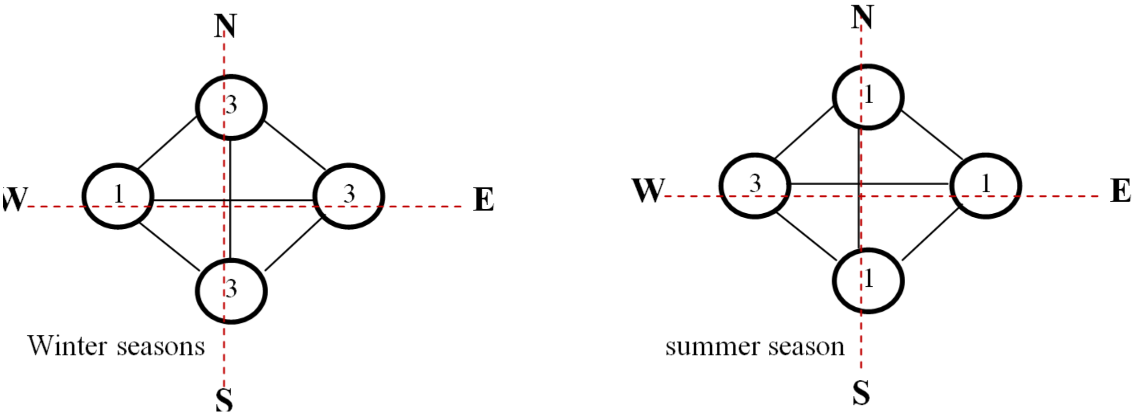


Figure 54: Justified graphs for wind effect in Rasht during the winter and summer

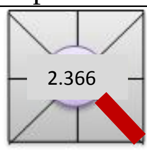
Finally, this research analyzed wind effect in traditional Rasht building from a three-dimensional perspective. In this step, the author evaluated the direction of the wind and the number of openings on each façade. Appendix B shows the wind direction and its effect on the schematic sections of a building's spaces and semi-open and open area, illustrating the results of the justified graph method.

2.9.2.3 Wind Effect Analysis at 37° N Latitude (Cool Climate): Urumye

In the cool climate region of Iran, the significant issue for spatial organization is to maximize the solar gain during the coldest months of the year and, more importantly, to create shelter from the wind. This is evident in the case study of Urumye in this cool climate region, and table26 demonstrates that the prevailing wind in Urumye is from the southwest in the coldest months of the year. Therefore, architects should organize spaces in Urumye that do not open onto that direction. The air temperature in this city is lower than zero at 1st of January, therefore wind in this cool climatic region considers as negative during winter time but, at 1st of July during summer time, the air temperature is lower than so it is considered as positive during summer time.

Table 26: Direction and speed (m/s) of the prevailing wind during the winter and summer in Urumye (Kasmaee M. , 2003).

	Jan	Feb	March
Urumye			

	July	August	Sep
Urumye			

TUE 01ST JAN, 2013

Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	-9 °c	-9 °c	-9 °c	-5 °c	2 °c	3 °c	-3 °c	-7 °c
Feels	-12 °c	-13 °c	-12 °c	-8 °c	-1 °c	0 °c	-6 °c	-11 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	0%	0%	0%	0%	2%	2%	1%	0%
Wind	1.78 m/s SW	1.78 m/s SW	2.23 m/s SSW	2.68 m/s SSW	3.12 m/s SW	2.68 m/s WSW	1.78 m/s SW	1.78 m/s SW
Gust	3.57 m/s	4.02 m/s	4.47 m/s	4.91 m/s	3.57 m/s	3.12 m/s	4.02 m/s	3.57 m/s
Humidity	53%	53%	53%	46%	45%	47%	60%	57%
Pressure	1028 mb	1026 mb	1025 mb	1024 mb	1021 mb	1020 mb	1022 mb	1024 mb

Figure 55: Climatic data of Urumye city at 1st of January (World weather online, 2014)

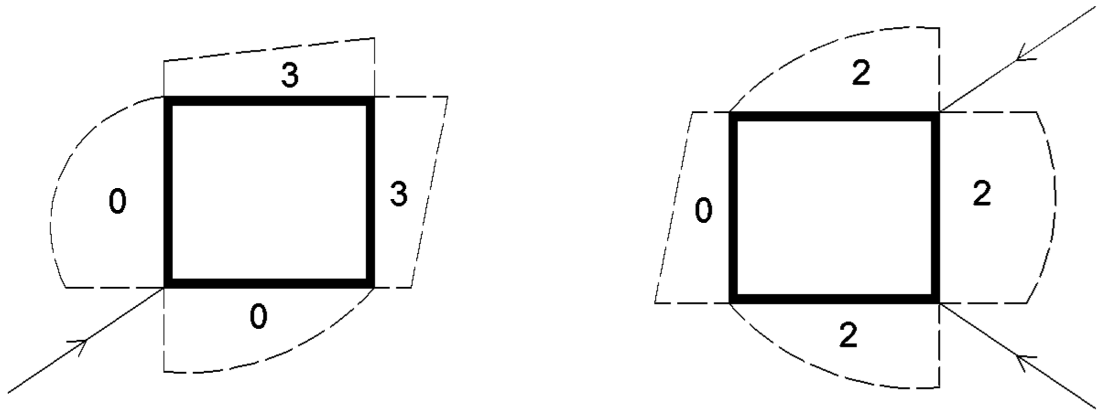
MON 01ST JUL, 2013

Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	17 °c	16 °c	19 °c	26 °c	32 °c	33 °c	32 °c	25 °c
Feels	17 °c	16 °c	20 °c	26 °c	31 °c	33 °c	29 °c	24 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	0%	0%	0%	0%	0%	0%	0%	0%
Wind	2.68 m/s E	2.23 m/s ESE	1.78 m/s SE	1.78 m/s WSW	3.12 m/s WSW	3.57 m/s W	1.78 m/s WSW	1.78 m/s ENE
Gust	5.36 m/s	4.91 m/s	3.57 m/s	2.23 m/s	4.02 m/s	4.02 m/s	1.78 m/s	3.57 m/s
Humidity	34%	36%	31%	22%	16%	12%	14%	23%
Pressure	1008 mb	1007 mb	1007 mb	1006 mb	1004 mb	1001 mb	1001 mb	1002 mb

Figure 56: Climatic data of Urumye city at 1st of July (World weather online, 2014)

In this cool climate condition, the average maximum and minimum temperatures during the summer are 38°Cand 28°C, respectively, but they drop to -2°C and -11°C, respectively, during the winter (Pourvahidi, 2010). Hence, spaces in Urumye that faces the wind have the lowest justified number (0) during the winter. In addition, because of the cool climate condition in Urumye, none of the spaces in that city have a justified number of three during the summer, so the maximum justified number there is two.

For this case study, the author drew the schematic plan for a traditional building in Urumye and the effect of wind flow on that building's envelope. Then, using the justified graph method, this research illustrated the effect of the wind on a plan in four different directions (Fig. 58).



Winter summer

Figure 57: Dotted line demonstrated the ventilated spaces in Urumye during the winter and summer

As with previous subsections, this research then translated the justified number of each space into the justified graph for wind effect at Urumye, demonstrating the best direction to minimize the wind exposure during the coldest months of the year (Fig. 59). Therefore, the spaces that face the wind have the lowest justified number (0), and those out of the wind have the highest justified number (3) in winter.

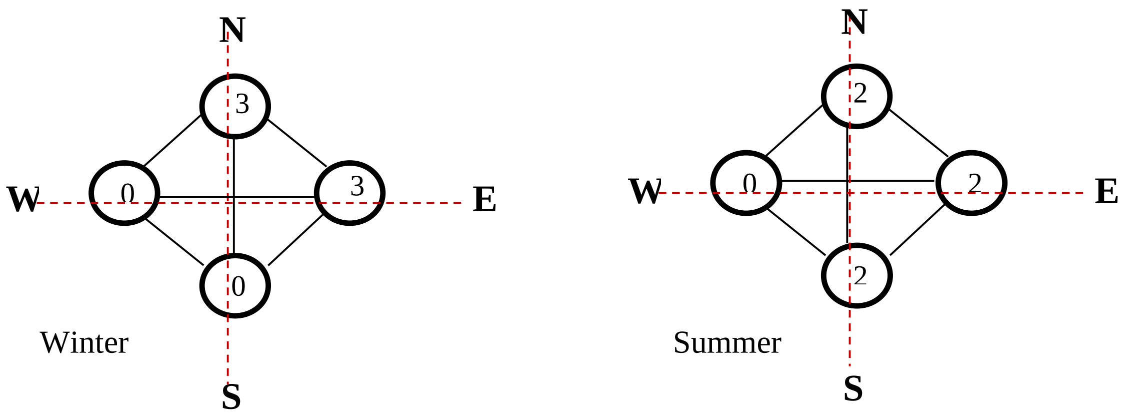


Figure 58: Justified graphs for wind effect in Urumye during the winter and summer

Finally, as before, the author analyzed the justified graph for effect of wind on three-dimensional perspective, tracking the wind direction and the number of openings on each façade of a building's schematic sections (Appendix C).

2.9.2.4 Wind effect Analysis at 32.24° N Latitude (Hot-Dry Climate): Dezful

The hot-dry region of Iran has a harsh summer and a mild winter; temperatures do not drop below zero during winter time (Pourvahidi, 2010). Within this harsh climate, this research selected Dezful as a case study. Table 27 represents the prevailing wind flow in Dezful throughout the year, which mainly flows from the south west during the summer. During the winter, the wind flows mostly from the east and southeast.

Table 27: Direction and speed (m/s) of the prevailing wind during the winter and summer in Dezful (Kasmaee M. , 2003).

	Jan	Feb	March
Dezful			

	July	August	Sep
Dezful			

In addition according to the climatic data which author found from metrological center of Defzul city, the air temperature at 1st of July is higher than the body temperature therefore the wind effect is negative during summer time. Also, at 1st of January, the air temperature is lower than the body temperature so it is negative as well.

TUE 01ST JAN, 2013

Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	13 °c	12 °c	10 °c	16 °c	20 °c	21 °c	17 °c	14 °c
Feels	13 °c	12 °c	10 °c	18 °c	22 °c	22 °c	17 °c	15 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	0%	0%	4%	0%	0%	0%	0%	0%
Wind	1.34 m/s NNW	1.34 m/s NNW	1.34 m/s NNW	0.89 m/s NNW	1.34 m/s WSW	1.78 m/s WSW	1.34 m/s WNW	0.89 m/s NNW
Gust	2.68 m/s	2.68 m/s	2.68 m/s	0.89 m/s	1.78 m/s	1.78 m/s	1.78 m/s	1.78 m/s
Humidity	44%	45%	46%	36%	27%	26%	40%	42%
Pressure	1021 mb	1020 mb	1020 mb	1021 mb	1019 mb	1019 mb	1020 mb	1021 mb

Figure 59: Climatic data of Dezful city at 1st of January (World weather online, 2014)

MON 01ST JUL, 2013

Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	38 °c	36 °c	37 °c	43 °c	47 °c	47 °c	46 °c	41 °c
Feels	37 °c	35 °c	38 °c	45 °c	52 °c	53 °c	49 °c	41 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	0%	0%	0%	0%	0%	0%	0%	0%
Wind	1.78 m/s N	1.78 m/s NE	1.34 m/s ENE	1.78 m/s SSE	2.23 m/s SW	3.57 m/s WSW	4.02 m/s W	3.57 m/s NW
Gust	4.02 m/s	3.57 m/s	1.78 m/s	1.78 m/s	2.68 m/s	4.47 m/s	4.91 m/s	6.70m/s
Humidity	11%	13%	13%	9%	7%	6%	7%	8%
Pressure	999 mb	999 mb	1000 mb	1000 mb	999 mb	997 mb	997 mb	997 mb

Figure 60: Climatic data of Dezful city at 1st of July (World weather online, 2014)

To that end, figure 61 presents an analysis of the prevailing wind in a schematic plan in Dezful, categorizing the facades of a building in terms of justified numbers from each direction. It should be mentioned that since of having air temperature higher than the body temperature during summer time, this study considered lowest justified number zero for all the façade. Because, having the wind flow with highest temperature than the body temperature has just negative effect during summer time. In addition, lowest justified number 1 instead of 0 stated for the facades where are placed on the wind direction. Because air temperature during winter time does not go below zero.

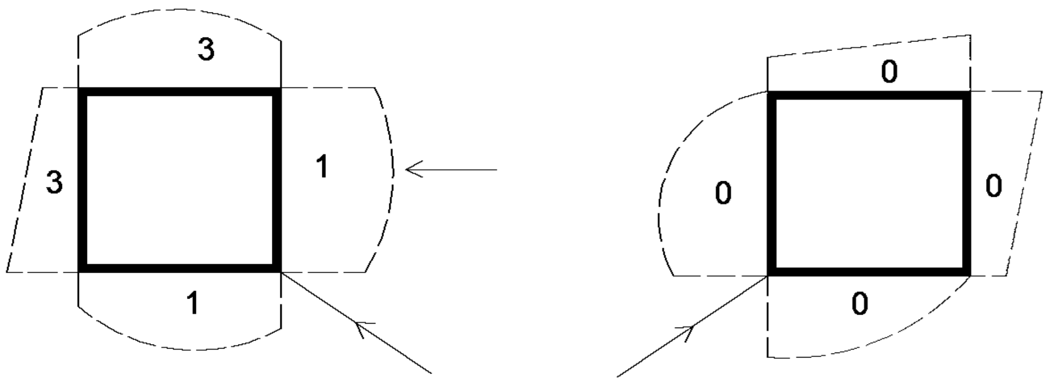


Figure 61: Dotted line demonstrated the ventilated spaces in Dezful during the winter and summer

Furthermore, the author translated the justified numbers from figure 61 into the justified graph for wind effect, indicating the best and worst directions for placing an opening on a building in Dezful (Fig.62).

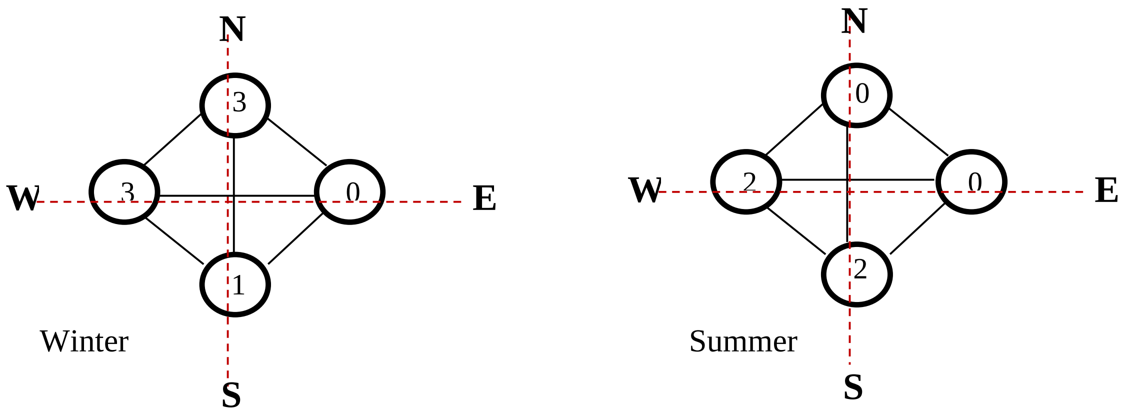


Figure 62: Justified graphs for wind effect in Dezful during the winter and summer

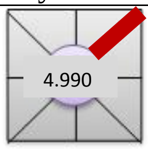
Finally, in appendix D, this study offered a three-dimensional analysis of wind direction and the number of the opening for semi-open, open and close spaces in a traditional building at Dezful city.

2.9.2.5 Wind effect Analysis at 33° N Latitude (Hot-Dry Climate with Cold Winter): Kashan

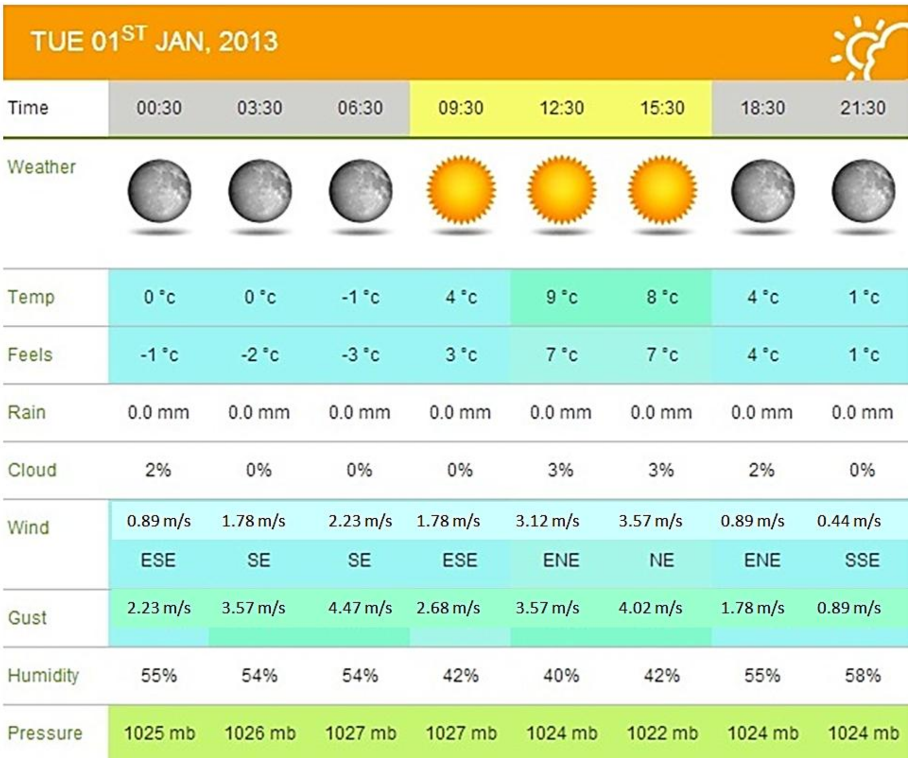
The hot-dry region of Iran with a cold winter has extreme differences in summer and winter temperatures. Within this extreme climate, the author chose Kashan as a case study. In Table 28, this study demonstrates the prevailing wind flow in Kashan during the winter (when the flow is mostly from the north) and summer (when the flow is mostly from the northeast)

Table 28: Direction and speed (m/s) of the prevailing wind during the winter and summer in Kashan (Kasmaee M. , 2003).

	Jan	Feb	March
Kashan			

	July	August	Sep
Kashan			

In addition the air temperature in 1st of January demonstrated that it is lower than the body temperature and inhabitant feel it as it is below zero during winter time. So wind effect is considered as negative during winter time (figure 63). However, the air temperature during summer time is lower than the body temperature thus the author indicated the wind effect as positive during hottest month of a year (figure 64).



TUE 01ST JAN, 2013

Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	0 °c	0 °c	-1 °c	4 °c	9 °c	8 °c	4 °c	1 °c
Feels	-1 °c	-2 °c	-3 °c	3 °c	7 °c	7 °c	4 °c	1 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	2%	0%	0%	0%	3%	3%	2%	0%
Wind	0.89 m/s ESE	1.78 m/s SE	2.23 m/s SE	1.78 m/s ESE	3.12 m/s ENE	3.57 m/s NE	0.89 m/s ENE	0.44 m/s SSE
Gust	2.23 m/s	3.57 m/s	4.47 m/s	2.68 m/s	3.57 m/s	4.02 m/s	1.78 m/s	0.89 m/s
Humidity	55%	54%	54%	42%	40%	42%	55%	58%
Pressure	1025 mb	1026 mb	1027 mb	1027 mb	1024 mb	1022 mb	1024 mb	1024 mb

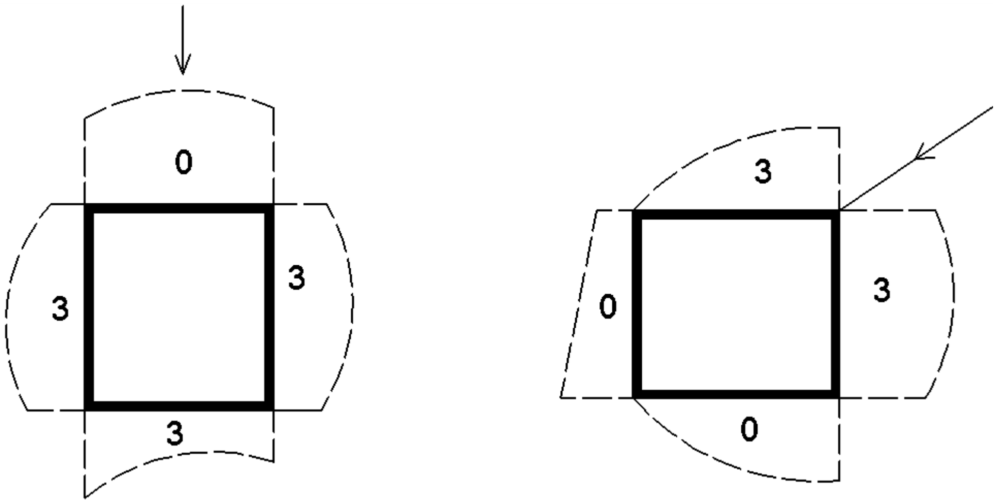
Figure 63: Climatic data of Kashan city at 1st of January (World weather online, 2014)

MON 01ST JUL, 2013

Time	00:30	03:30	06:30	09:30	12:30	15:30	18:30	21:30
Weather								
Temp	28 °c	25 °c	25 °c	31 °c	35 °c	36 °c	35 °c	31 °c
Feels	27 °c	24 °c	26 °c	30 °c	34 °c	36 °c	33 °c	29 °c
Rain	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm	0.0 mm
Cloud	0%	0%	0%	0%	0%	0%	0%	0%
Wind	0.89 m/s ENE	0.89 m/s NE	0.89 m/s N	2.68 m/s NNE	4.02 m/s NNE	4.47 m/s NNE	3.12 m/s ENE	1.78 m/s SE
Gust	1.34 m/s	1.34 m/s	0.89 m/s	3.12 m/s	4.91 m/s	4.91 m/s	3.57 m/s	2.23m/s
Humidity	25%	29%	26%	20%	14%	11%	11%	13%
Pressure	1006 mb	1006 mb	1007 mb	1006 mb	1004 mb	1002 mb	1001 mb	1002 mb

Figure 64: Climatic data of Kashan city at 1st of July (World weather online, 2014)

As with the analyses in the previous subsections, author presents a simplified analysis of the prevailing wind in the plan for a tradition building in Kashan, categorizing the facades in terms of justified numbers (Fig.66).



winter summer

Figure 65: Dotted line demonstrated the ventilated spaces in Kashan during the winter and summer

Moreover, this research translated the justified numbers into the justified graph for better estimating the wind effect to specify the best and worst facades for placing an opening on a building in Kashan (Fig. 67).

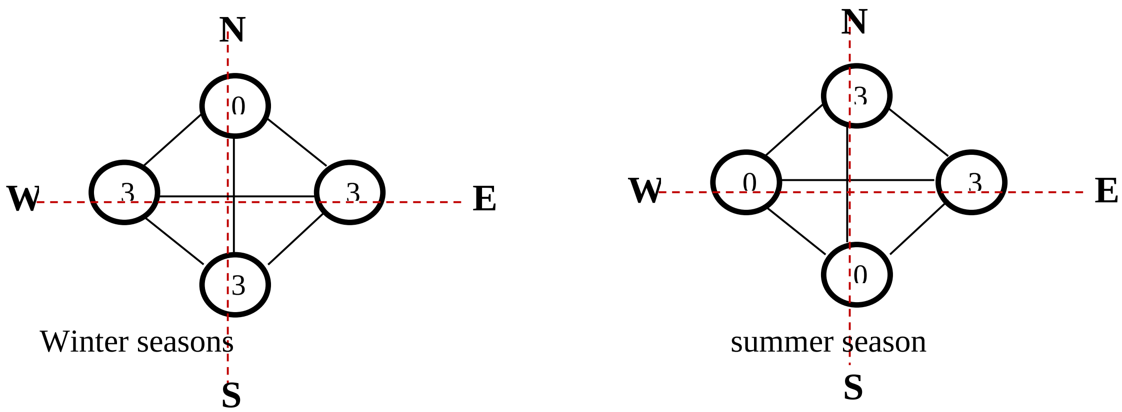


Figure 66: Justified graphs for wind effect in Kashan during the winter and summer

Finally, the author presents a three-dimensional evaluation of the close, semi-open and open spaces according to the number of openings and direction of the wind on a traditional building in Kashan (Appendix E).

Chapter 3

APPLYING THE DEVELOPED JUSTIFIED GRAPH METHOD ON CASE STUDIES

As a climatic response through ages, the inhabitants exploit movement through the spaces of traditional houses. In the context of primitive accommodations, nomads performed seasonal movements through long-distance changes, between hot and cold regions to use the benefits of the seasons. In this study the movements of inhabitants within the houses were evaluated with the justified graph method. According to the previous research of the author, Iran has five different climatic regions such as hot-dry with cold winter climate, hot-dry climate, cool climate, temperate humid climate and hot-humid climate (Fig.67). For this study randomly selected traditional houses, which were aligned to the north and built in, the late Qajar and Pahlavi's periods were analyzed. Most of these traditional buildings have five to ten bedrooms.

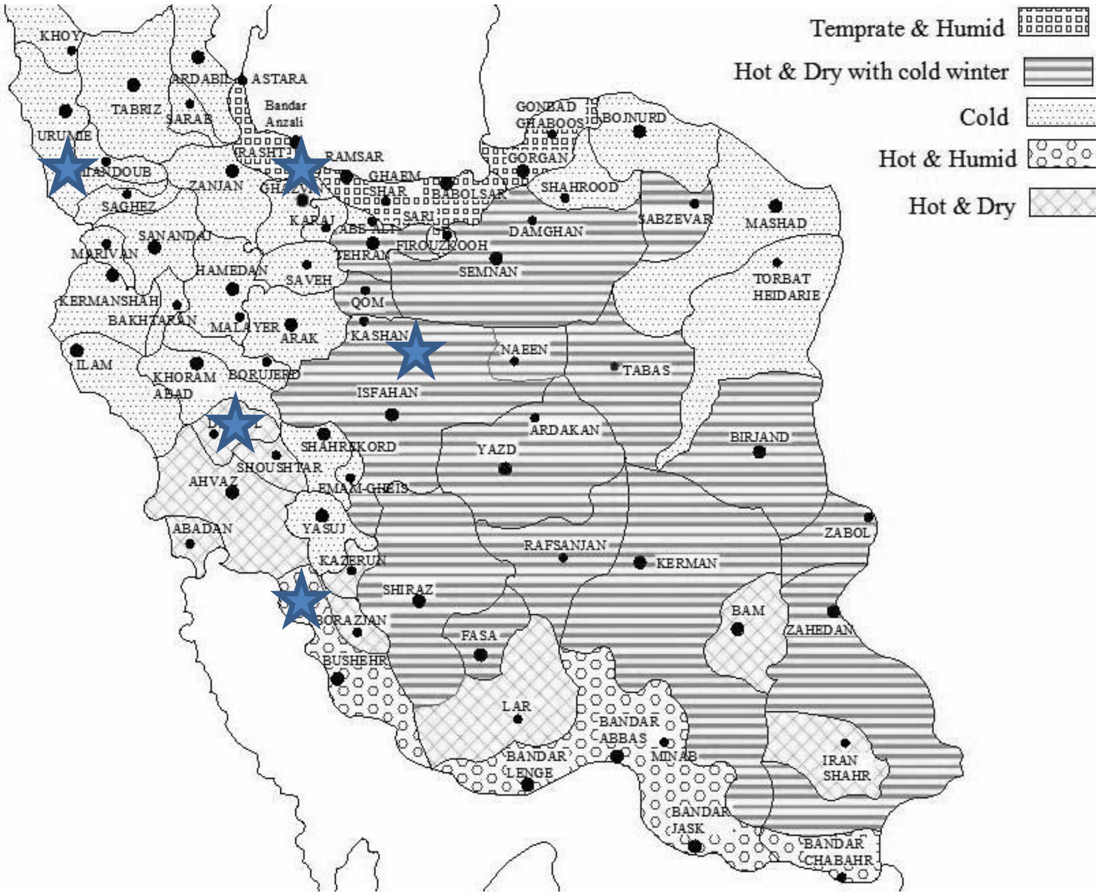


Figure 67: Five climatic region of Iran (Pourvahidi & Ozdeniz, 2013) the stars illustrating the cities where the traditional building are located.

3.1 Hot-Humid Climate (29º N Latitude): Bushehr

Figures 68–72 depict a traditional building in Bushehr, located in a hot-humid climate.

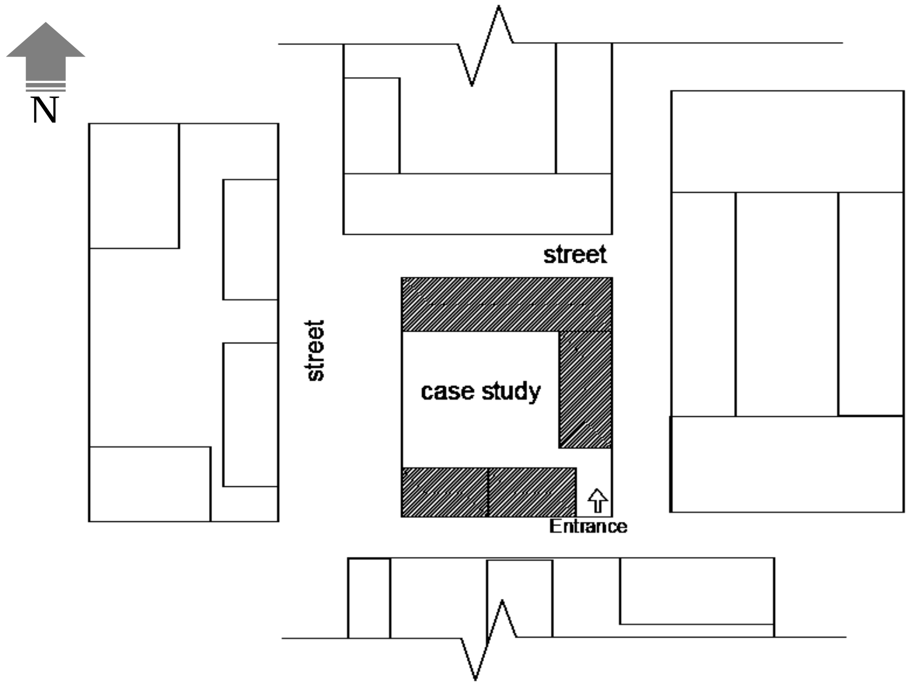


Figure 68: site plan of traditional building in Bushehr city (Memarian, 2006)

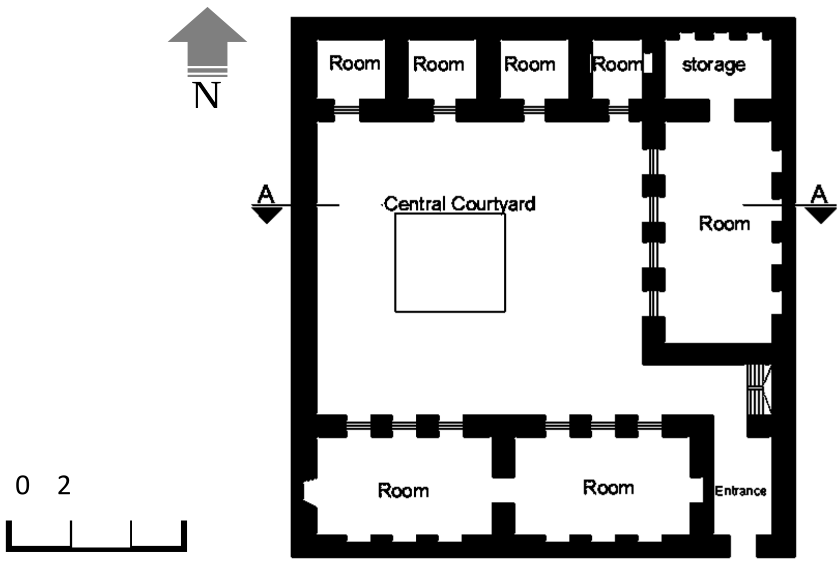


Figure 69: Ground-floor plan of a traditional building in Bushehr (Memarian, 2006)

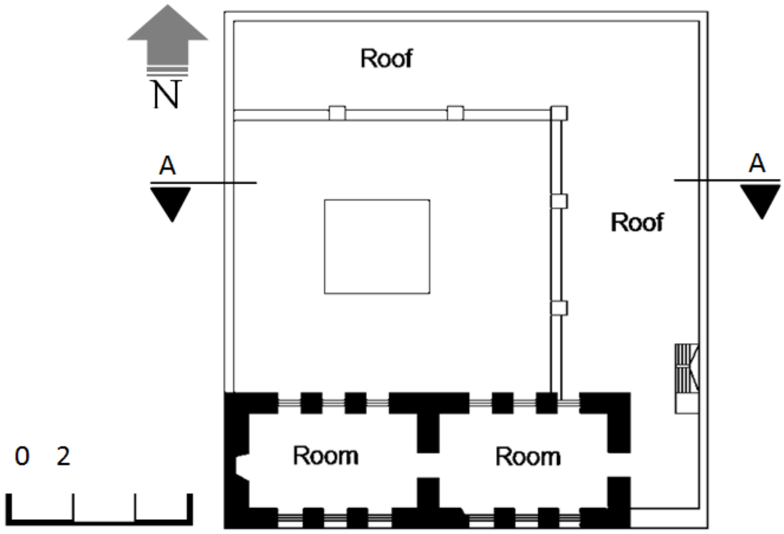


Figure 70: First-floor plan of a traditional building in Bushehr (Memarian, 2006)


Figure 71: Section A-A of a traditional building in Bushehr (Memarian, 2006)

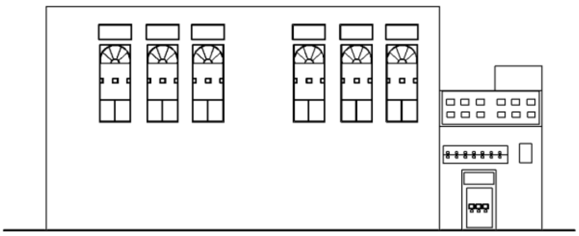


Figure 72: South elevation of a traditional building in Bushehr (Memarian, 2006)

In the following section, this study presents the justified graph for solar gain in terms of a matrix analysis.

3.1.1 Solar Gain Analysis of a Traditional Building in Bushehr

The azimuth angle for the traditional building depicted in figures 68–70 is 180°degree. Having translated the justified graph for solar gain at 180°azimuth into the plan view, the justified numbers for solar gain are as follows: three for the south, one for the east and west, and zero for the north during the winter; and during summer, two for the south and east and one for the north and west (Fig.23). Furthermore, as previously mentioned, understating the effect of solar radiation on vertical surfaces is not enough; the effect of solar radiation on floors and roofs must also be considered (Table 8). Therefore, according to the results of the justified graph for solar gain, Figures 73 and 74 present the value of solar gain for each closed space in that traditional building.

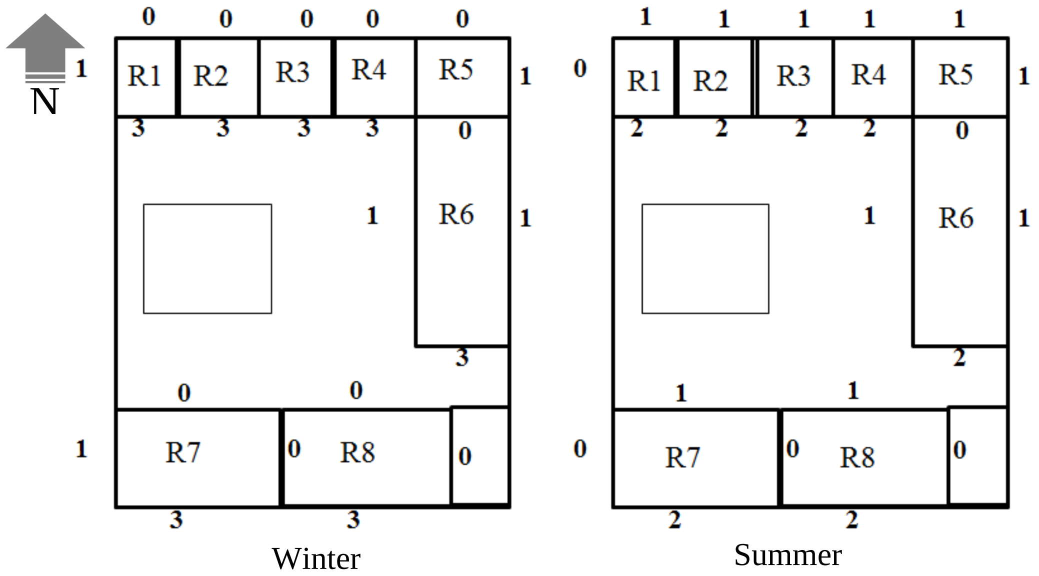


Figure 73: Justified numbers for solar gain in each closed space on the ground floor of a traditional building in Bushehr

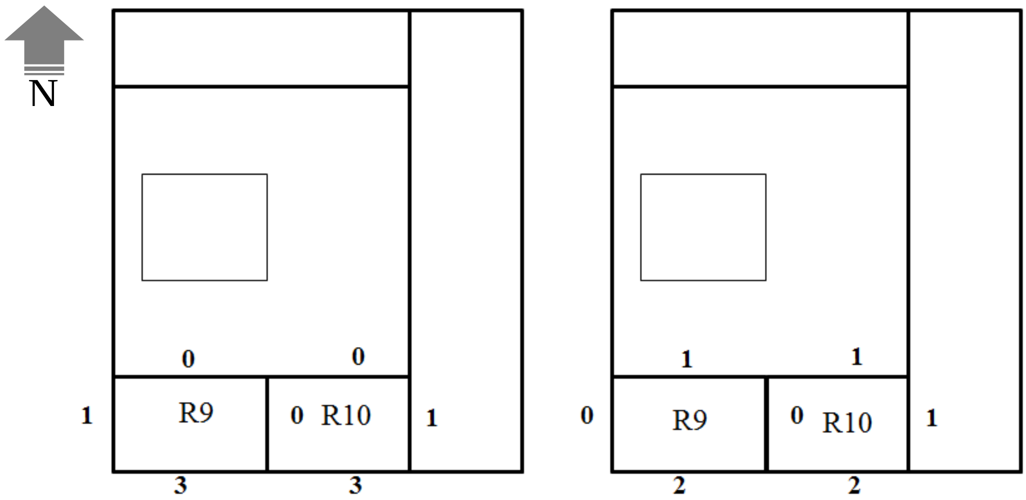


Figure 74: Justified numbers for solar gain in each closed space on the first floor of a traditional building in Bushehr

This research has defined the value of each space by translating the data for the solar radiation effect on ground-floor spaces into a matrix analysis. That matrix analysis included the south wall (SW), north wall (NW), east wall (EW), and west wall (WW). In addition, author considered the solar effect on the floor (SF) in the calculation of the matrix analysis, and figures 75 and 76 reveal the solar gain value (Sn) of each space that corresponds with the justified graph for solar gain.

Ground floor (winter)	**Ground floor (summer)**
Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum	**Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum**
R1: [3] + [0] + [0] + [1] + [1] = 5	R1: [2] + [1] + [0] + [0] + [2] = 5
R2: [3] + [0] + [0] + [0] + [1] = 4	R2: [2] + [1] + [0] + [0] + [2] = 5
R3: [3] + [0] + [0] + [0] + [1] = 4	R3: [2] + [1] + [0] + [0] + [2] = 5
R4: [3] + [0] + [0] + [0] + [1] = 4	R4: [2] + [1] + [0] + [0] + [2] = 5
R5: [0] + [0] + [1] + [0] + [1] = 2	R5: [0] + [1] + [1] + [0] + [2] = 4
R6: [3] + [0] + [1] + [1] + [1] = 6	R6: [2] + [0] + [1] + [1] + [2] = 6
R7: [3] + [0] + [0] + [1] + [1] = 5	R7: [2] + [1] + [0] + [0] + [2] = 5
R8: [3] + [0] + [0] + [0] + [1] = 4	R8: [2] + [1] + [0] + [0] + [2] = 5

Figure 75: Matrix analysis reveals the "Sn" of each closed space on the ground floor

First floor winter time	**First floor summer time**
Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum	**Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum**
R9: [3] + [0] + [0] + [1] + [2] = 6	R9: [2] + [1] + [0] + [0] + [1] = 4
R10: [3] + [0] + [1] + [0] + [2] = 6	R10: [2] + [1] + [1] + [0] + [1] = 5

Figure 76: Matrix analysis reveals the "Sn" of each closed space on the first floor

The solar gain value of the rooms on the ground floor demonstrates that R5 has the lowest value (2) during the winter and R6, R9 and R10 have the highest value (6). Furthermore, R6 has the highest value (7) during the summer. However, R5–R9 and R8 all have the lowest value (4) during the summer. Consequently, during the winter, the closed spaces on the first floor are the best in terms of thermal comfort because they absorb more solar gain from the building envelope; conversely, the rooms on the ground floor are the worst for thermal comfort during the coldest months of the year because they absorb less solar gain at that time. The solar value of the R6 on the ground floor is (6), which has the most comfortable condition from gaining less solar gain during the summer. So during the summer, spaces on the ground floor are the most comfortable in terms of gaining less solar gain

3.1.2 Wind Effect Analysis of a Traditional Building in Bushehr

As previously mentioned, the prevailing wind defines the justified graph for wind effect, and this research defined the graph for each Iranian climate region in Chapter 2. The justified graph for wind effect in Bushehr (Fig.50) demonstrates the following justified numbers: one for the north and west facades and three for the south and east facades during the winter; and during the summer, zero for the south and east façade, two for the north and three for the west facades.

This study then determined the effect of prevailing wind on closed spaces according to the wind direction and the number of the openings on a traditional Iranian building (appendix A). Nevertheless, it should be noted that in the hot-humid climate of Bushehr, the average of mean max and mean min air temperature during the summer is 35°C to 40°C and the maximum relative humid is 70%. Thus, the high relative humidity causes less fluctuation in temperature during the days and nights there (Pourvahidi, 2010). Furthermore, due to this relative lack of fluctuation, the given justified numbers should be limited to the night, when the humidity is lowest during the summer.

For this subsection, the author also evaluated the wind effect value (Vn) by considering the three-dimensional prevailing wind (PW) effect for each spaces according to table 15 and also the two-dimensional realm of the SW, NW, EW, and WW for the matrix analysis (Figs. 77 and 78).

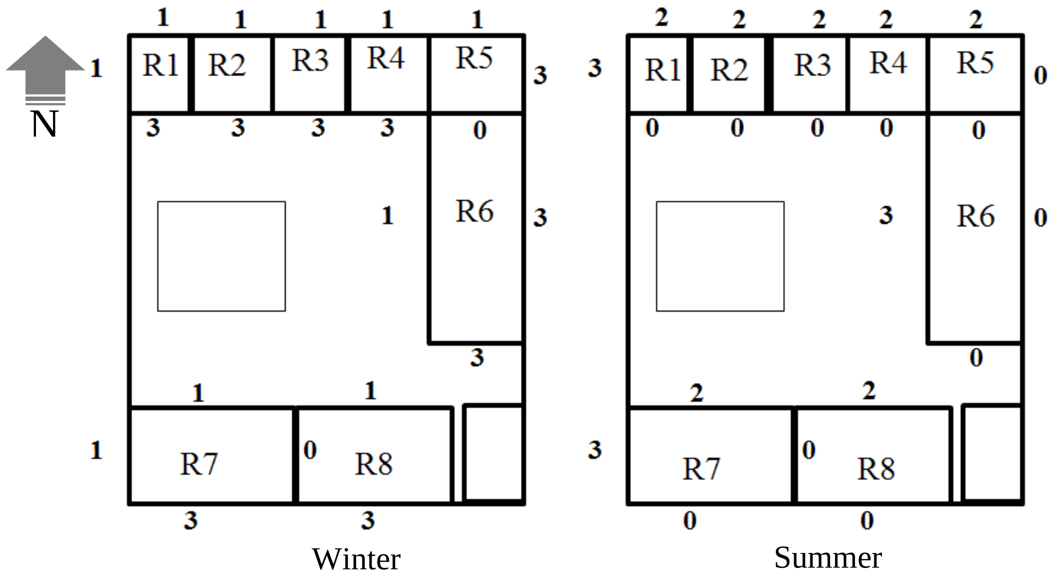


Figure 77: Justified numbers for the wind effect in each closed space on the ground floor of a traditional building in Bushehr

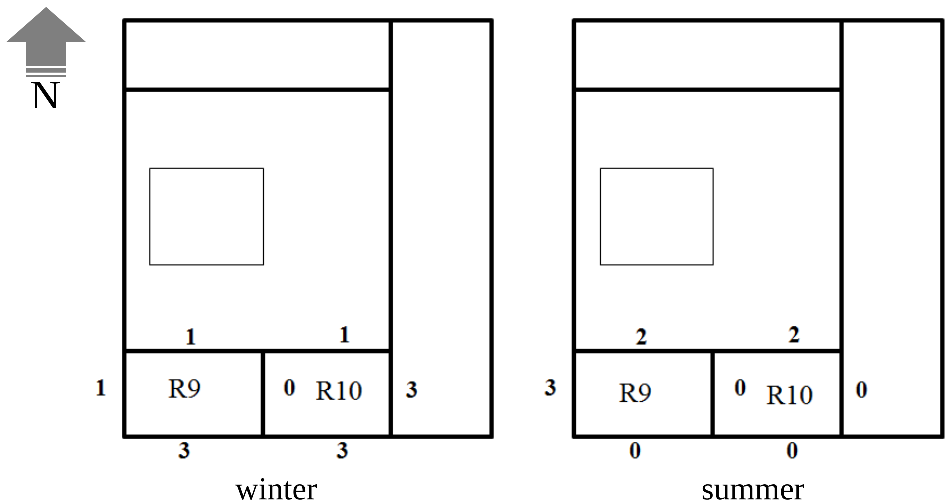


Figure 78: Justified numbers for the wind effect in each closed space on the first floor of a traditional building in Bushehr

Figures 79 and 80 present the matrix analysis of the justified numbers for wind effect in each closed space during the winter and summer.

Ground floor (winter)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R1: [3] + [1] + [0] + [1] + [1] = 6

R2: [3] + [1] + [0] + [0] + [1] = 5

R3: [3] + [1] + [0] + [0] + [1] = 5

R4: [3] + [0] + [0] + [0] + [1] = 4

R5: [0] + [0] + [3] + [0] + [0] = 3

R6: [3] + [0] + [3] + [1] + [1] = 8

R7: [3] + [1] + [0] + [1] + [1] = 6

Ground floor (summer)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R1: [0] + [2] + [0] + [3] + [1] = 6

R2: [0] + [2] + [0] + [0] + [1] = 3

R3: [0] + [2] + [0] + [0] + [1] = 3

R4: [0] + [2] + [0] + [0] + [1] = 3

R5: [0] + [2] + [0] + [0] + [0] = 2

R6: [0] + [0] + [2] + [3] + [1] = 6

R7: [0] + [2] + [0] + [3] + [1] = 6

Figure 79: Matrix analysis reveals the "Vn" for each closed space on the ground floor

First floor (winter)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R9: [3] + [1] + [0] + [1] + [0] = 5

R10: [3] + [1] + [3] + [0] + [0] = 7

First floor (summer)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R9: [0] + [2] + [0] + [3] + [3] = 8

R10: [0] + [2] + [0] + [0] + [3] = 5

Figure 80: Matrix analysis reveals the "Vn" for each closed space on the first floor

The results for "Vn" demonstrate that the ground floor has the best place (R6, in particular) to protect against the wind during the winter. Conversely, the best space (R9, in particular) to let wind enter to the building during the summer is on the first floor.

Finally, for each closed space in this traditional building, all the data on solar gain and wind effect can be summed up in a matrix analysis (Fig. 81).

Ground floor (winter)	**Ground floor (summer)**
R1: [Sn] + [Vn] = [5] + [6] = 11	R1: [Sn] + [Vn] = [5] + [6] = 11
R2: [Sn] + [Vn] = [4] + [5] = 9	R2: [Sn] + [Vn] = [5] + [3] = 8
R3: [Sn] + [Vn] = [4] + [5] = 9	R3: [Sn] + [Vn] = [5] + [3] = 8
R4: [Sn] + [Vn] = [4] + [4] = 8	R4: [Sn] + [Vn] = [5] + [3] = 8
R5: [Sn] + [Vn] = [2] + [3] = 5	R5: [Sn] + [Vn] = [4] + [2] = 6
R6: [Sn] + [Vn] = [6] + [8] = 14	R6: [Sn] + [Vn] = [6] + [6] = 12
R7: [Sn] + [Vn] = [5] + [6] = 11	R7: [Sn] + [Vn] = [5] + [6] = 11
R8: [Sn] + [Vn] = [6] + [7] = 13	R8: [Sn] + [Vn] = [5] + [4] = 9
First floor winter time	**First floor summer time**
R9: [Sn] + [Vn] = [6] + [5] = 11	R9: [Sn] + [Vn] = [4] + [8] = 12
R10: [Sn] + [Vn] = [6] + [7] = 13	R10: [Sn] + [Vn] = [5] + [5] = 10

Figure 81: Matrix analysis reveals the final values for each closed space during the winter and summer

The outcome demonstrates that R6 on the ground floor has the best thermal comfort conditions during the winter and R5, also on the ground floor, has the worst thermal comfort conditions in that season. Furthermore, during the summer, R6 on the ground floor and R9 on the first floor have the best thermal comfort conditions, and R5, again, has the worst thermal comfort conditions.

Ultimately, using the final values from the matrix analysis, this research offer a schematic plan for this traditional building to demonstrate the best and worst thermal comfort zones during the winter and summer (Fig. 82). In this plan, the rooms colored dark grey have the best thermal comfort conditions and the rooms colored light grey have the worst thermal comfort conditions.

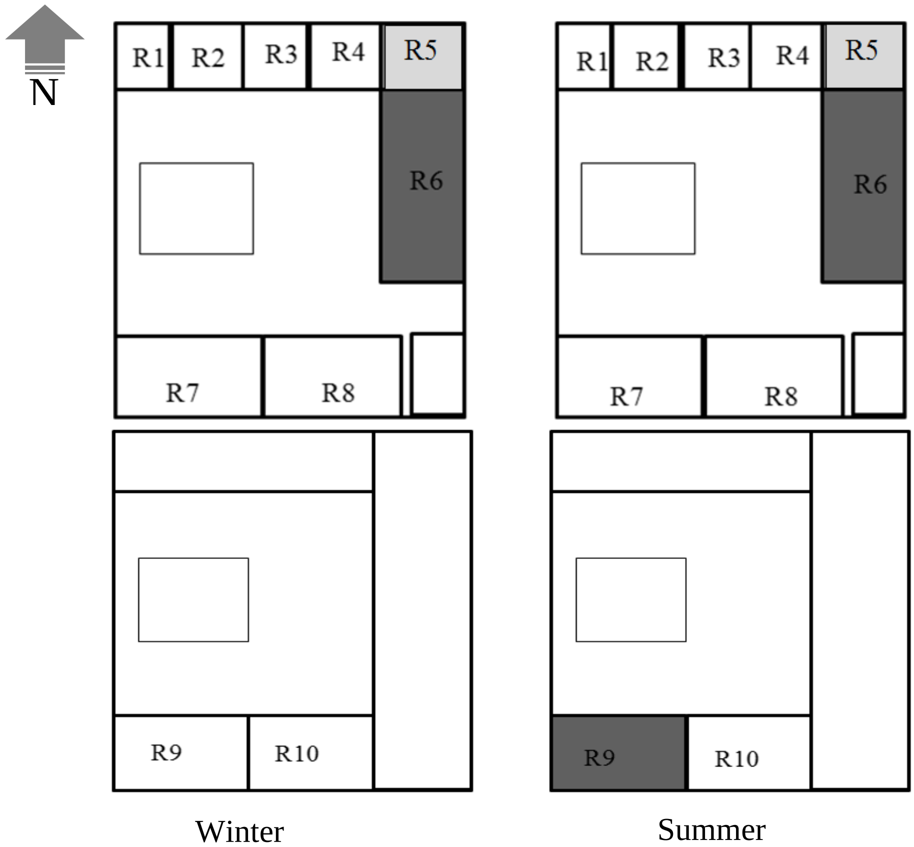


Figure 82: Evaluation of a traditional building in terms of thermal comfort factors in the hot-humid climatic region of Iran during the winter and summer (dark grey = best thermal comfort; light grey = worst thermal comfort)

3.1.3 Analysis of Open and Semi-open Spaces in a Traditional Building at Bushehr

Open and semi-open spaces in a hot-humid climate are very important for the thermal comfort of inhabitants during the summer. Thus, the author has applied the justified graph method and matrix analysis to define the best place to have open and semi-open spaces in this climate. Consequently, this study used Sketch Up software to find the shaded areas of a traditional building in Bushehr on July 1(hottest month of a year) and January 1(coldest month of a year) (Figs. 83 and 84).

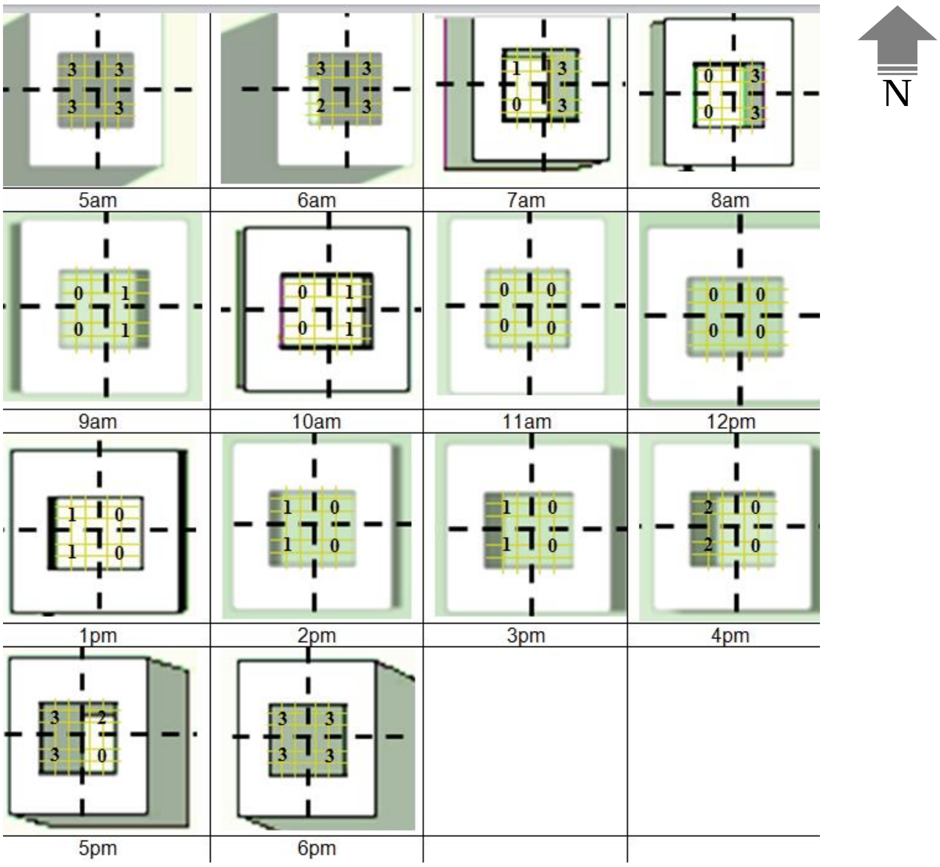


Figure 83: Defining the justified numbers for shaded areas on July 1 (5 a.m.–6 p.m.)

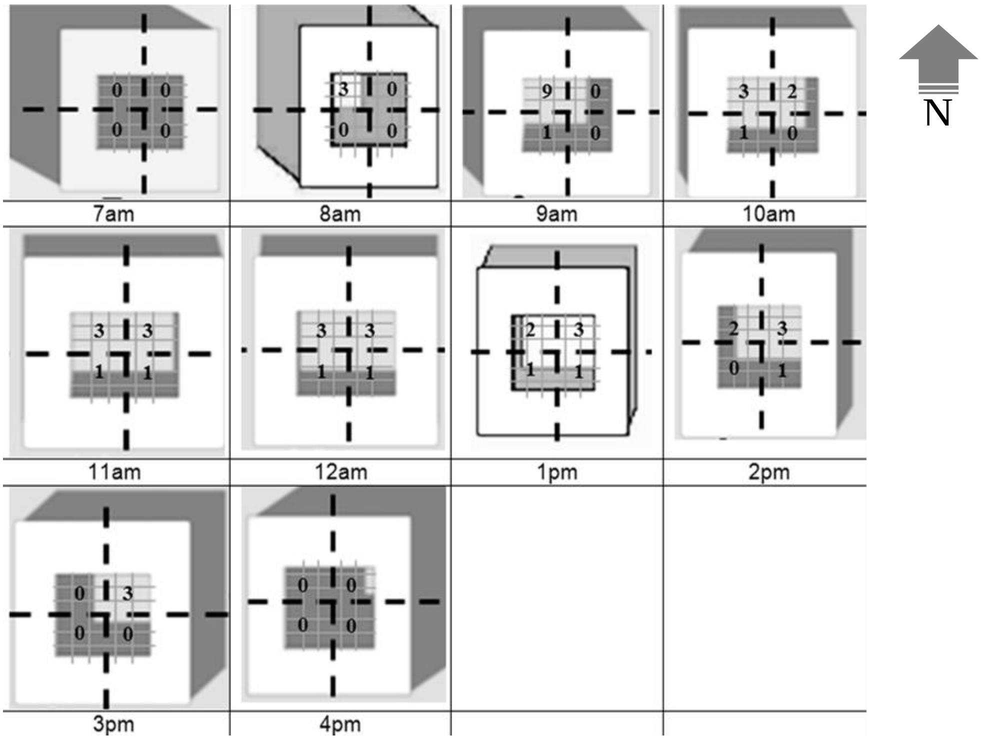


Figure 84: Defining the justified numbers for shaded areas on January 1 (7 a.m.–4 p.m.)

This research then translated the justified numbers for shaded areas into a matrix analysis to calculate the value of each open and semi-open space. The final calculations for open and semi-open spaces are as follows:

Justified numbers in terms of the matrix analysis for July 1 (5a.m.– 6p.m.)

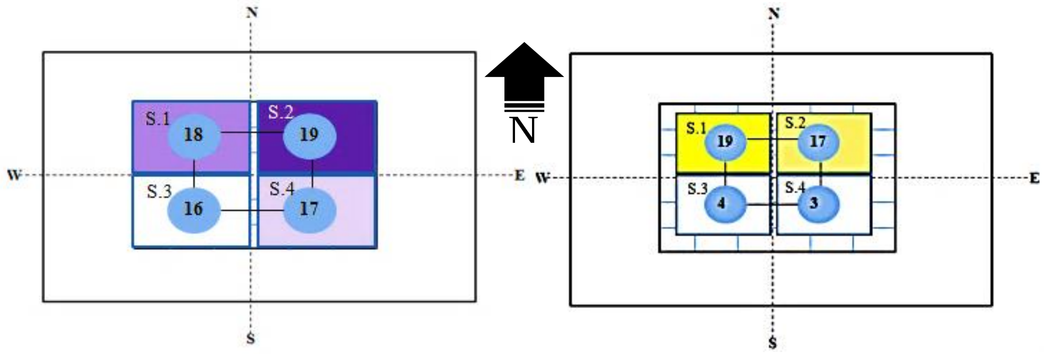
- Open Space 1(S1)= Sum [5a.m., 6p.m.] = 18
- Open Space 2(S2)= Sum [5a.m., 6p.m.] = 19
- Open Space 3(S3)= Sum [5a.m., 6p.m.] = 16
- Open Space 4(S4)= Sum [5a.m., 6p.m.] = 17

Justified numbers in terms of the matrix analysis for January 1 (7 a.m.–4 p.m.)

- Open Space 1(S1)= Sum [7a.m., 4p.m.] = 19
- Open Space 2(S2)= Sum [7a.m., 4p.m.] = 17
- Open Space 3(S3)= Sum [7a.m., 4p.m.] = 4
- Open Space 4(S4)= Sum [7a.m., 4p.m.] = 3

The matrix analysis for July 1 demonstrates that Open Space 2 has the highest value and, thus, the best thermal comfort conditions in terms of solar gain. Furthermore, the matrix analysis for January 1 shows that Open Space 1 and then Open Space 2 have the higher values rather than the other spaces, meaning that they collect the most solar gain (and, thus, have the most thermal comfort) during the coldest months of the year.

The author then represented the value of each open and semi-open space as a justified graph (Fig.86). Thus, the best direction to have open and semi-open spaces in a traditional building in the hot-humid climate of Bushehr is a northern direction toward the south façade.



summer winter

Figure 85: Justified graph of open and semi-open spaces in a traditional building at Bushehr during the winter and summer

In the case of traditional building in this hot-humid climate, semi-open spaces (*eyvans*) that have an L shape are located exactly where Open Space 1 and Open Space 2 are positioned in figure 85. This confirms that the justified graph method yields appropriate results for the thermal comfort conditions of open and semi-open spaces in such a hot-humid climate. Moreover, in this traditional building, R1–R3 and R6 on the ground floor have more openings toward Open Space 1 and Open Space 2 to gather more solar radiation during the winter (Fig.86).

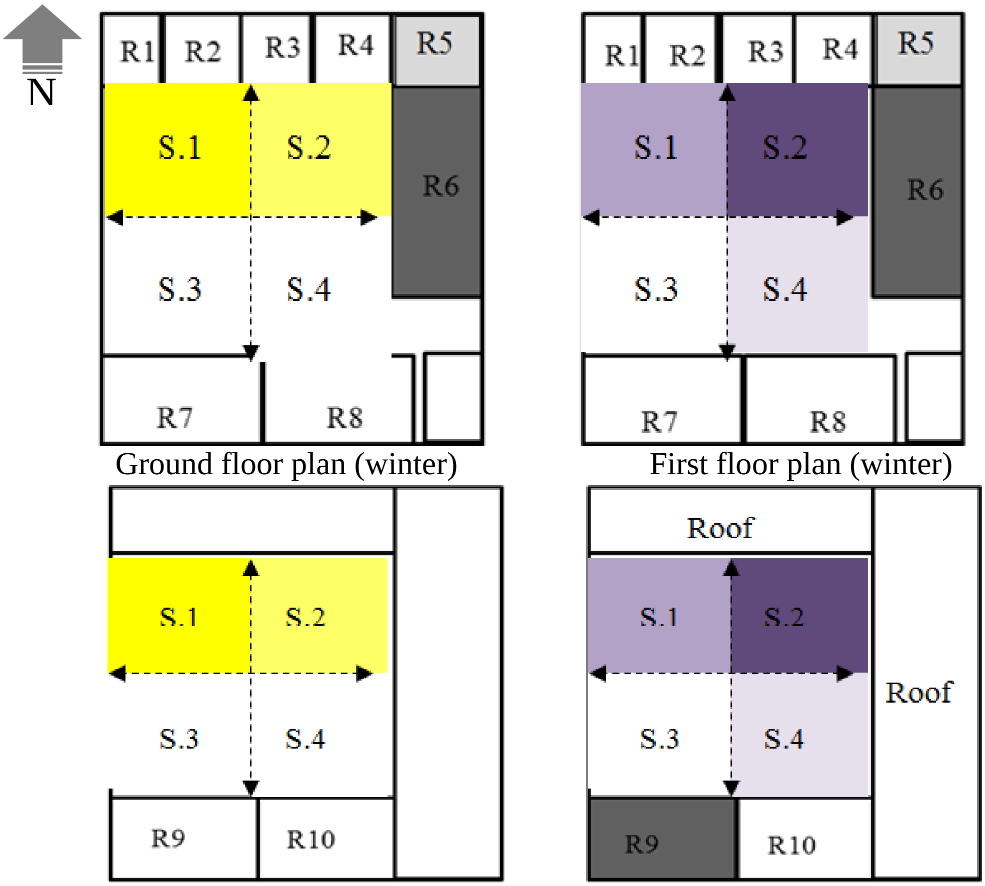


Figure 86: Evaluation of thermal comfort in open and semi-open spaces on the ground floor and first floor of a traditional building in Bushehr during the winter and summer

3.2 Hot-Dry Climate with a Cold Winter (33° N Latitude): Kashan

This study chose a traditional building in Kashan as a case study for a hot-dry climate with a cold winter. In the following section, the author applies the justified graph method for solar gain to this case study.

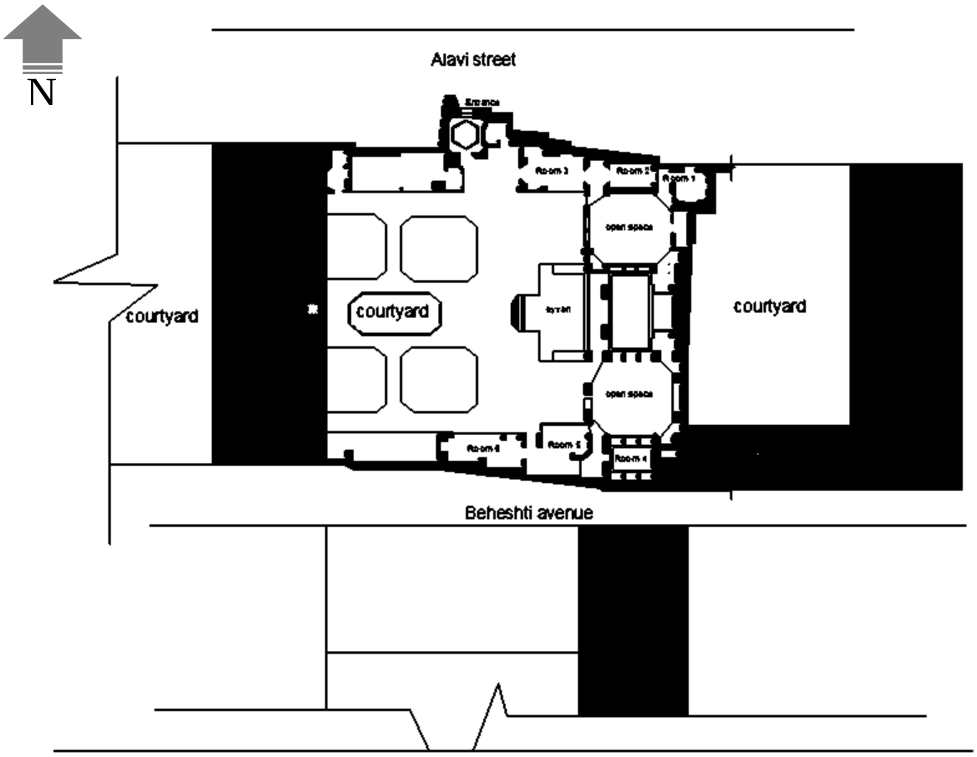


Figure 87: Site plan of the traditional building in Kashan city (University, 2005)

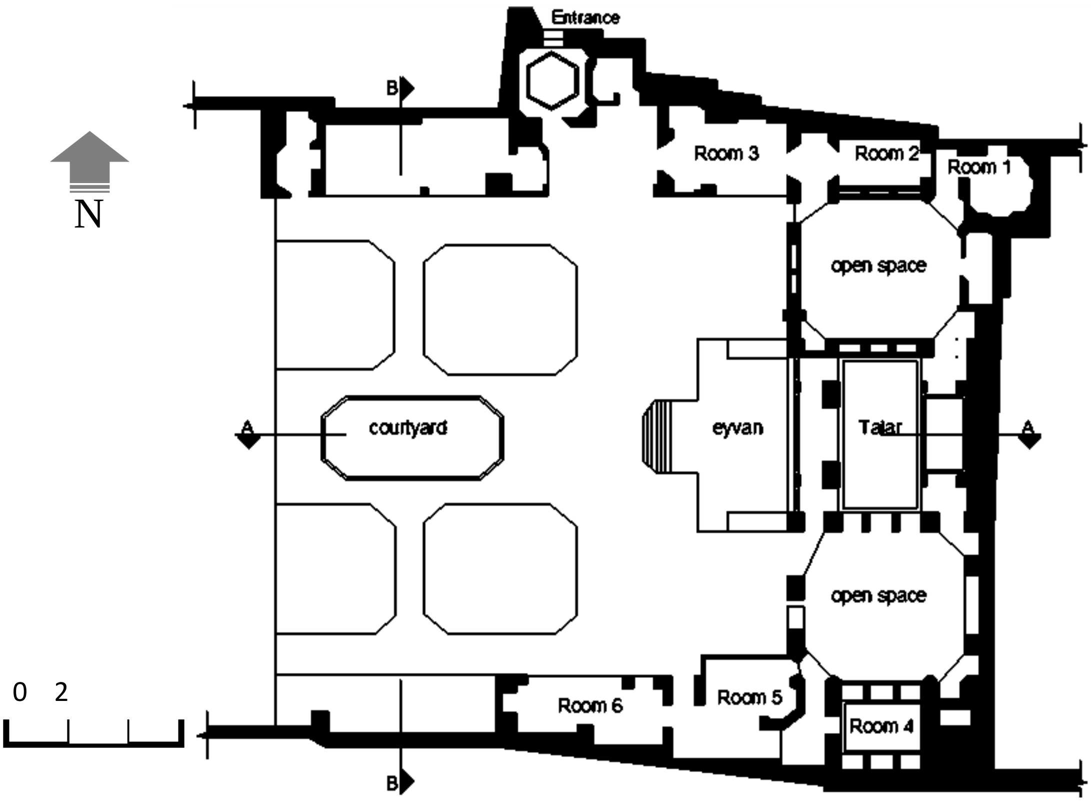


Figure 88: Ground-floor plan of a traditional building in Kashan (University, 2005)

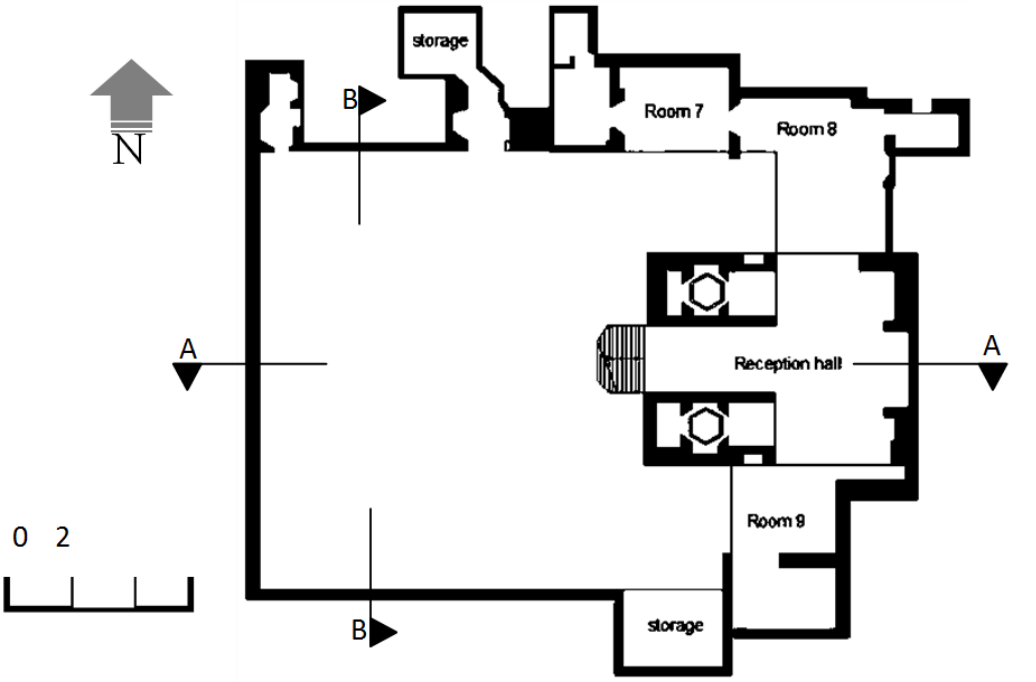


Figure 89: Basment-floor plan of a traditional building in Kashan (University, 2005)

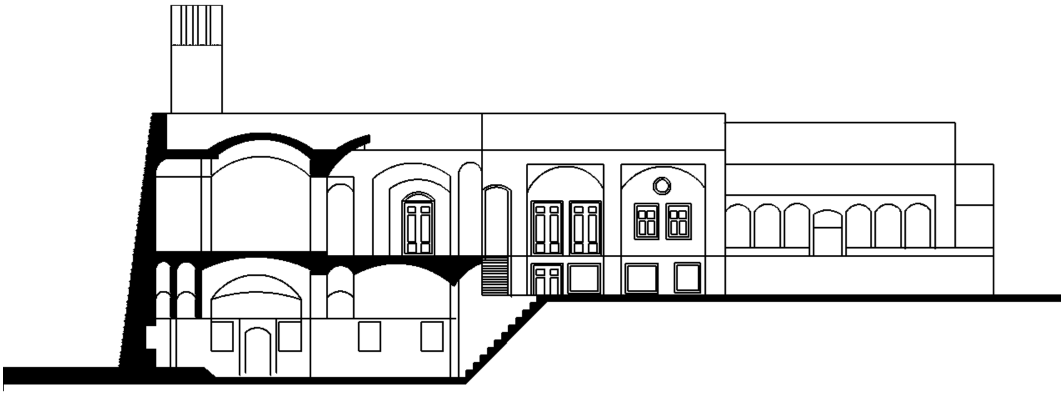


Figure 90: Section A-A of a traditional building in in Kashan (University, 2005)

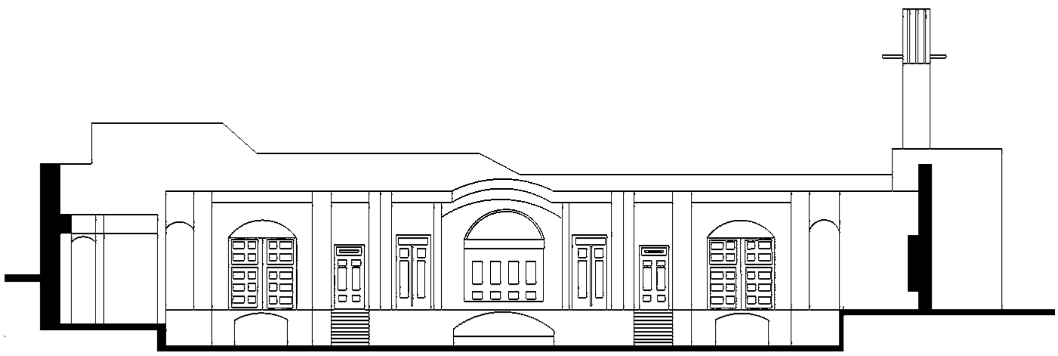


Figure 91: Section B-B of a traditional building in in Kashan (University, 2005)

3.2.1 Solar Gain Analysis of a Traditional Building in Kashan

First, this study determined the solar gain on the building envelope at 180° azimuth angle during the summer and winter (Fig. 30). The justified numbers for solar gain are as follows: three for the south, one for the east and west, and zero for the north during the winter; and during summer, one for the north and east, zero for the west and three for south. Then, the author used the justified graph method to determine the interaction of solar energy and the surface area of each floor in a traditional building (Table 8). Finally, this study translated all the data into a plan to calculate the solar gain of each closed space in a traditional building at Kashan in terms of a matrix analysis (Figs. 92-93).

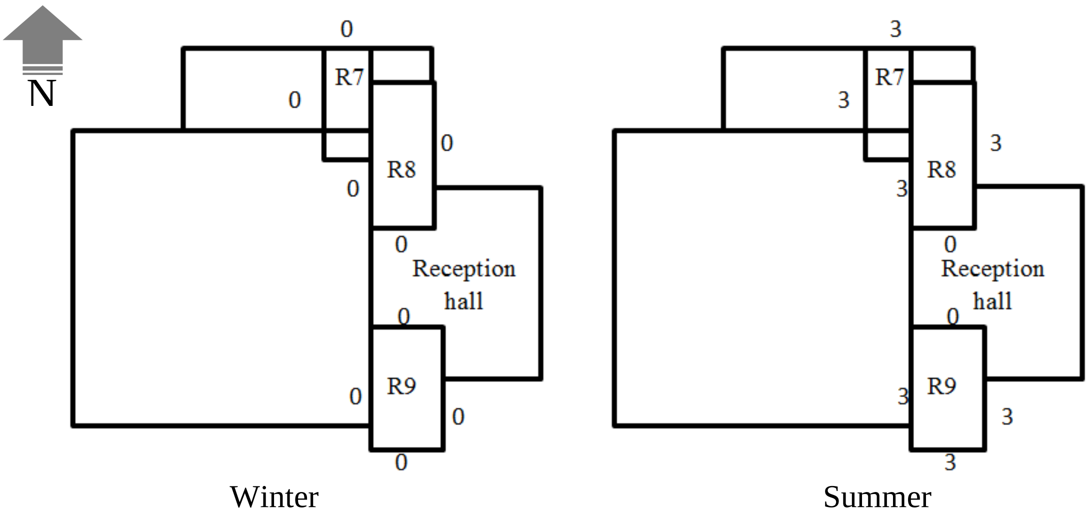
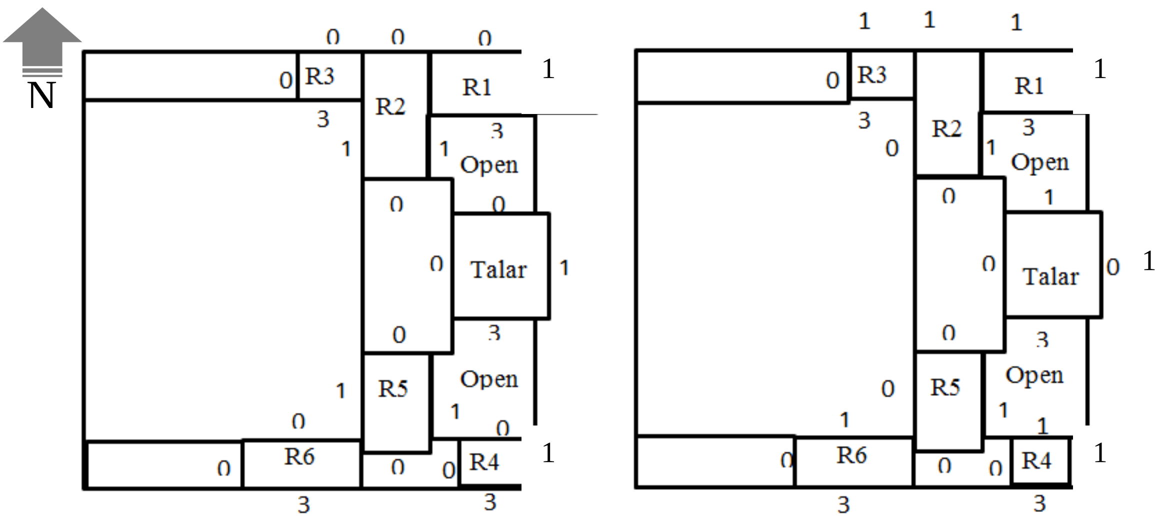


Figure 92: Justified numbers for solar gain in each closed space on the basement floor of a traditional building in Kashan



Winter Summer

Figure 93: Justified numbers for solar gain in each closed space on the ground floor of a traditional building in Kashan

Basement floor (winter)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

R7: [0] + [0] + [0] + [0] + [0] = 0

R8: [0] + [0] + [0] + [0] + [0] = 0

R9: [0] + [0] + [0] + [0] + [0] = 0

Basement floor (summer)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

R7: [3] + [3] + [0] + [3] + [3] = 12

R8: [0] + [3] + [3] + [3] + [3] = 12

R9: [3] + [0] + [3] + [3] + [3] = 12

Figure 94: Matrix analysis reveals the “Sn” of each closed space on the on basmnet floor

Ground floor (winter)	Ground floor (summer)
Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum	**Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum**
R1: [3] + [0] + [1] + [0] + [1] = 5	R1: [3] + [1] + [1] + [0] + [2] = 7
R2: [0] + [0] + [1] + [1] + [1] = 3	R2: [0] + [1] + [1] + [0] + [2] = 4
R3: [3] + [0] + [0] + [0] + [1] = 4	R3: [3] + [1] + [0] + [0] + [2] = 6
R4: [3] + [0] + [1] + [0] + [1] = 5	R4: [3] + [1] + [1] + [0] + [2] = 7
R5: [0] + [0] + [1] + [1] + [1] = 3	R5: [0] + [0] + [0] + [0] + [2] = 2
R6: [3] + [0] + [0] + [0] + [1] = 4	R6: [3] + [1] + [0] + [0] + [2] = 6
Talar: [3] + [0] + [1] + [0] + [1] = 5	Talar: [3] + [1] + [1] + [0] + [2] = 7

Figure 95: Matrix analysis reveals the “Sn” of each closed space on the on ground floor

The outcome of the solar gain matrix analysis confirms that the basement rooms (R7–R9) in a traditional building at Kashan have the best thermal comfort conditions (in terms of gaining less solar gain) during the summer because they have the highest solar gain values. Conversely, R1, R4 and Talar on the ground floor have the best thermal comfort conditions during the winter. In addition, R7, R8 and R9 have the worst thermal comfort conditions during the winter, and R5 has the worst thermal comfort conditions in the summer.

3.2.2 Wind EffectAnalysis of a Traditional Building in Kashan

For the wind effect analysis, this research translated the justified graph for wind into the plan for a traditional building. The justified numbers for that graph are as follows: one for the south and east facades, three for the north façade, and zero for west façade during the winter; and during the summer, zero for the south and east facades and two for the west and north facades (Fig. 66). Figures 96 and 97show the translation of this data into the layout of a traditional building in Kashan.

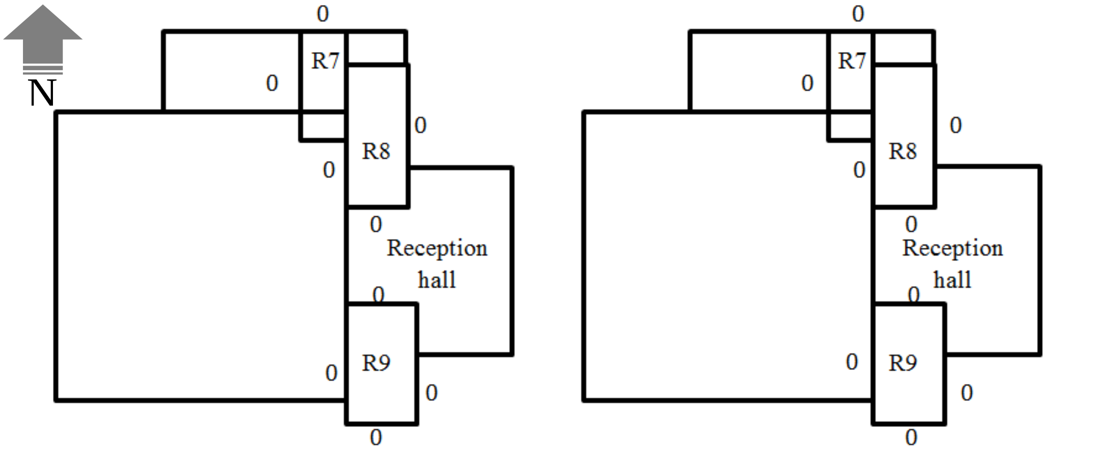


Figure 96: Justified numbers for the wind effect in each closed space on the basement floor of a traditional building in Kashan

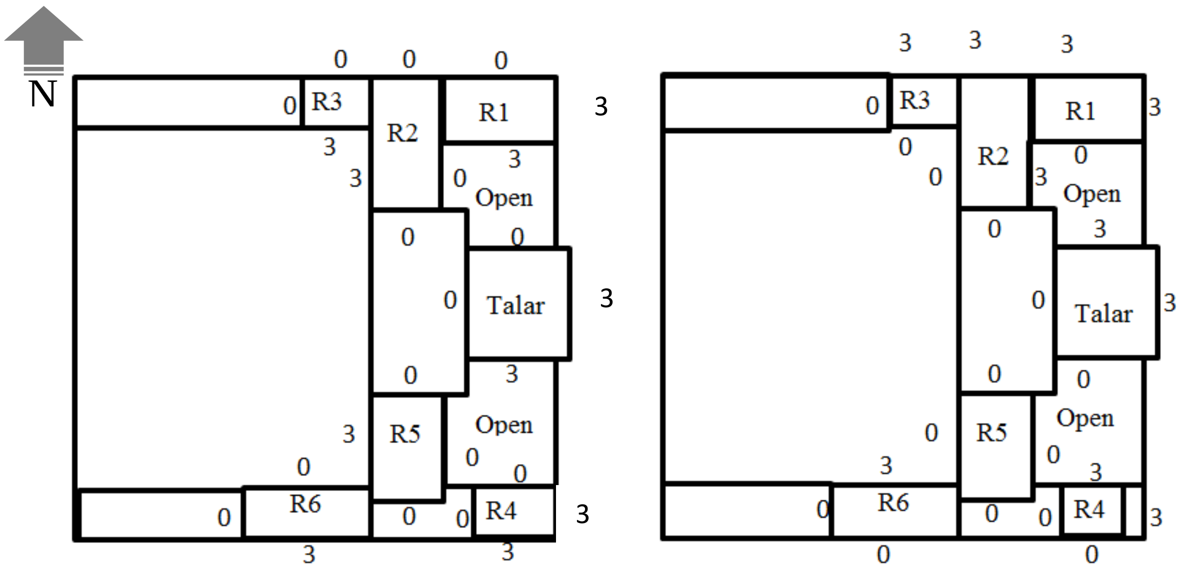


Figure 97: Justified numbers for the wind effect in each closed space on the ground floor of a traditional building in Kashan

In addition, this study summed up the three-dimensional perspective analysis (appendix E) via a matrix analysis. After these investigations, the author summarized the wind data on a plan to calculate the prevailing wind effect on each space using a matrix analysis (Figs. 98-99).

Ground floor (winter)	**Ground floor (summer)**
Vn:[SW]+[NW]+[EW]+[WW]+[PW]=Sum	**Vn:[SW]+[NW]+[EW]+[WW]+[PW]=Sum**
R1: [3] + [0] + [3] + [0] + [1] = 7	R1: [0] + [3] + [3] + [0] + [1] = 7
R2: [0] + [0] + [0] + [3] + [0] = 3	R2: [0] + [3] + [3] + [0] + [1] = 7
R3: [3] + [0] + [0] + [0] + [1] = 4	R3: [0] + [3] + [0] + [0] + [1] = 4
R4: [3] + [0] + [3] + [0] + [0] = 6	R4: [0] + [3] + [3] + [0] + [1] = 6
R5: [0] + [0] + [0] + [3] + [0] = 3	R5: [0] + [0] + [0] + [0] + [3] = 3
R6: [3] + [0] + [0] + [0] + [0] = 3	R6: [0] + [3] + [0] + [0] + [3] = 6
Talar: [3] + [0] + [3] + [0] + [1] = 7	Talar: [0] + [3] + [3] + [0] + [1] = 7

Figure 98: Matrix analysis reveals the "Vn" for each closed space on the ground floor

Basement floor (winter)	**Basement floor (summer)**
Vn:[SW]+[NW]+[EW]+[WW]+[PW]=Sum	**Vn:[SW]+[NW]+[EW]+[WW]+[PW]=Sum**
R7: [0] + [0] + [0] + [0] + [0] = 0	R7: [3] + [0] + [0] + [0] + [0] = 0
R8: [0] + [0] + [0] + [0] + [0] = 0	R8: [0] + [0] + [0] + [0] + [0] = 0
R9: [0] + [0] + [0] + [0] + [0] = 0	R9: [0] + [0] + [0] + [0] + [0] = 0

Figure 99: Matrix analysis reveals the "Vn" for each closed space on the on basement floor

Consequently, combining the results of the solar gain and wind effect analyses, the matrix reveals the final results (Fig. 100).

Ground floor winter time

R1: [S.n] + [V.n] = [4] + [7] = 11

R2: [S.n] + [V.n] = [3] + [3] = 6

R3: [S.n] + [V.n] = [4] + [4] = 8

R4: [S.n] + [V.n] = [4] + [6] = 10

R5: [S.n] + [V.n] = [3] + [3] = 6

R6: [S.n] + [V.n] = [4] + [3] = 7

Talar: [S.n] + [V.n] = [5] + [7] = 12

Ground floor summer time

R1: [S.n] + [V.n] = [5] + [7] = 12

R2: [S.n] + [V.n] = [4] + [7] = 11

R3: [S.n] + [V.n] = [6] + [3] = 9

R4: [S.n] + [V.n] = [5] + [6] = 11

R5: [S.n] + [V.n] = [2] + [2] = 4

R6: [S.n] + [V.n] = [6] + [6] = 12

Talar: [S.n] + [V.n] = [7] + [7] = 14

Basement floor winter time

R7: [S.n] + [V.n] = [0] + [0] = 0

R8: [S.n] + [V.n] = [0] + [0] = 0

R9: [S.n] + [V.n] = [0] + [0] = 0

Basement floor summer time

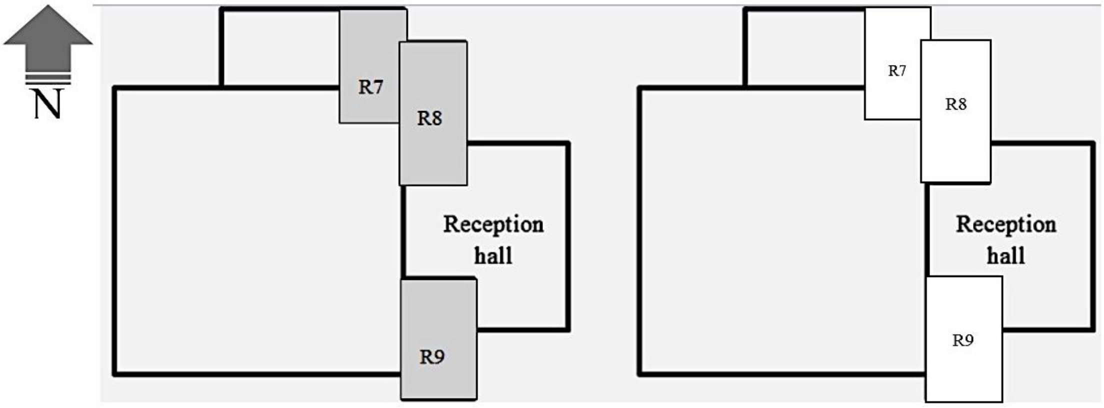
R7: [S.n] + [V.n] = [12] + [0] = 12

R8: [S.n] + [V.n] = [12] + [0] = 12

R9: [S.n] + [V.n] = [12] + [0] = 12

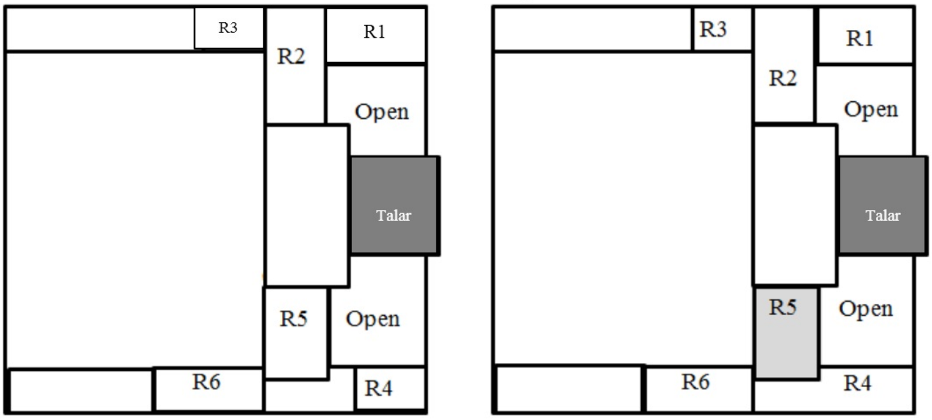
Figure 100: Matrix analysis reveals the final values for each closed space during the winter and summer

The combined results demonstrate that closed spaces in the basement (R7–R9) have the worst thermal comfort conditions during the winter, but Talar has the best thermal comfort conditions during the summer. Talar on ground floor has the best thermal comfort conditions during the winter. This is evident when translating the combined results into a schematic floor plan, in which the best thermal comfort zones are dark grey and the worst thermal comfort zones are light grey.



Winter summer

Basement floor plan



Winter summer

Ground floor plan

Figure 101: Evaluation of a traditional building in terms of thermal comfort factors in the hot-dry with cold winter climatic region of Iran during the winter and summer (dark grey = best thermal comfort; light grey = worst thermal comfort)

3.2.3 Analysis of Open and Semi-open Spaces in a Traditional Building at Kashan

For the analysis of open and semi-open spaces, this research investigated the justified numbers for January 1 and July 1 for the case study in Kashan (Figs. 102-103).

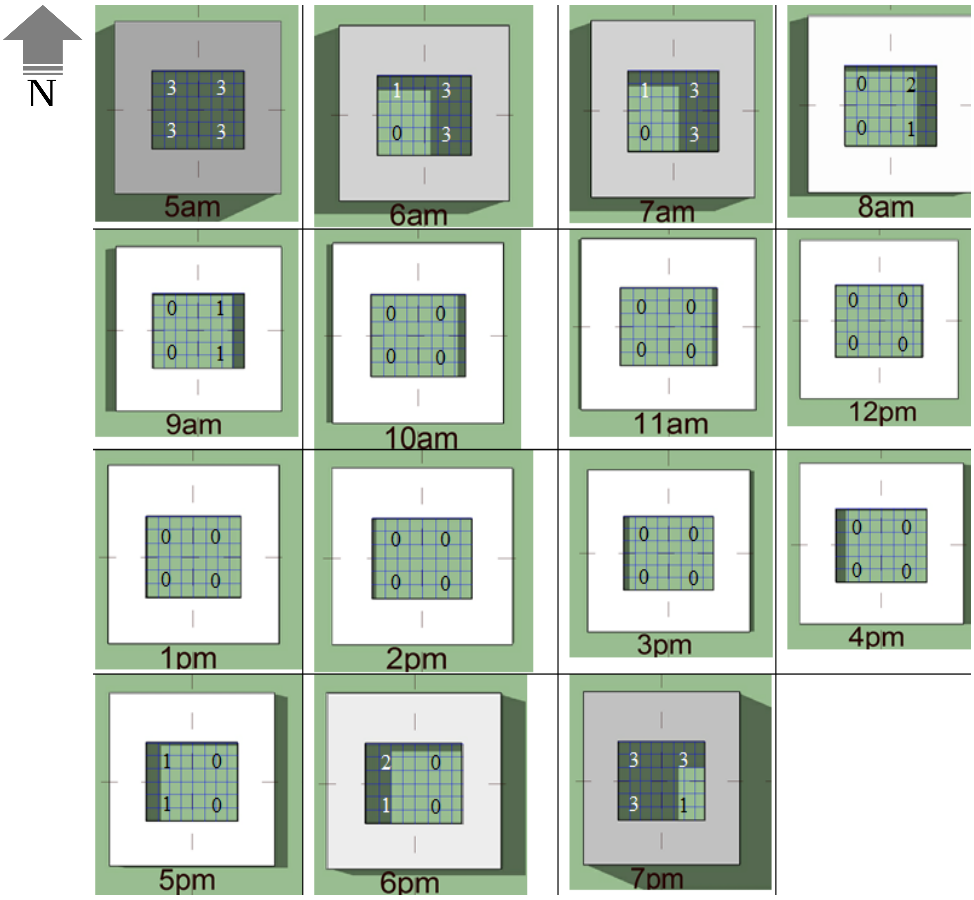


Figure 102: Defining the justified numbers for shaded areas on July 1 (5 a.m.–7 p.m.)

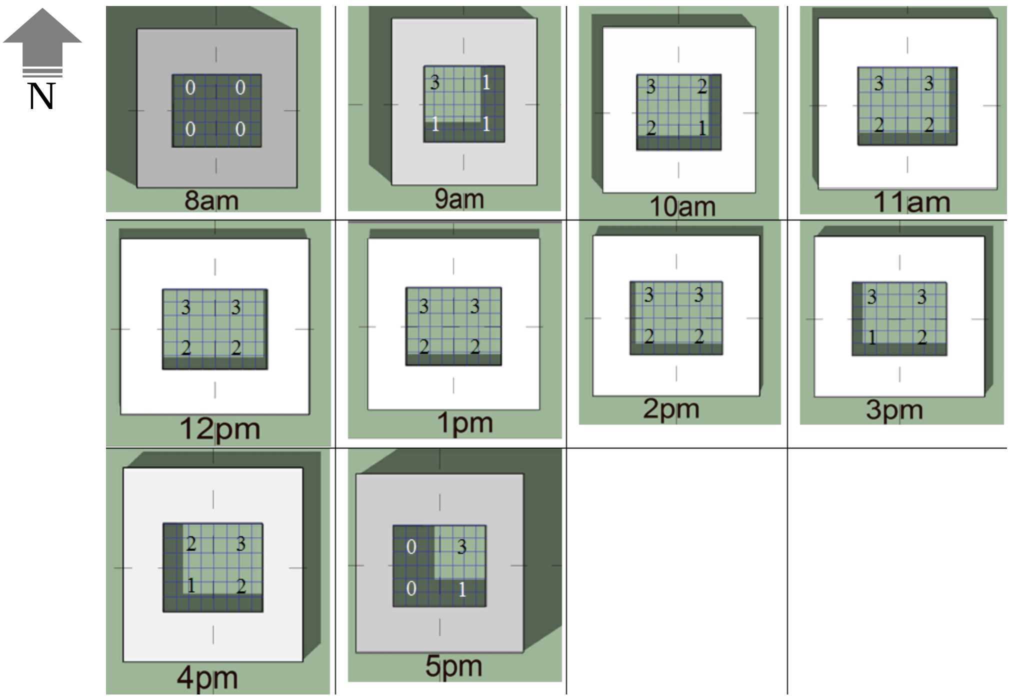


Figure 103: Defining the justified numbers for shaded areas on January 1 (8 a.m.–5 p.m.)

The outcome of the analysis signifies that Open Space 2 has a higher solar gain value (2) than other spaces in the building during the winter. Open Space 2 also has the best thermal comfort conditions during the summer. The final values of the open and semi-open spaces on January 1 and July 1 are as follows:

Justified numbers in terms of the matrix analysis for July 1 (5 a.m., 7 p.m.)

- Open space 1 (S1) = Sum [5am, 7pm] = 11
- Open space 2 (S2) = Sum [5am, 7pm] = 15
- Open space 3 (S3) = Sum [5am, 7pm] = 8
- Open space 4 (S4) = Sum [5am, 7pm] = 12

Justified numbers in terms of the matrix analysis for January 1 (8 a.m., 5 p.m.)

- Open space 1 (S1) = Sum [8am, 5pm] = 14
- Open space 2 (S2) = Sum [8am, 5pm] = 24
- Open space 3 (S3) = Sum [8am, 5pm] = 13
- Open space 4 (S4) = Sum [8am, 5pm] = 15

Finally, the author displayed the results of the open and semi-open spaces using justified graphs for the winter and summer (Fig. 104).

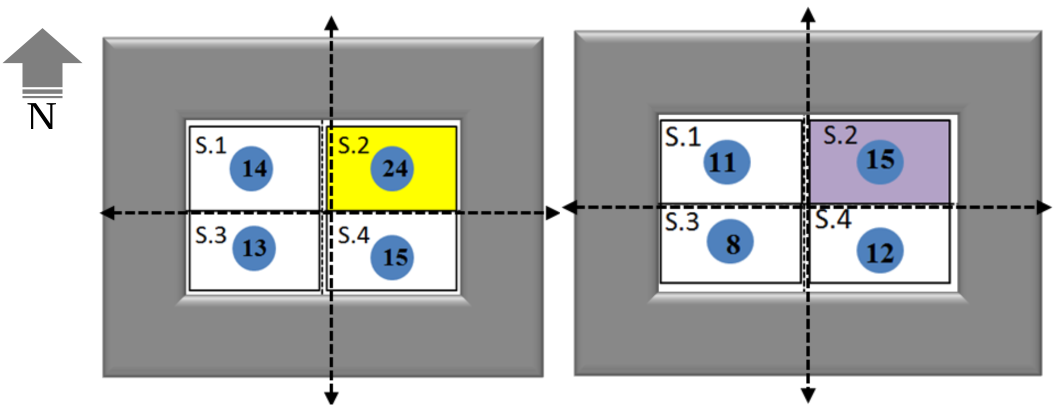


Figure 104: Justified graph of semi-open and open in Kashan city during winter and summer time

All the outcomes for open and semi-open spaces are evident for the summer and winter at a traditional building in Kashan's hot-dry climate with a cold winter.

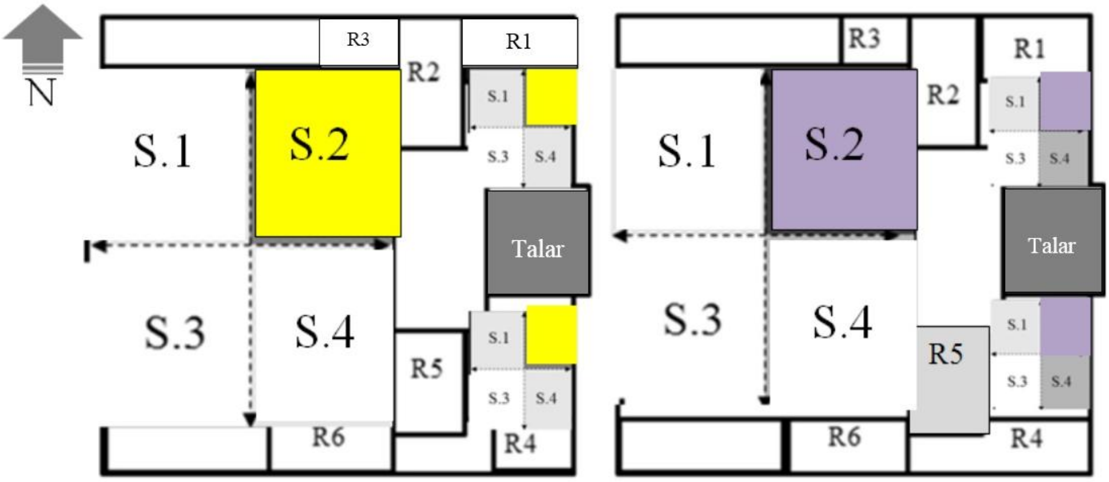


Figure 105: Evaluation of thermal comfort in open and semi-open spaces on the ground floor and first floor of a traditional building in Kashan during the winter and summer

3.3 Hot-dry climate (32.24ºN degree latitude), Dezful city

For this hot-dry climate region, author chose a traditional building in Dezful. As with the previous sections, this research used the justified graph method for solar gain and then wind effect in a traditional building at Dezful.

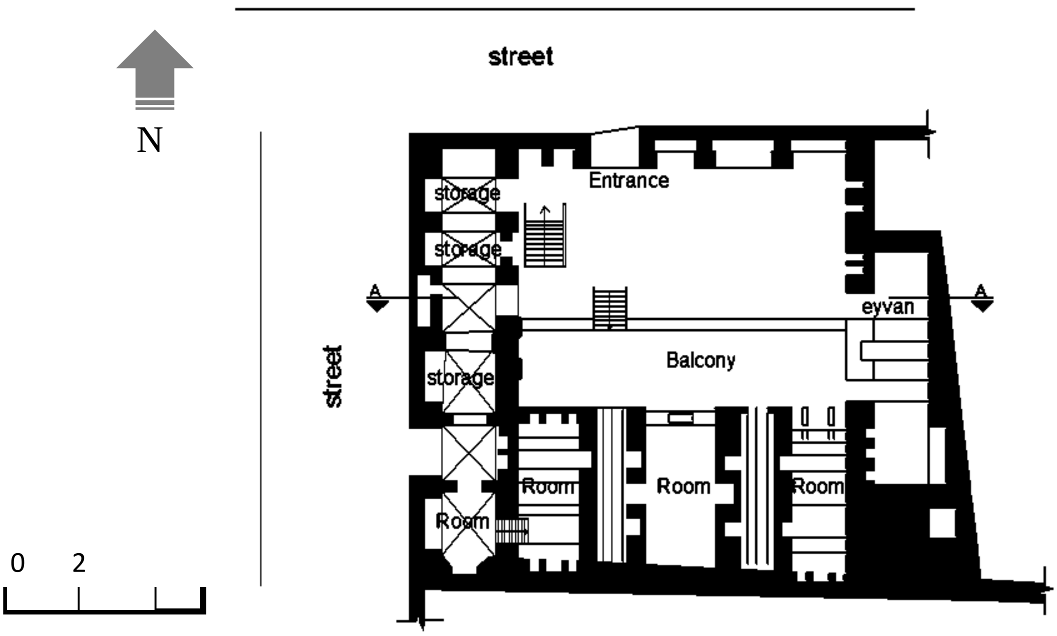


Figure 106: Ground-floor plan of a traditional building in Dezful (Ghobadian, 2009)

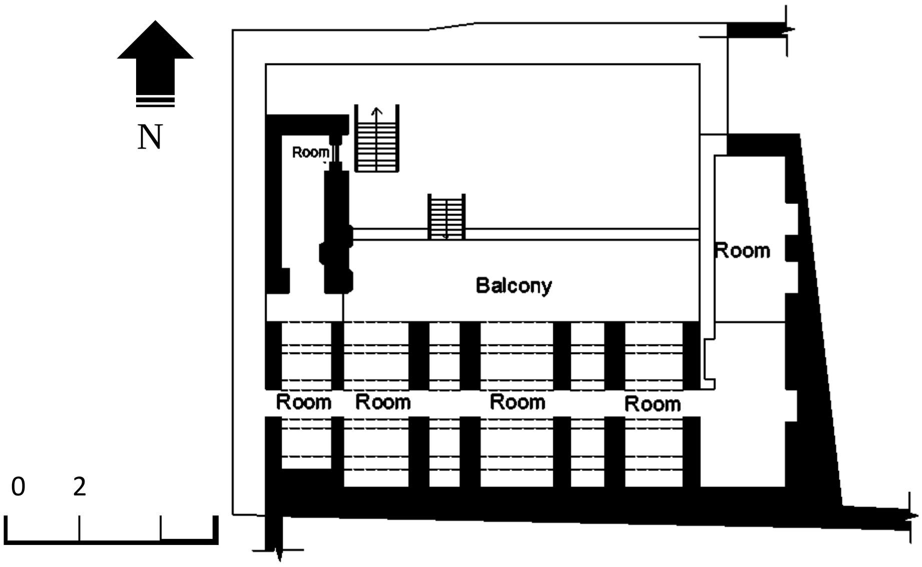


Figure 107: First-floor plan of a traditional building in Dezful (Ghobadian, 2009)

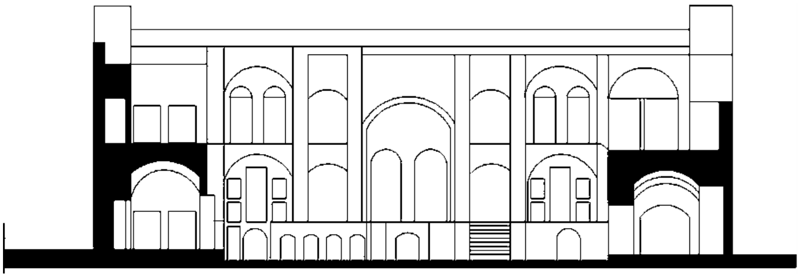


Figure 108: Section A-A of a traditional building in Dezful (Ghobadian, 2009)

3.3.1 Solar Gain Analysis of a Traditional Building in Dezful

This study translated the data from the justified graph for solar gain into the closed spaces of a traditional building at 180° azimuth. The justified numbers for this building are as follows: three for the south, one for the east and west, and zero for the north; and during the summer, two for the north and south and zero for the east and west (Fig.30). Figures109 and 110 represent the justified numbers for solar gain in each closed space during the winter and summer.

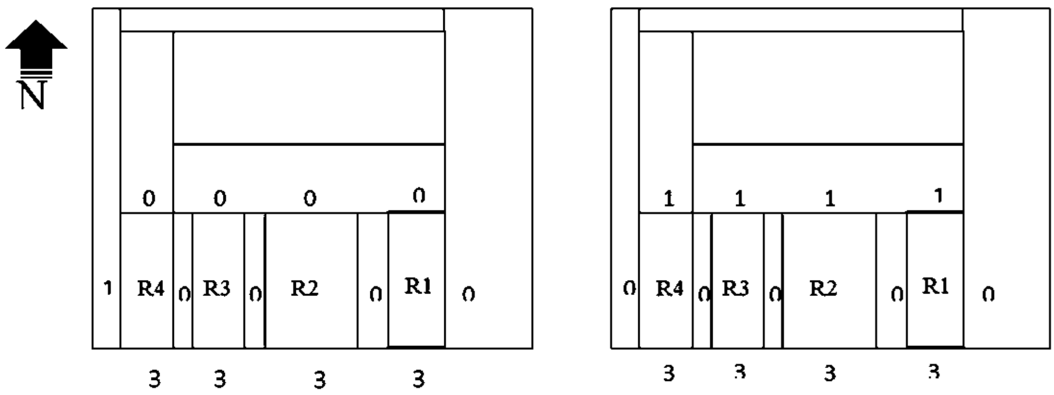


Figure 109: Justified numbers for solar gain in each closed space on the ground floor of a traditional building in Dezful

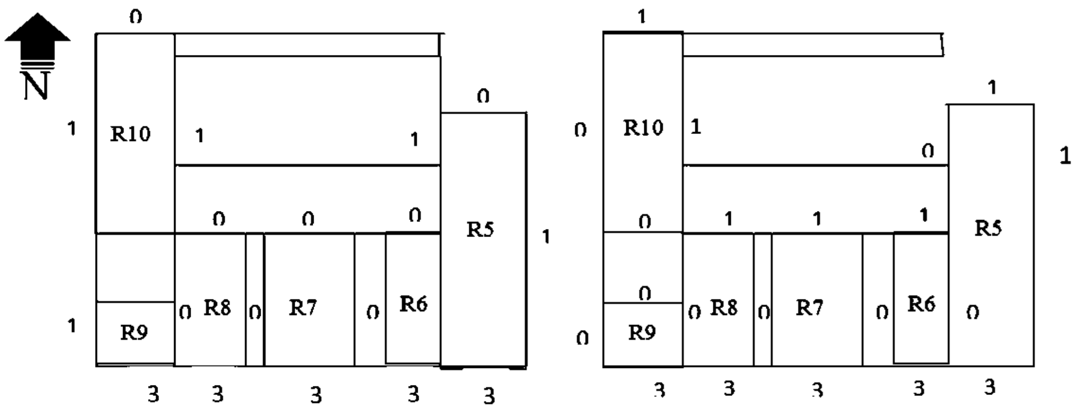


Figure 110: Justified numbers for solar gain in each closed space on the first floor of a traditional building in Dezful

The matrix analysis below demonstrates the solar gain values for each space (Figs. 111 and 112).

Ground floor (winter)	**Ground floor (summer)**
Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum	**Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum**
R1: [3] + [0] + [0] + [0] + [2] = 5	R1: [3] + [1] + [0] + [0] + [1] = 5
R2: [3] + [0] + [0] + [0] + [2] = 5	R2: [3] + [1] + [0] + [0] + [1] = 5
R3: [3] + [0] + [0] + [0] + [2] = 5	R3: [3] + [1] + [0] + [0] + [1] = 5
R4: [3] + [0] + [0] + [1] + [2] = 6	R4: [3] + [1] + [0] + [0] + [1] = 5

Figure 111: Matrix analysis reveals the "Sn" of each closed space on the ground floor

First floor (winter)	**First floor (summer)**
Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum	**Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum**
R5: [3] + [0] + [1] + [1] + [1] = 5	R5: [3] + [1] + [1] + [0] + [2] = 7
R6: [3] + [0] + [0] + [0] + [1] = 4	R6: [3] + [1] + [0] + [0] + [2] = 6
R7: [3] + [0] + [0] + [0] + [1] = 4	R7: [3] + [1] + [0] + [0] + [2] = 6
R8: [3] + [0] + [0] + [0] + [1] = 4	R8: [3] + [1] + [0] + [0] + [2] = 6
R9: [3] + [0] + [0] + [1] + [1] = 5	R9: [3] + [0] + [0] + [0] + [2] = 5
R10: [0] + [0] + [1] + [1] + [1] = 3	R10: [0] + [1] + [1] + [0] + [2] = 4

Figure 112: Matrix analysis reveals the "Sn" of each closed space on the first floor

3.3.2 Wind EffectAnalysis of a Traditional Building in Dezful

This research translated the data from the justified graph for wind effect into the spaces of a traditional building as the first step in the wind effect analysis. The justified numbers for wind effect according the prevailing wind in Dezful are as follows: one for the south and east facades, three for the north façade, and three for the west facade during the winter.

Significantly, in the hot-dry climate of Dezful, the highest temperatures during the summer range between 40°C to 50°C, and during the night, it ranges from 20°C to 25°C (Pourvahidi, 2010). Thus, all the façade defined as justified number zero, since the air temperature during the hottest month of a year is higher than the body temperature so wind has not have any effect for cooling the spaces. Consequently, the author considers the wind effect as negative during summer time. These justified numbers led to the wind effect value for each closed space.

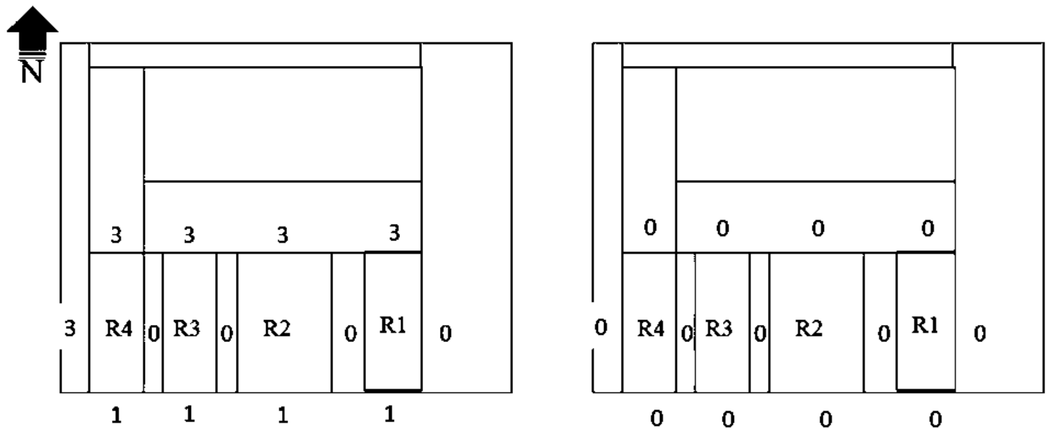


Figure 113: Justified numbers for the wind effect in each closed space on the ground floor of a traditional building in Dezful

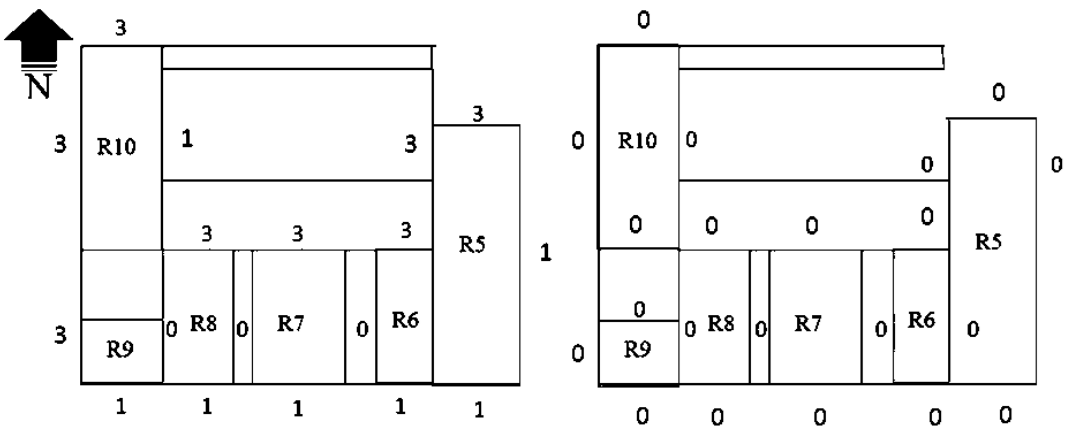


Figure 114: Justified numbers for the wind effect in each closed space on the first floor of a traditional building in Dezful

The wind effect value of each closed space is present in the following matrix analysis (Figs. 115 and 116).

Ground floor (winter)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R1: [1] + [3] + [0] + [0] + [0] = 5

R2: [1] + [3] + [0] + [0] + [0] = 4

R3: [1] + [3] + [0] + [0] + [0] = 4

R4: [1] + [3] + [0] + [3] + [0] = 7

Ground floor (summer)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R1: [0] + [0] + [0] + [0] + [0] = 0

R2: [0] + [0] + [0] + [0] + [0] = 0

R3: [0] + [0] + [0] + [0] + [0] = 0

R4: [0] + [0] + [0] + [0] + [0] = 0

Figure 115: Matrix analysis reveals the "Vn" for each closed space on the ground floor

First floor (winter)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R5: [1] + [3] + [1] + [3] + [1] = 8

R6: [1] + [3] + [0] + [0] + [0] = 4

R7: [1] + [3] + [0] + [0] + [0] = 4

R8: [1] + [3] + [0] + [0] + [0] = 4

R9: [1] + [0] + [0] + [3] + [0] = 4

R10: [0] + [3] + [1] + [3] + [1] = 8

First floor (summer)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R5: [0] + [0] + [0] + [0] + [0] = 0

R6: [0] + [0] + [0] + [0] + [0] = 0

R7: [0] + [0] + [0] + [0] + [0] = 0

R8: [0] + [0] + [0] + [0] + [0] = 0

R9: [0] + [0] + [0] + [0] + [0] = 0

R10: [0] + [0] + [0] + [0] + [0] = 0

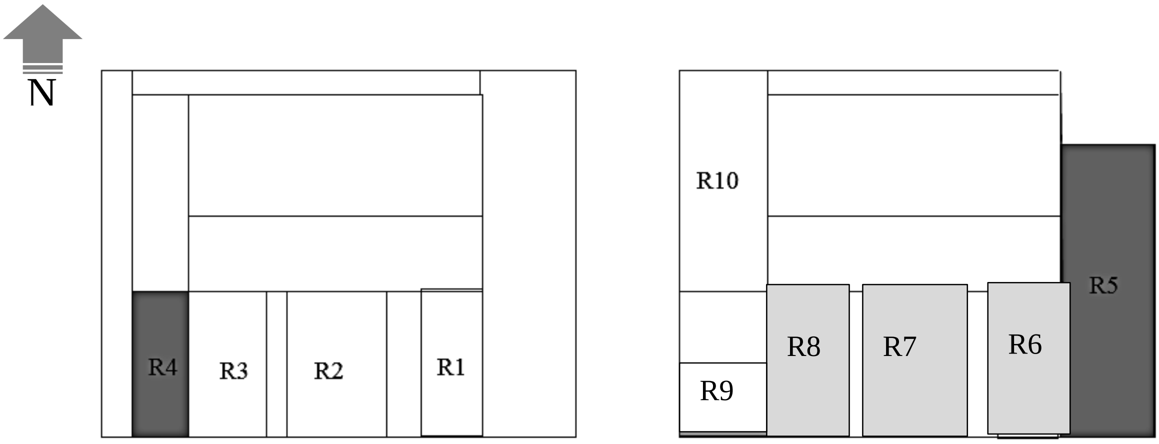
Figure 116: Matrix analysis reveals the "Vn" for each closed space on the first floor

As in previous sections, the final step is to sum up the values for solar gain and wind effect as a matrix calculation (Fig. 117).

Ground floor (winter)	**Ground floor (summer)**
R1: [S.n] + [V.n] = [5] + [5] = 10	R1: [S.n] + [V.n] = [5] + [0] = 5
R2: [S.n] + [V.n] = [5] + [4] = 9	R2: [S.n] + [V.n] = [5] + [0] = 5
R3: [S.n] + [V.n] = [5] + [4] = 9	R3: [S.n] + [V.n] = [5] + [0] = 5
R4: [S.n] + [V.n] = [6] + [7] = 13	R4: [S.n] + [V.n] = [5] + [0] = 5
First floor (winter)	**First floor (summer)**
R5: [S.n] + [V.n] = [5] + [8] = 13	R5: [S.n] + [V.n] = [7] + [0] = 7
R6: [S.n] + [V.n] = [4] + [4] = 8	R6: [S.n] + [V.n] = [6] + [0] = 6
R7: [S.n] + [V.n] = [4] + [4] = 8	R7: [S.n] + [V.n] = [6] + [0] = 6
R8: [S.n] + [V.n] = [4] + [4] = 8	R8: [S.n] + [V.n] = [6] + [0] = 6
R9: [S.n] + [V.n] = [5] + [4] = 9	R9: [S.n] + [V.n] = [5] + [0] = 5
R10: [S.n] + [V.n] = [3] + [8] = 11	R10: [S.n] + [V.n] = [4] + [0] = 5

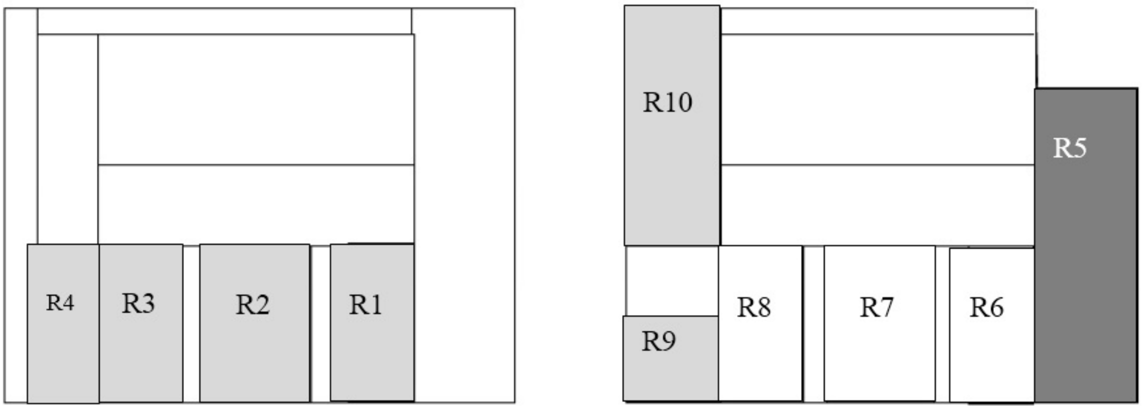
Figure 117: Matrix analysis reveals the final values for each closed space during the winter and summer

The outcome of this combinatory analysis reveals that R4 and R5 have the highest justified numbers during the winter. Furthermore, during the summer, R5 standing on the first floor has the highest justified number. Figures 118 and 119are a schematic floor plan with the best (dark grey) and worst (light grey) rooms for thermal comfort, based on the combination of solar gain and wind effect.



Winter

Figure 118: Evaluation of a traditional building in terms of thermal comfort factors in the hot-dry climatic region of Iran during the winter (dark grey = best thermal comfort; light grey = worst thermal comfort)



Summer

Figure 119: Evaluation of a traditional building in terms of thermal comfort factors in the hot-dry climatic region of Iran during the summer (dark grey = best thermal comfort; light grey = worst thermal comfort)

3.3.3Analysis of Open and Semi-Open Spaces in a Traditional Building at Dezful

Open and semi-open spaces in a hot-dry climate are very significant for the thermal comfort of inhabitants during the summer. Thus, the author has applied the justified graph method and matrix analysis to define the best place to have open and semi-open spaces in this climate. Therefore, this study used Sketch Up software to find the shaded areas of a traditional building in Dezful on July 1(hottest month of a year) and January 1(coldest month of a year) (Figs. 120 and 121).

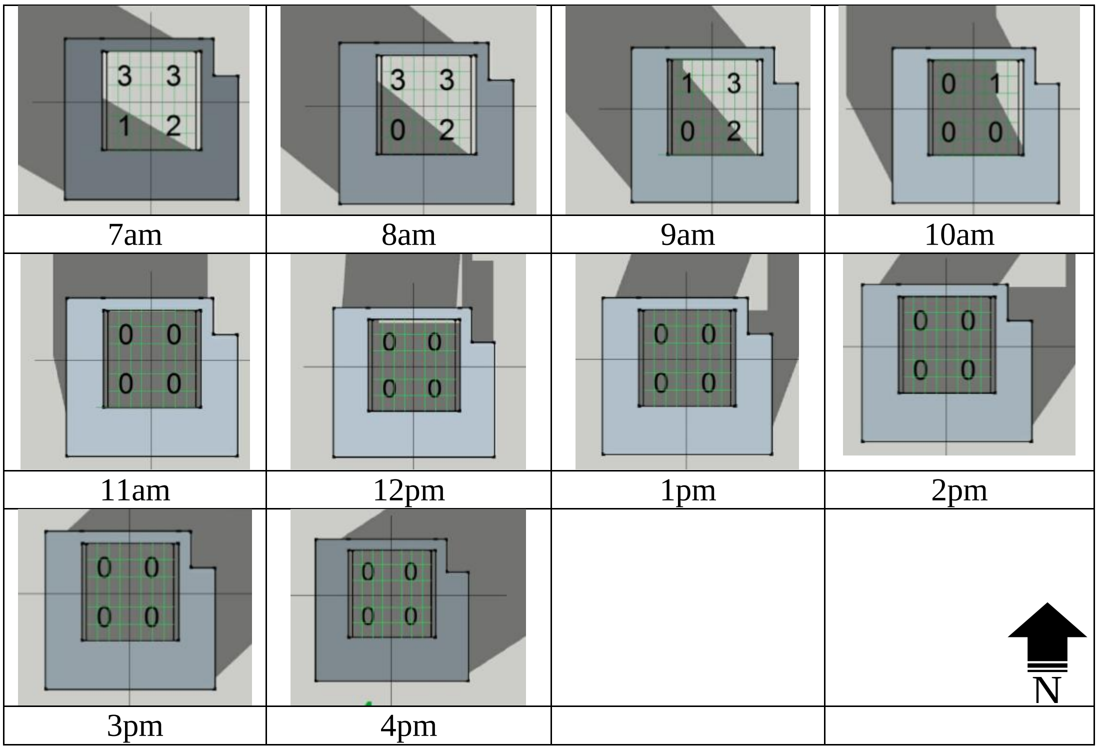
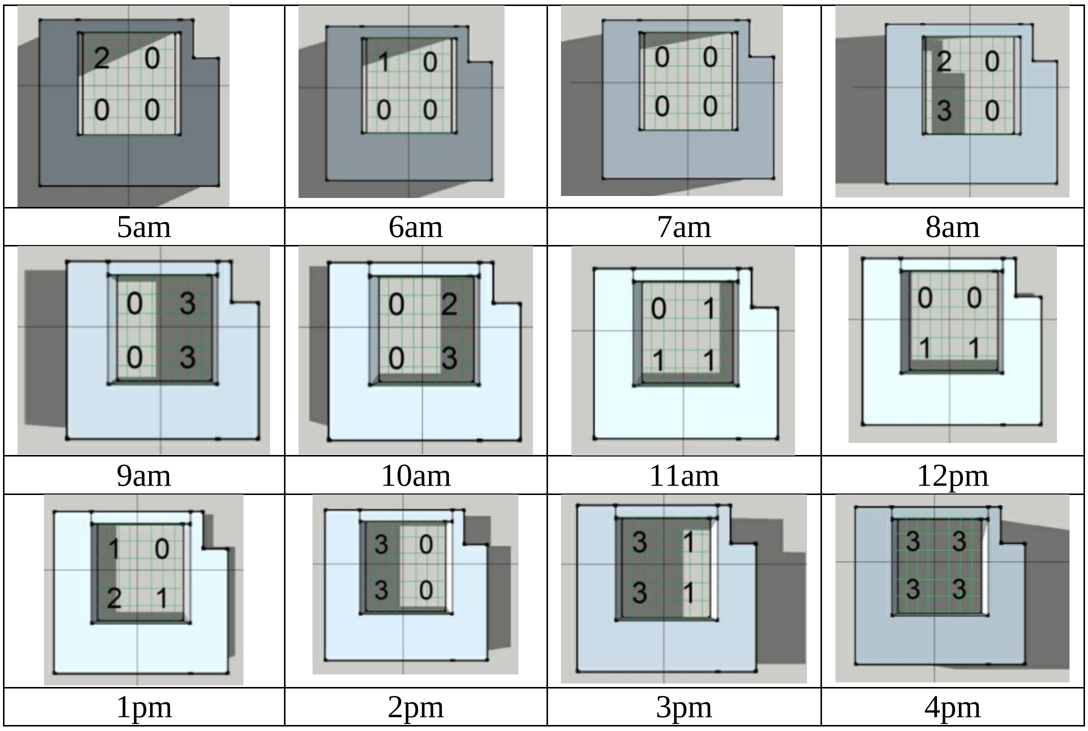


Figure 120: Defining the justified numbers for shaded areas on January 1 (7 a.m.–4 p.m.)



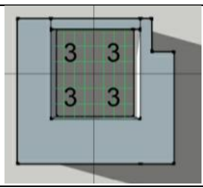
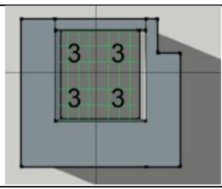
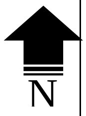
			
5pm	6pm		

Figure 121: Defining the justified numbers for shaded areas on July 1 (5 a.m.–6 p.m.)

The outcome of the analysis signifies that Open Space 3has a higher solar gain value (S3) than other spaces in the building during the summer. However, since of having no winter season in this climate, semi-open and open space demonstrated the justified zero during the 1st of January. The final values of the open and semi-open spaces on January 1 and July 1 are as follows:

Justified numbers in terms of the matrix analysis for July 1 (5 a.m., 6 p.m.)

- Open space 1 (S1) = Sum [5am, 6pm] = 21
- Open space 2 (S2) = Sum [5am, 6pm] = 16
- Open space 3 (S3) = Sum [5am, 6pm] = 22
- Open space 4 (S4) = Sum [5am, 6pm] = 19

Justified numbers in terms of the matrix analysis for January 1 (7 a.m., 4 p.m.)

- Open space 1 (S1) = Sum [7am, 4pm] = 7
- Open space 2 (S2) = Sum [7am, 4pm] = 10
- Open space 3 (S3) = Sum [7am, 4pm] = 1
- Open space 4 (S4) = Sum [7am, 4pm] = 6

Finally, the author displayed the results of the open and semi-open spaces using justified graphs for the winter and summer (Fig. 122).

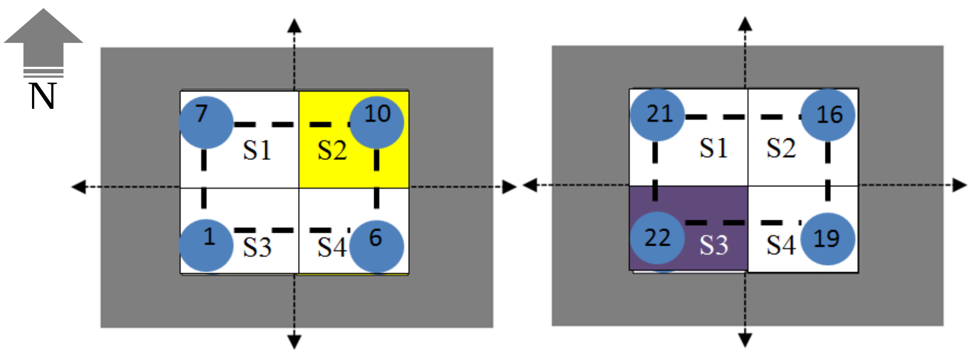


Figure 122: Justified graph of semi-open and open in Dezful city during winter and summer time

All the outcomes for open and semi-open spaces are evident for the summer and winter at a traditional building in Dezful hot-dry climate.

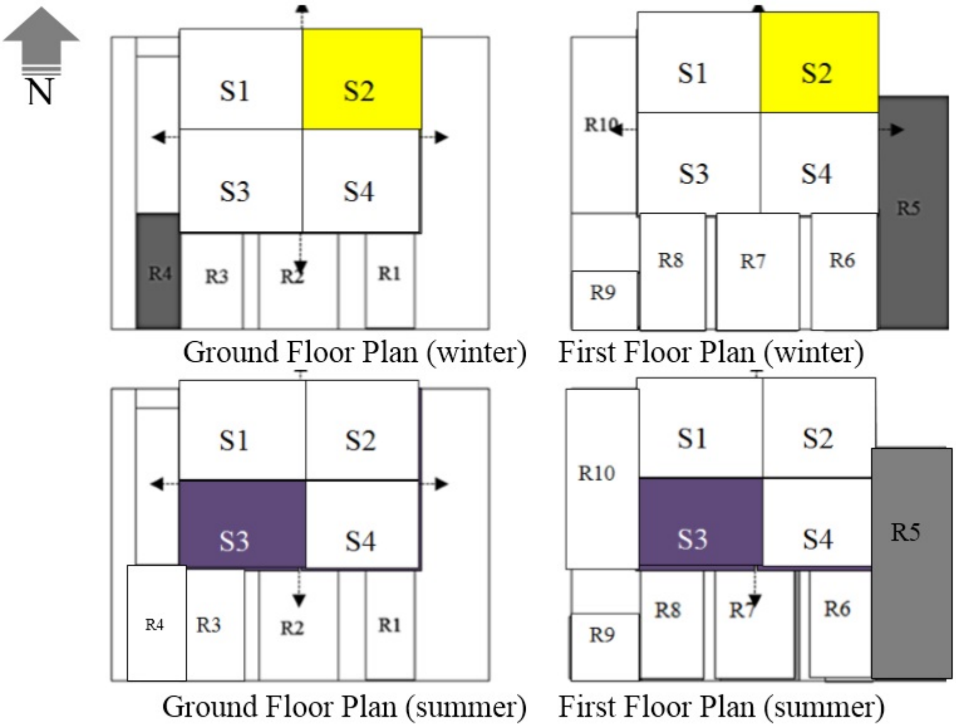


Figure 123: Evaluation of thermal comfort in open and semi-open spaces on the ground floor and first floor of a traditional building in Dezful during the winter and summer

3.4 Cool Climate (37° N Latitude): Urumye

This research chose a traditional building in Urumye as indicative of buildings in the cool climate region of Iran, applying the justified graph method to analyze solar gain in the next subsection. The chosen traditional building is surrounded by vast courtyard in a low dense texture.

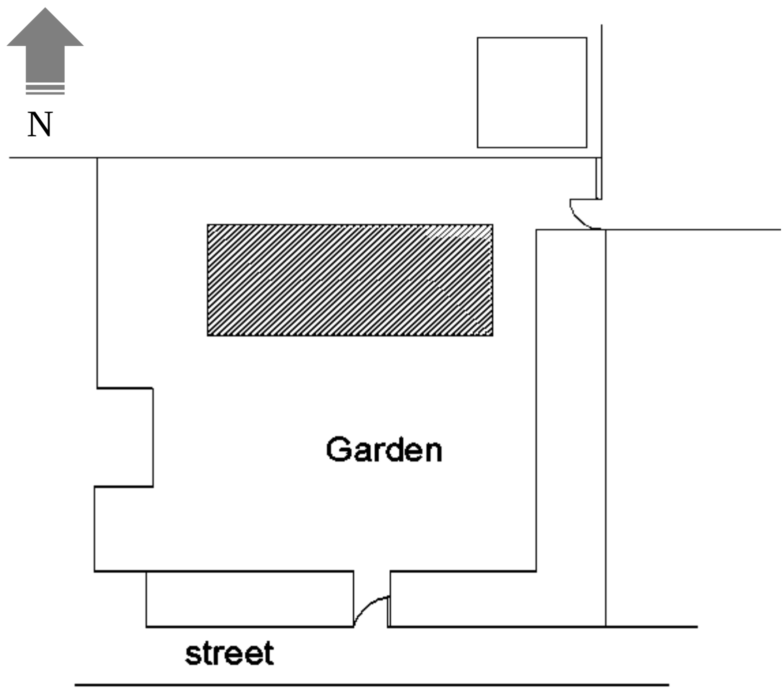
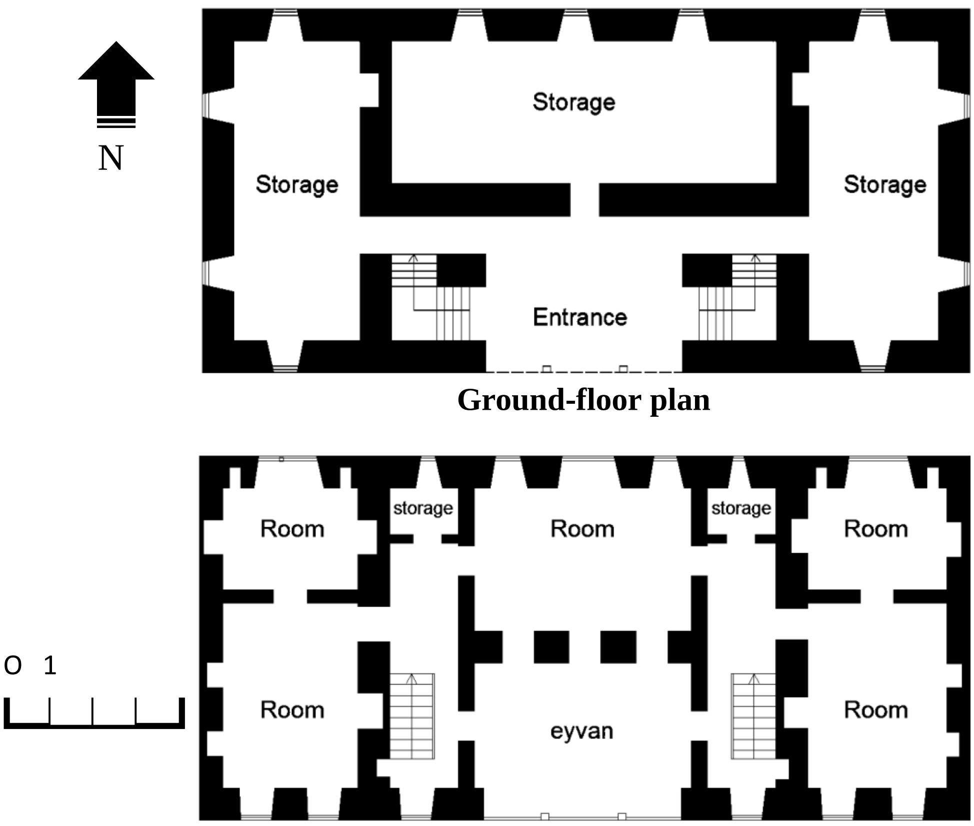


Figure 124: Compact settlement pattern in cool climatic region of Iran (Ghobadian, 2009)



First-floor plan

Figure 125: Ground-floor plan and first-floor plan of a traditional building in Urumye (Sartip M., 2009)

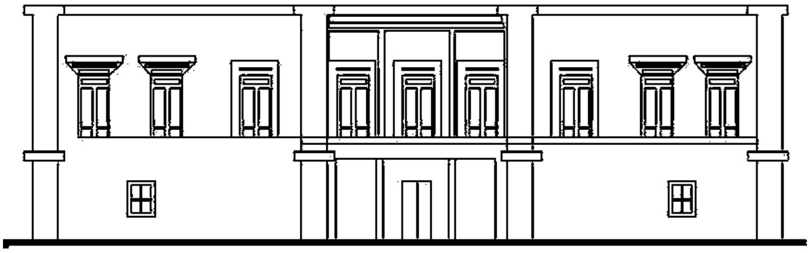


Figure 126: South elevation of a traditional building in Urumye (Sartip M., 2009)

Applying the justified method had been continues on next section on the case study in this cool climatic region.

3.4.1 Solar Gain Analysis of a Traditional Building in Urumye

In the first stage of evaluation, the author translated the justified numbers for solar gain into the closed spaces of a traditional building at 180° azimuth in Urumye. The justified numbers for that translation are as follows: three for the south façade, one for the east and west facades, and zero for the north façade during the winter; and during the summer, one for the south and west facades, two for the north façade, and zero for the east façade (Fig. 37). Consequently, this research entered this data (with the solar effect on each floor and slab) for evaluation in a matrix analysis for each closed space (Fig. 127).

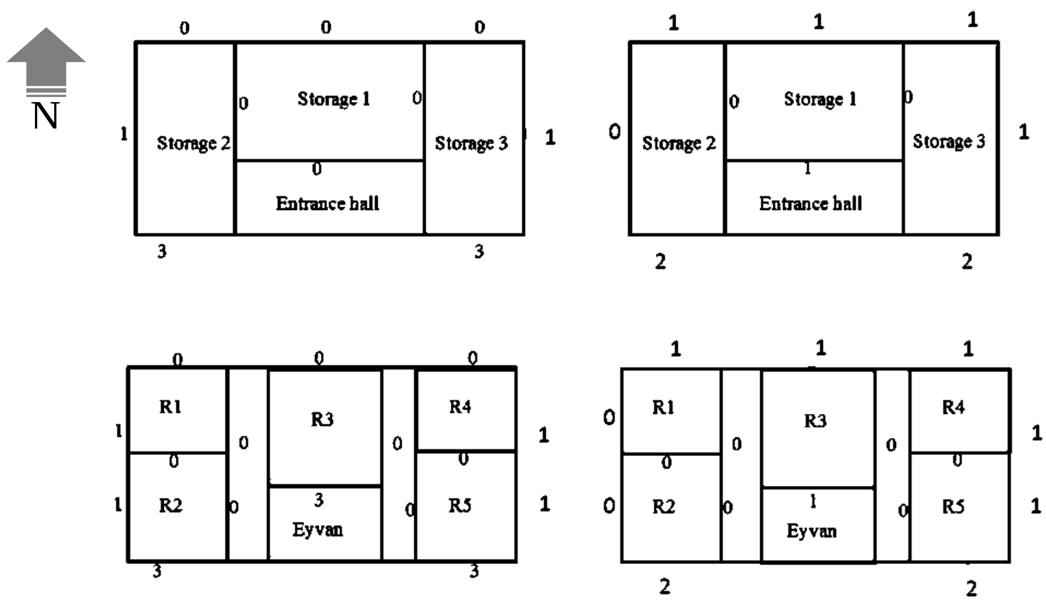


Figure 127: Justified numbers for solar gain in each closed space on the ground floor and first floor plan of a traditional building in Urumye

Thus, Figure 128 displays the calculations based on the data for each closed space.

Ground floor (winter)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

Strg1: [0] + [0] + [0] + [0] + [1] = 1

Strg 2: [3] + [0] + [0] + [1] + [1] = 5

Strg 3: [3] + [0] + [1] + [0] + [1] = 5

Ground floor (summer)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

Strg 1: [1] + [1] + [0] + [0] + [3] = 5

Strg 2: [2] + [1] + [0] + [0] + [3] = 6

Strg 3: [2] + [1] + [1] + [0] + [3] = 7

First floor (winter)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

R1: [0] + [0] + [0] + [1] + [2] = 3

R2: [3] + [0] + [0] + [1] + [2] = 6

R3: [3] + [0] + [0] + [0] + [2] = 5

R4: [0] + [0] + [1] + [0] + [2] = 3

R5: [3] + [0] + [1] + [0] + [2] = 6

First floor (summer)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

R1: [0] + [1] + [0] + [0] + [2] = 3

R2: [2] + [0] + [0] + [0] + [2] = 4

R3: [1] + [1] + [0] + [0] + [2] = 4

R4: [0] + [1] + [1] + [0] + [2] = 4

R5: [2] + [0] + [1] + [0] + [2] = 5

Figure 128: Matrix analysis reveals the "Sn' of each closed space on the ground floor and first floor.

The results of the matrix analysis demonstrate that Storage 2 has the best thermal comfort conditions in terms of gaining solar gain during the winter. Furthermore, Storage 2 has the highest solar gain value during the summer as well. Finally, R4, having the lowest solar gain value in the winter and has the worst thermal comfort conditions during the coldest month of the year, and for the same reason, R5 has the worst thermal comfort conditions during the summer.

3.4.2 Wind Effect Analysis of a Traditional Building in Urumye

According to the justified graph method, a wind effect analysis begins with the translation of data from the justified graph for wind into the closed spaces of the case study. The justified numbers for that graph are as follows: three for the north and east facades and zero for the west and south facades during the winter; and during the summer, one for the north and west facades and two for the east and south facades (Fig.58). Consequently, the author entered these data into a matrix analysis (Fig. 129).

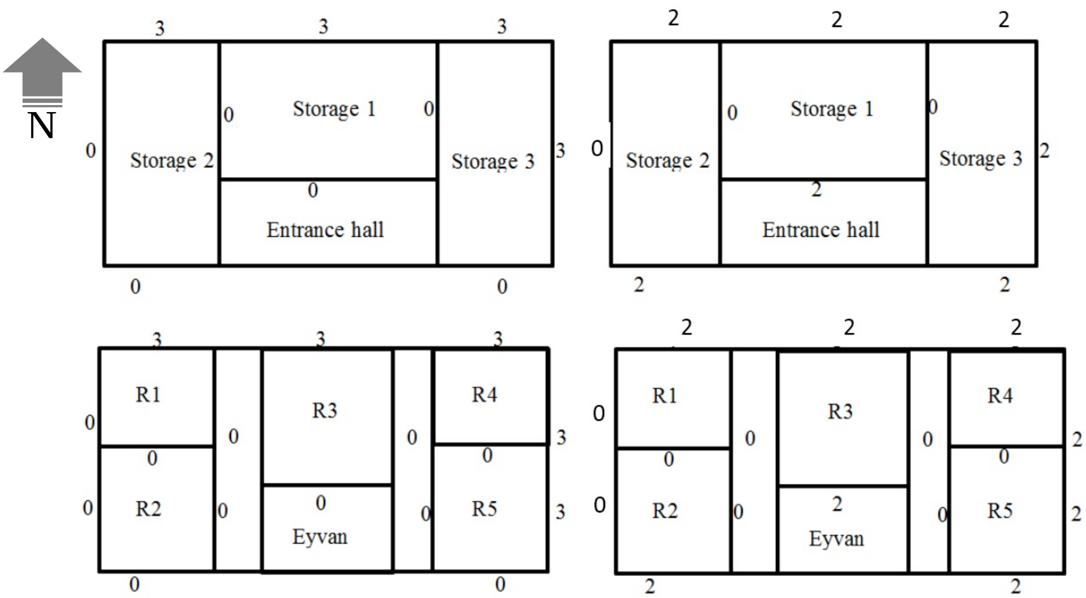


Figure 129: Justified numbers for the wind effect in each closed space on the ground floor of a traditional building in Urumye

Ground floor (winter)

Vn:[S.w]+[N.w]+[E.w]+[W.w]+[P.w]=Sum

Stg1: [0] + [3] + [0] + [0] + [0] = 3

Stg 2: [0] + [3] + [0] + [0] + [0] = 3

Stg 3: [0] + [3] + [3] + [0] + [0] = 6

Ground floor (summer)

Vn:[S.w]+[N.w]+[E.w]+[W.w]+[P.w]=Sum

Stg 1: [2] + [2] + [0] + [0] + [1] = 5

Stg 2: [2] + [2] + [1] + [0] + [1] = 6

Stg 3: [2] + [2] + [0] + [2] + [1] = 7

First floor (winter)	**First floor (summer)**
Vn:[S.w]+[N.w]+[E.w]+[W.w]+[P.w]=Sum	**Vn:[S.w]+[N.w]+[E.w]+[W.w]+[P.w]=Sum**
R1: [0] + [3] + [0] + [0] + [2] = 5	R1: [0] + [2] + [0] + [0] + [1] = 3
R2: [0] + [0] + [0] + [0] + [2] = 2	R2: [2] + [0] + [0] + [0] + [3] = 5
R3: [0] + [3] + [0] + [0] + [0] = 3	R3: [2] + [2] + [0] + [0] + [3] = 7
R4: [0] + [3] + [3] + [0] + [2] = 8	R4: [0] + [2] + [2] + [0] + [1] = 5
R5: [0] + [0] + [3] + [0] + [2] = 5	R5: [2] + [0] + [2] + [0] + [3] = 7

Figure 130: Matrix analysis reveals the "Vn" for each closed space on the ground floor

The wind analysis demonstrates that during the winter, R4 has the best thermal comfort conditions in terms of wind effect and R2 has the worst thermal comfort conditions in terms of catching more wind during winter time. During the summer, R5, R4 and storage 3 have the best and R1 has the worst thermal comfort conditions in terms of catching less wind.

This research then collected all the data on solar gain and wind effect to determine to total environmental effect on thermal comfort for each closed space (Fig. 131).

Ground floor (winter)	**Ground floor (summer)**
Stg1: [S.n] + [V.n] = [1] + [3] = 4	Stg 1: [S.n] + [V.n] = [5] + [5] = 10
Stg 2: [S.n] + [V.n] = [5] + [3] = 8	Stg 2: [S.n] + [V.n] = [6] + [6] = 12
Stg 3: [S.n] + [V.n] = [5] + [6] = 11	Stg 3: [S.n] + [V.n] = [7] + [7] = 14

First floor (winter)	**First floor (summer)**
R1: [S.n] + [V.n] = [3] + [5] = 8	R1: [S.n] + [V.n] = [3] + [3] = 6
R2: [S.n] + [V.n] = [6] + [2] = 8	R2: [S.n] + [V.n] = [4] + [5] = 9
R3: [S.n] + [V.n] = [5] + [3] = 8	R3: [S.n] + [V.n] = [4] + [7] = 11
R4: [S.n] + [V.n] = [3] + [8] = 11	R4: [S.n] + [V.n] = [4] + [5] = 9
R5: [S.n] + [V.n] = [6] + [5] = 11	R5: [S.n] + [V.n] = [5] + [7] = 12

Figure 131: Matrix analysis reveals the final values for each closed space during the winter and summer

R4 and R5 on the first floor and Storage 3 on the ground floor have the best overall thermal comfort conditions during the winter. Storage 3 on the ground floor has the best thermal comfort conditions during the summer. However, summers in this region of Iran are very short, and the winters are long. Therefore, traditional buildings in this region are organized to accommodate the colder weather.

Finally, figure 132 presents a schematic of the ground floor and first floor of a traditional building from this region to illustrate the overall results for the best (dark grey) and worst (light grey) thermal comfort zones in the architecture.

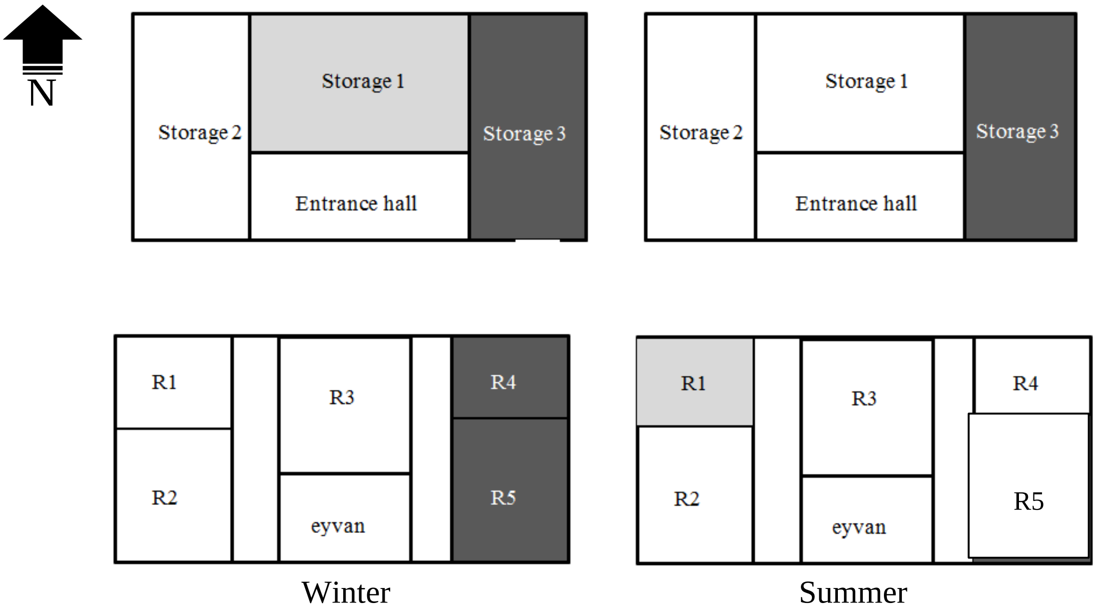


Figure 132: Evaluation of a traditional building in terms of thermal comfort factors in the cool climatic region of Iran during the winter and summer (dark grey = best thermal comfort; light grey = worst thermal comfort)

The analysis continued by applying the justified graph on semi-open and open space on the next part.

3.4.3 Analysis of Open and Semi-Open Spaces in a Traditional Building at Urumye

This study used Sketch Up software in this research to analyze the open and semi-open spaces in a traditional building at Urumye, determining the shaded and sunny areas at different hours of the day. Then, for consistency with the justified graph method, the author defined the justified numbers of each open and semi-open space according to the shaded squares. Figures133 and 134 indicate the justified numbers according to the shaded areas of a building in Urumye during the winter and summer.

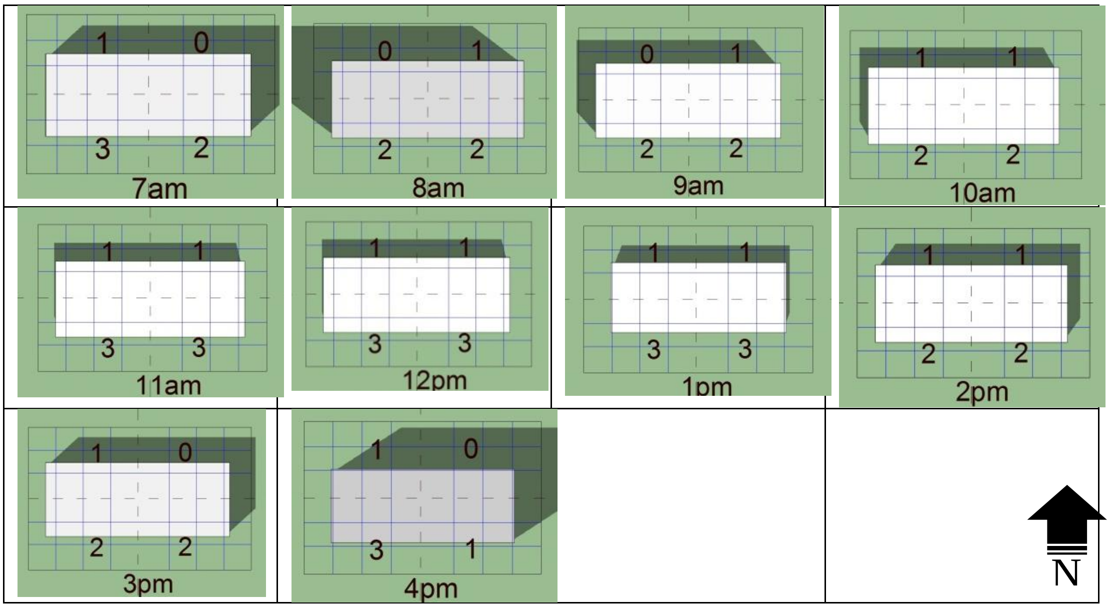


Figure 133: Defining the justified numbers for shaded areas on January 1 (7 a.m.–4 p.m.)

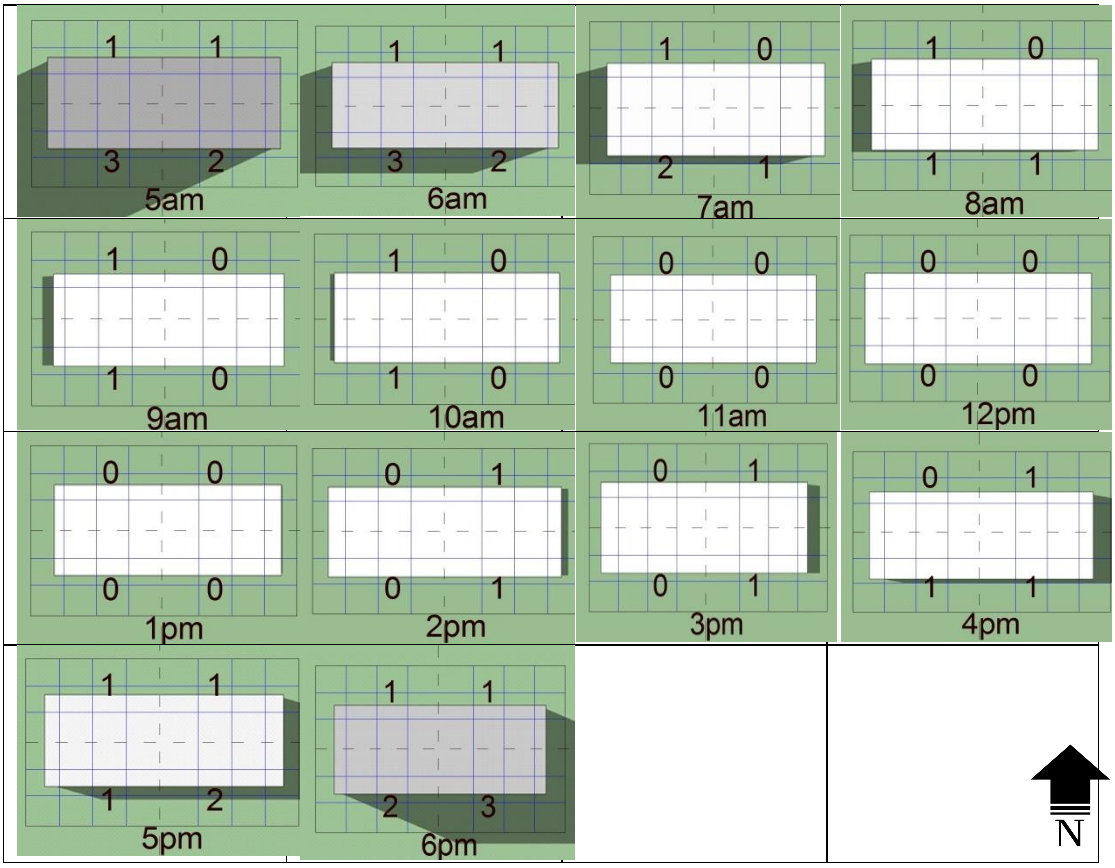


Figure 134: Defining the justified numbers for shaded areas on July 1 (5 a.m.–6 p.m.)

This research then used a matrix analysis to calculate the collected data from the shaded areas for each space, as illustrated below:

Justified number in terms of the matrix analysis for January 1 (7 a.m., 4 p.m.)

- Open space 1 (S1) = Sum [7am, 4pm] = 8
- Open space 2 (S2) = Sum [7am, 4pm] = 7
- Open space 3 (S3) = Sum [7am, 4pm] = 25
- Open space 4 (S4) = Sum [7am, 4pm] = 22

Justified numbers in terms of the matrix analysis for July 1 (5 a.m., 6 p.m.)

- Open space 1 (S1) = Sum [5am, 6pm] = 8
- Open space 2 (S2) = Sum [5am, 6pm] = 7
- Open space 3 (S3) = Sum [5am, 6pm] = 15
- Open space 4 (S4) = Sum [5am, 6pm] = 14

The matrix analysis demonstrates that Open Space 3, having the most solar gain, has the best thermal comfort conditions during the winter, whereas Open Space 2 has the worst thermal comfort conditions during that season. Open Space 3 also has the best thermal comfort conditions during the summer. Thus, this evaluation demonstrates that traditional buildings in Urumye have been organized so that Open Spaces 3 and 4 gather as much solar gain as possible in the cooler winters in this part of Iran; these spaces are also advantageous for solar gain in the short summers of this region.

In Figure 135, this study represented the justified graph for open and semi-open spaces in a traditional building at Urumye.

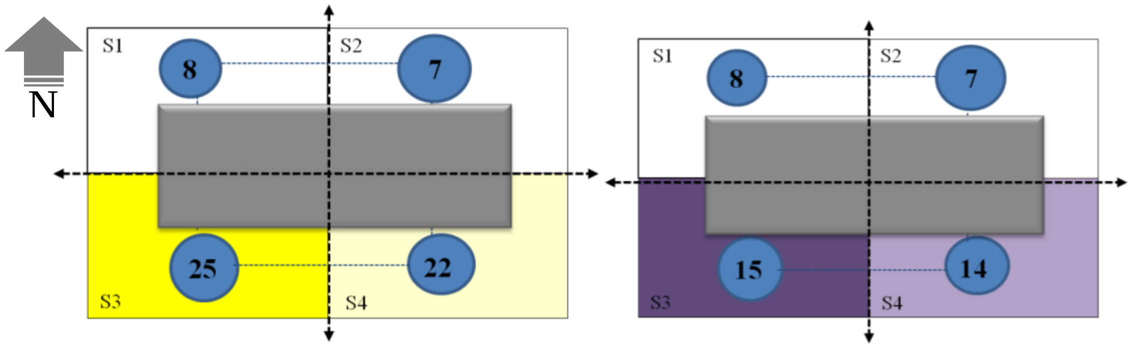


Figure 135: Justified graph of open and semi-open spaces in a traditional building at Urumye during the winter and summer

The author also designed the schematic plan for a traditional building in Urumye to demonstrate the outcome of this analysis for both the summer and winter (Fig. 136).

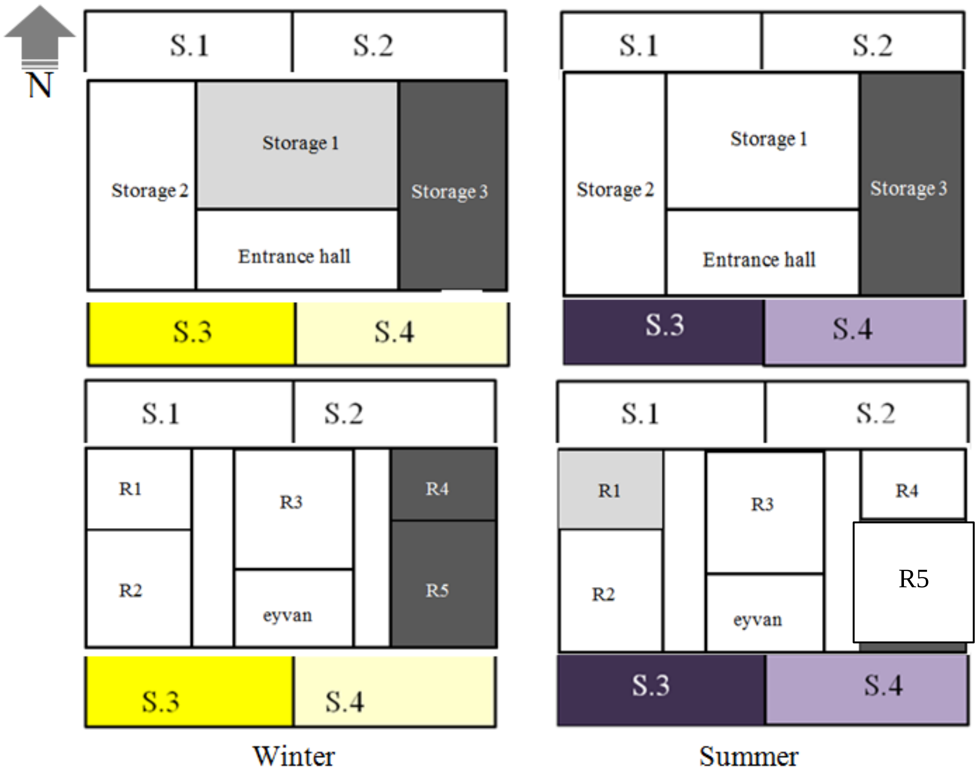


Figure 136: Evaluation of thermal comfort in open and semi-open spaces on the ground floor and first floor of a traditional building in Urumye during the winter and summer

3.5 Temperate-Humid Climate (37° N Latitude): Rasht

In the temperate-humid climate of Rasht, this research chose a traditional building as a case study, using the plan, elevation, and section of that building to apply the justified graph method.

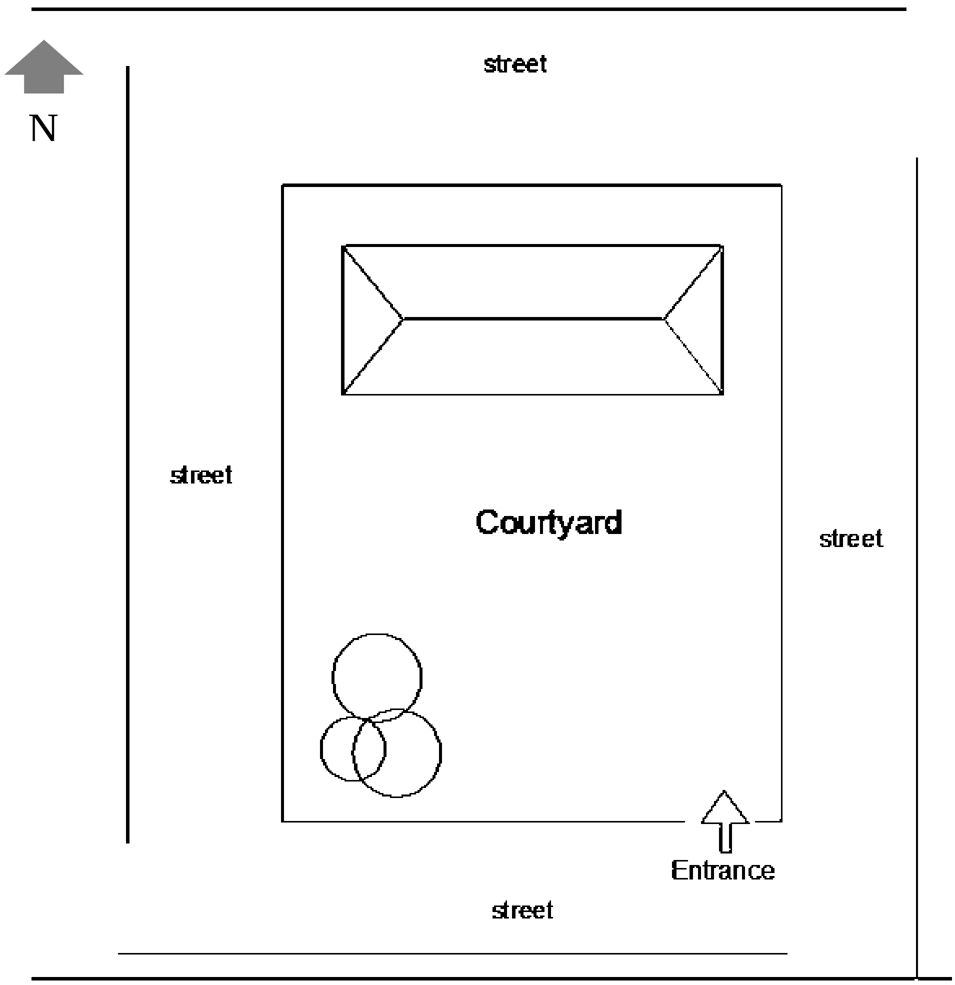


Figure 137: Site plan of traditional building in Rasht city (Memarian, 2006)

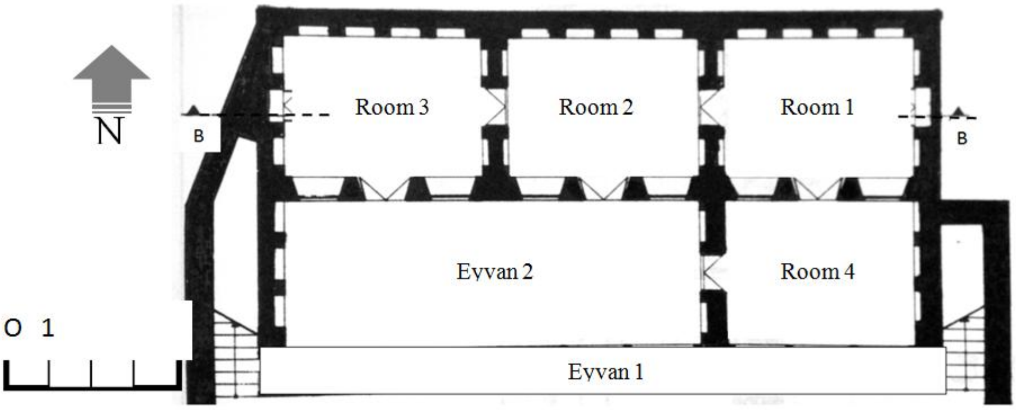


Figure 138: Ground-floor plan of a traditional building in Rasht (Memarian, 2006)

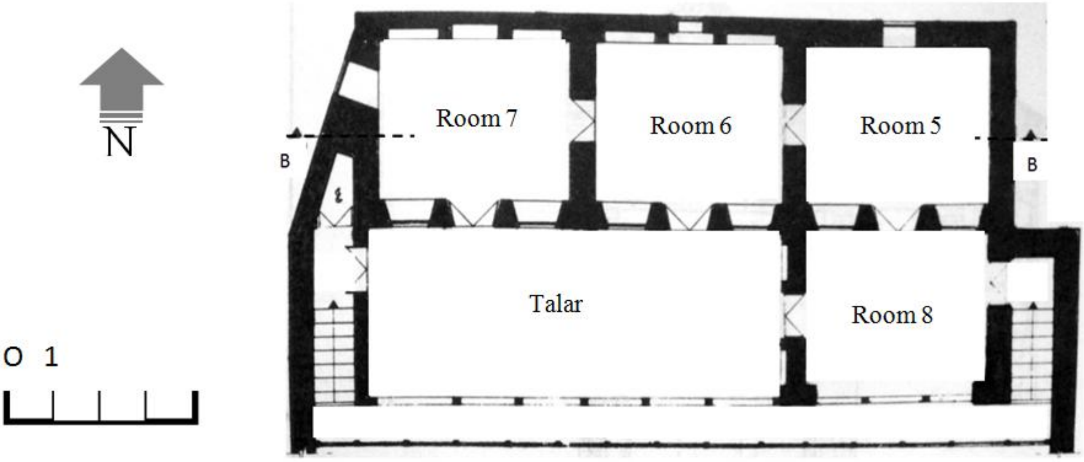


Figure 139: First-floor plan of a traditional building in Rasht (Memarian, 2006)

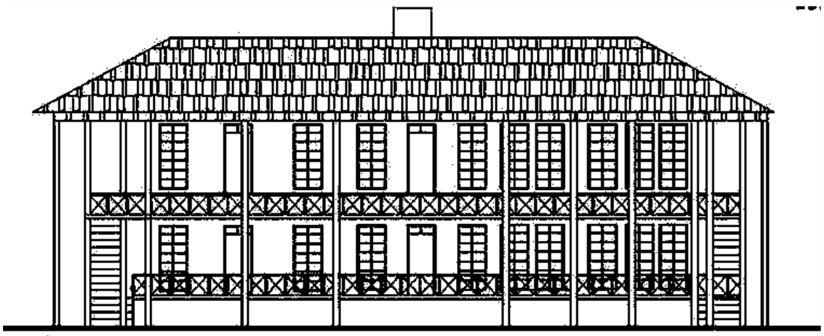


Figure 140: South elevation of a traditional building in Rasht (Memarian, 2006)

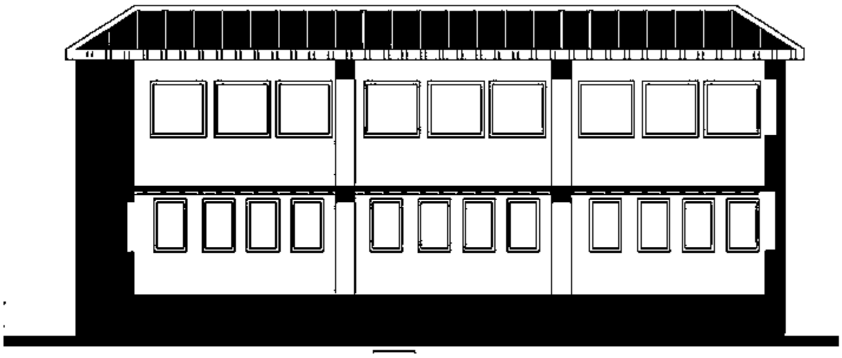


Figure 141: Section B-B of a traditional building in Rasht (Memarian, 2006)

By having the plan, section and elevation of traditional building in Rasht city, this research apply a justified method for evaluation on the following parts.

3.5.1 Solar Gain Analysis of a Traditional Building in Rasht

The first stage for evaluating the solar gain effect on a building's envelope is translating the data from the justified graph for solar gain (Fig.31) into the spaces of the case study. The justified numbers on the graph are as follows: three for the south façade, one for the east and west facades, and zero for the north facade during the winter; and during the summer, two for the south, zero for west facades, one for the north and east facade. The figures below (Fig. 142) represent the justified amount of solar radiation on the ground floor and first floor plan of a traditional building in Rasht during the winter and summer.

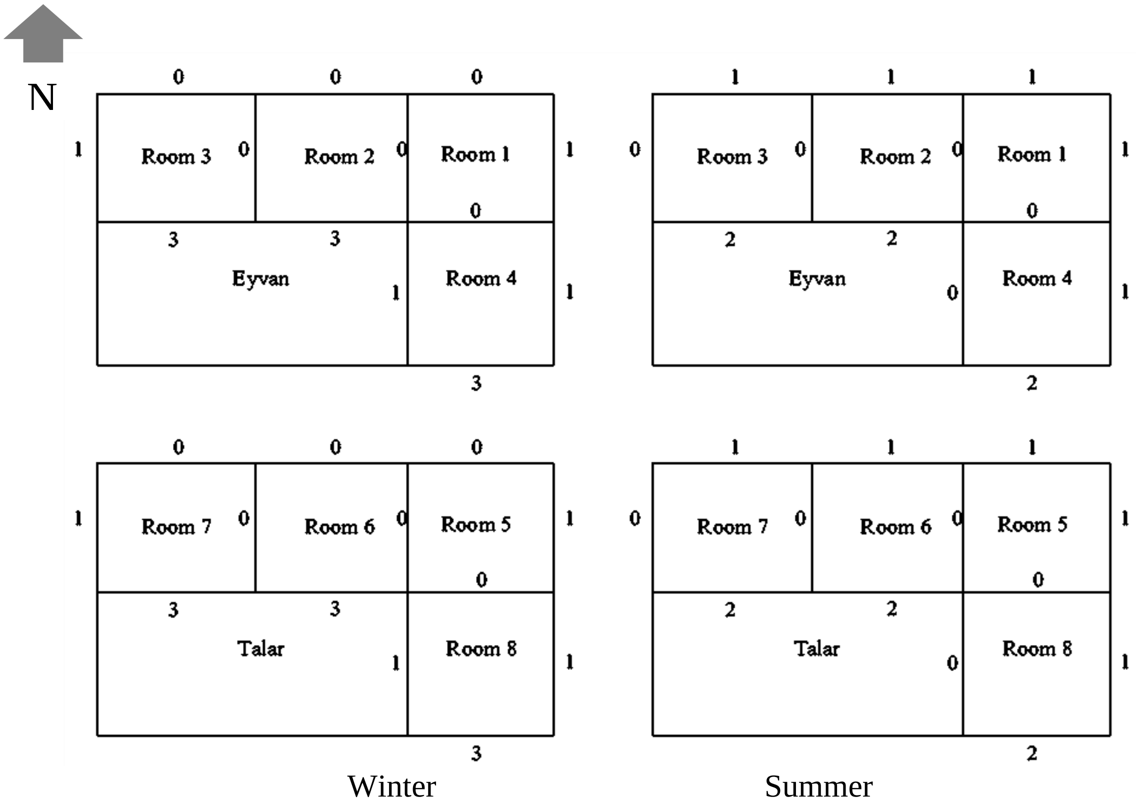


Figure 142: Justified numbers for solar gain in each closed space on the ground floor and first floor plan of a traditional building in Rasht during winter and summer

The author then performed a matrix analysis using the data from the solar gain calculations to determine the solar gain value for each space in the architecture (Fig. 143).

Ground floor (winter)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

R1: [0] + [0] + [1] + [0] + [0] = 1

R2: [3] + [0] + [0] + [0] + [0] = 3

R3: [3] + [0] + [0] + [1] + [0] = 4

R4: [3] + [0] + [1] + [1] + [0] = 5

Ground floor (summer)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

R1: [0] + [1] + [1] + [0] + [3] = 5

R2: [2] + [1] + [0] + [0] + [3] = 6

R3: [2] + [1] + [0] + [0] + [3] = 6

R4: [2] + [0] + [1] + [0] + [3] = 6

First floor (winter)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

R5: [0] + [0] + [1] + [0] + [1] = 2

R6: [3] + [0] + [0] + [0] + [1] = 4

R7: [3] + [0] + [0] + [0] + [1] = 4

R8: [3] + [0] + [1] + [1] + [1] = 6

First floor (summer)

Sn: [SW] + [NW] + [EW] + [WW] + [SF] = Sum

R5: [0] + [1] + [1] + [0] + [2] = 4

R6: [2] + [1] + [0] + [0] + [2] = 5

R7: [2] + [1] + [0] + [0] + [2] = 5

R8: [2] + [0] + [1] + [0] + [2] = 5

Figure 143: Matrix analysis reveals the “Sn” of each closed space on the ground floor and first floor

The solar gain values gathered from the matrix analysis indicate that the first-floor spaces (R8, in particular) have the best conditions for thermal comfort in the winter because they are exposed to more solar energy. Furthermore, the spaces on the ground floor (R2, R3 and R4 in particular) have the best conditions for thermal comfort in the summer because they are exposed less solar energy.

3.5.2 Wind effect Analysis of a Traditional Building in Rasht

For the wind analysis, this research translated the justified graph for wind effect into the ground and first floor plan of a traditional building in Rasht. The justified numbers for that graph are as follows: three for the south, east, and north facades and one for the west façade during the winter; and during the summer, one for the south, east, and north facades and three for the west façade (Fig.54). The figures below demonstrate the translation of the wind effect data for each space in the traditional building (Fig. 144).

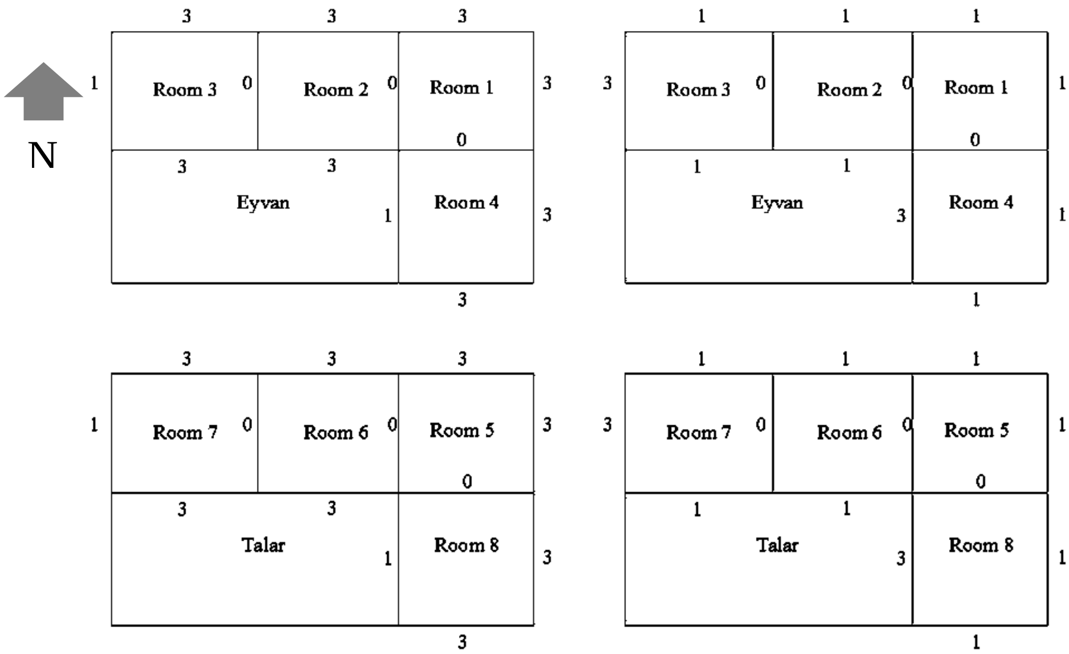


Figure 144: Justified numbers for the wind effect in each closed space on the ground floor of a traditional building in Rasht during winter

This study then used the wind data to calculate the effect if the wind's value for each space of a traditional building in Rasht during the summer and winter via a matrix analysis (Fig. 145).

Ground floor (winter)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R1: [0] + [3] + [3] + [0] + [3] = 9

R2: [3] + [3] + [0] + [0] + [3] = 9

R3: [3] + [3] + [0] + [1] + [3] = 10

R4: [3] + [0] + [3] + [1] + [0] = 10

First floor (winter)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R5: [0] + [3] + [3] + [0] + [2] = 8

R6: [3] + [3] + [0] + [0] + [2] = 8

R7: [3] + [3] + [0] + [1] + [0] = 7

R8: [3] + [0] + [3] + [1] + [0] = 7

Ground floor (summer)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R1: [0] + [1] + [1] + [0] + [0] = 2

R2: [1] + [1] + [0] + [0] + [0] = 2

R3: [1] + [1] + [0] + [3] + [0] = 5

R4: [1] + [0] + [1] + [3] + [2] = 7

First floor (summer)

Vn: [SW] + [NW] + [EW] + [WW] + [PW] = Sum

R5: [0] + [1] + [1] + [0] + [1] = 3

R6: [1] + [1] + [0] + [0] + [1] = 3

R7: [1] + [1] + [0] + [3] + [3] = 8

R8: [1] + [0] + [1] + [3] + [3] = 8

Figure 145: Matrix analysis reveals the “Vn” for each closed space on the ground floor

The wind effect values for R3 and R4 on the ground floor indicate that they have the best thermal comfort conditions in terms of not gaining any wind flow during the winter. However, R7 and R8 on the first floor have the best thermal comfort conditions in terms of having more air flow during the summer.

Finally, the author summed up the solar gain and wind effect values for each space of the building, using a matrix analysis (Fig. 146).

Ground floor (winter)	**Ground floor (summer)**
R1: [Sn] + [Vn] = [1] + [9] = 10	R1: [Sn] + [Vn] = [5] + [2] = 7
R2: [Sn] + [Vn] = [3] + [9] = 12	R2: [Sn] + [Vn] = [6] + [2] = 8
R3: [Sn] + [Vn] = [4] + [10] = 14	R3: [Sn] + [Vn] = [6] + [5] = 11
R4: [Sn] + [Vn] = [5] + [10] = 15	R4: [Sn] + [Vn] = [6] + [7] = 13
First floor (winter)	**First floor (summer)**
R5: [Sn] + [Vn] = [2] + [8] = 10	R5: [Sn] + [Vn] = [4] + [3] = 7
R6: [Sn] + [Vn] = [4] + [8] = 12	R6: [Sn] + [Vn] = [5] + [3] = 8
R7: [Sn] + [Vn] = [4] + [7] = 11	R7: [Sn] + [Vn] = [5] + [8] = 13
R8: [Sn] + [Vn] = [6] + [7] = 13	R8: [Sn] + [Vn] = [5] + [8] = 13

Figure 146: Matrix analysis reveals the final values for each closed space during the winter and summer

The combinatory outcome demonstrates that R4 on the ground floor has the best thermal comfort conditions during the winter, and R7, R8 on the first floor and also R4 on ground floor have the best thermal comfort conditions during the summer.

This study then developed a schematic of the ground floor and first floor of a traditional building in Rasht, indicating the best overall thermal comfort zones (dark grey) and the worst overall thermal comfort zones (light grey) among the rooms (Fig. 147).

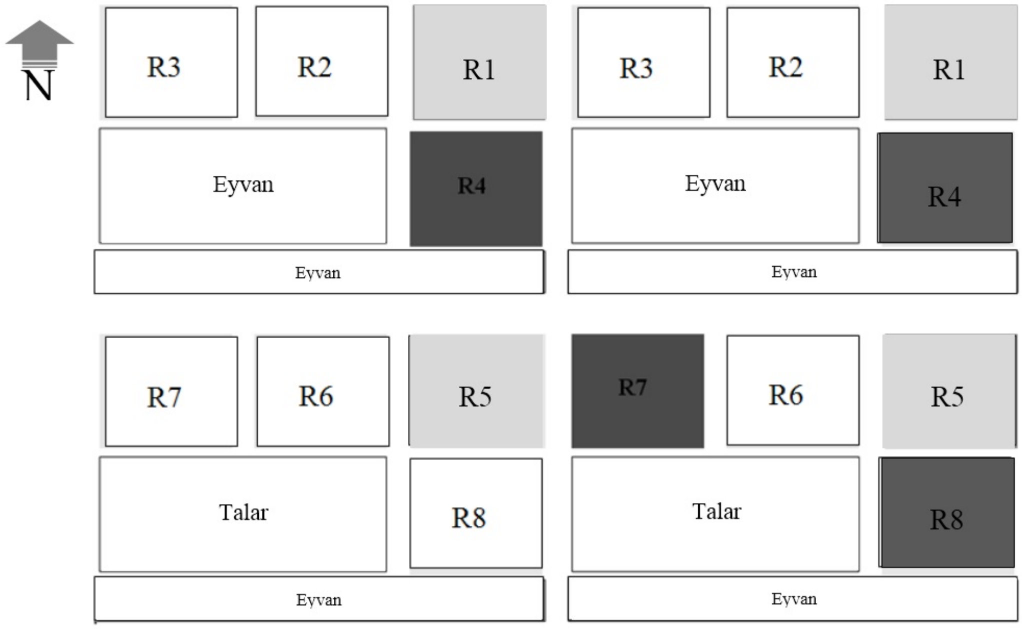


Figure 147: Evaluation of a traditional building in terms of thermal comfort factors in the hot-humid climatic region of Iran during the winter and summer (dark grey = best thermal comfort; light grey = worst thermal comfort)

3.5.3 Analysis on Semi-Open and Open Spaces on Traditional Building in Rasht city

The first step in this analysis is to find the shaded areas in open and semi-open spaces of a traditional building in Rasht to determine the justified numbers for those spaces. Figures 148 and 149 show the shaded areas of the building and the justified number for each of the four spaces at different hours of the day on January 1 and July 1.

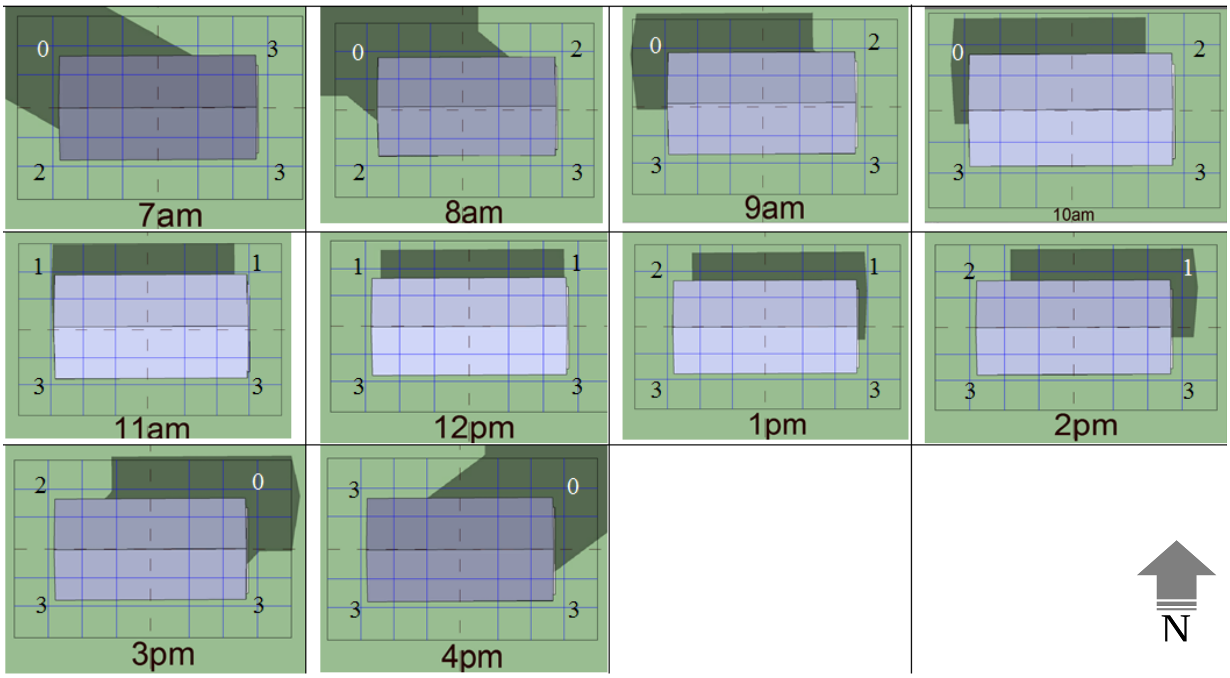


Figure 148: Defining the justified numbers for shaded areas on January 1 (7 a.m.–4 p.m.)

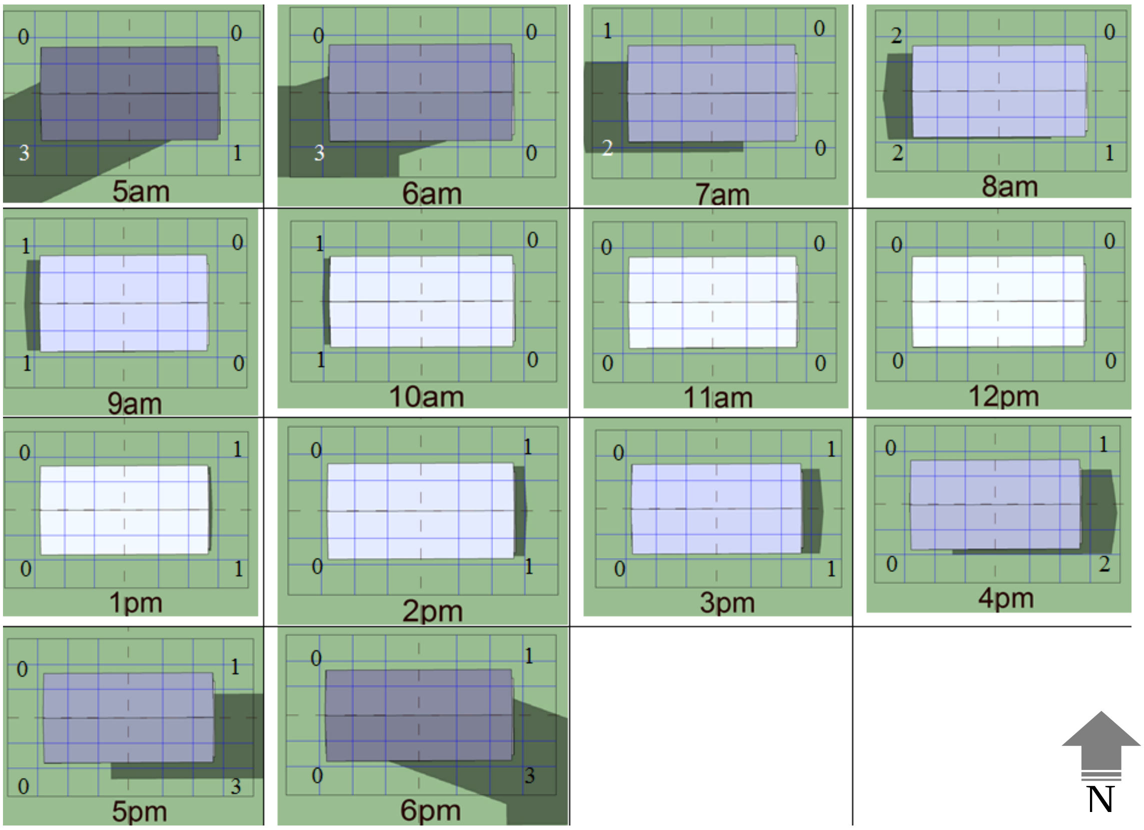


Figure 149: Defining the justified numbers for shaded areas on July 1 (5 a.m.–6 p.m.)

The author has represented the analysis of the justified numbers for each of the four spaces on January 1 and July 1:

- Justified numbers in terms of the matrix analysis for January 1 (7 a.m., 4 p.m.)
- Open space 1 (S1) = Sum [7am, 4pm] = 11
- Open space 2 (S2) = Sum [7am, 4pm] = 13
- Open space 3 (S3) = Sum [7am, 4pm] = 27
- Open space 4 (S4) = Sum [7am, 4pm] = 30

- Justified numbers in terms of the matrix analysis for July 1 (5 a.m., 6 p.m.)
- Open space 1 (S1) = Sum [5am, 6pm] = 5
- Open space 2 (S2) = Sum [5am, 6pm] = 6
- Open space 3 (S3) = Sum [5am, 6pm] = 12
- Open space 4 (S4) = Sum [5am, 6pm] = 13

The outcome of the matrix analysis demonstrates that Open Space 4has the best thermal comfort conditions during both the winter and summer. Furthermore, the justified graph below (Fig. 150) confirms the Open Space 4 and then Open Space 3 have the best positions in the architecture during both the winter and summer.

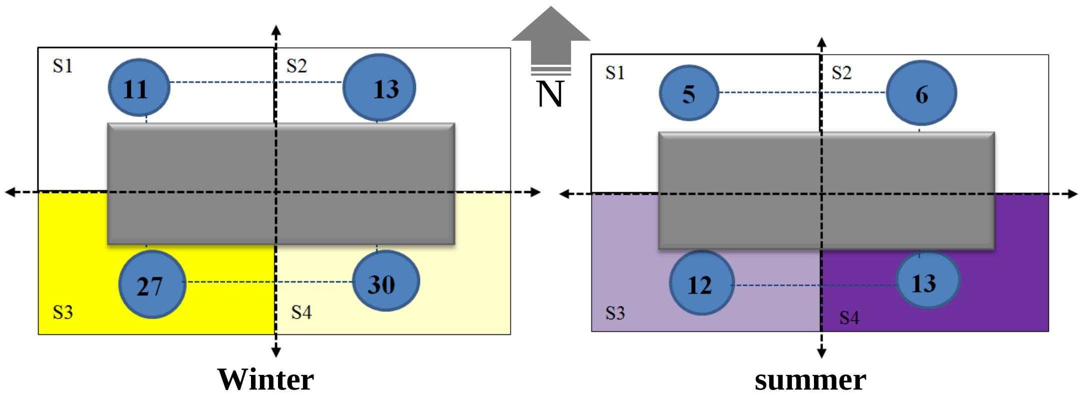


Figure 150: Justified graph of open and semi-open spaces in a traditional building at Rasht during the winter and summer

Finally, using the results of the justified graph, this research displayed the best open and semi-open spaces in a schematic of the ground floor and first floor of the case study in Rasht (Fig. 151).

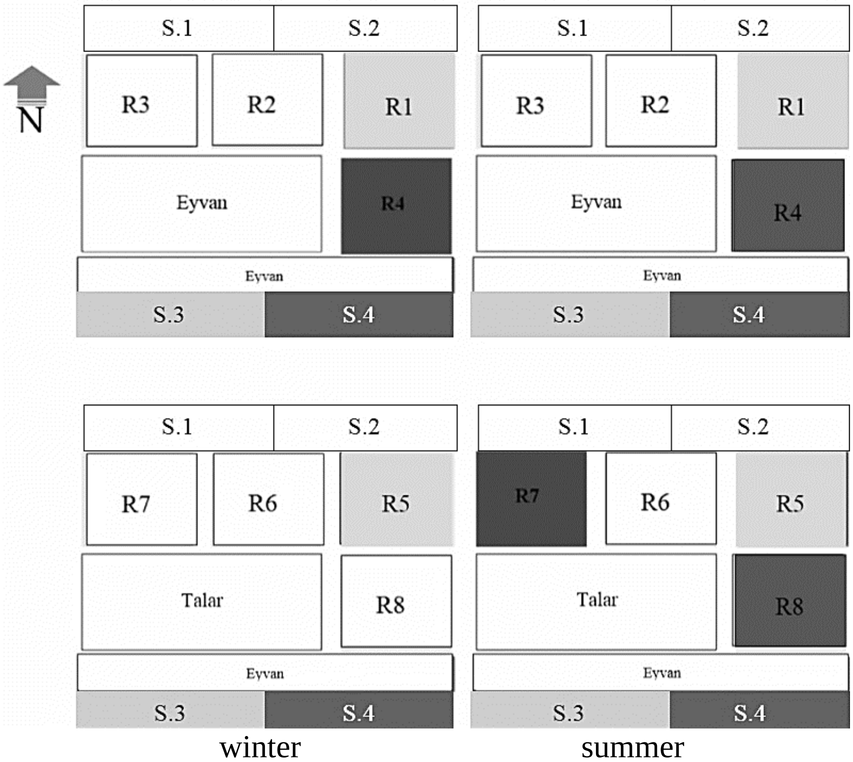


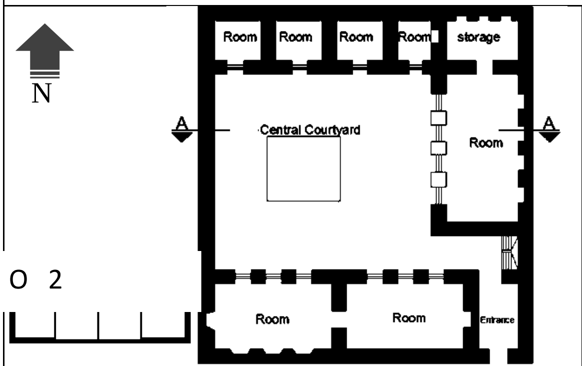
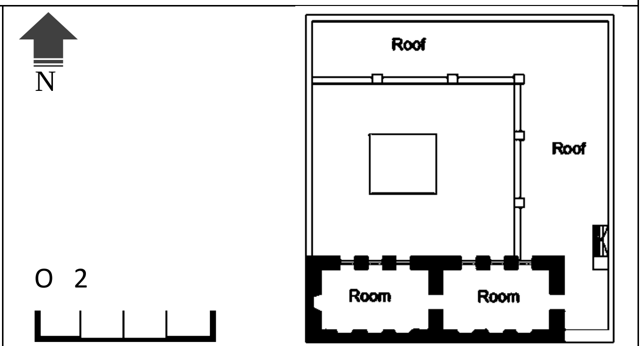
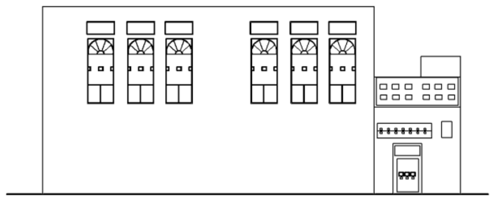
Figure 151: Evaluation of thermal comfort in open and semi-open spaces on the ground floor and first floor of a traditional building in Rasht during the winter and summer

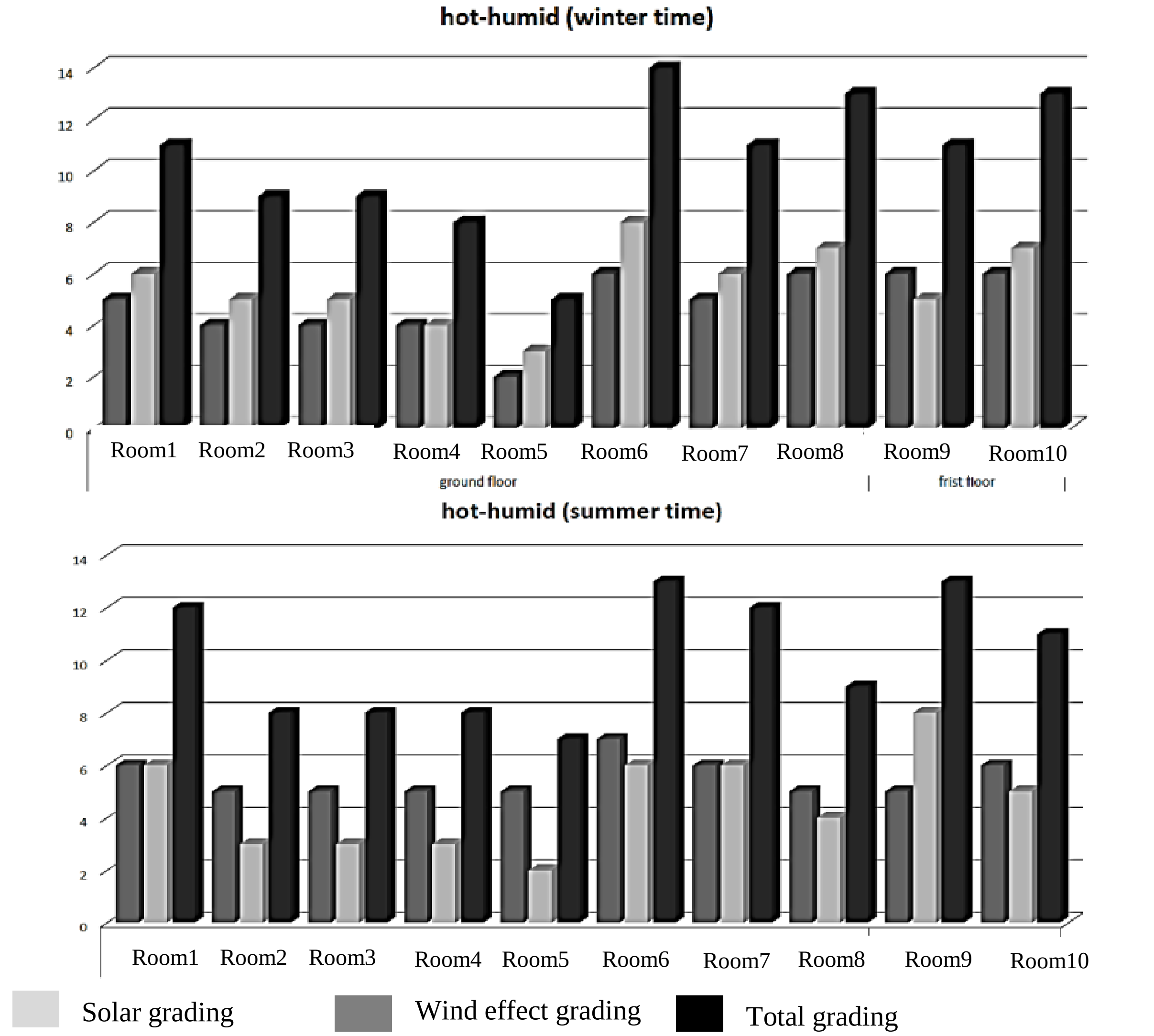
3.6 Discussion

Findings of this study for traditional houses in Bushehr (hot-humid climate), Kashan (hot-dry with a cold winter climate), Dezful (hot-dry climate), Urumye (cool climate), and Rasht (temperate-humid climate) were given in Tables 29-33. There is not any wind catcher in the selected case studies and just the effect of prevailing wind toward the building envelope has been investigated. Because one of the objectives of this research is evaluating the space organization just by considering the effect of climate so the cooling element like wind catchers are not considered during evaluation.

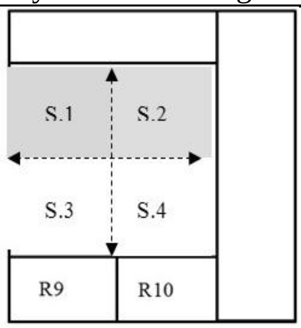
In addition, thickness of the wall has an effect for considering the thermal value of the spaces. During the night, wall can lose the heat by transferring and radiation. Hence, this study chose the case studies in hot-dry with cold winter, hot-dry and cool climatic region which were made by adobe and brick and have thickness more than one meter, which during the day the temperature of the wall could be persist in low and average degree. However, in hot-humid and temperate-humid climatic region, thickness of the wall is not important for creating thermal comfortable condition inside of the buildings. So this research does not consider any limitation for choosing the thickness of the wall in case studies in hot-humid and temperate-humid climatic regions. The finding demonstrated the best thermal comfortable spaces during winter and summer time in the selected case studies.

Table 29: Evaluation of traditional buildings in terms of thermal comfort factors in hot-humid climatic regions of Iran (dark grey display the best and light grey display the worse thermal comfort condition)

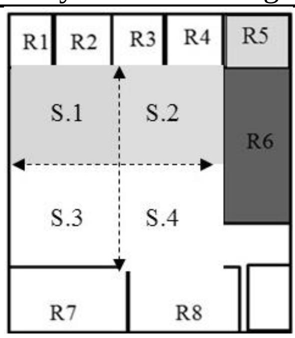
Hot-humid climate	
	
Ground Floor Plan (Memarian, 2006)	First Floor Plan (Memarian, 2006)
	
Section A-A (Memarian, 2006)	South Elevation (Memarian, 2006)



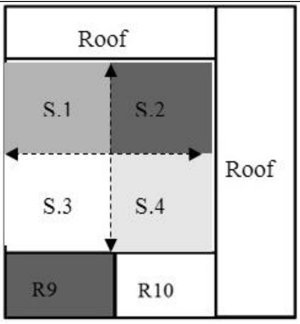
Matrix analysis result during winter time	Matrix analysis result during summer time



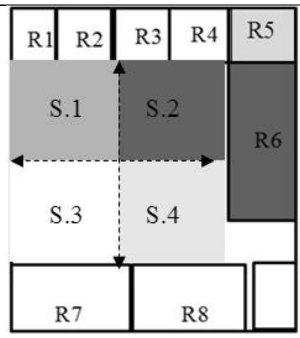
Evaluation of spaces in terms of thermal comfort factor on the First Floor Plan (winter time)



Evaluation of spaces in terms of thermal comfort factor on the Ground Floor Plan (winter time)



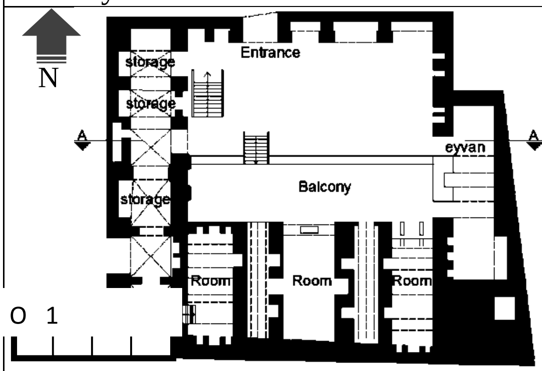
Evaluation of spaces in terms of thermal comfort factor on the First Floor Plan (summer time)



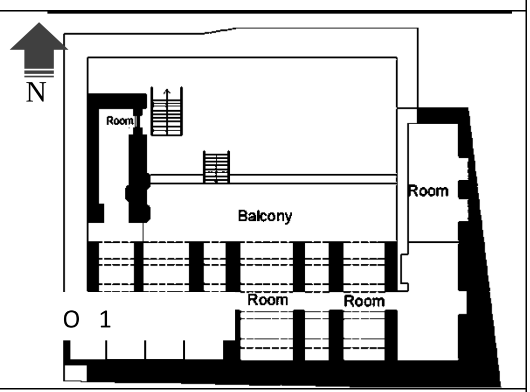
Evaluation of spaces in terms of thermal comfort factor on the Ground Floor Plan (summer time)

Table 30: Evaluation of traditional buildings in terms of thermal comfort factors in hot-dry climatic regions of Iran (dark grey displays the best and light grey displays the worse thermal comfort condition).

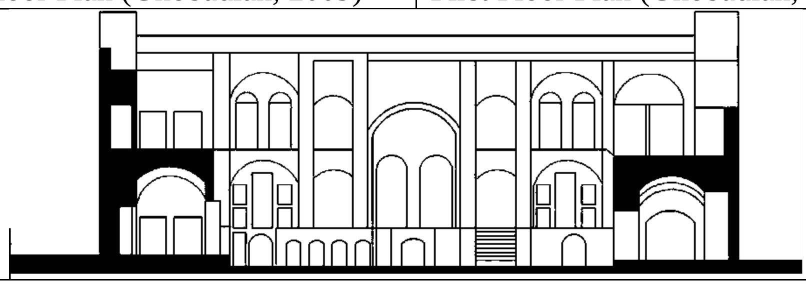
Hot dry climate



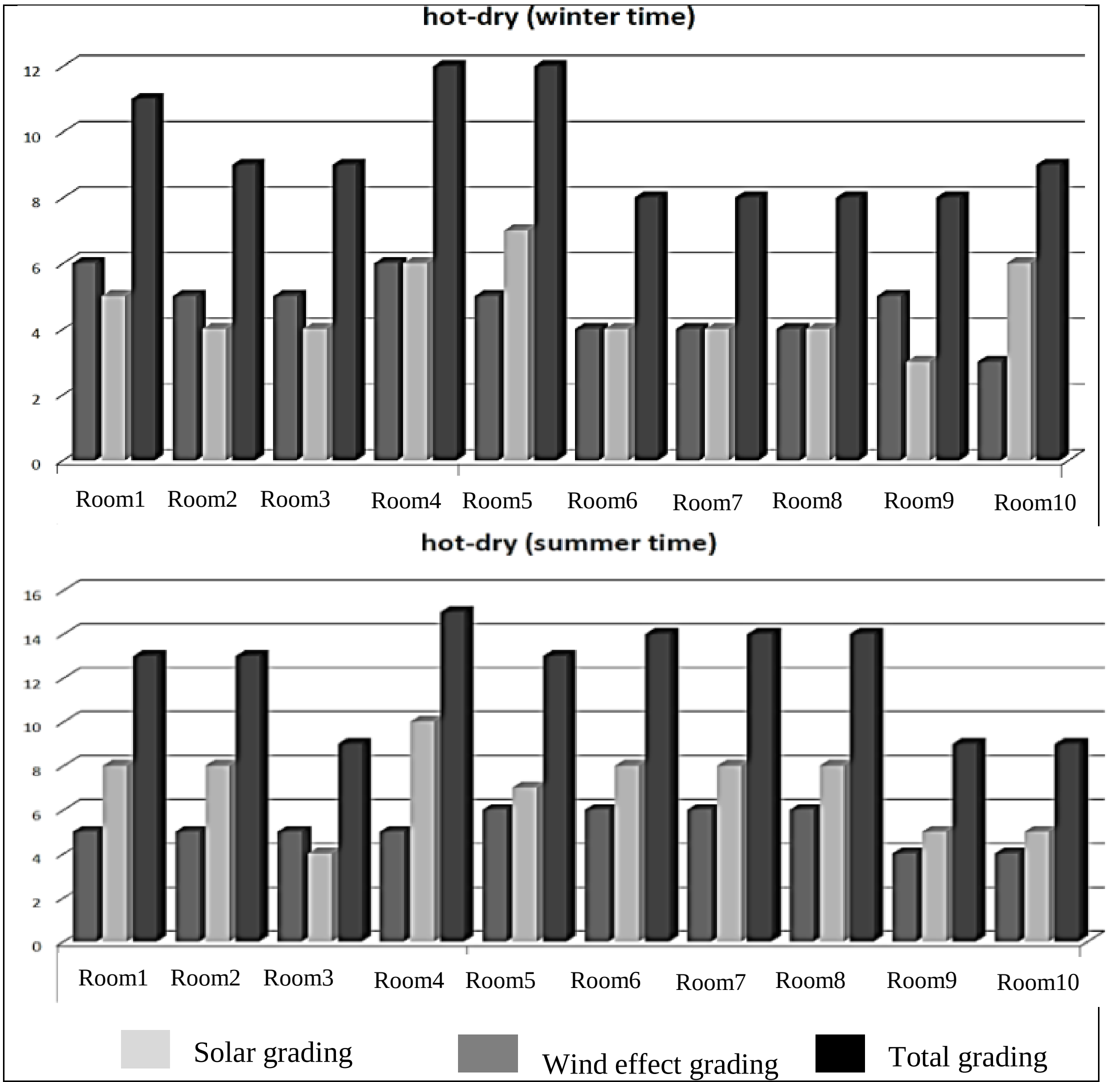
Ground Floor Plan (Ghobadian, 2009)

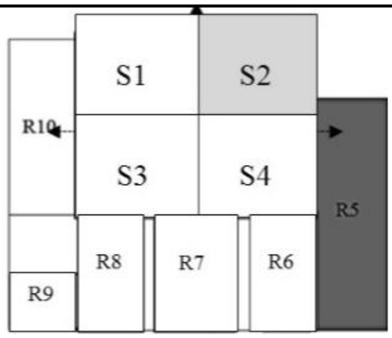
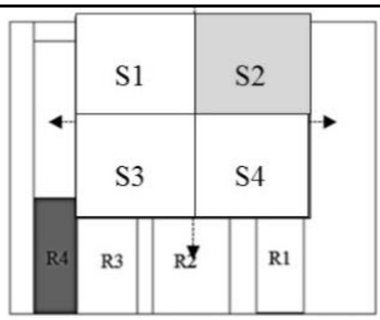


First Floor Plan (Ghobadian, 2009)



Section A-A (Ghobadian, 2009)



Matrix analysis result during winter time	Matrix analysis result during summer time
 Evaluation of spaces in terms of thermal comfort factor on the First Floor Plan (winter time)	 Evaluation of spaces in terms of thermal comfort factor on the Ground Floor Plan (winter time)

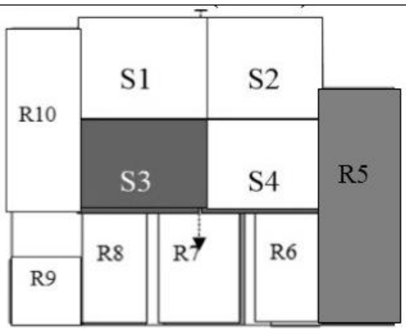
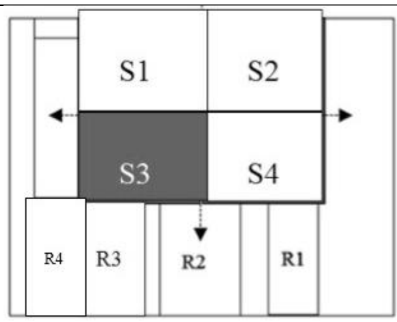
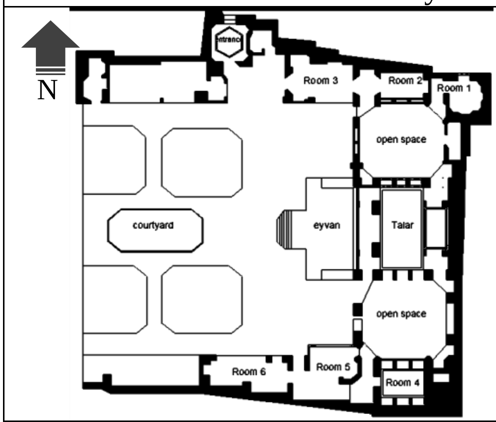
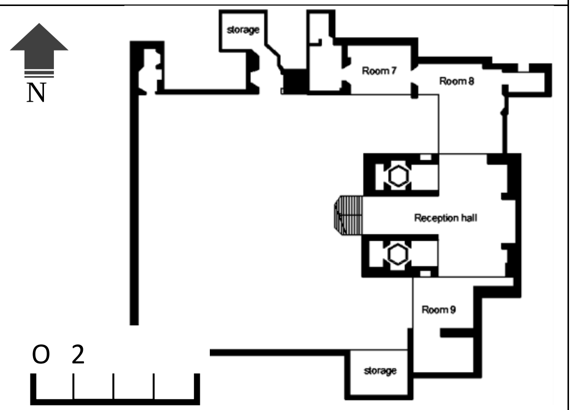
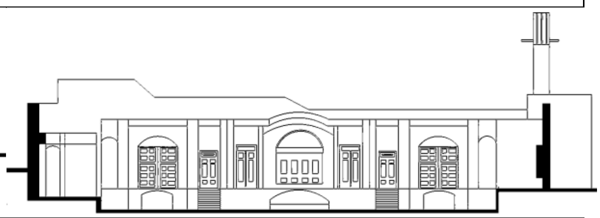
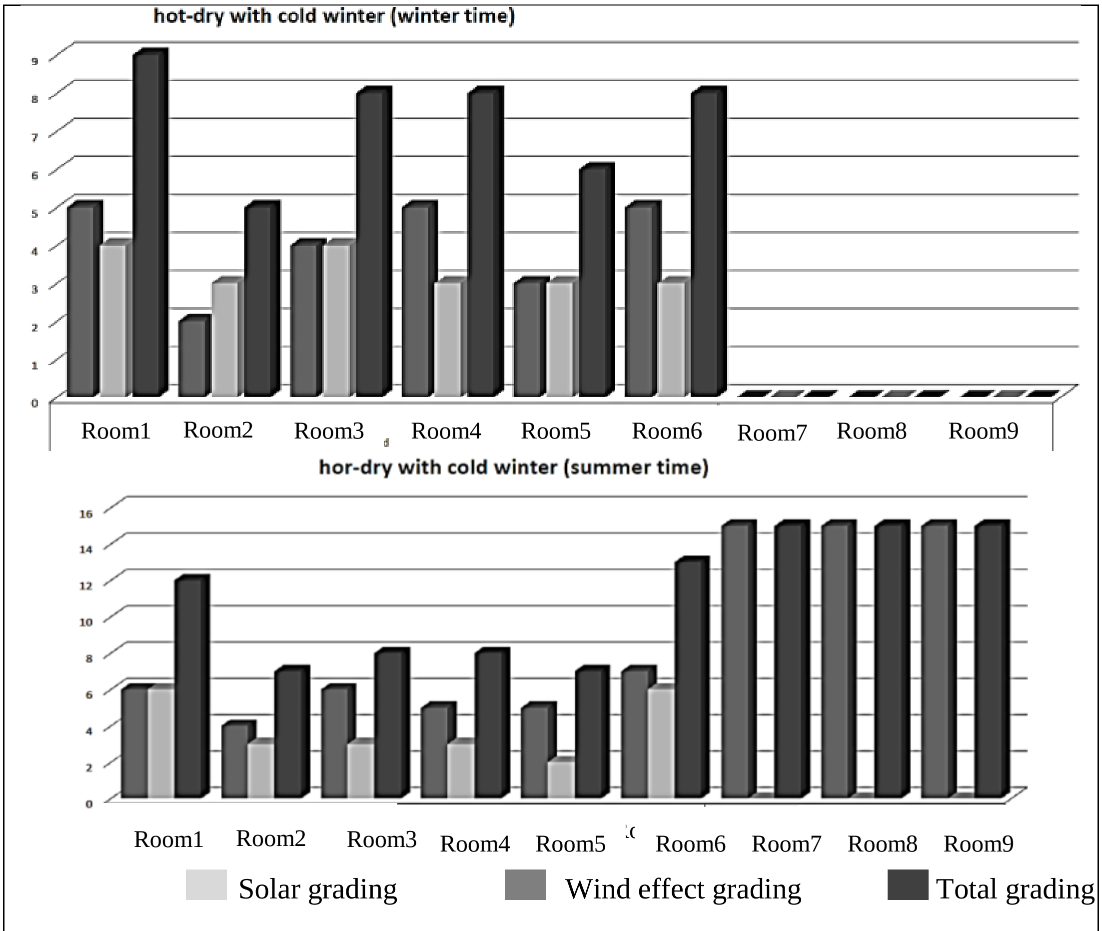
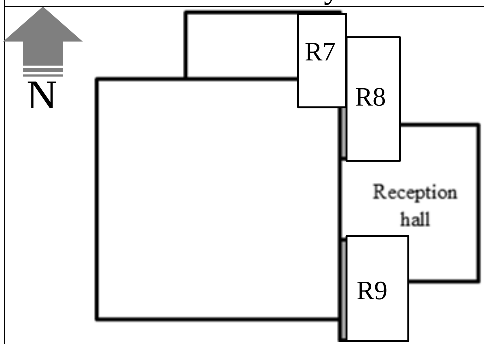
 Evaluation of spaces in terms of thermal comfort factor on the First Floor Plan (summer time)	 Evaluation of spaces in terms of thermal comfort factor on the Ground Floor Plan (summer time)

Table 31: Evaluation of traditional building spaces in terms of thermal comfort factors in hot-dry with cold winter climatic regions of Iran (dark grey display the best thermal comfort and light grey present the worse thermal comfort condition)

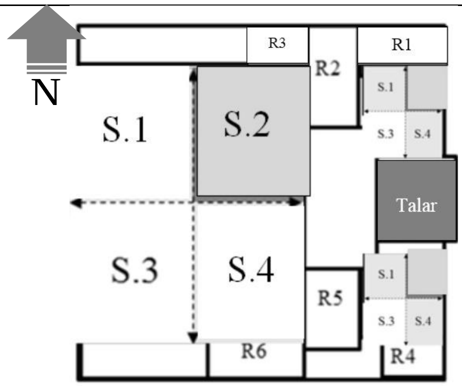
Hot dry with cold winter climate	
	
Ground Floor Plan (University, 2005)	Basement Plan (University, 2005)
	
Section A-A (University, 2005)	Section B-B (University, 2005)



Matrix analysis result during winter time and summer time



Evaluation of spaces in terms of thermal comfort factor on the Basement Plan (winter time)



Evaluation of spaces in terms of thermal comfort factor on the Ground Floor Plan (winter time)

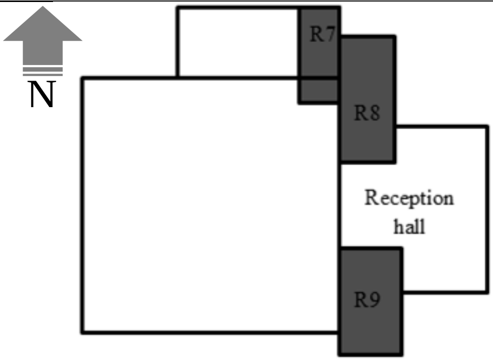
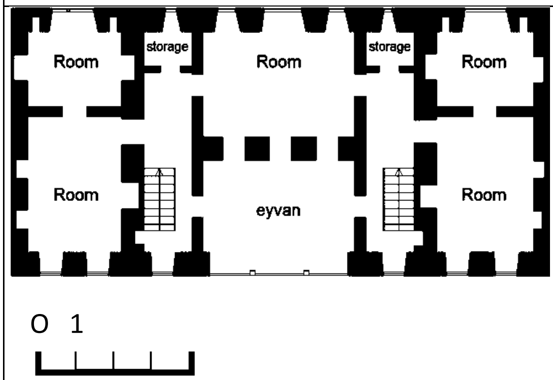
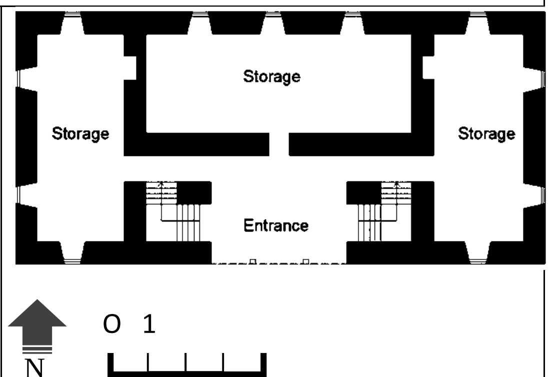
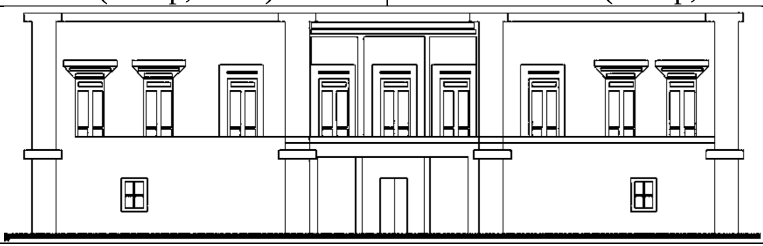
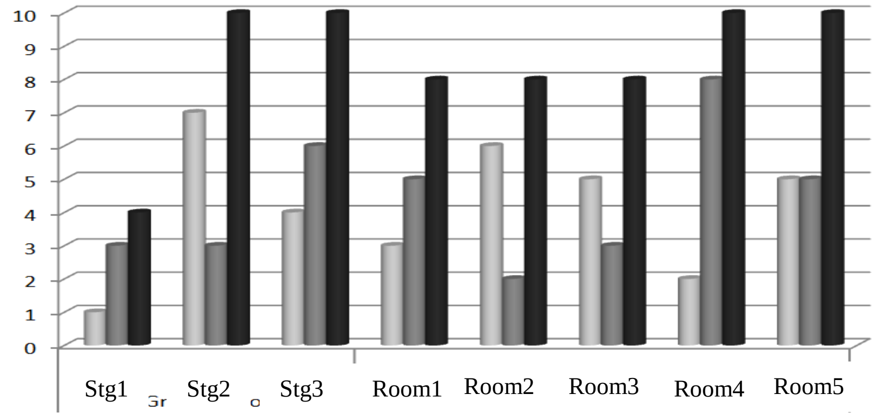
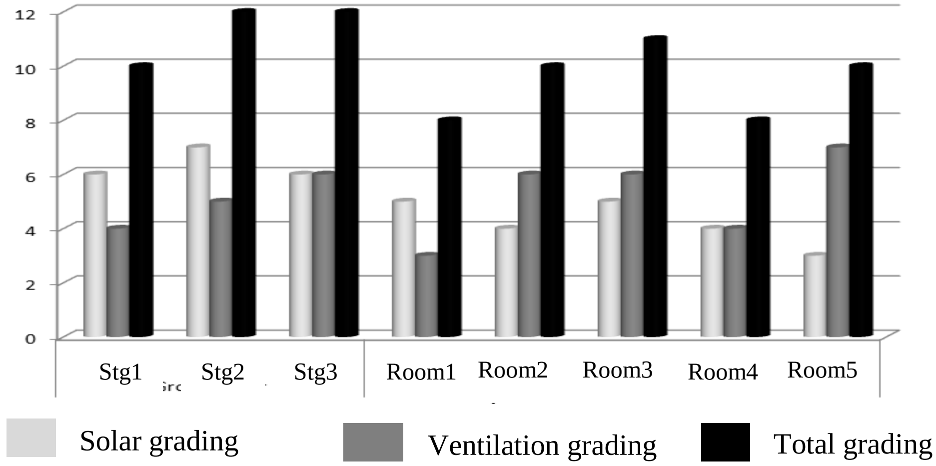
 Evaluation of spaces in terms of thermal comfort factor on the Basement Plan (summer time)	 Evaluation of spaces in terms of thermal comfort factor on the Ground Floor Plan (summer time)

Table 32: Evaluation of traditional building spaces in terms of thermal comfort factors in cool climatic regions of Iran (dark grey display the best thermal comfort and light grey present the worse thermal comfort condition)

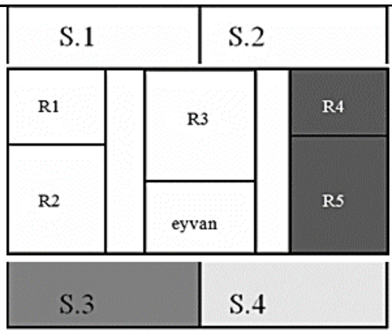
Cool climate	
	
Ground Floor Plan (Sartip, 2009)	First Floor Plan(Sartip, 2009)
	
South Elevation (Sartip, 2009)	
Cool climate winter time	



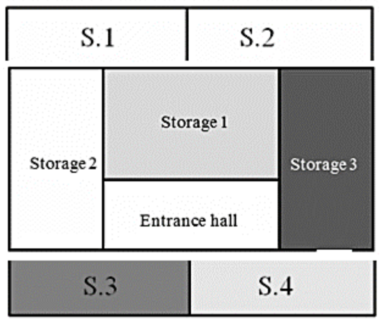
Cool climate summer time



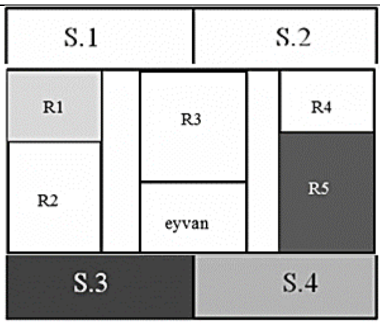
Matrix analysis result during winter time	Matrix analysis result during summer time

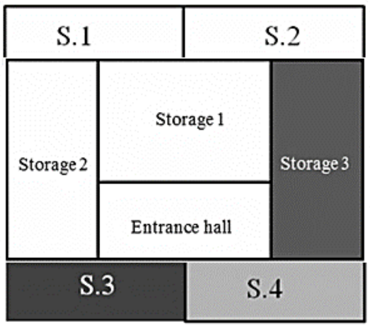


Evaluation of spaces in terms of thermal comfort factor on the First Floor Plan (winter time)



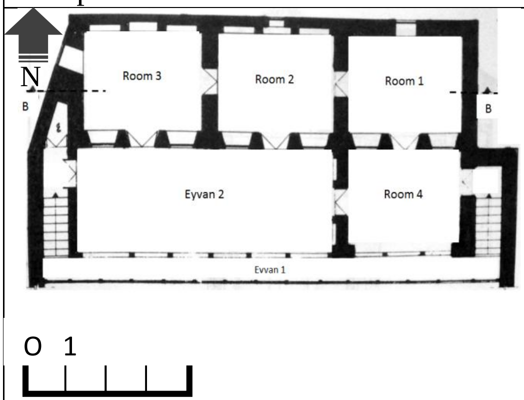
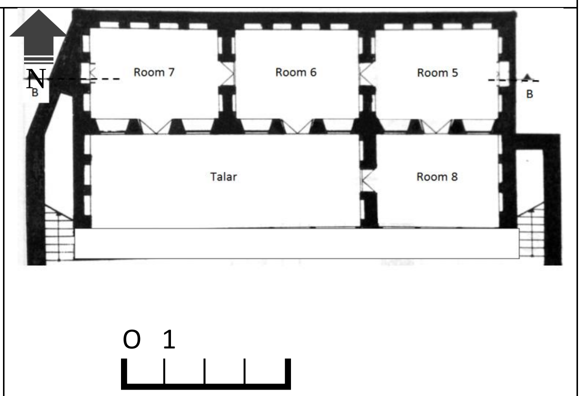
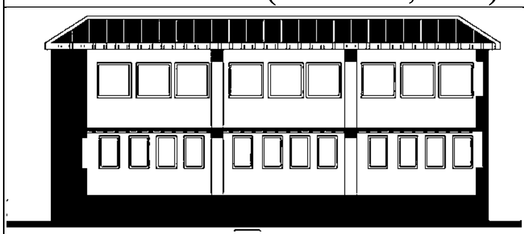
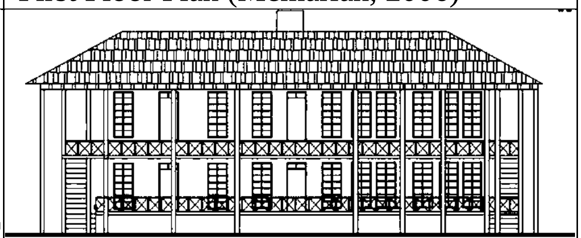
Evaluation of spaces in terms of thermal comfort factor on the Ground Floor Plan (winter time)

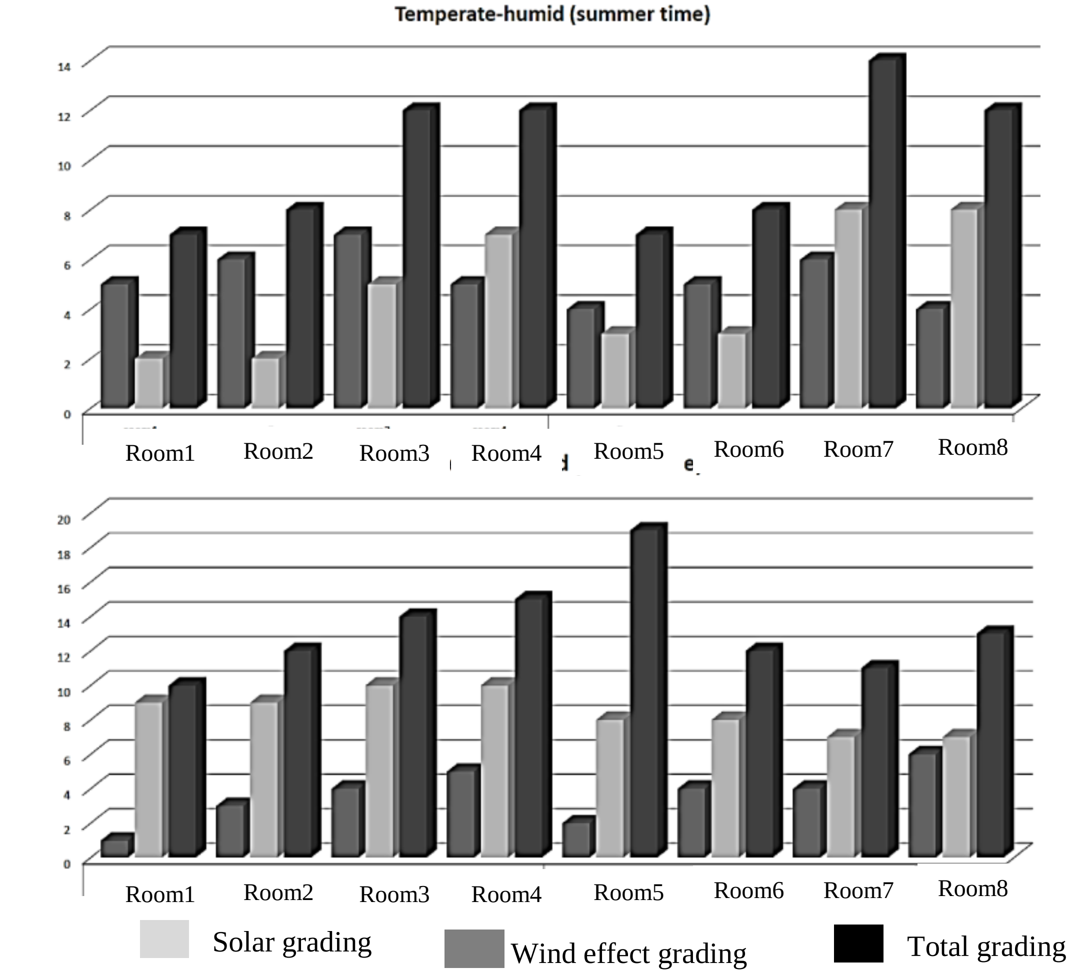
<table>
<tr>
<td>

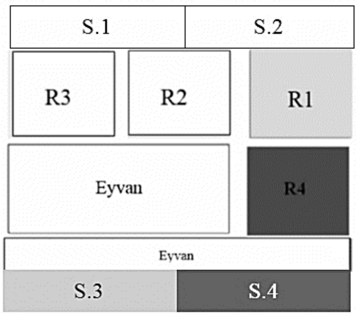
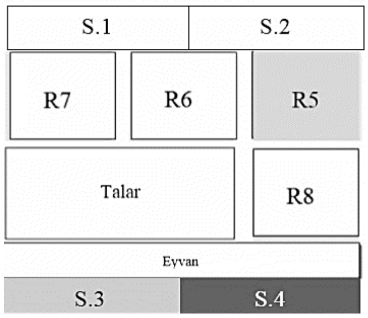
Evaluation of spaces in terms of thermal comfort factor on the
First Floor Plan (summer time)</td>
<td>

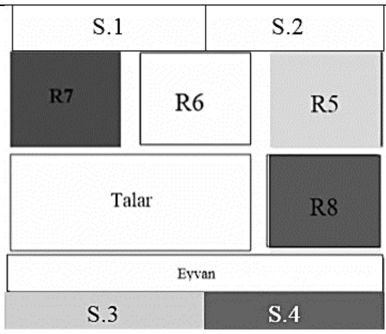
Evaluation of spaces in terms of thermal comfort factor on the
Ground Floor Plan
(summer time)</td>
</tr>
</table>

Table 33: Evaluation of traditional buildings terms of thermal comfort factors in temperate-humid climatic regions of Iran (dark grey display the best and light grey displays the worse thermal comfort condition).

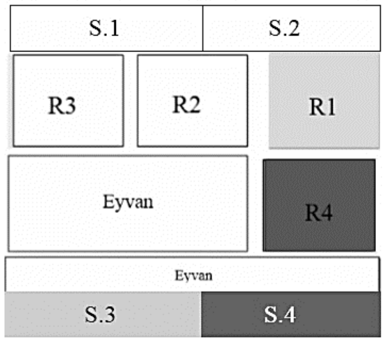
<table>
<tr><td colspan="2">Temperate-humid climate</td></tr>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr><td>Ground Floor Plan (Memarian, 2006)</td><td>First Floor Plan (Memarian, 2006)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Section B-B (Memarian, 2006)</td><td>South Elevation (Memarian, 2006)</td></tr>
</table>



Matrix analysis result during winter time	Matrix analysis result during summer time
 Evaluation of spaces in terms of thermal comfort factor on the First Floor Plan (winter time)	 Evaluation of spaces in terms of thermal comfort factor on the Ground Floor Plan (winter time)



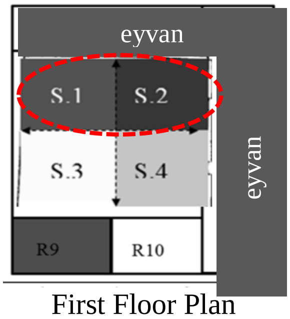
Evaluation of spaces in terms of thermal comfort factor on the First Floor Plan (summer time)

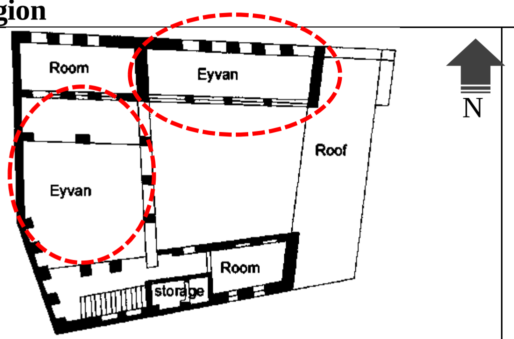


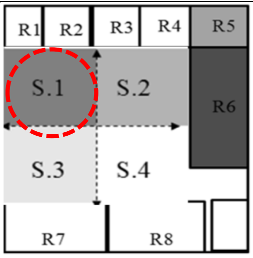
Evaluation of spaces in terms of thermal comfort factor on the Ground Floor Plan (summer time)

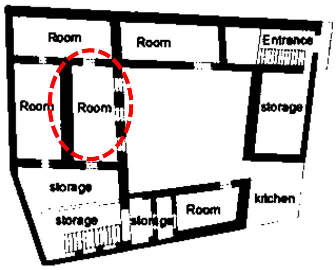
The outcomes of the justified graph method have been as expected for each climatic region. However, the cool climatic region offered an interesting discrepancy. Besides the some of the rooms on first floor also the ground floor has the best thermal comfort during winter, but the first floor spaces are the inhabitants preferred living space. The inhabitants use the heat from ground-floor kitchen to warm the first-floor spaces, which was a significant and clever solution. According to the justified graph method, the best spaces for thermal comfort in the hot-humid region were semi-open spaces, such as the *eyvan.* It is positioned to face the prevailing wind and to receive less solar gain. Another example of the justified graph method's effectiveness is that in temperate-humid region, the first floor is the most thermally comfortable space in winter and the ground floor is the most thermally comfortable space in summer. This result specifically correlates with the inhabitants' vertical movement through the spaces during the different seasons, as noted by Sartip (2009).The outcome from each climatic region allows for a comparison of the justified graph method with existing research to verify the seasonal movements of inhabitants (Table 34 to table 38).

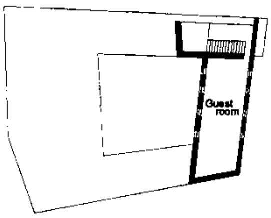
Table 34: Comparing the results of justified graph method with the existing research.

<table>
<tr><th>Justified graph method’s outcome</th><th colspan="2">Existing research: (Memarian & Sadoughi, 2011)(Memarian, 2006)(Pourvahidi, 2010) (Sartip, 2009) (Sadigh, 2011) (Ghobadian, 2009)</th></tr>
<tr><td colspan="3">Hot-humid Climatic Region</td></tr>
<tr><td>

First Floor Plan
Justified graph method’s conclusion is that the best closed and semi-open spaces are located on the first floor plan during summer time</td><td>

Eyvan’s location are in the same direction with the justified method’s best direction for having open and semi-open spaces (S.1 and S.2)</td><td>Seasonal movement in this hot-humid climatic region occur vertically through the space. Inhabitants move to the first floor during summer time since it receives the best breezes during evening and night time. Inhabitants sleep on the roof during night.
</td></tr>
<tr><td>

Ground Floor Plan
Justified graph method’s conclusion is that the best closed spaces are located on ground floor plan during winter time</td><td>

In this example, selected room has lots of opening toward S.1 which justified method demonstrated it as the best direction for catching more sunshine.


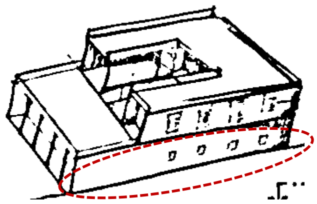
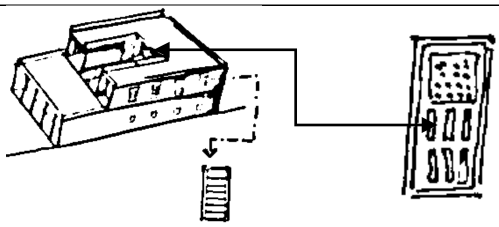
Best room during winter and summer is located at the same direction like justified method’s results reveal it.</td><td>Ground floor had been used during winter time. So, the number of openings is less on ground floor.
</td></tr>
<tr><td>Justified graph method suggested that the best percentage ratio of the opening is ten–twenty percent.</td><td>
Openings with shading devices/ windows designed with less amount of glass.</td><td>The design of opening in this climatic region design to enter less sun heat inside the building so opening have shading devices. Beside since of humidity, inhabitant open the window during evening and night time.</td></tr>
</table>

Table 35: Comparing the result of justified graph method with the existing research

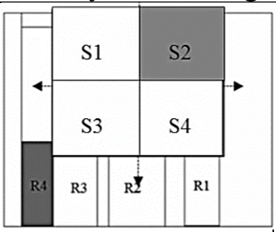
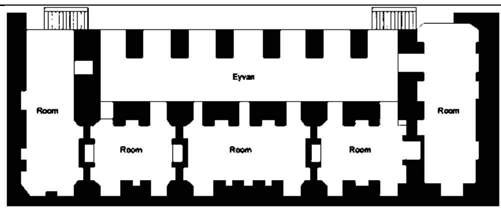
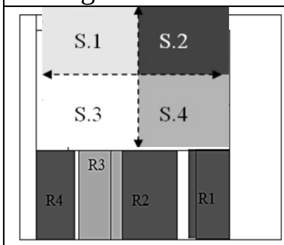
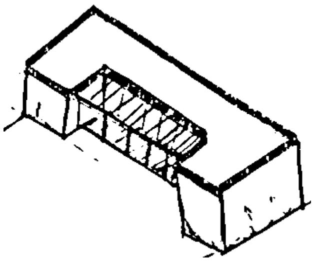
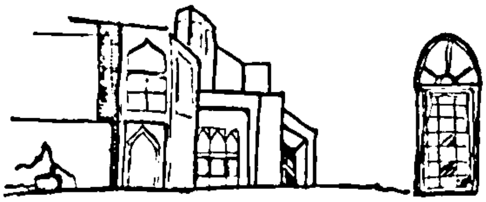
Justified graph method's outcome	**Existing research:** (Memarian & Sadoughi, 2011)(Memarian, 2006)(Pourvahidi, 2010) (Sartip, 2009) (Sadigh, 2011) (Ghobadian, 2009)	
Hot-dry climatic region		
 Ground Floor Plan Justified graph method indicated that the best closed spaces are located on the ground floor during winter time	 Winter use of ground floor.	Traditional buildings in hot-dry climatic region has similar characteristic with hot-dry with cold winter climate. The inhabitants prefer to move to the ground floor during winter time.
 First Floor Plan Justified graph method indicated that the best closed and semi-open spaces are located on the first floor during summer time	Roofs are comfortable open spaces during summer time at night. 	During the hottest month of the year inhabitants move to the roof at night time for sleeping.
Justified graph method suggested the best percentage ratio of the opening is twenty-thirty percent for hot-dry climatic region.		The size of the openings is same as hot-dry with cold winter climate. In this climate summer is so hot, the ratio of openings should be less in order not to let sun sunshine inside the building.

Table 36: Comparing the result of justified graph method with existing research

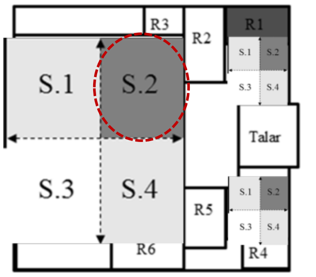
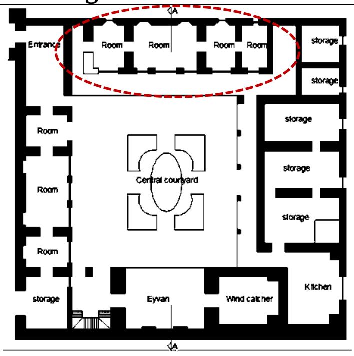
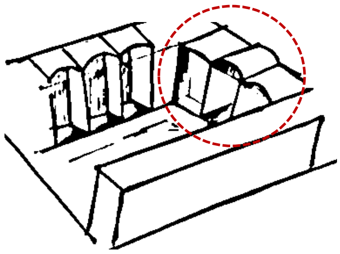
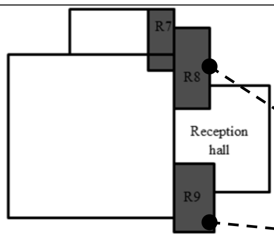
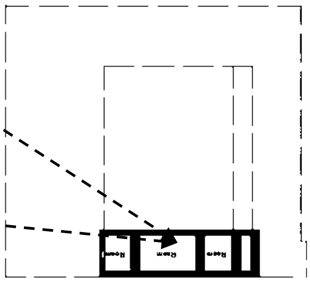
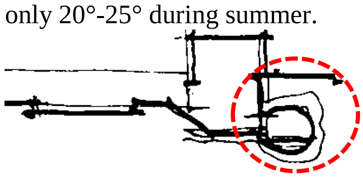
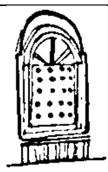
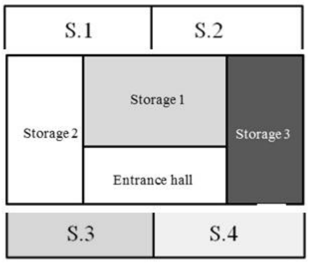
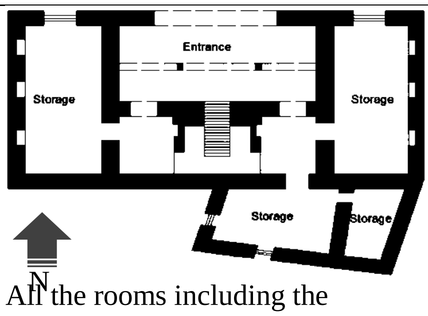
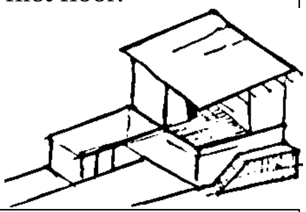
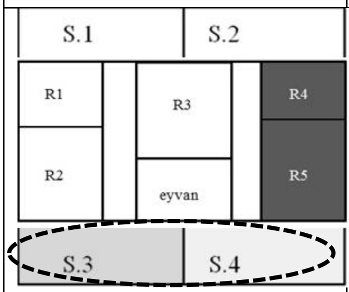
Justified graph method's outcome	**Existing research:** (Memarian & Sadoughi, 2011)(Memarian, 2006)(Pourvahidi, 2010) (Sartip, 2009) (Sadigh, 2011) (Ghobadian, 2009)	
Hot-dry with cold winter climatic region		
 Ground Floor Plan N Justified graph method concluded that the best-closed spaces are located on the ground floor during winter time.	 Justified graph illustrated the best semi-open spaces to get more solar gain is S.2. All the winter spaces are arranged on the same direction.	This region has cold winter so inhabitants stay on ground floor during winter time. 
 Basement Plan Justified graph method concluded that the best closed spaces are located on the basement during summer time.	 The example of traditional building in Yazd city also demonstrated the same result with justified graph's outcome. Since, rooms on the basement floor do not receive sunshine and have the best comfortable condition during summer time.	The climatic condition of hot-dry with cold winter climatic region causes the movement of inhabitants to the basement during summer time. Since the fluctuation of temperature of ground floor and basement is only 20°-25° during summer. 
Justified graph method suggested the best ratio of the openings as twenty–thirty percent.	 Inhabitants open the windows just during the evening and night times.	The size of the openings is same as the hot-dry. Basement floor plan has no opening in order to be cooler during summer time.

Table 37: Comparing the results of justified graph method with the existing research

<table>
<tr><th>Justified graph method's outcome</th><th colspan="2">Existing research: (Memarian & Sadoughi, 2011)(Memarian, 2006)(Pourvahidi, 2010) (Sartip, 2009) (Sadigh, 2011) (Ghobadian, 2009)</th></tr>
<tr><td colspan="3">Cool Climatic Region</td></tr>
<tr><td>

Ground Floor Plan

Justified graph method concluded that the best closed spaces are located on ground floor.</td>
<td>

All the rooms including the kitchen and storage are organized on the first floor plan. The ground floor functions make upper floor warmer during winter time. The functions of the stores are mostly for keeping animals and for cooking so these functions keep the upper floor warmer.</td>
<td>Cool climatic region has two types of traditional building. One type is similar to hot-dry with cold winter climate which has a central courtyard. The other type has two storeys without any courtyard.
Kitchen and storge is on the ground floor and the living room and bedrooms are on the first floor.
</td></tr>
<tr><td>

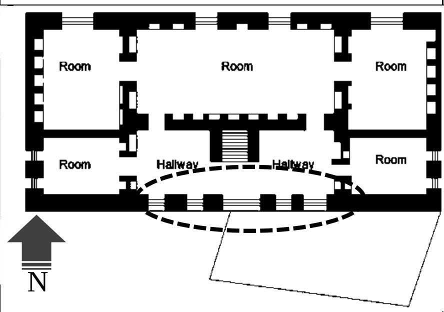
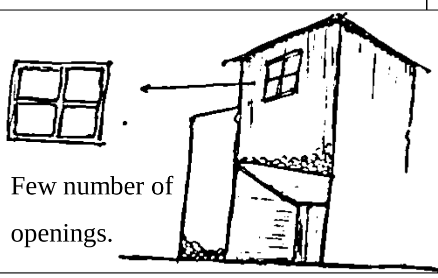
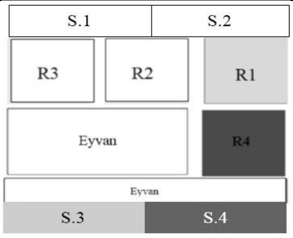
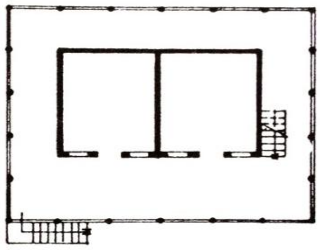
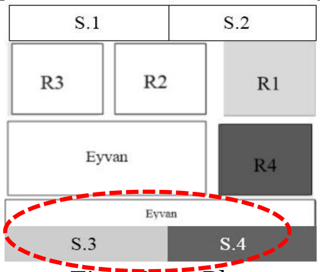
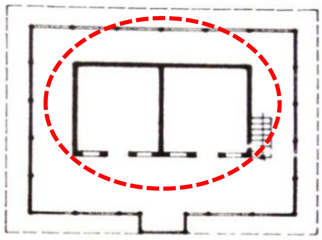
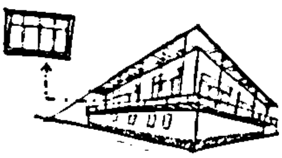
First Floor Plan
Justified graph method conclude that the best closed spaces are located on first floor plan during winter time</td>
<td>
</td>
<td>Justified graph method illustrated that space 3 and space 4 have the best location for getting more heat during winter time. Traditional building in this region have also more rooms on this side.</td></tr>
<tr><td>Justified graph method suggested the best ratio of the openings as thirty-forty percent.</td>
<td>
</td>
<td>The percentage of openings should get the sunshine from south but not the prevailing winds in winter.</td></tr>
</table>

Table 38: Comparing the result of justified graph method with the existing research

Justified graph method's outcome	**Existing research:** (Memarian & Sadoughi, 2011)(Memarian, 2006)(Pourvahidi, 2010) (Sartip, 2009) (Sadigh, 2011) (Ghobadian, 2009)	
Temperate-humid climatic region		
 Ground Floor Plan Justified graph method indicated that the best closed spaces are located on ground floor during winter.	 Inhabitants used the ground floor during winter time Occupants enjoy the shade and breeze of balconies and semi-open spaces. Since inside the buildings it will be stuffy and warm during summer time.	Temperate-humid climatic region has same characteristic with hot-humid climate. In this region inhabitant prefer to move to ground floor during winter time. Because it is the warmer than the first floor.
 First Floor Plan Justified graph method indicated that the best closed and semi-open spaces are located on the first floor during summer.	 Inhabitants prefer to go to the First floor during the summer time for achieving more wind flow. Justified graph method demonstrated that space 3 and space 4 has the best comfortable condition for achieving less solar gain during summer and more during winter. Case studies also proved that all the spaces are organized toward space3 and space 4.	During the hottest month of the year movement occur vertically in this region. Occupants move to the first floor for getting the best wind flow. Wind flow decreases humidity and provides comfortable condition during summer.
Justified graph method suggested the best ratio of the opening as forty–eighty percent.	 Opening in this climate should create cross ventilation for decreasing humidity so the best ratio was suggested as forty–eighty percent.	The ratio of the opening in this region is larger than the other climatic region. Since it has temperate climate and much relative humidity. The large openings cause cross ventilation and cooling.

The results of tables 28 to table 32 demonstrated that most of the traditional buildings in Iran are constructed to address environmental issues in addition to cultural and religious beliefs. Nasr (2003) proved that Iranian life responds to the environment since of harsh climatic situation. Thus, seasonal movement throughout a building is one of those responses. The frequency with which inhabitants use particular spaces within a building is a seasonal matter and not just a consequence of overall patterns of access and circulation. Hence, it is not easy to display seasonal movement on with graph theory. It is crucial to note that existing access graphs do not track the seasonal movements. This is why the authors developed the access graph into the justified graph.

Some studies have completely ignored seasonal movements driven by summer weather, even though those studies address climatic conditions (Orhun et al., 1995). Seasonal movements vary widely according to building type. In some traditional Iranian building in the temperate-humid region, seasonal movements are vertical. Alternately, in a courtyard house, seasonal movement take place around the perimeter of the courtyard, although occupants may move to the basement or to the first and second floors, to take advantage of cool winds and lower temperatures. In winter, the inhabitants mostly stay in rooms with the least amount of openings (Memarian& Brown, 2006). In addition, the daily movement also happened by the inhabitants through the spaces in this kind of traditional building. For instance, in hot-dry and hot-dry with cold winter climatic region during summer time, in the morning and afternoon, occupant move to the basement which has 20 to 25° differentiation of temperature with the ground floor. Afterwards, in evening and night all the activities have been continued in central courtyard. In the night time inhabitant preferred to sleep on the roof which is cooler than the other spaces. Thus, this study could be determined that rather than the seasonal movement, there is daily movement as well through the spaces of traditional buildings in some of the climatic region of Iran.

The outcomes of the justified graphs with the seasonal movements of inhabitants were compared. This comparison revealed the applicability of the justified graph method in terms of thermal comfort factors. For the temperate-humid climate of Iran, the first floor has the best thermal comfort conditions during summer. However, the ground floor has the best thermal comfort conditions during winter. Ghobadian (2009) reached to the same conclusion when he mentioned that inhabitants in this climate region move vertically through their buildings to adjust themselves to the seasons. Likewise, for the hot-dry with cold winter climate of Iran, the results of the justified graphs confirm Memarian's (2006) research that inhabitants of this region seek the basement as a comfortable place during the summer.

Azami (2005) noted that in hot-dry climate with a cold winter, most of the traditional buildings have large *eyvans* (semi-open spaces facing the courtyard) and are open to the cool summer winds. These large *eyvans* can create comfortable conditions for the inhabitants in the afternoon and evening; these spaces have the best thermal comfort conditions in summer. So, justified graph result of summer, matched the movements reported by others, of inhabitants through spaces seasonally.

The method is applicable to the hot-humid climate region of Iran as well. Under humid conditions, inhabitant of this region prefer to move to the first floor during summer (Memarian, 2006), and the analysis showed that the thermal comfort value of rooms on the first floor is higher than the ground floor spaces during summer.

At the end, this research could claim that the developed justified graph is applicable for both traditional and also modern buildings where less than three stories have. Since, the result of developed justified graph on traditional building prove that the method answer the proper result according to the climatic condition. Therefore, applying the developed method for organizing spaces by considering the climate on modern building would be step toward wasting less energy in the future.

Chapter 4

CONCLUSION

In the previous studies of space syntax, researchers did not discuss about the factors that have an effect on circulation and movement of inhabitants through the spaces of a building. Most importantly, climatic issue, which has an imperative effect on the movement of inhabitants in Iranian traditional building was not handled in space syntax. Space syntax method without considering the climatic issue is kind of one-dimensional method, which cannot give the appropriate result in architecture field. Therefore, this research developed and justified the access graph that is the main tool of space syntax method in order to investigate the climatic issue. This has an effect on the organization of spaces and it is not just the cultural issues that shape the traditional buildings. Thus, this research attempts to analyze thermal comfort issues graphically. It used the fundamentals of access graphs. However, access graphs have limitations when performing climatic evaluations because they merely consist of bullets and lines that demonstrate the connectivity of spaces. The bullets and lines of access graphs can be made to demonstrate the amount of privacy available through the degrees of connectivity between spaces, according to their relative locations. Thus, how to adapt the graphical connectivity to evaluate thermal comfort issues throughout a building was investigated in this study.

The developed justified graph method also uses bullets to analyze spaces. To set the method to work, the authors limited the criteria to evaluate solar gain and wind effect as the two categories for thermal comfort, because they covered several other thermal comfort factors. The method used the suitable building layout in terms of thermal comfort. Thermal comfort factor is defined graphically for the evaluation of the method.

The solar gain and wind effect data for graphical representation is a simplified methodology. In this methodology zero represents the worst thermal comfort conditions and three represents the best thermal comfort conditions. Solar gain factor deliberated as negative during winter and positive factor during summer time. Furthermore, wind effect also considered as positive factor during summer and negative factor during winter time. Hence, the justified number of zero to three defined for each space according to positive and negative effect of solar gain and wind effect during hottest and coldest season of a year. Furthermore, the author developed and justified a graph method for solar gain in different steps as follow:

- Step 1: Considering solar radiation as positive factor during winter and negative factor during summer time.
- Step 2: Finding the solar radiation and sunshine period data according to the different azimuth angle of the building
- Step 3: Identifying the intervals of amount of solar radiation (MJ/m^2 day) and sunshine period on building envelope (hours/day) for defining the justified number

- Step 4: Preparing the chart for finding the average amount of solar radiation and sunshine period on vertical surfaces at different latitude, during summer and winter
- Step 5: Solar gain justified graph has been defined by finding the averages amount of solar radiation and sunshine period.

Following step had done for developing and justifying the wind effect method:

- Step 1: Studying effect of wind as positive factor during summer and negative factor during winter time by considering the body temperature and air temperature.
- Step 2: Finding the direction of the prevailing wind during summer and winter.
- Step 3: Classifying the justified number consistent with the direction of prevailing wind and air pressure for each specific city.
- Step 4: Drawing the prevailing wind direction on the schematic plan of a building and justifying the number for the facades where are located under the wind direction.
- Step 5: Developing and justifying the effect of the wind's graph by finding the justified number on the each facades of a building accroding the direction of the prevailing wind and air pressure during summer and winter time.

All these simulation had been done for close and semi-open and open spaces. Since, the semi-open and open spaces also have a significant role for creating thermal comfort condition for the occupants during summer time in hot-dry, hot-dry with cold winter, hot-humid and temperate-humid climatic region of Iran. These steps, support the research to define the method which could demonstrate the effect of climate on space organization and also to be considered as the developed and justified method of access graph which is applicable for analyzing the climatic issue on traditional building.

The case studies surveyed, supported the hypothesis that the justified graph method is applicable to the five climatic regions of Iran. The outcome of justified graphs correlates with the seasonal movement of the inhabitants. The best comfortable spaces during summer and winter also demonstrated the same result.

Hence, the developed justified graph method can be used to study the effect of climate on space organization of traditional Iranian buildings. Moreover, this developed and justified graph method is applicable for organizing the spaces by considering the effect of climate on modern building which has maximum three stories as well.

Finally, it should be mentioned that although there are lots of simulation programs but the architects need faster methods to design a building from climatic data. So it is better to reach to this aim graphically. Hence, the purpose of this research was to develop a faster method of organizing spaces from climatic data, which justified graph method achieved by using graphics. Furthermore, applying the method on modern building could do the further study which applying a justified graph method on modern building would be the step toward assisting the architect for organizing spaces by considering the climatic issue and also having a green environment.

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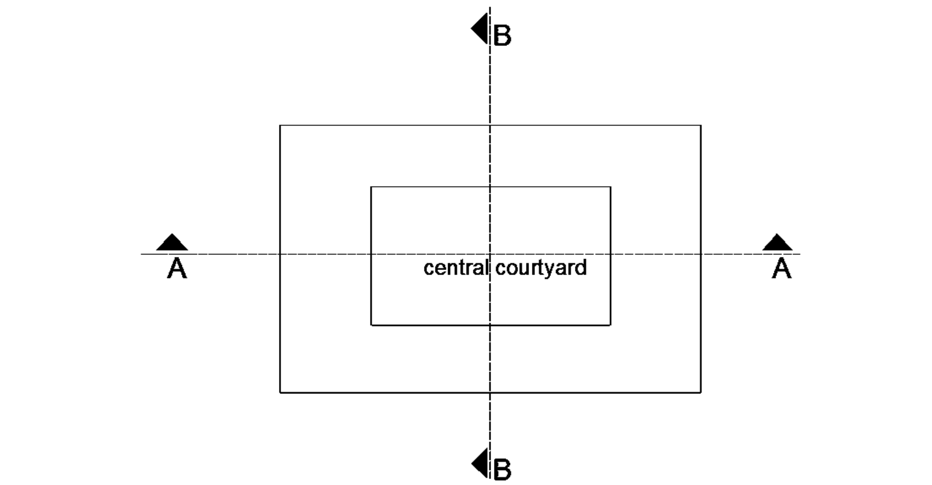
APPENDICES

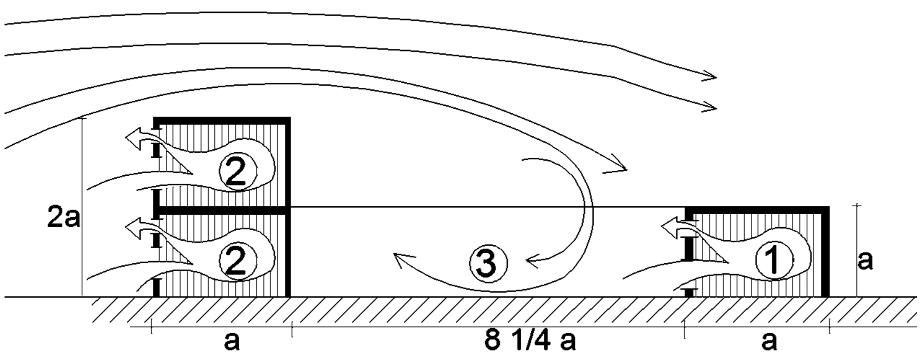
Appendix A: Justified Numbers for Sections A-A and B-B According to the Prevailing Wind Direction and Number of Openings During the Summer and Winter in Bushehr

Schematic plan of traditional building

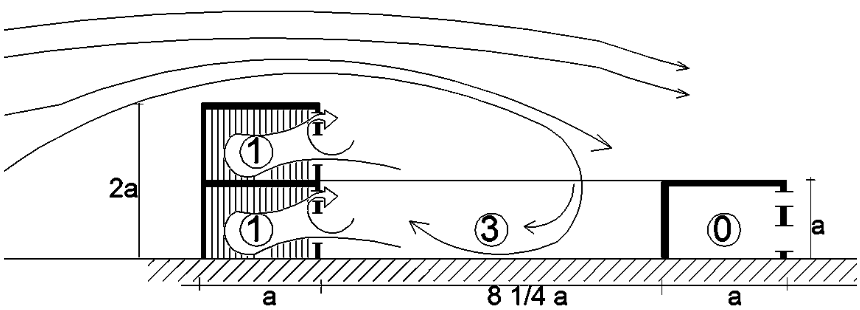


Section A-A — **SUMMER**

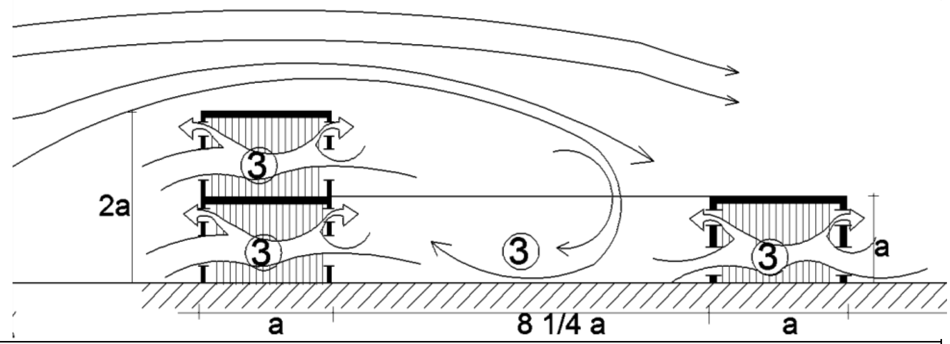
1opening west



1opening east



2openings

Section A-A	WINTER	
		
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		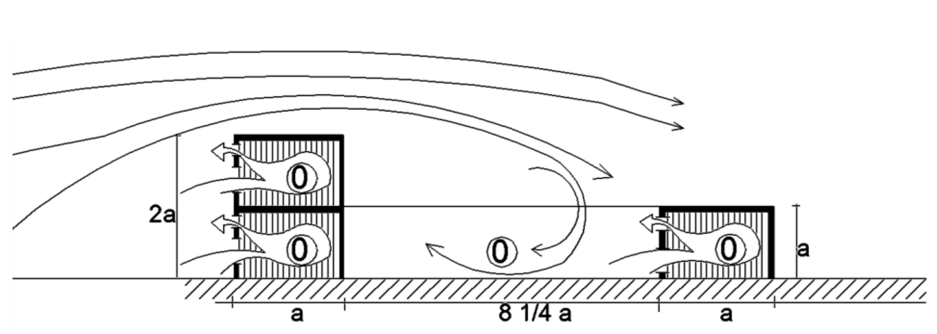
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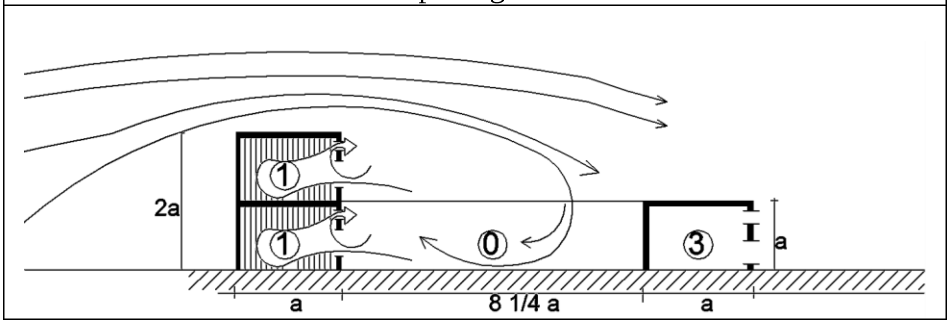
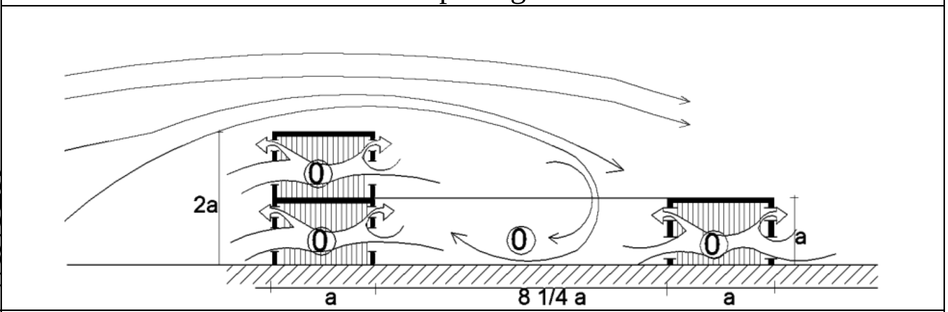
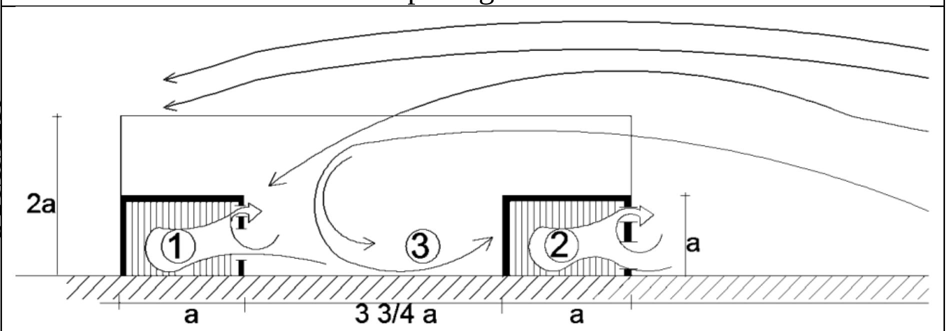
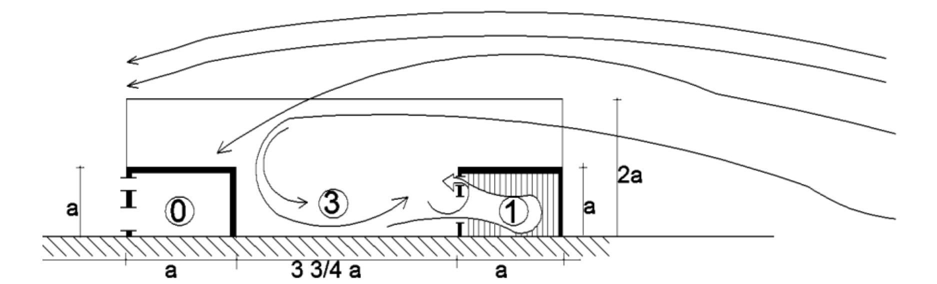
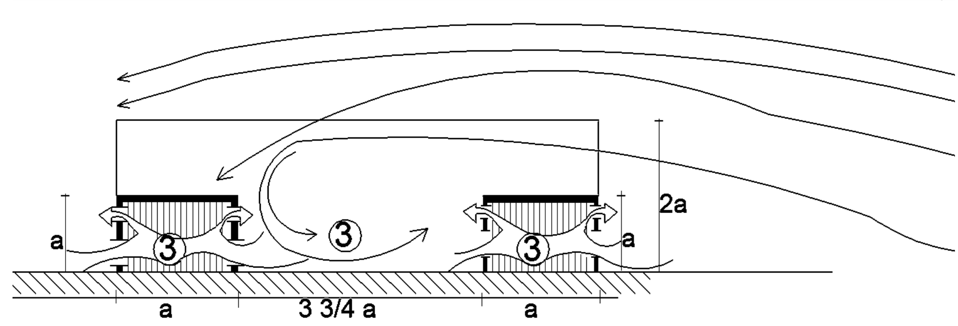
		
		2openings
		
		1opening north
Section B-B	**SUMMER**	
		1opening south

Section
B-B

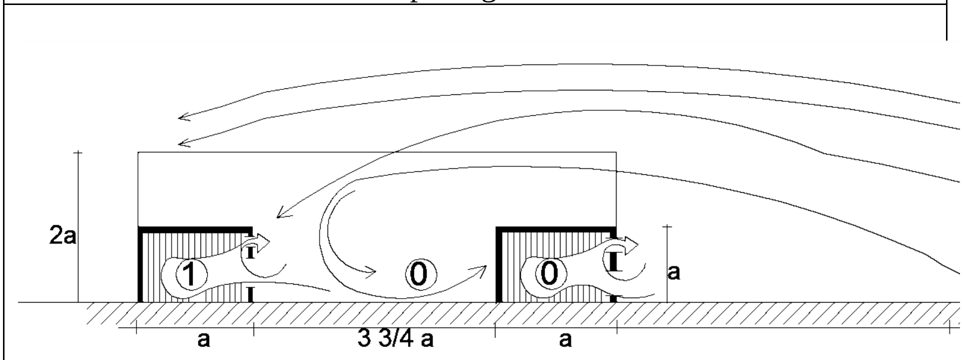
WINTER



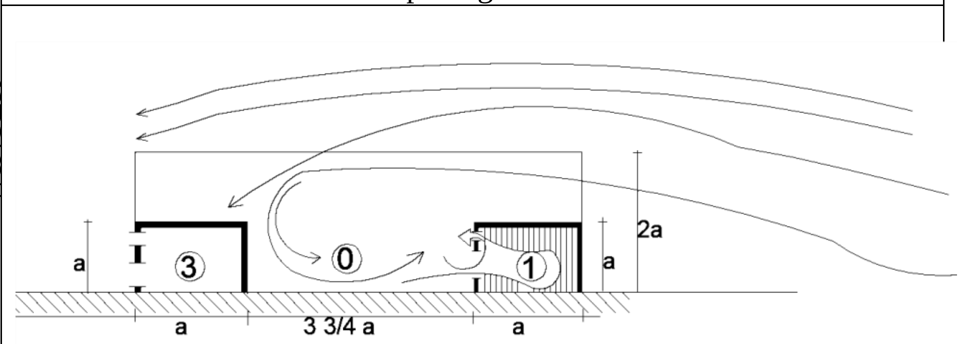
2openings



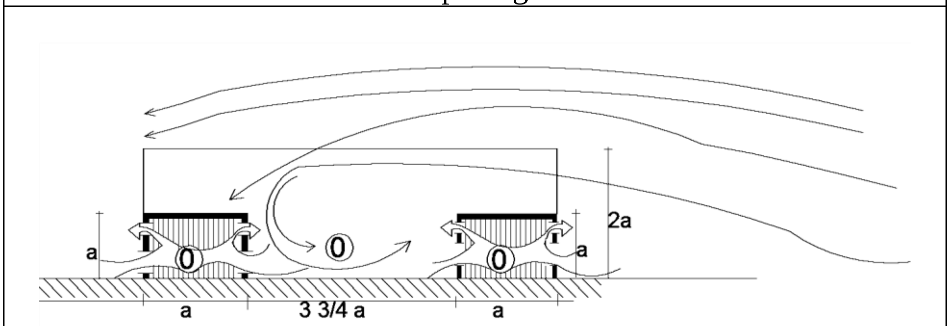
1opening north



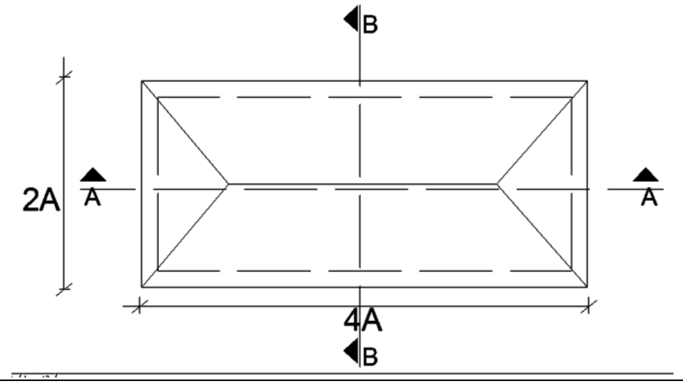
1opening south



2openings



Appendix B: Justified Numbers for Sections A-A and B-B According to the Prevailing Wind Direction and Number of Openings During the Summer and Winter in Rasht

<table>
<tr><td>Schematic plan of traditional building</td><td></td><td>
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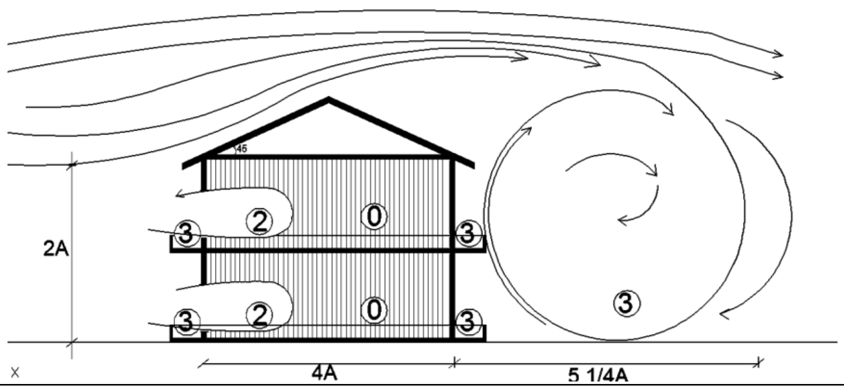
<tr><td>
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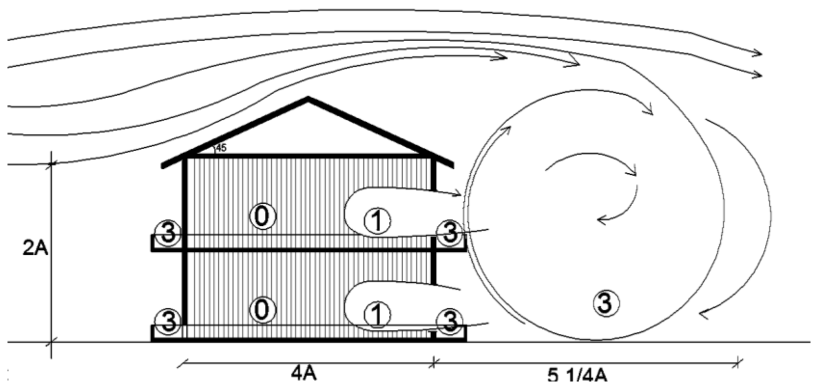
<tr><td>
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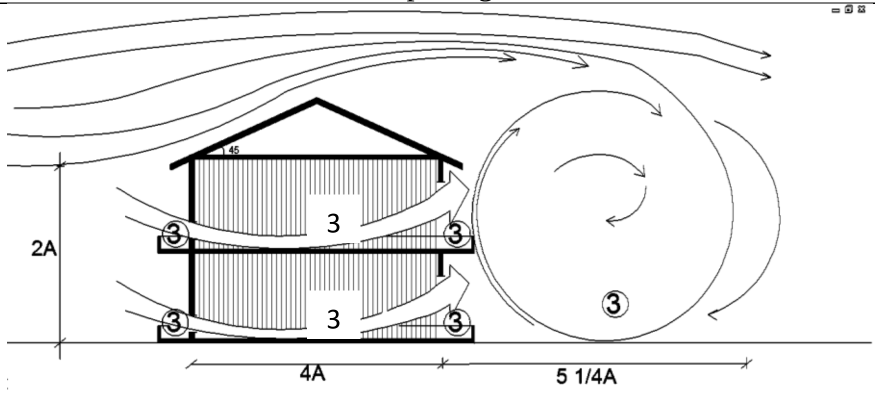
<tr><td>2openings</td></tr>
<tr><td>
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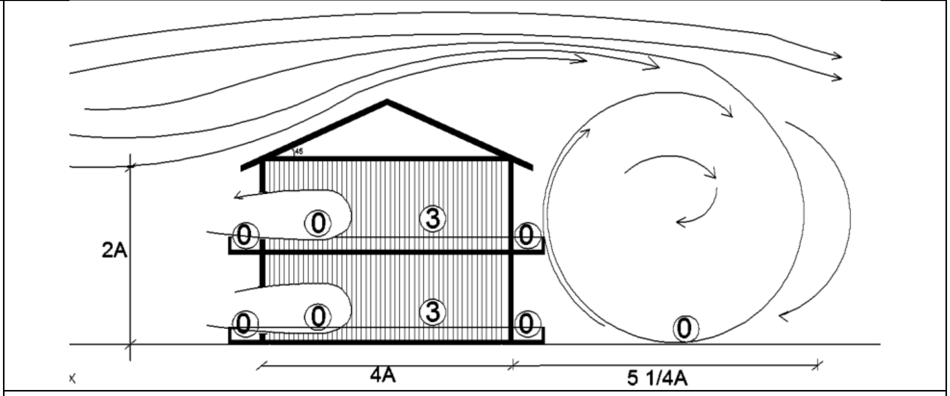

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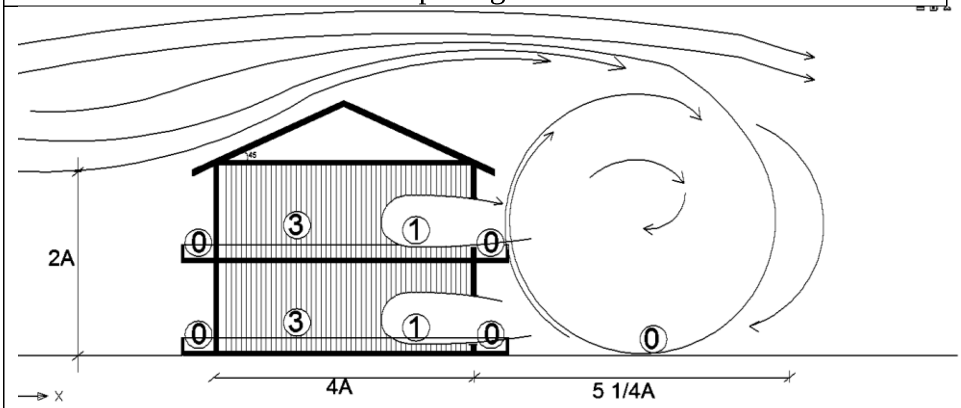
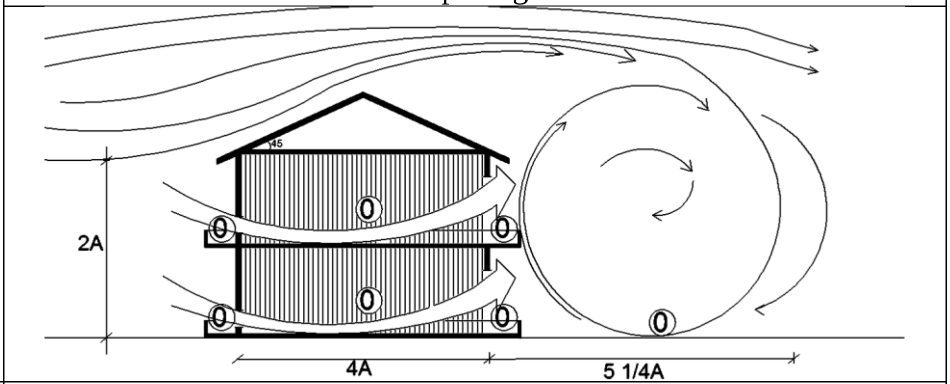
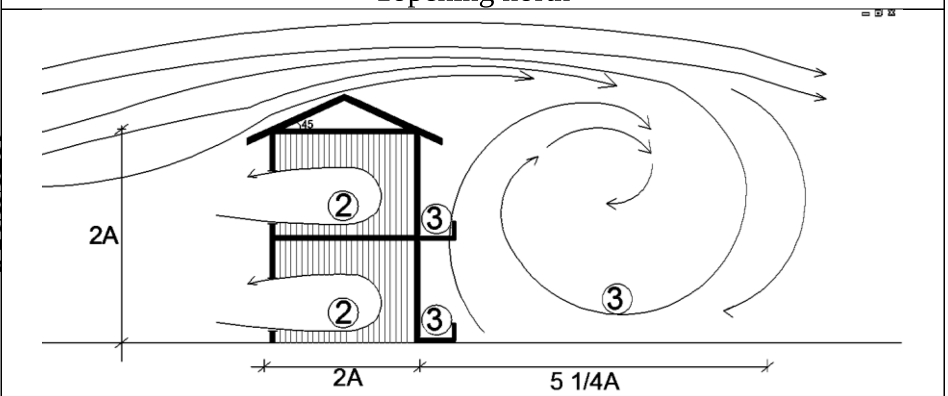


2openings



1opening north



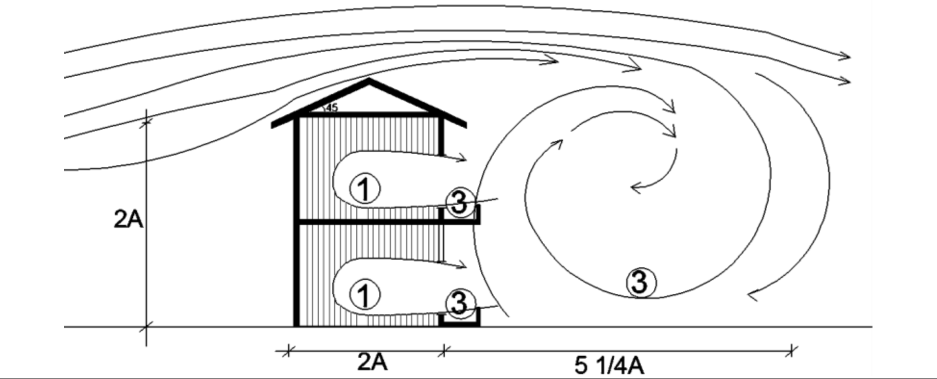
1opening south

Section B-B

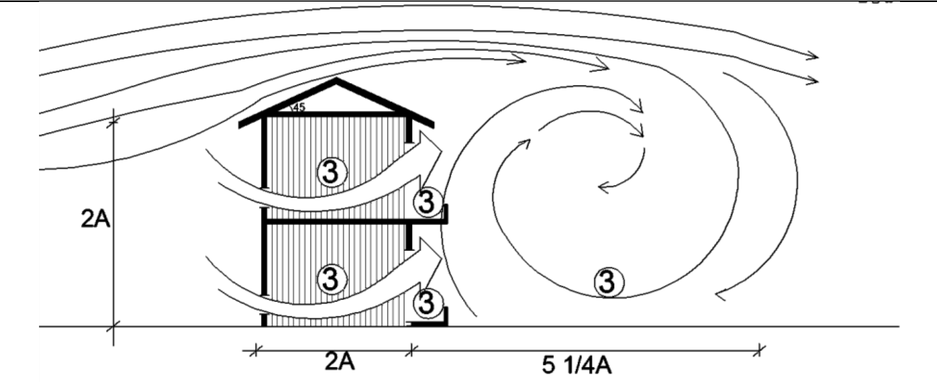
SUMMER

Section B-B

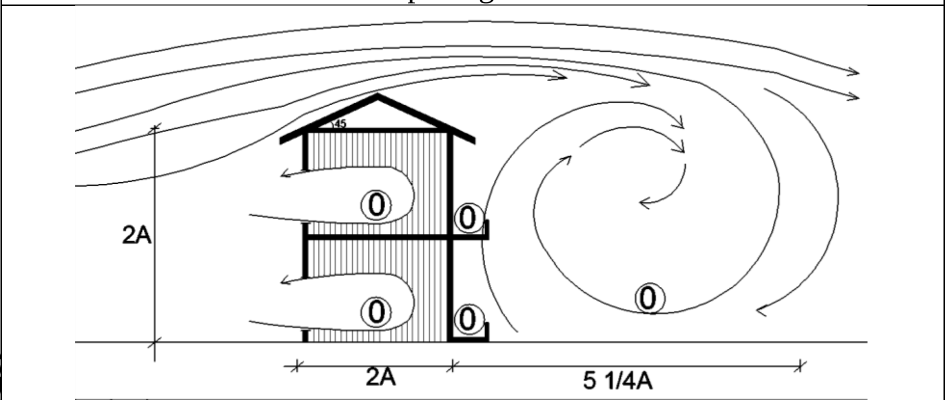
WINTER



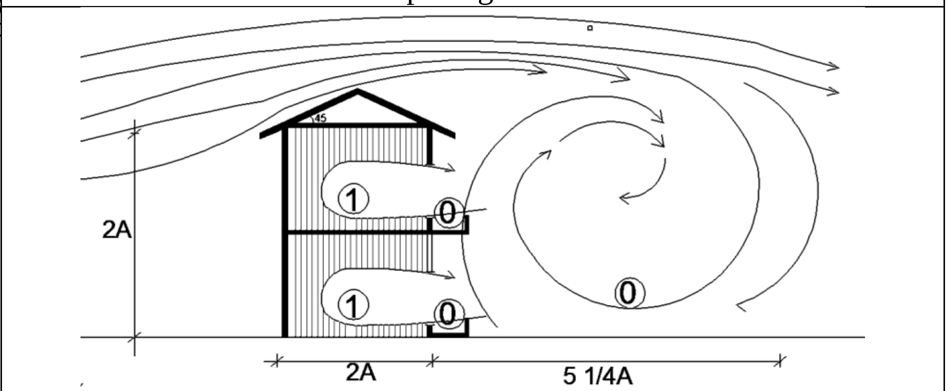
2openings



1opening north



1opening south



2openings

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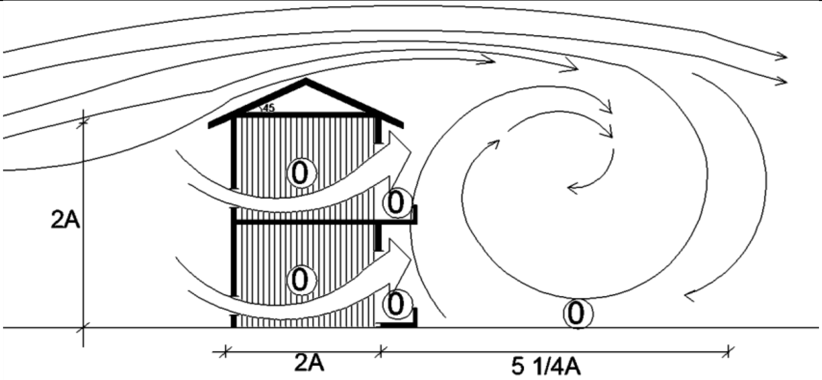
<tr><td></td><td></td><td>
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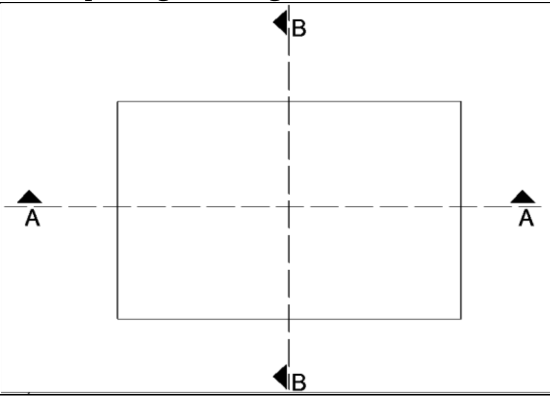
Appendix C: Justified Numbers for Sections A-A and B-B According to the Prevailing Wind Direction and Number of Openings During the Summer and Winter in Urumye

<table>
<tr><td>Schematic plan of traditional building</td><td></td><td>
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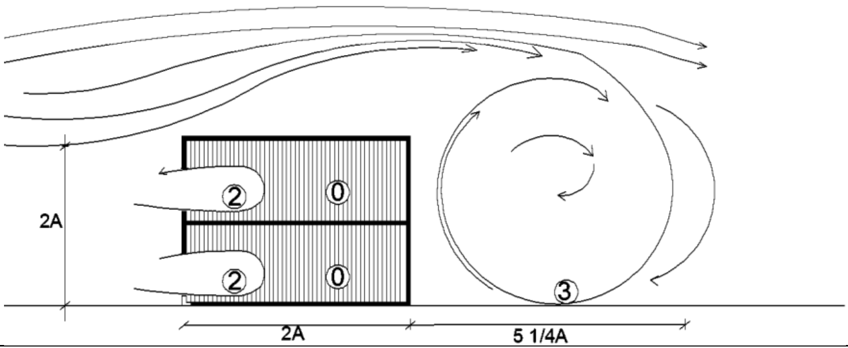
<tr><td>
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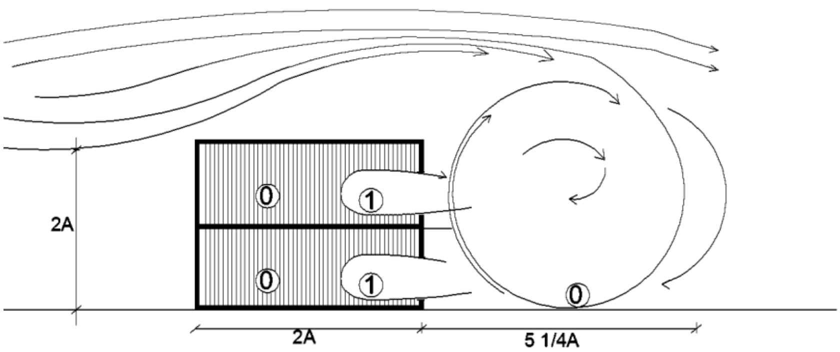
<tr><td>1opening east</td></tr>
<tr><td>
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<tr><td>2openings</td></tr>
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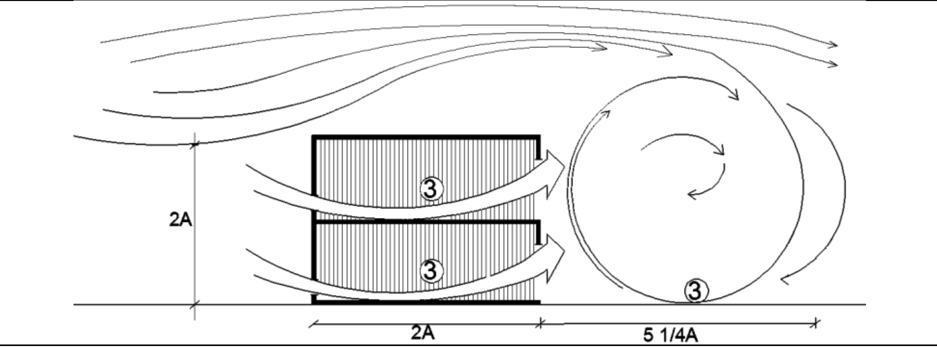
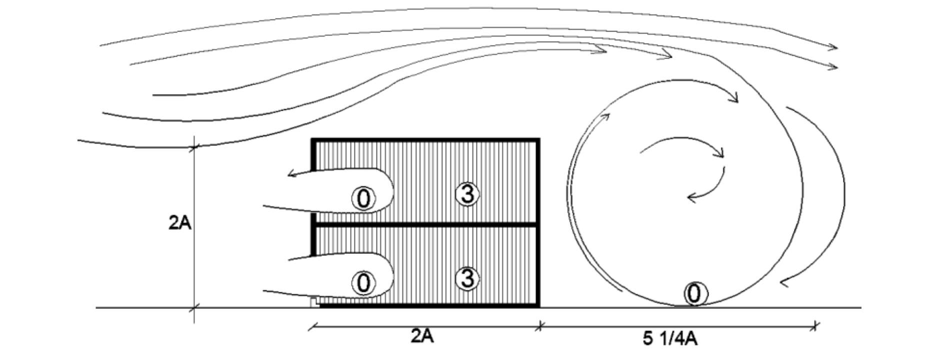
Section A-A

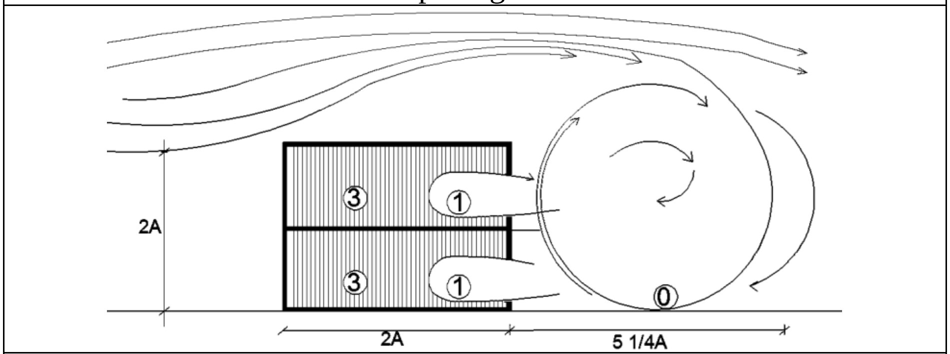
WINTER



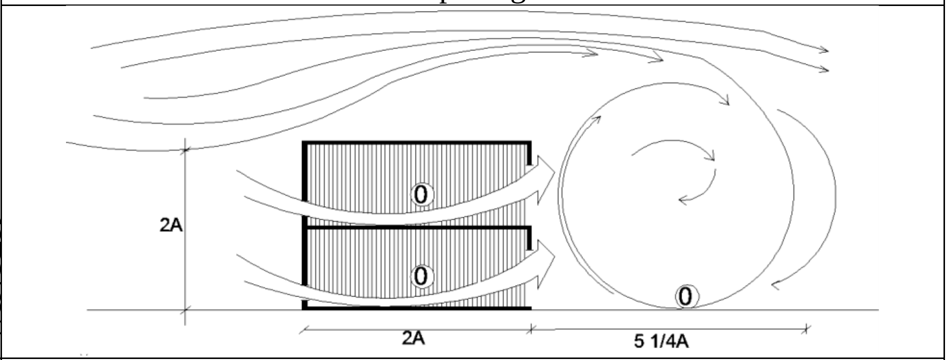
1opening west



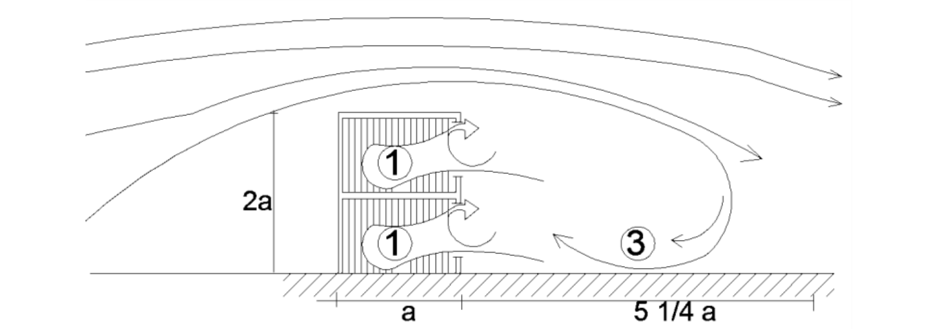
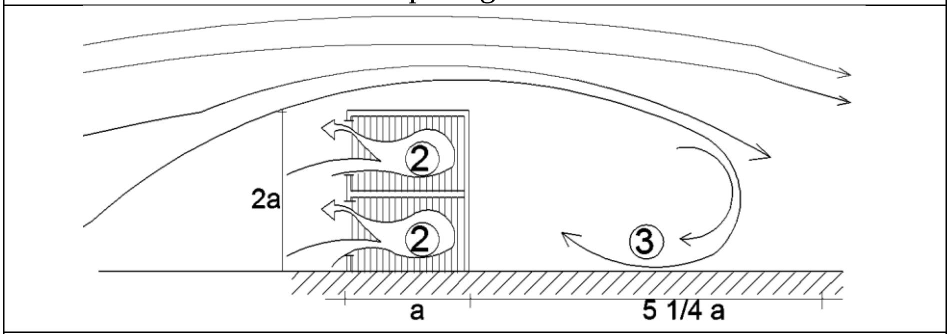
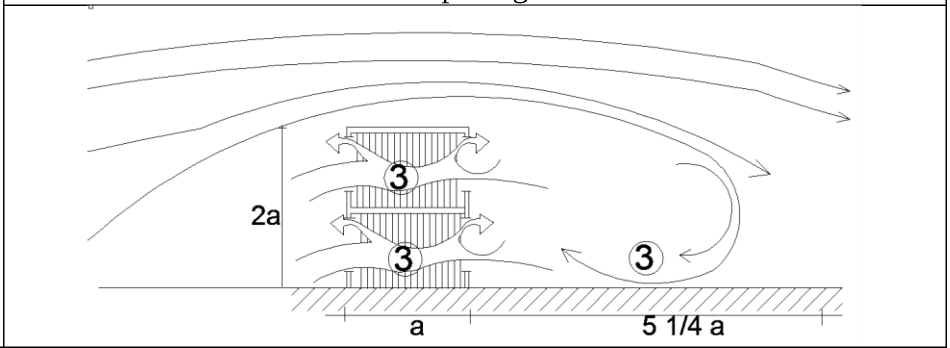
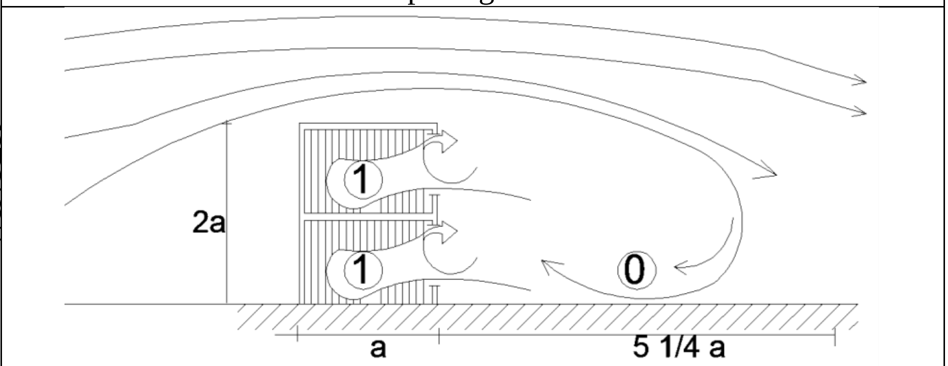
1opening east

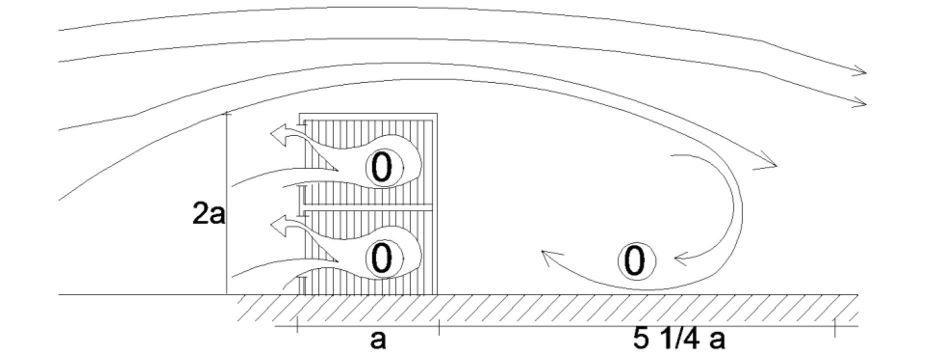
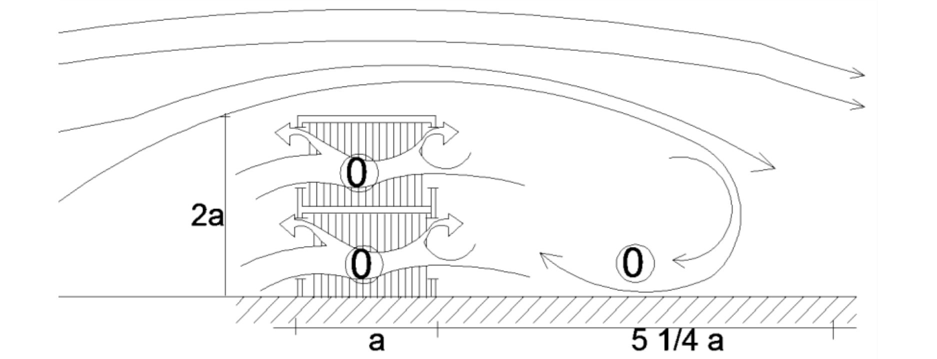


2openings

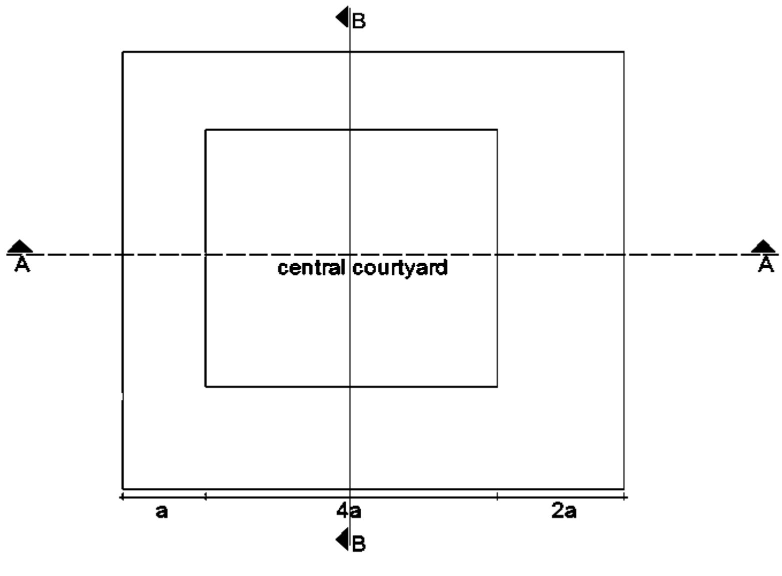
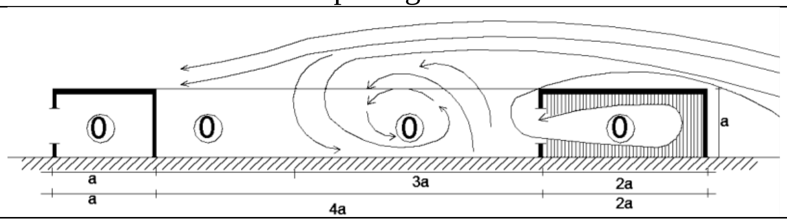


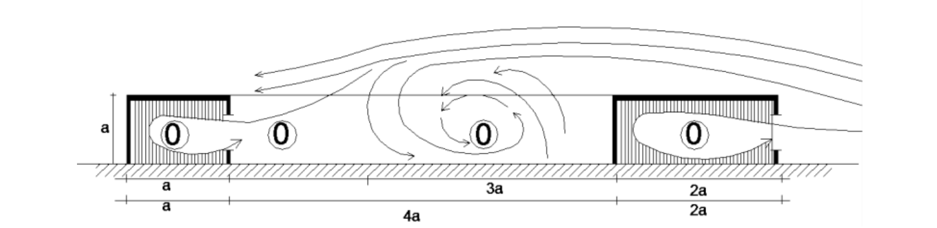
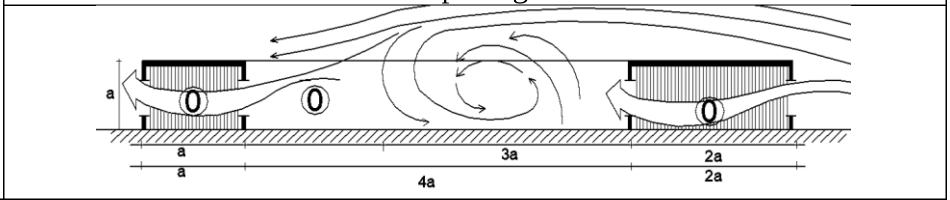
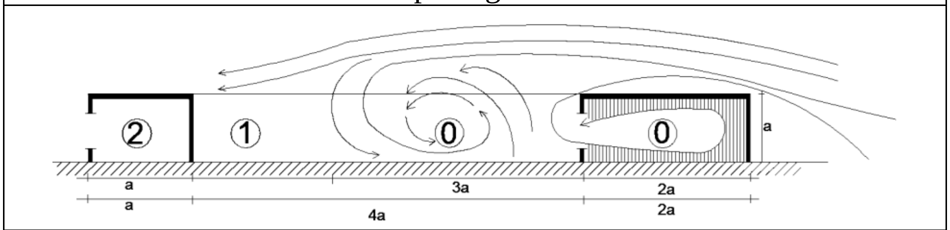
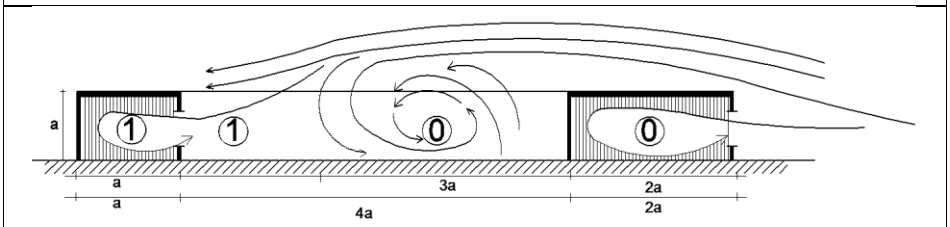
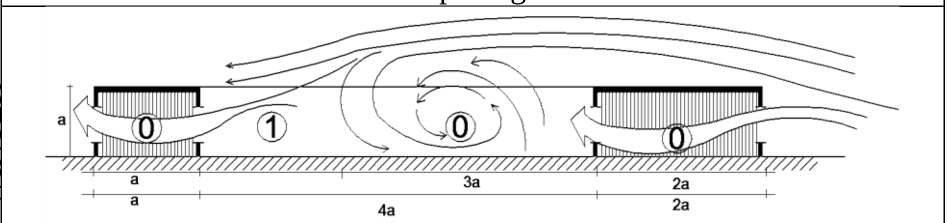
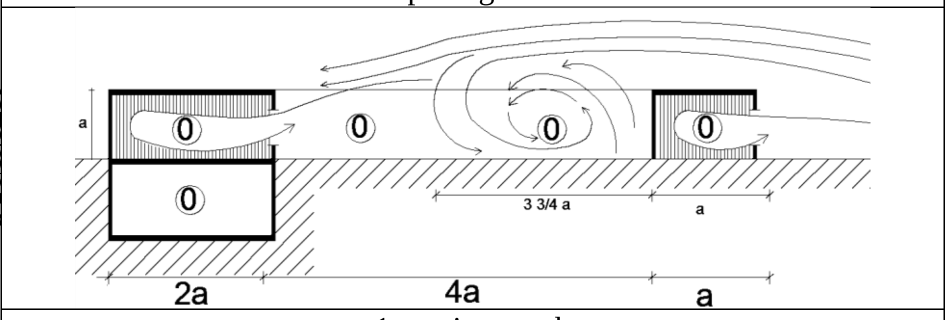
S e c | S | 1opening north

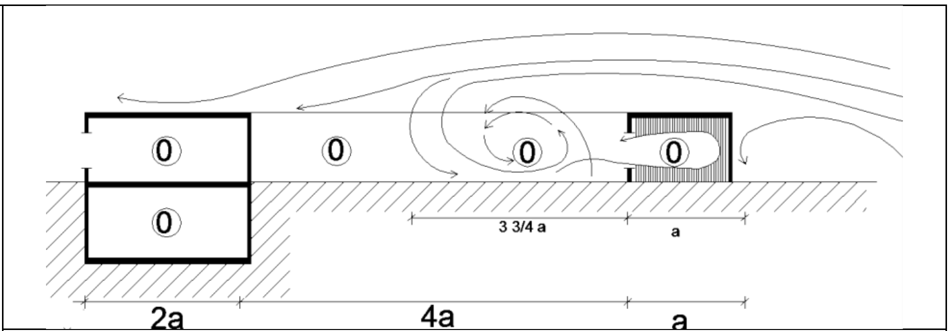
		
		1opening south
		
		2openings
		
Section B-B	WINTER	1opening north
		
		1opening south

		
		2openings
		

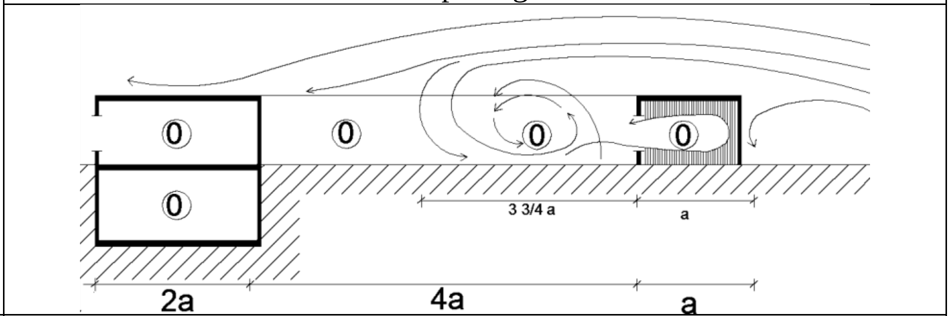
Appendix D: Justified Numbers for Sections A-A and B-B According to the Prevailing Wind Direction and Number of Openings During the Summer and Winter in Dezful

Schematic plan of traditional building		
Section A-A	SUMMER	1opening west
		

		1opening east
		
		2openings
		
Section A-A	WINTER	1opening west
		
		1opening east
		
		2openings
		
Section B-B	SUMMER	1opening north
		
		1opening south



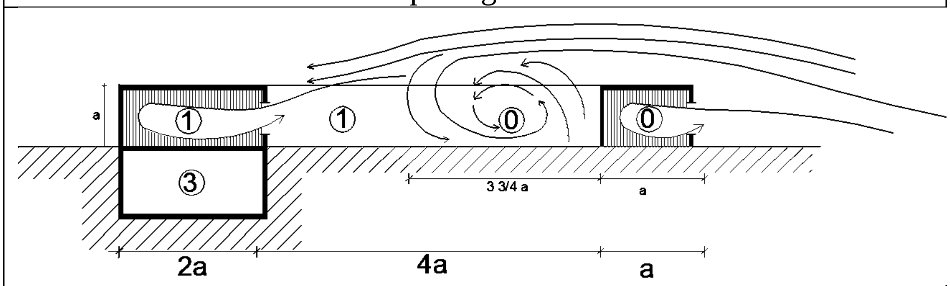
2openings



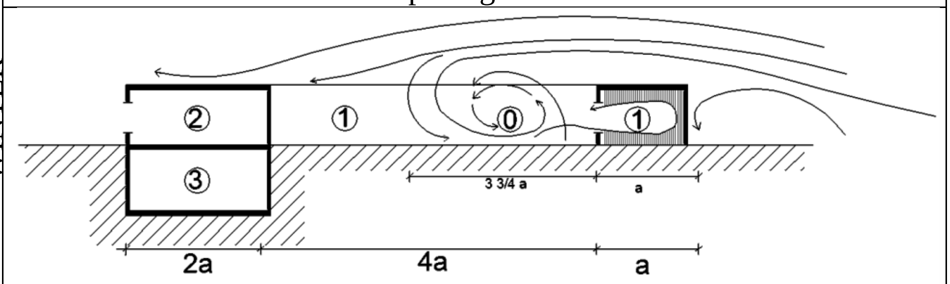
Section B-B

WINTER

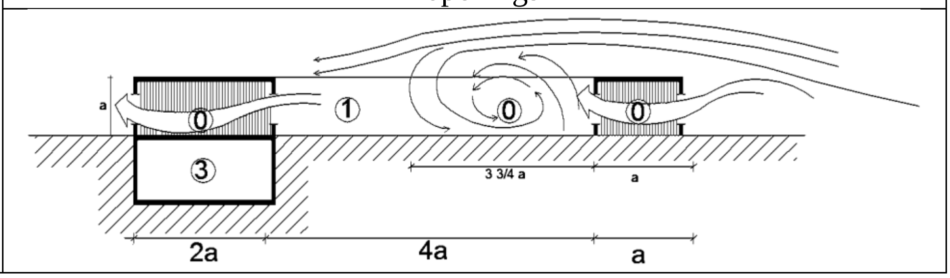
1opening north



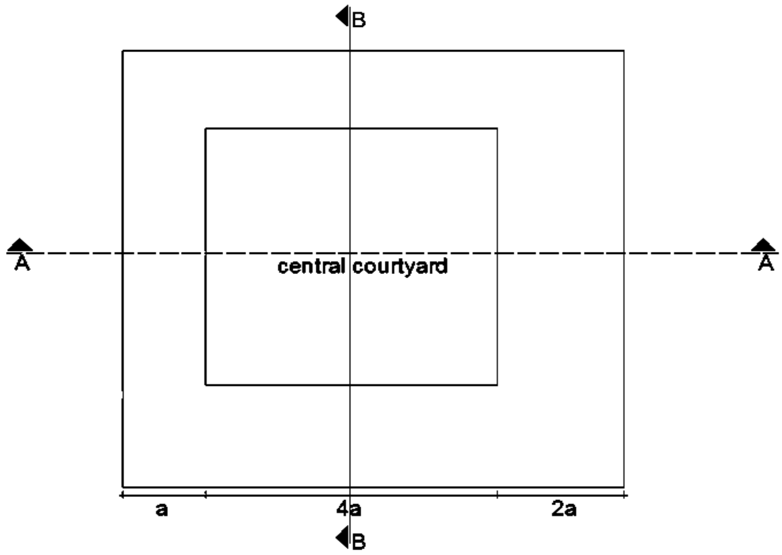
1opening south



2openings



Appendix E: Justified Numbers for Sections A-A and B-B According to the Prevailing Wind Direction and Number of Openings during the Summer and Winter in Kashan

<table>
<tr><td>Schematic plan of traditional building</td><td></td><td>
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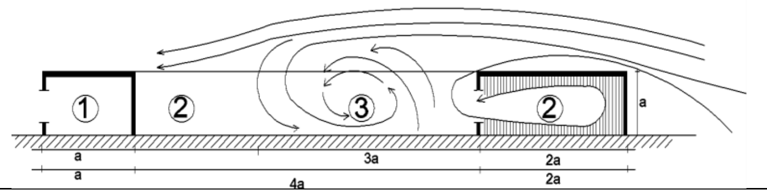
<tr><td>
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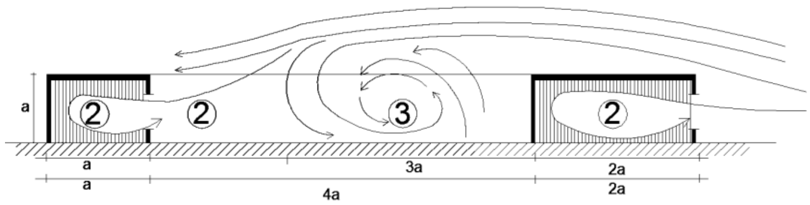
<tr><td>
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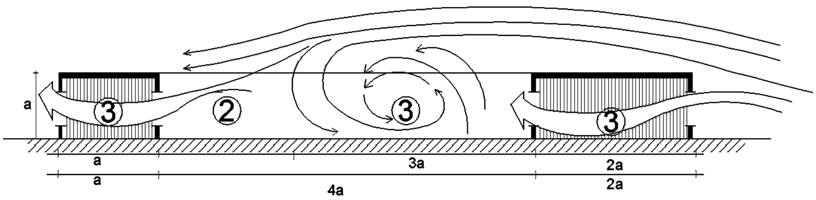
<tr><td>2openings</td></tr>
<tr><td>
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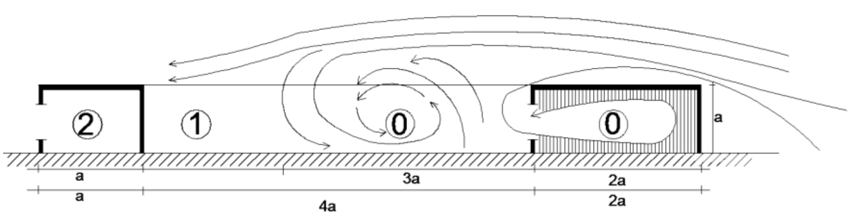
<tr><td>
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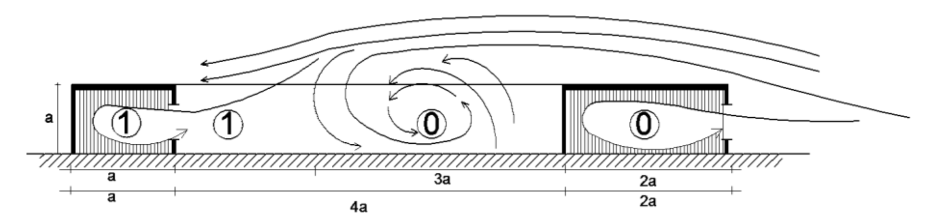
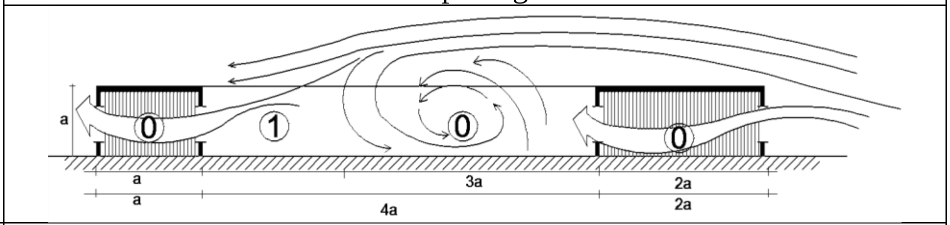


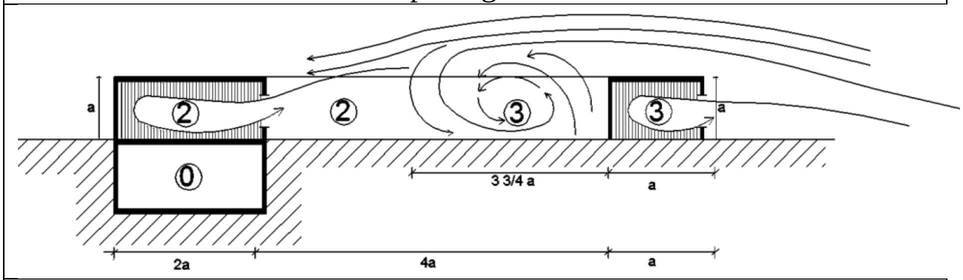
2openings



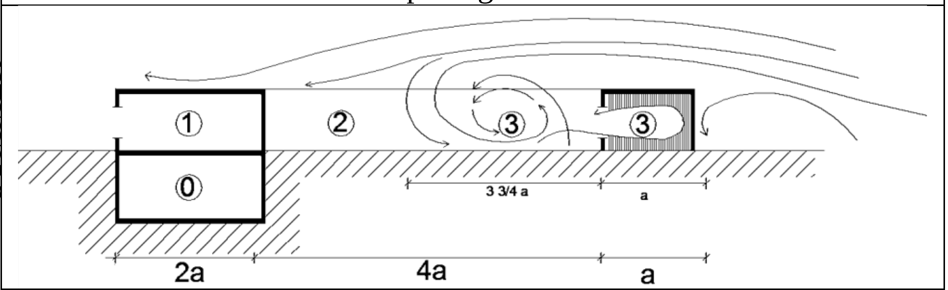
Section B-B

SUMMER

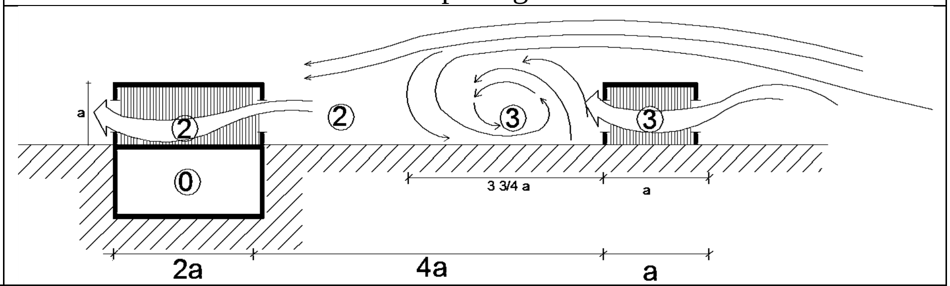
1opening north



1opening south



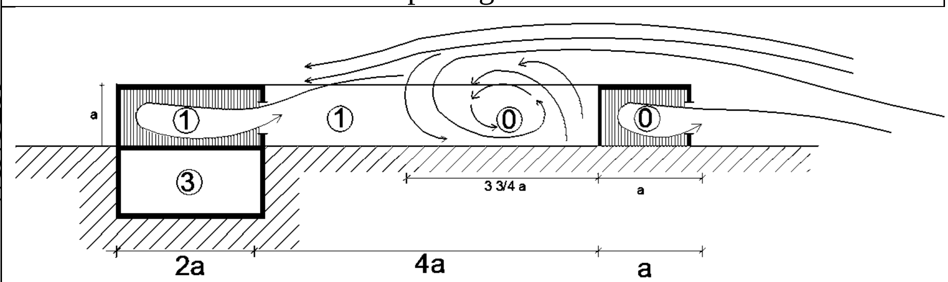
2openings



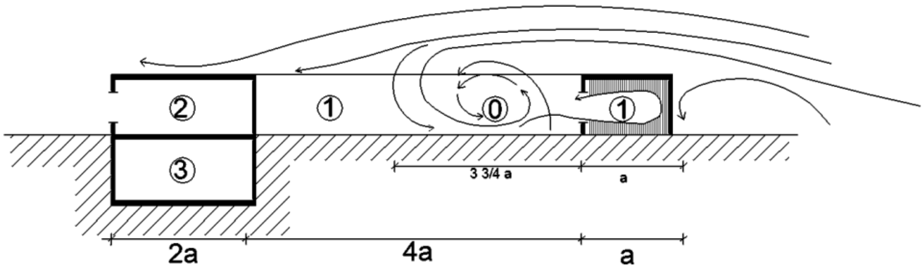
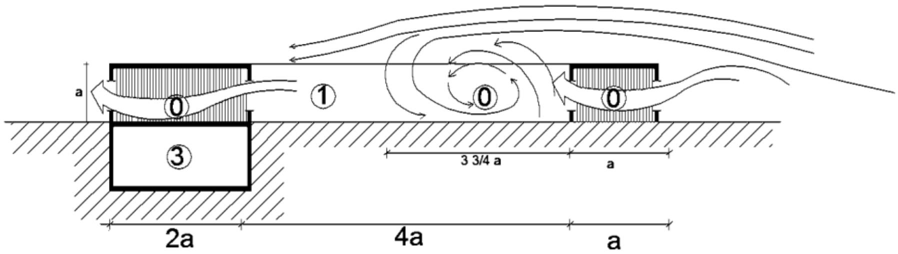
Section B-B

WINTER

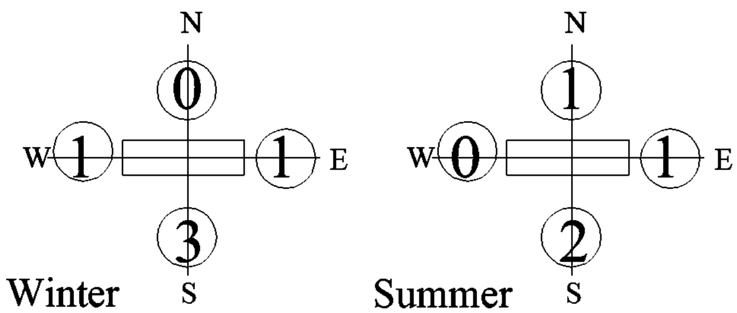
1opening north

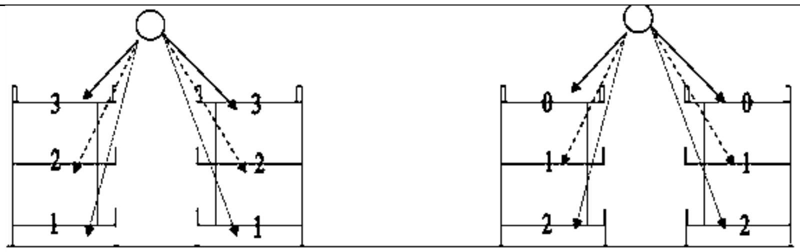
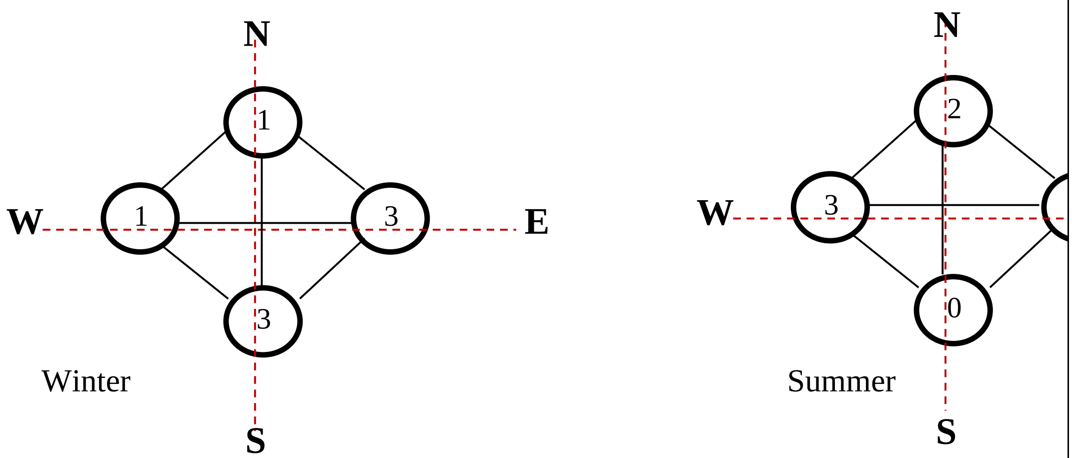
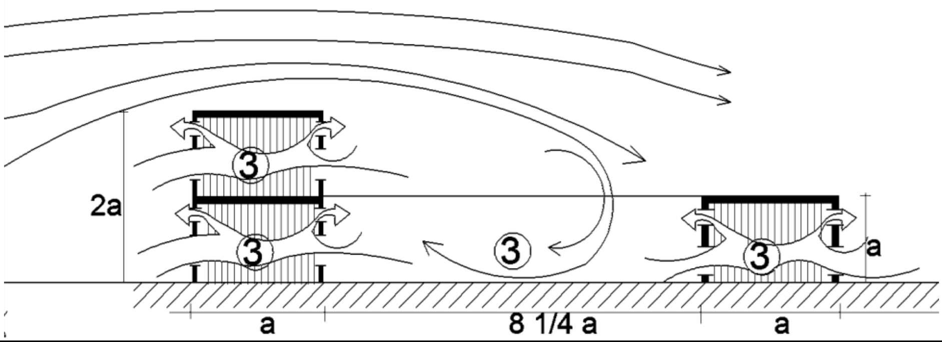
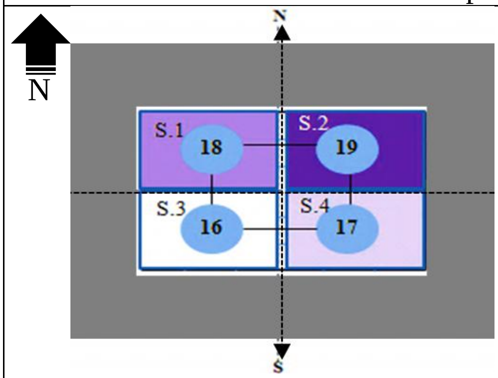
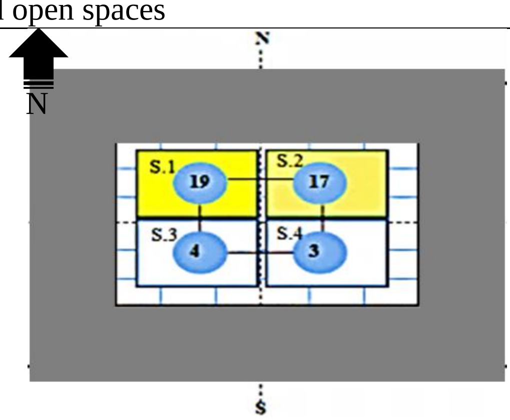


1opening south

		
		2openings
		

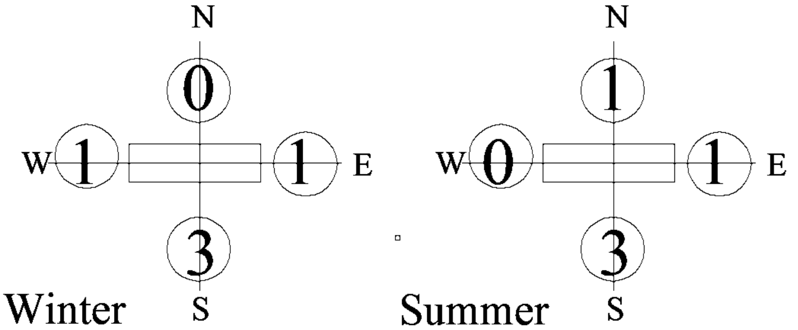
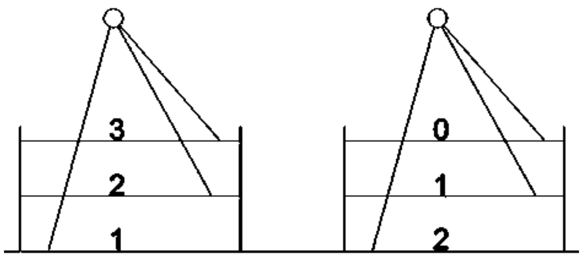
Appendix F: Justified graph method signifies the characteristics of hot-humid climatic regions in terms of thermal comfort factors

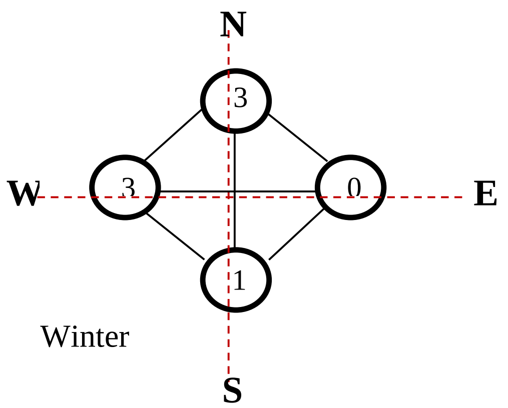
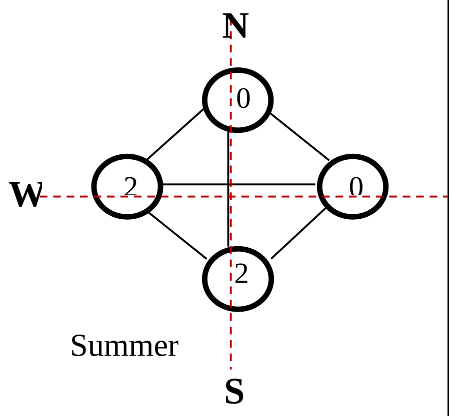
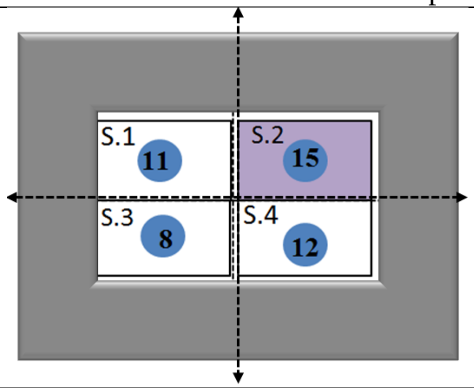
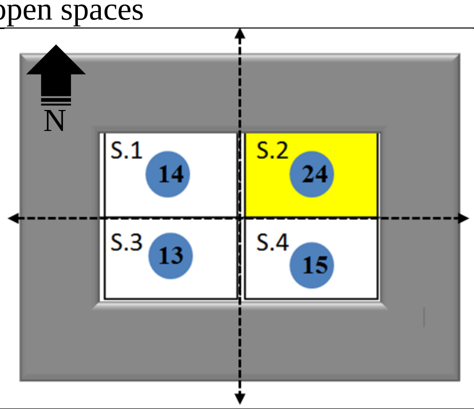
Justified graph method in terms of thermal comfort factors	
Bushehr city 29°N degree latitude (hot-humid climate)	
Close spaces	
Sun radiation (180° azimuth angle)	
	
Winter time	Summer time
Justified number for floors and roof	

	
Winter time	Summer time
Wind effect	
	
Winter time	Summer time
The best ventilated spaces during winter and summer time	
	
Summer time	
The best ratios of opening in different climatic regions of Iran defined by justified number 3	
10-20%(3)	
Semi-open and open spaces	
	

Summer time	Winter time

Appendix G: Justified graph method signifies the characteristics of hot-dry climatic regions in terms of thermal comfort factors

Justified graph method in terms of thermal comfort factors	
Dezful city 32°N degree latitude (hot-humid climate)	
Close spaces	
Sun radiation (180° azimuth angle)	
	
Winter time	Summer time
Justified number for floors and roof	
	
Winter time	Summer time

Wind effect	
	
Winter time	Summer time
The best ventilated spaces during winter and summer time	
The air temperature during summer time is higher than the body temperature thus wind has negative effect consequently, the author did not consider the wind for ventilating the spaces in hottest month of a year.	
The best ratios of opening in different climatic regions of Iran defined by justified number 3	
20-30%(3)	
Semi-open and open spaces	
	
Summer time	Winter time

Appendix H: Justified graph method signifies the characteristics of hot-dry with cold winter climatic regions in terms of thermal comfort factors

Justified graph method in terms of thermal comfort factors
Kashan city 33°N degree latitude (hot-dry with cold winter climate)
Close spaces
Sun radiation (180° azimuth angle)

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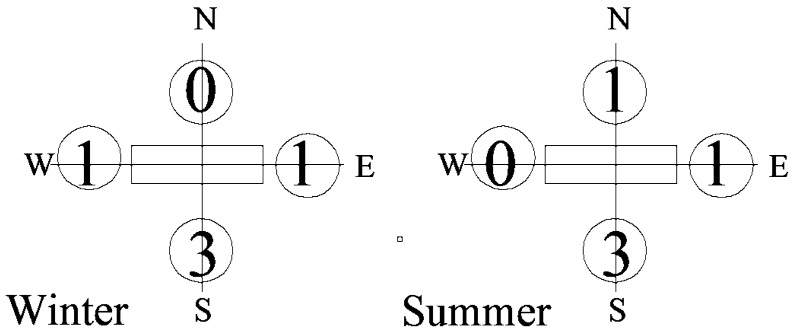
<tr><td colspan="2">
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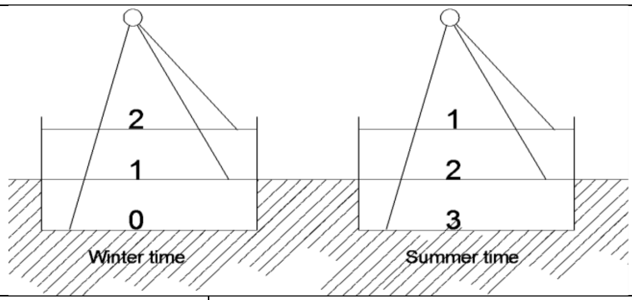
<tr><td>Winter time</td><td>Summer time</td></tr>
<tr><td colspan="2">Justified number for floors and roof</td></tr>
<tr><td colspan="2">
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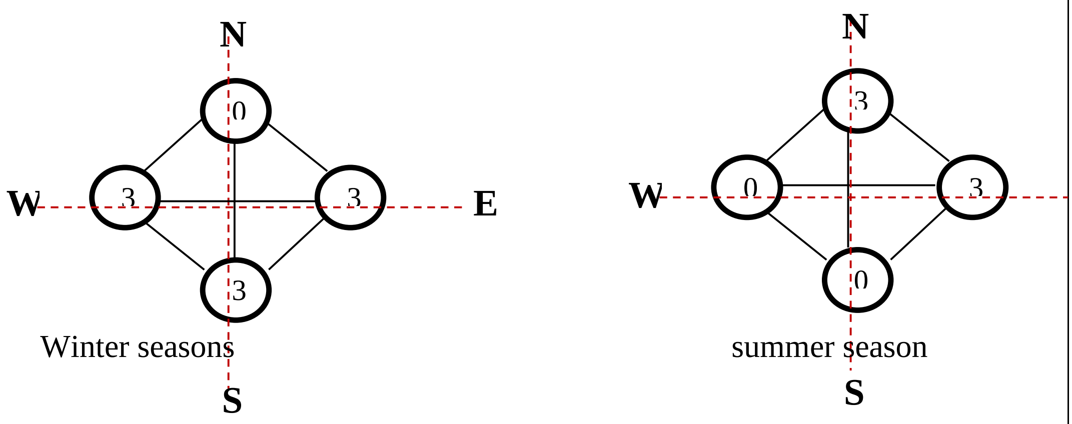
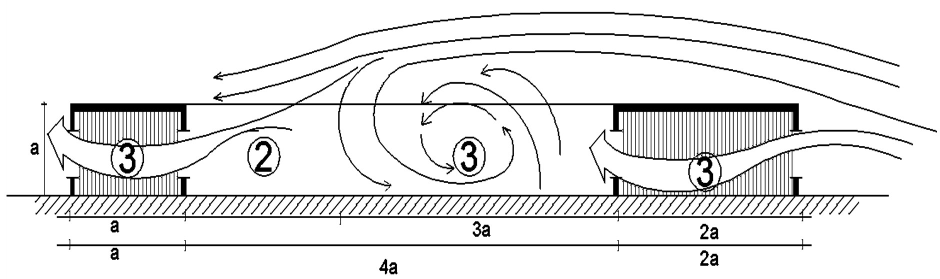
<tr><td colspan="2">Wind effect</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Winter time</td><td>Summer time</td></tr>
<tr><td colspan="2">The best ventilated spaces during summer time</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td colspan="2">Summer time</td></tr>
<tr><td colspan="2">The best ratios of opening in different climatic regions of Iran defined by justified number 3</td></tr>
<tr><td colspan="2">20-30%(3)</td></tr>
<tr><td colspan="2">Semi-open and open spaces</td></tr>
</table>

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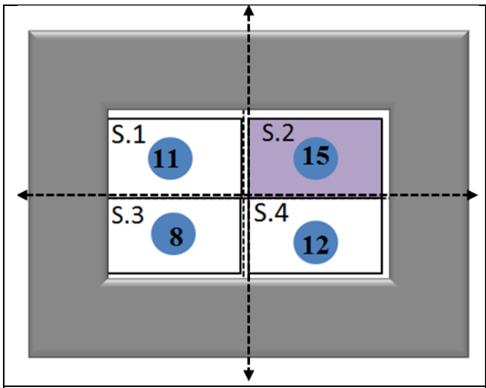
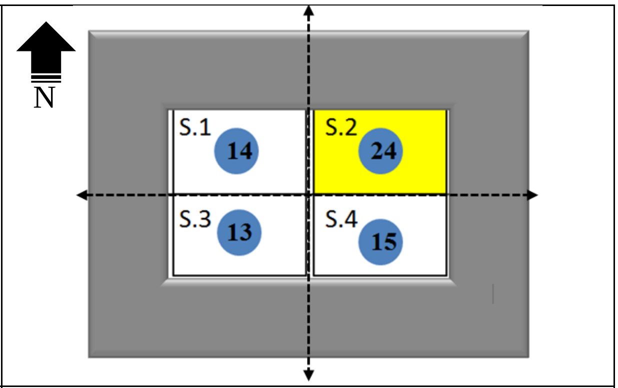
<tr><td>
</td><td>
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<tr><td>Summer time</td><td>Winter time</td></tr>
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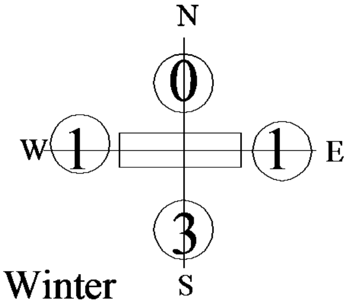
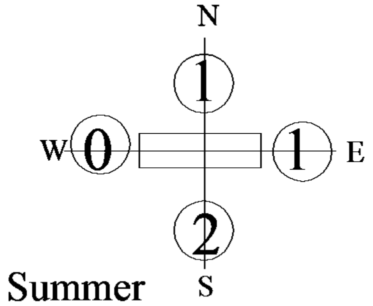
Appendix I: Justified graph method signifies the characteristics of cool climatic regions in terms of thermal comfort factors

<table>
<tr><td colspan="2">Justified graph method in terms of thermal comfort factors</td></tr>
<tr><td colspan="2">Urumye city 37°N degree latitude (hot-humid climate)</td></tr>
<tr><td colspan="2">Close spaces</td></tr>
<tr><td colspan="2">Sun radiation (180° azimuth angle)</td></tr>
<tr><td>
</td><td>
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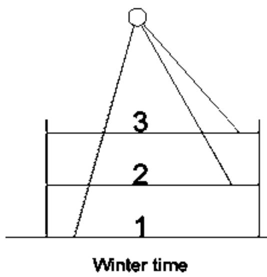
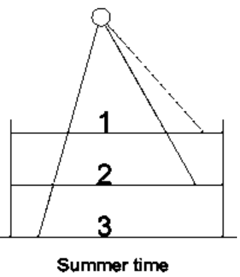
<tr><td>Winter time</td><td>Summer time</td></tr>
<tr><td colspan="2">Justified number for floors and roof</td></tr>
<tr><td>
</td><td>
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<tr><td>Winter time</td><td>Summer time</td></tr>
<tr><td colspan="2">Wind effect</td></tr>
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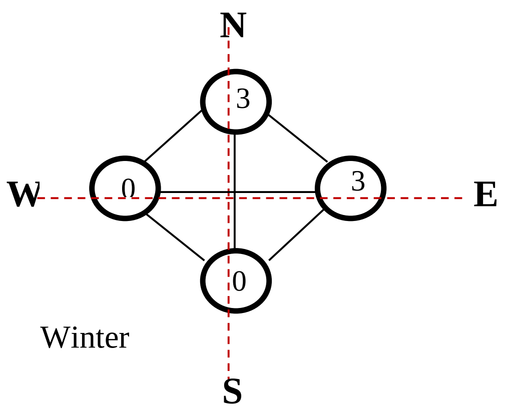
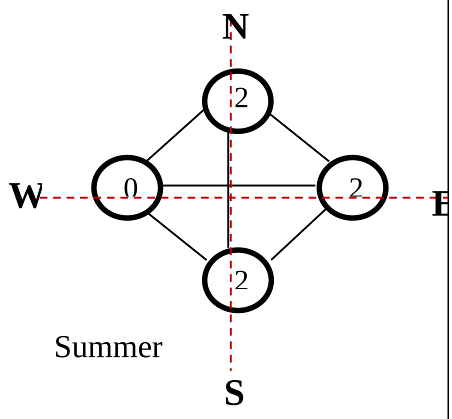
<table>
<tr><td>
</td><td>
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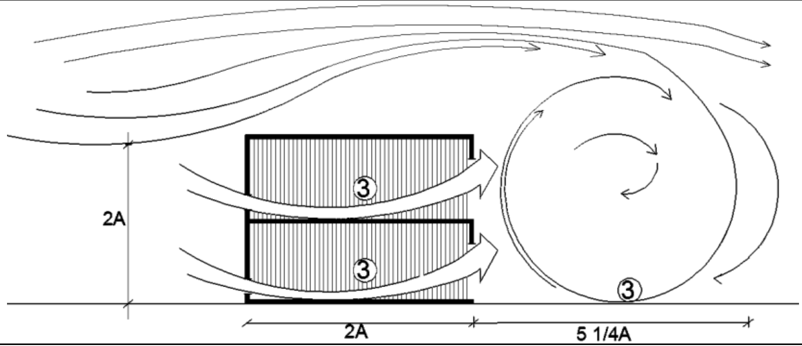
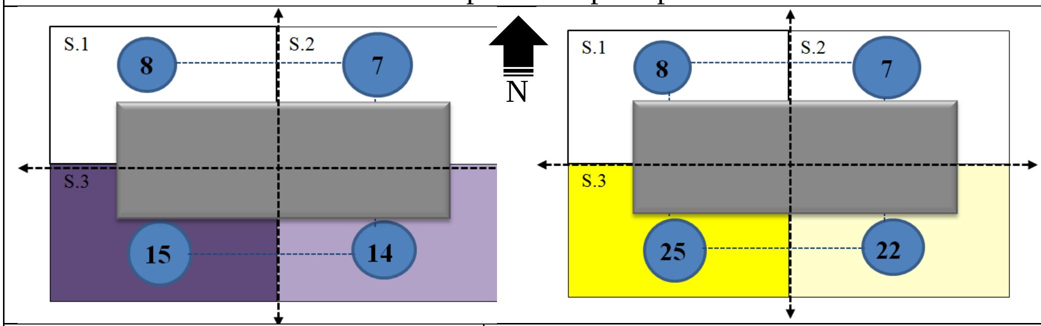
<tr><td>Winter time</td><td>Summer time</td></tr>
<tr><td colspan="2">The best ventilated spaces during summer time</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td colspan="2">Summer time</td></tr>
<tr><td colspan="2">The best ratios of opening in different climatic regions of Iran defined by justified number 3</td></tr>
<tr><td colspan="2">30-40%(3)</td></tr>
<tr><td colspan="2">Semi-open and open spaces</td></tr>
<tr><td colspan="2">
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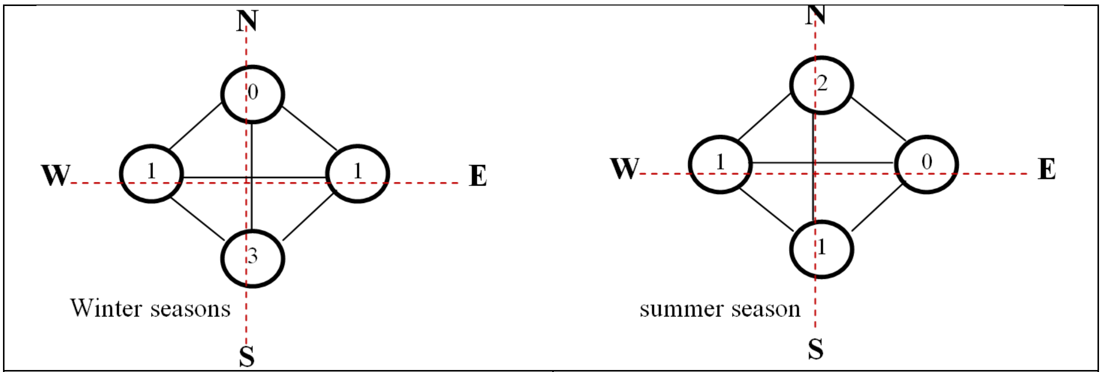
<tr><td>Summer time</td><td>Winter time</td></tr>
</table>

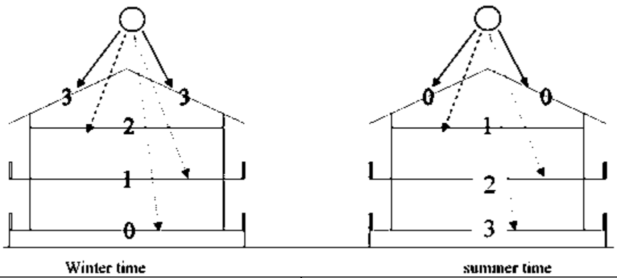
Appendix J: Justified graph method signifies the characteristics of temperate-humid climatic regions in terms of thermal comfort factors

Justified graph method in terms of thermal comfort factors
Rasht city 37°N degree latitude (hot-humid climate)
Close spaces
Sun radiation (180° azimuth angle)



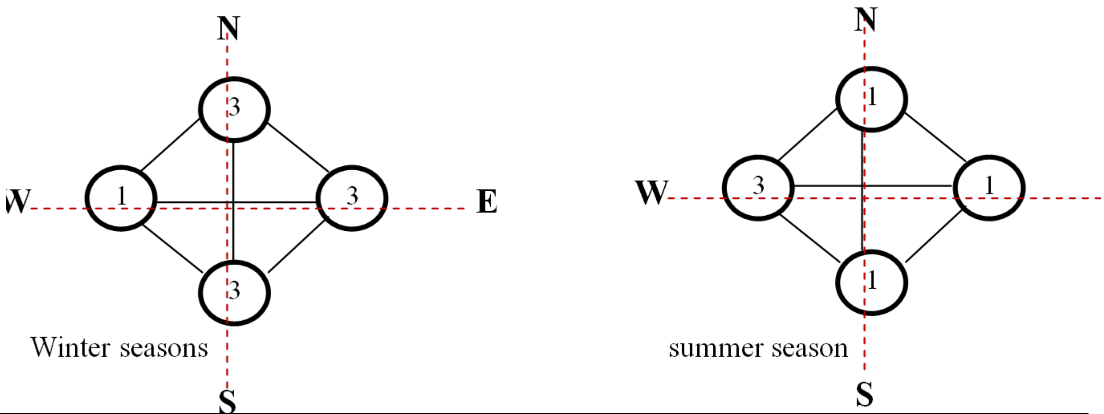
Winter time	Summer time

Justified number for floors and roof



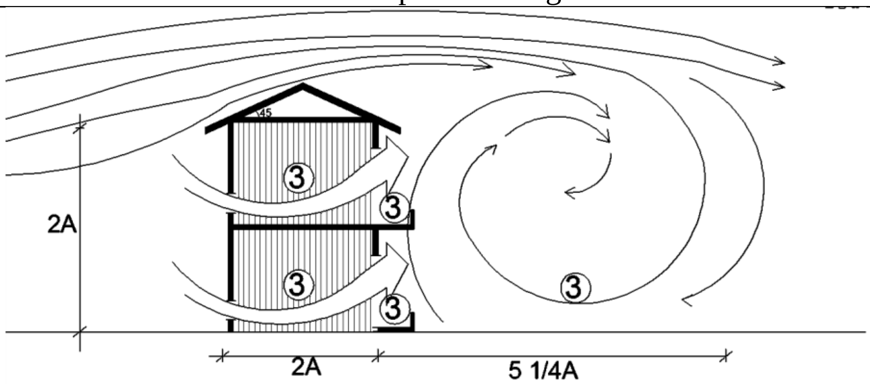
Winter time	Summer time

Wind effect



Winter time	Summer time

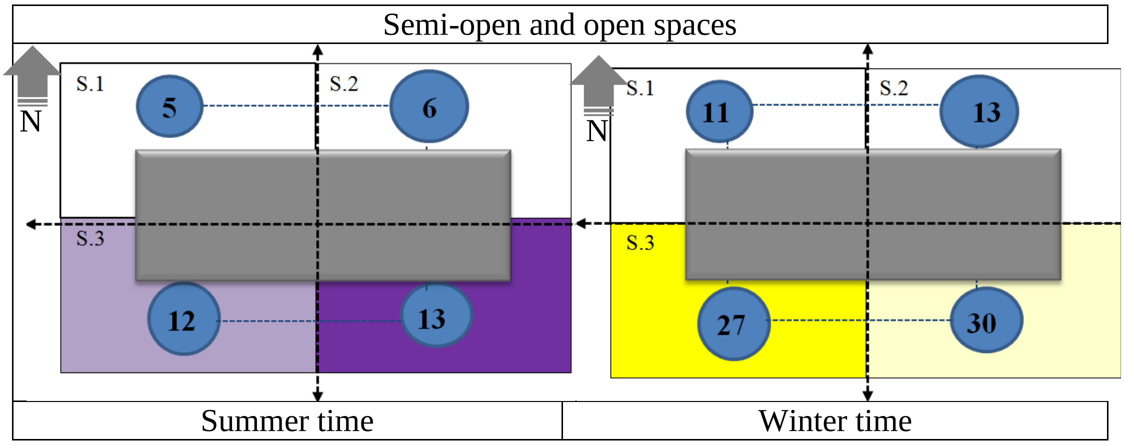
The best ventilated spaces during summer time



Summer time

The best ratios of opening in different climatic regions of Iran defined by justified number 3

40-80%(3)


Semi-open and open spaces
N
S.1
S.2
S.3
5
6
12
13
N
S.1
S.2
S.3
11
13
27
30
Summer time
Winter time