“Climatic Guides for Designing Open Spaces in Residential Complexes of Yazd”

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Climatic Guides for Designing Open Spaces in Residential Complexes of Yazd

Abstract

Human's disregard to nature and consequently his living environment's distance from natural endowments and potentials have caused many problems. Human's living spaces are less desirable for him, and have destroyed his comfort in many cases, as man-made things. In this regard, public open spaces in residential areas can be mentioned because they are usually considered among the most vulnerable spaces due to having the least thermal comfort and spatial quality. This is because they are able to provide comfort only if they interact with nature and use natural energy sources such as sun, wind, plants etc. In this regard, this study focused on providing comfort specifically thermal comfort in residential public open spaces by using natural endowments and energies especially the sun and shade provided by solar radiation.

This study aimed to analyze the climatic factors in Yazd meteorological station, especially the temperature and radiation analysis and making this information meaningful regarding human's thermal comfort in open spaces to introduce the climate potentials specifically the sun. Then, some traditional houses in Yazd were analyzed, their length, width and heights were surveyed, the real shade masks of the walls in yards were measured, and a logical relationship was observed between solar radiation and yard proportions and how the shade is formed in these yards. Therefore, it could be concluded what the role of these proportions and the best yard proportions is to provide the thermal comfort in open spaces.

Key words:

Climate, open spaces, shade and sun mask, thermal comfort

1. Introduction

With the rapid advancement in technology and the increase of urbanization process, human's living spaces have lost its vital connection with nature. Disregard to nature and natural potentials in the present era has caused many problems for human beings. These include environmental pollution, adverse psychological consequences resulting from separation from nature, destruction of fossil energy resources etc. and finally depriving human from health and comfort.

So, being exposed to these crises once again has led mankind to seek modern solutions to harmonize with nature and natural forces. Therefore, many thoughts are formed based on using natural forces and less dependence on non-renewable energies.

A building, even in the worst possible design, can be modified by spending money and using mechanical devices, but the specific nature of open spaces in residential complexes denies the possibility of modifying the situation and using mechanical cooling and heating equipment.

The present project attempts to investigate the possibility of making thermal comfort in open spaces of some traditional houses in Yazd by drawing the sun shade and mask. Designing residential complexes is not complete by disregarding the (public) open spaces. Considerable time of people's lives is spent in open environments (streets, neighborhood, etc) rather than the closed environment inside the building. In addition, climate control of open spaces impacts the people outside and inside buildings in two ways namely direct and indirect. The direct impact is on the welfare of people in open spaces which could desirably impact their presence and experience of the space and consequently impact the life and joy of the complex by appropriate designing of public open spaces. The indirect effect is on environmental regulation of the interior spaces by modifying the residential complexes at microclimate and mesoclimate.

2. Literature review

In studies of domestic architecture and sustainable architecture, general studies have been conducted on receiving the maximum and minimum energy that specifically has dealt with interior spaces, but so far no applied study has been conducted with specific details on the impact of energy intake in relation to open spaces of residential complexes.

3. Methodology

Due to the presence in the location and case study of houses in Yazd, the study was conducted by observation, field study and library study. It was conducted in two general stages:

-Drawing the climate plan of houses (domestic residential architecture) in Yazd, through observation and field studies

-Drawing the sun and shade mask and sunshine investigation in each of the residential open spaces.

4. General introduction of Yazd city and types of yards in houses of Yazd

4.1-Yazd

Yazd has a long history according to historical books. For Zoroastrian, it is considered a holy city and a shrine for Persians of India and revered like the Mecca for Muslims. Yazd in Persian shares the root word for God and means pure, holy and worthy of praise and the creator of goodness.

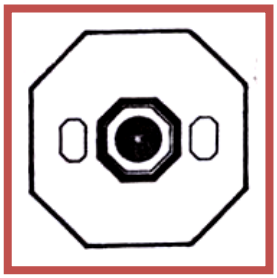
Yazd is located in the East of Isfahan and south of Lut desert and with latitude of 31 degrees and 25´ in the center of Iran. The absolute minimum mean temperature is 16 °C and the maximum absolute is 45 °C. The number of sunny days is 300 days thus Yazd has a desert climate.

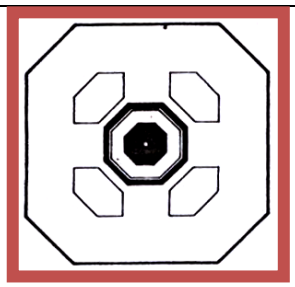
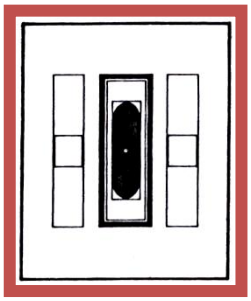
4.2 Types of yards

Yard is the heart of a traditional house and is the most private open space and this characteristic places the yard in a higher order than other open spaces. The houses only have the view of yard in a compressed format and back to back. Tall walls determine the exterior limit of the house from outside.

Types of typical yards in traditional houses are formed according to the material and spiritual needs and in compliance with hierarchy of private and public spheres. They are known as Narenjestan, Exterior and Interior [Table 1] and the yard dimension is proportional to the number and type of rooms around it.

Table 1: Types of yards in traditional houses in Iran

4-2-1-	Narenjestan yard	A very small yard with an area that can be covered in order to avoid citrus trees to get frostbitten in winter. In the book, Architectural Culture of Iran, Narenjestan is described as: a place that can be covered and orange and other trees can be planted in its garden. Narenjestan's yard is a small yard in the interior set and in addition to providing light for the surrounding spaces; it provides the possibility of keeping the plants that are sensitive to freezing nights of winter in desert areas .[1]	

4-2-2-	Exterior yard	It is a small square or rectangular yard which is open to guests and the ones who are not a relative and namahrams in the house.	
4-2-3-	Interior Yard	It is a big yard whose proportion accords with the location of the rooms around the house and at times it is very close to the garden size. This yard generally has a rectangular shape and is specifically for the family life, and in hierarchy of private and public spheres, it is the most private yard and others should not enter it.	

The unique features of such yards such as sitting lower than street level, the tall external walls and the solar orientation of the house, that is, the diameters of the yard fall on north-south axis or one of its sides align toward Qibla, which makes a construction that provides the highest shade during the hottest times of summer and the deepest penetration of warming sunlight to the depth of the rooms in winter.
By this solar orientation, the yard's four axes become specific areas and each front of the yard is allocated to a specific season.

5. Factors affecting thermal comfort in open spaces

5.1 Human and thermal comfort

One of the primary concerns of human beings is to deal with unwanted heat and cold environment. Body organs particularly the brain cells have a desirable efficiency when they operate at a constant temperature. Therefore, to gain physical and mental comfort, the body temperature should remain constant despite changes in the surrounding temperature and if, by proper designing, the surrounding temperature is controlled and kept constant, the activity of body organs to regulate and stabilize the heat would be reduced, the efficiency of physical and mental abilities will increase. Hence, thermal comfort is defined as the sum of situations that human mind is satisfied with its surrounding (thermal) environment. [2]

5.2 Factors affecting thermal comfort in public open spaces

Thermal comfort is defined as the sum of situations that human mind is satisfied with its surrounding (thermal) environment. According to the definition, thermal comfort is a range of temperature and humidity in which mechanisms of body temperature regulation has its least activity [3]. Creating thermal comfort in open spaces is not possible unless gaining a thorough understanding of the factors affecting the thermal condition of these spaces because these factors change their surrounding climatic factors by intensifying or weakening the climatic factors at micro-scale. Therefore, first we need to know the influential factors. Based on the research, among the natural factors affecting thermal comfort, solar radiation and man-made structures will be considered more.

Solar radiation is among the most important heating and cooling natural energies which affects the environment temperature and increases or decreases it. The man-made structures also include orientations, dimensions of buildings and open spaces, density, height, geometry, material form etc. [4]

6. Analysis of Yazd climate information

This section aims to make the climate information of Iran's Meteorological Organization applicable. In other words, we want to know what effects temperature and solar radiation among all the climate factors have based on thermal comfort. Since 64.66% of the country's land area of 1,046,446 square kilometers is in arid and ultra-arid climate [5], determining the range of thermal comfort in this climate was a priority. Therefore, Yazd, located at longitude of 054°24'E and altitude of 1230 meters above sea level, with dry and cold climate and no humid month was considered an ideal example of arid climate [6].

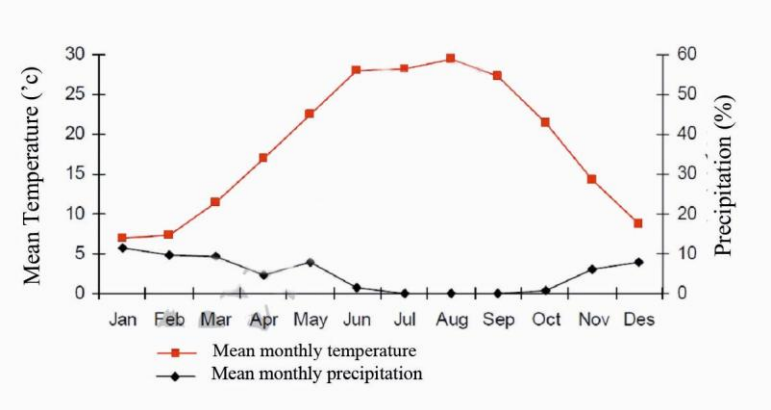


Figure 1-Climagram of Yazd station from 1997 to 2006. [7]

6.1- Detection of heat and cool and comfort times

According to Penwarden criteria and based on temperature reports from meteorological station of Yazd, comfort times, times of solar energy or wind needs and heat and cool times in open spaces are detected. Temperature of 16 to 22 °C creates a sense of definite comfort. Temperature of 4 to 16 °C and 21 to 25 °C, respectively, give a sense of comfort at sunny and windy conditions. At temperatures higher than 25 °C, the weather is hot and even the wind does not help to relieve the hot weather. It is cold at -4 °C with the sun and no wind, and at lower than 3 °C at nights with no wind [8].

By calculating the mean monthly and annual relative humidity and the mean monthly and annual dry temperature of Yazd station during the statistical period of 10 years, 1997 to 2006, (Table 2) and determining the monthly and annual situation of the mentioned station on thermal comfort graph (Figure2), the upper and lower limits of thermal comfort in summer was modified based on Olgyay's chart [9]. To this end, given lower and upper limits of thermal comfort for Yazd city is 21.2 ° C and 28 ° C according to Olgyay's chart (Figure 2) and that Yazd city is located in northern latitude of '54, ^{0} 31, the resulting altitude difference of the location from the baseline latitude (40 °N) is 8.1°**.**

Table 2: The mean monthly and annual dry temperature and relative humidity of Yazd station (1997 to 2006),[10].

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Dry temperature	6.49	9.98	14.62	20.84	26.28	31.18	33.44	33.54	27.66	21.39	12.89	8.1	20.34
Relative humidity (%)	52.8	36.3	30.4	25.6	18.9	13.6	14.5	13.3	14.6	21.8	37.5	50.6	26.9

By checking the temperature every three hours and according to Penwarden diagram, times, heat, cold and comfort in open spaces is presented. The information in the mentioned table can be elaborated as follows. Heat is probable from early April to early May and from late October to late November from around 9 AM till sunset and from late June up to mid-August all day long. Cold is more likely from late night till dawn especially between 3 and 4 AM, from late December till late February. At times in December, January and February around noon and sometimes in the morning and evening of March, May and November, it is possible to feel comfortable. In other times of the year, it is possible to feel thermal comfort in case of proper utilization of radiation, shade and wind. (Meteorological organization's data of Yazd, thermal times, cooling, comfort in open spaces in Yazd)

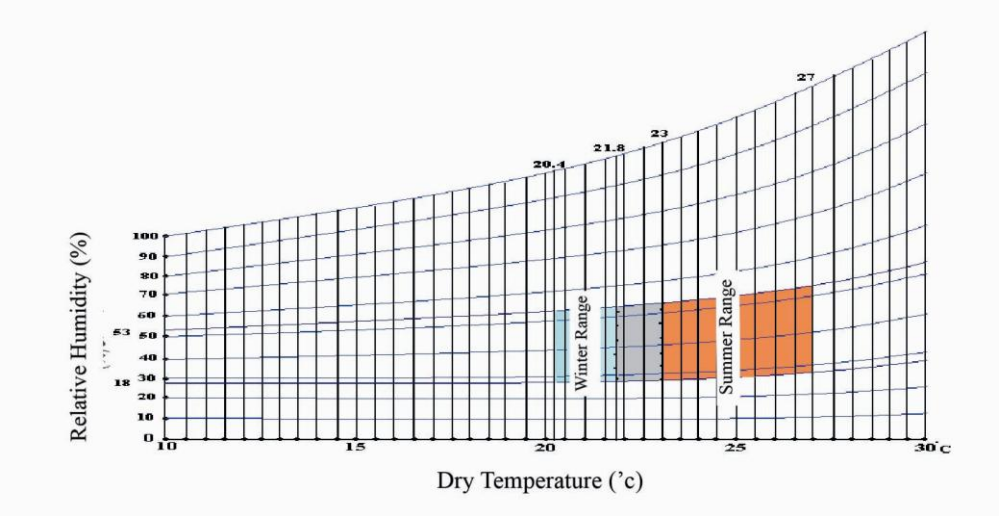


Figure 2: Table of bio-climate thermal comfort in summer and winter for the city of Yazd, [11].

6- 2 Determining the times that sun and shade are required

The sun and shade needs in open spaces are recognized according to Penwaden criteria and air temperature in Yazd meteorological station (Figure 3) (As can be seen on the vertical axis of this table as dry temperature, needed sunlight, etc). Thermal comfort is obtained in temperatures lower than 4.4 ° C in case of sunshine. The sunrise in open spaces is permitted from 4.4 °C up to 12 °C. In a temperature between 12 to 22 °C, the sunrise in open spaces has no problem. In a temperature above 22 °C, the sunshine is irritating [12]. By using the temperature data for every three hours in Yazd and according to Penwarden criteria, the times sun and shade are required in open spaces are presented in the table. The information of the mentioned table include: from early April till early June and from early September to early November from 9 AM till sunset and from early June to early September all day long, the sunshine disturbs people's comfort. In short times in the mornings in December, January and February, solar radiation is the only requirement to have comfort in open spaces. From late December till late January, from around 6 AM till sunset and sometimes during morning and evenings for short times in November, December, February and March, it is possible to tolerate the sun. In other times of the year, solar radiation is fine if the wind is blowing (Figure 3).

As can be observed in data from Yazd meteorological station regarding sunny times and cloud coverage in the sky, in 3 cold months of December, January and February in which according to shade and sun requirement, sunshine is rather essential and fine in open spaces, the weather is sunny in 50% of the times. In hot times from mid June till early October, the weather is sunny in 90% of the times. As can be interpreted from meteorological data and since Yazd is located in hot and dry desert climate, its sky is sunny most of the time.

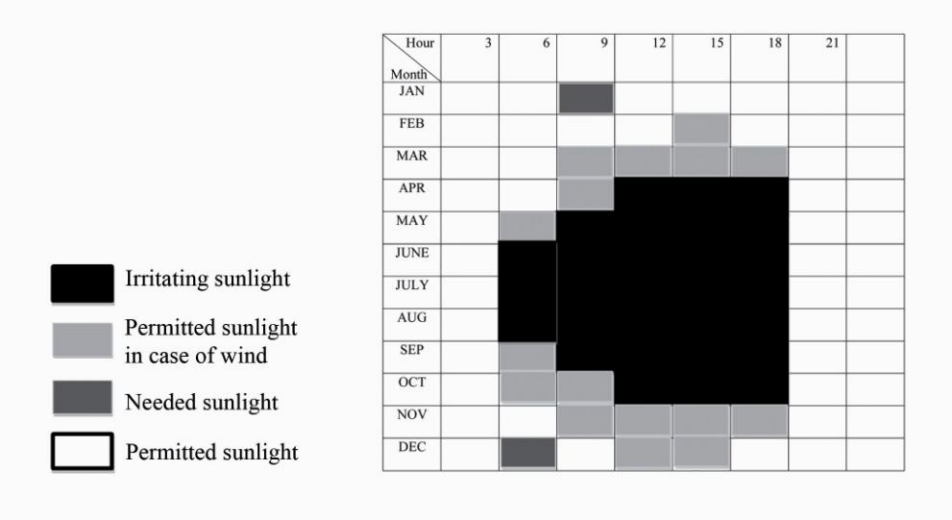


Figure 3- The times that shade and sun are required in open spaces of Yazd
(Yazd meteorological station data (1952-2000))

7. Analyzing the influence of man-made structures on thermal comfort

In this section, aiming to utilize these potentials and controlling the undesirable situation, the man-made structures of the residential complex (orientation, dimensions, proportions, materials and other things related to open spaces) will be analyzed. As mentioned, man-made structures in small and moderate scales affect the climate conditions, and create an artificial climate that is different from the meteorological data of the region. But how can this man-made climate be created in accordance with human thermal comfort by maximum use of the potential resources of the environment? In this regard, the effects of man-made structures on climatic phenomena such as weather temperature and radiation in residential complexes are investigated in this section. To investigate the effect of man-made structures on thermal conditions of open spaces, plan of several housing complexes in Yazd will be examined as subjects with certain assumptions.

As we know, sunlight is always necessary to create a natural lighting but since this light is converted to heat, it must be controlled based on climatic conditions. In open spaces such as streets, yards etc. what causes the increase in temperature due to solar radiation is the little heat that is directly taken from the sun and mostly from the indirect heat which is received from objects on the earth [13]. According to studies, the cooling effects of the plants in lowering the temperature in cities is felt when the area of green spaces encompass 10% to 20% of the city area. This can be found in the historical texture of Yazd city. Therefore, small dispersed green spaces are more effective in modifying the surrounding air in comparison with large, compacted green spaces [14].

Given the relationship between solar radiation, shade and temperature, in order to reach to a favorable state, the solar radiation intensity on various surfaces, sun and shade levels in open spaces and external walls of buildings should be controlled. Therefore, the ideal condition to utilize solar radiation is considered as follows: use of minimum radiation and heat (maximum shade) during the warm months and maximum utilization of radiation and heat (sun) during cold times of the year. Detection of sun and shade conditions in various levels (including open spaces and building) is performed with respect to the shade mask. Therefore, first the concept of shade mask is investigated from the perspective of the people residing in the complex.

7.1 Shades – Sun mask

The shade mask is determined in accordance to the people living in the complex, for instance, consider an observer standing in a wide area, environmental conditions are such that he can see the sky hemisphere from one horizon to the other, now if a dark object is placed in front of the observer's sight so that he cannot see a part of the sky and the sun is hidden from his sight (behind the mask) while passing that point, the person is placed in the shade. By drawing the hidden part figure on a horizontal surface using solar direction chart, the shade mask of the object is attained. This opaque object can be a tree or any vertical surface or cloud, horizontal shade and other types of horizontal surfaces [15]. The following figures clarify the concept of shade sun mask (Figure 4 and 5).

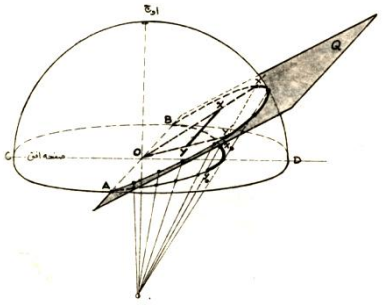


Figure 4- Stereograph of a direct horizontal line shade mask,[16]

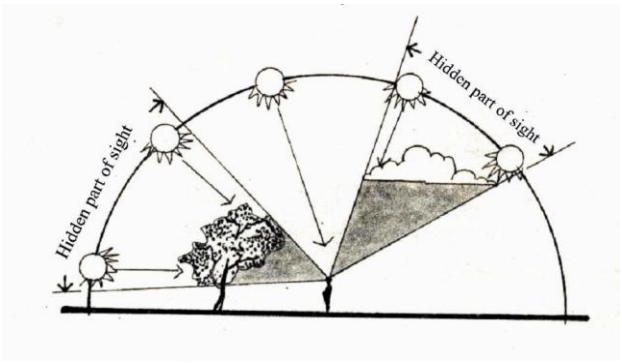


Figure 5- Opaque objects such as tree, cloud etc that hide a part of sky hemisphere,[17]

7.2 The sun and shade mask in yard

According to the concept of shade mask, a yard is considered to be in a shade when the sun in the sky cannot be observed from inside the yard; otherwise the yard is located in a sunny area. In yards etc., the proportion issue (the proportion of wall heights H, to width W) and orientation are considered as important factors in determining shade and sun in open spaces which can be an important factor in thermal comfort of open spaces. In this regard, by investigating the real shade mask of several yards of Yazd houses, the relationship of yard proportions such as length, width and height and the size of shade can be found.

8. Investigation of shade and sun mask in several houses of Yazd

The purpose of investigating shade and sun mask in several houses of Yazd is to reach guidelines and rules for thermal comfort in open spaces of residential complexes such as issuing climatic rules for the best orientation and the best yard proportions. In this regard, real shade and sun mask was investigated for 10 old houses in Yazd which provided the best thermal comfort without any mechanical or electronic utilities. This could be a great help for designers to provide the thermal comfort in open spaces of residential complexes nowadays. The studied houses are located almost in one district. Their names are as follows: Arab Mohit's house, Ebrahim Pour's house, Fazeli's house, the Laris' house, Malek Zadeh's house, Koochak Arabha's house, Nazeri's house, Shahid Sadooghi's house, Shafi Pour's house, an old house in Yazd. The investigation of dimensions and proportion of yards and their real shade and sun mask is presented in the following table:

Table 3: the summary of investigation on Yazd houses data

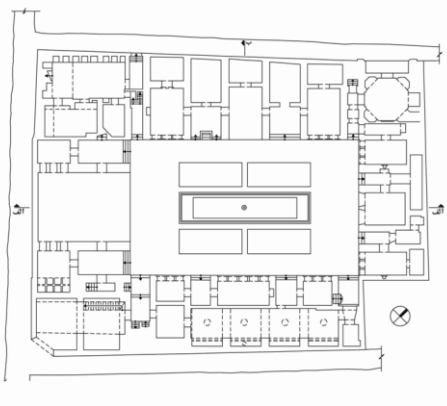
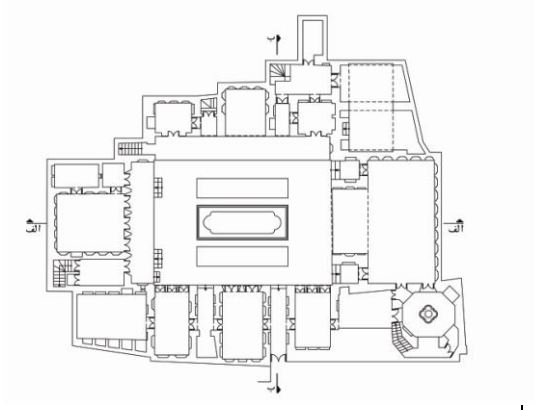
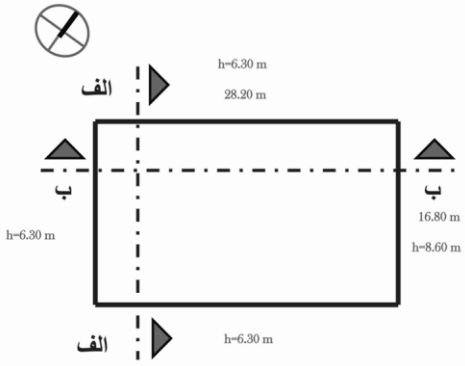
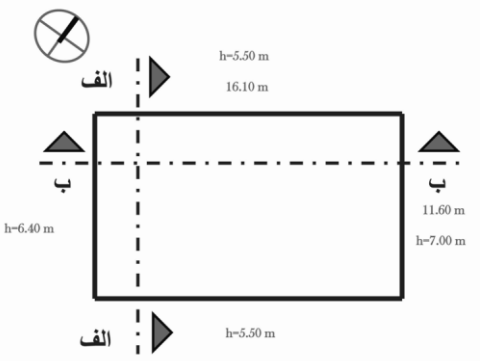
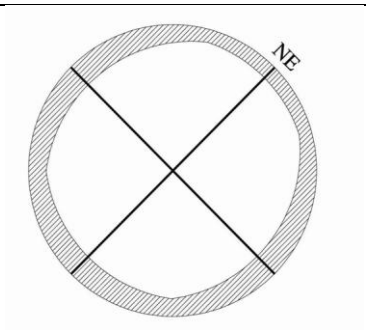
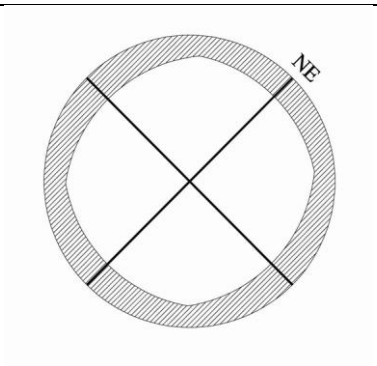
	Laris' house	**Arab Mohit's house**
Plan		
Proportions and yard's wall sizes		
Yard's orientation		
Proportion of length, width and height of yard	H/W=0.38 L/W=1.70	H/W=0.41 L/W=1.40

Table 3: the summary of investigation on Yazd houses data

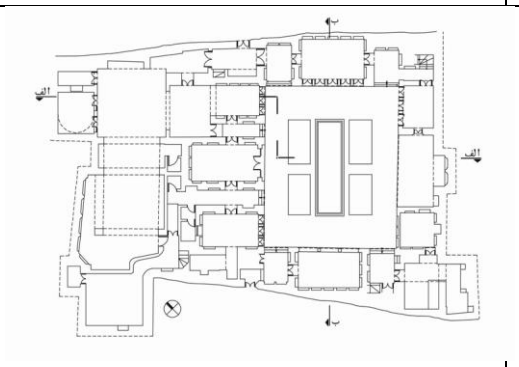
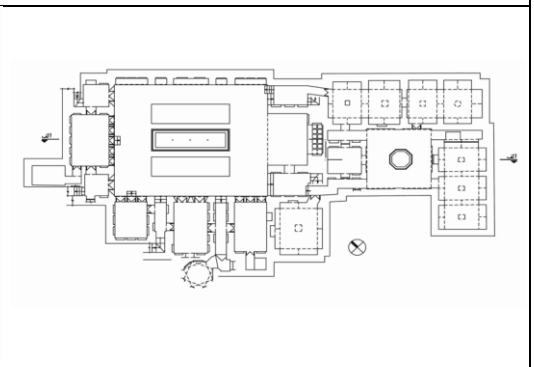
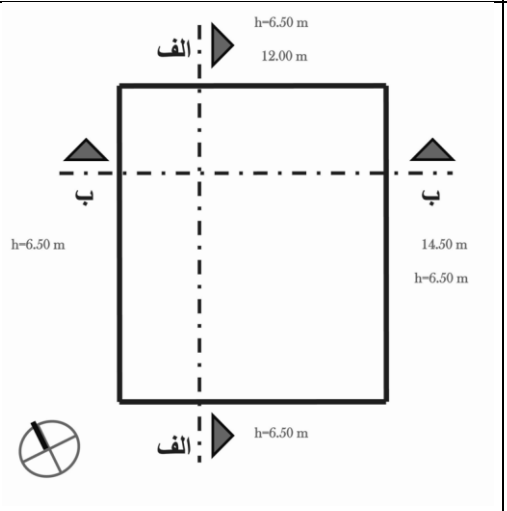
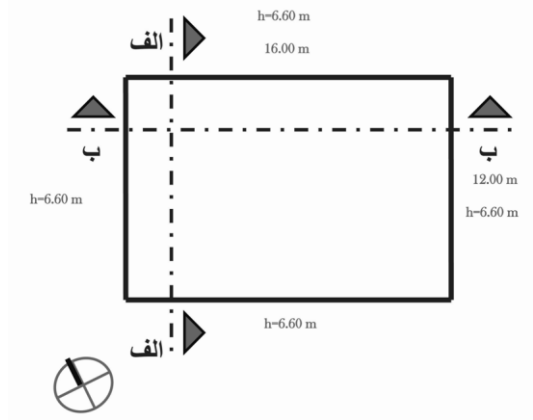
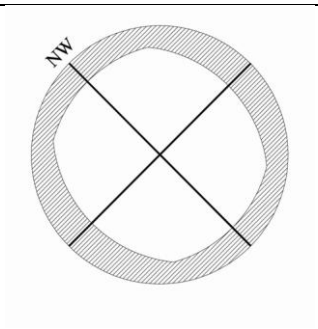
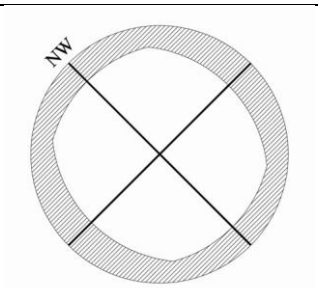
	Shahid Sadooghi's house	Malek Zadeh's house
Plan		
Proportions and yard's wall sizes		
Yard's orientation		
Proportion of length, width and height of yard	H/W=0.54 L/W=1.20	H/W=0.54 L/W=1.20

Table 3: the summary of investigation on Yazd houses data

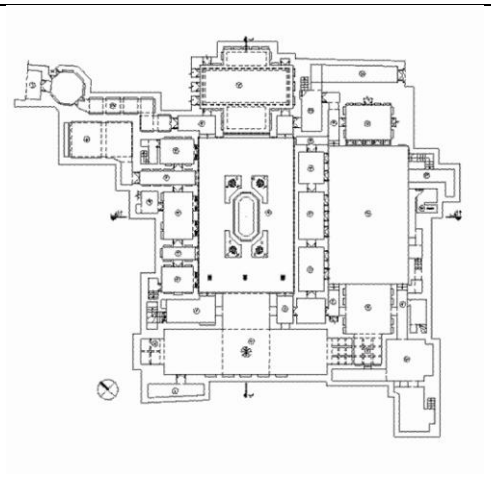
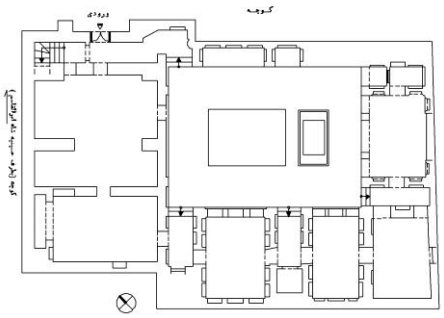
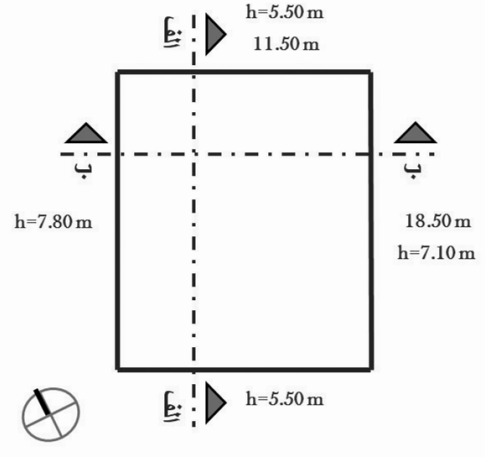
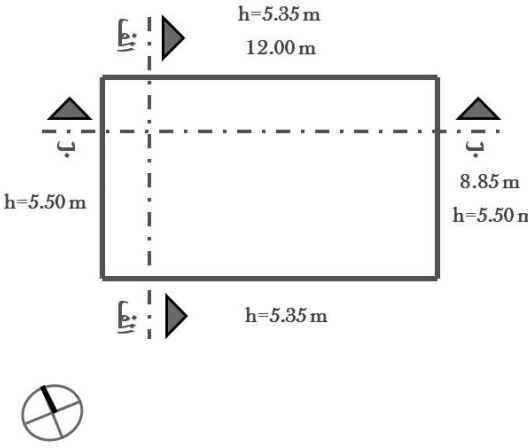
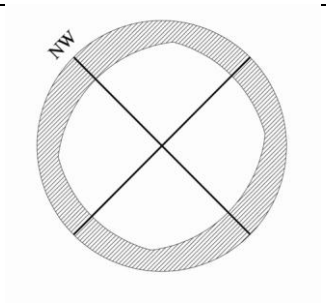
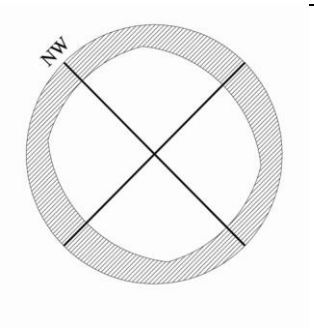
	Shafi Pour's house	Ebrahim Pour's house
Plan		
Proportions and yard's wall sizes		
Yard's orientation		
Proportion of length, width and height of yard	H/W=0.65 L/W=1.60	H/W=0.44 L/W=1.35

Table 3: the summary of investigation on Yazd houses data

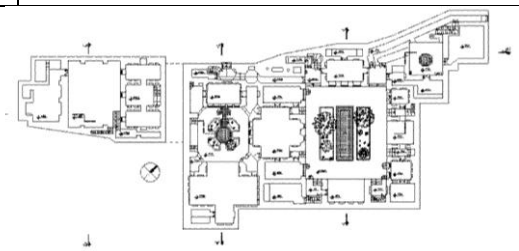
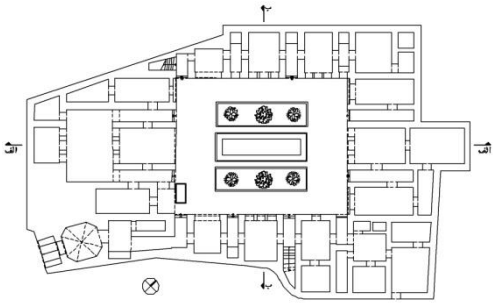
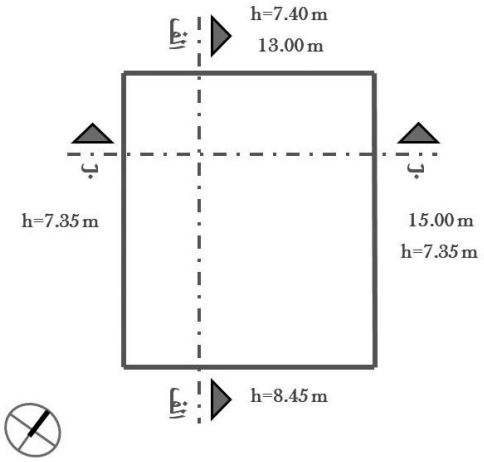
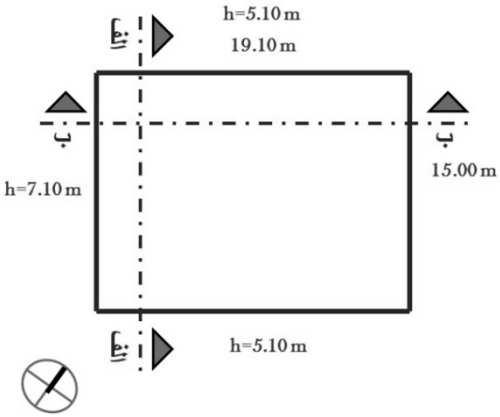
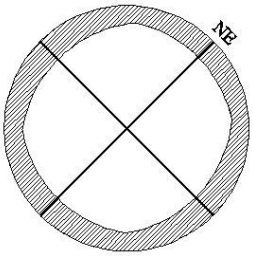
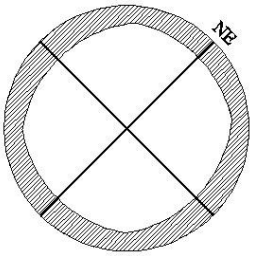
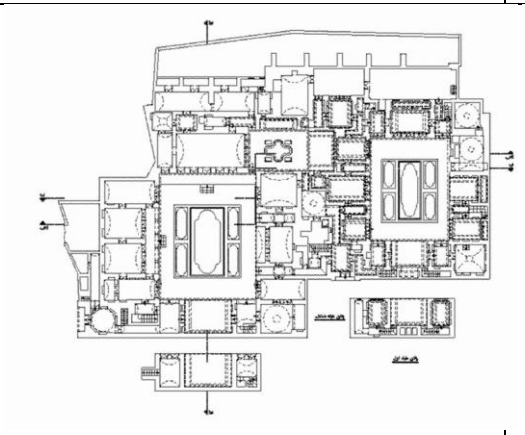
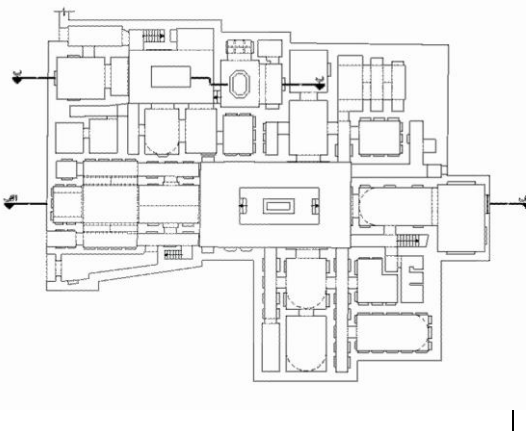
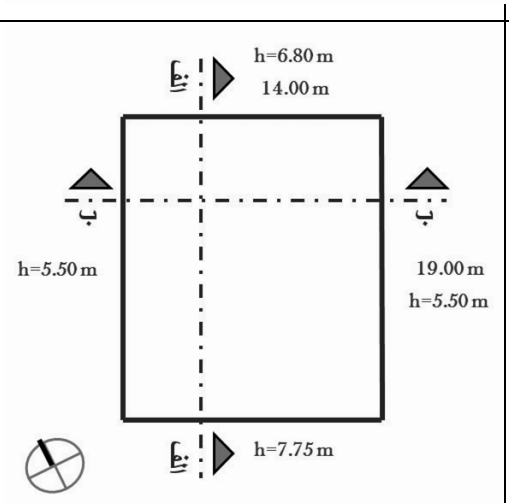
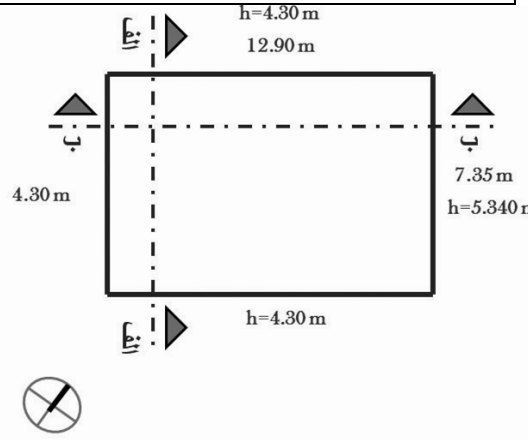
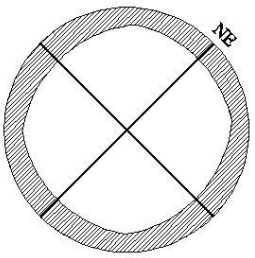
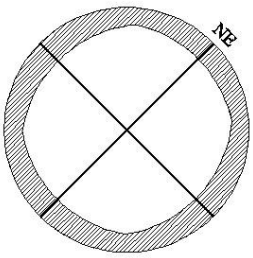
	Koochak Arabha's house	Fazeli's house
Plan		
Proportions and yard's wall sizes		
Yard's orientation		
Proportion of length, width and height of yard	H/W=0.56 L/W=1.20	H/W=0.33 L/W=1.30

Table 3: the summary of investigation on Yazd houses data

	Another Old house in Yazd	**Nazeri's house**
Plan		
Proportions and yard's wall sizes		
Yard's orientation		
Proportion of length, width and height of yard	H/W=0.4 L/W=1.35	H/W=0.58 L/W=1.75

9. conclusion and issuing sectional orders

All in all, the yards or open spaces can be labeled fewer than two headings: the wide open spaces and the deep open spaces. In wide open spaces, the proportion of height to width of the yard is H:W<1.This means the proportion of height to yard width is less than 1. Yet, in deep open spaces, the proportion of height to width of yard is H:W>1.This means the proportion of height to the width of yard is more than 1.In wide open spaces, there is so much sunlight in the space, therefore, wide open spaces with any kind of orientation provide better conditions in cold times. However, deep open spaces provide more shade during the year and their orientation in creating the ideal shade and sun situation is prominent. (Rafi far, V., Architecture Master's Thesis, Supervisor: Razjouyan, M.)

In general, according to the dimensions of the studied yards, all the yards can be labeled as wide open spaces: H:W<1. By comparing shade masks, it can be concluded as: 0.33<H:W<0.6), also by comparing yard dimensions, it can be concluded that it is (1.2<H:W<1.7) which is almost equal to golden ratio. Regarding the effect of orientation on solar radiation, it can be said that northeast-southwest yards are solar absorber in the morning during hot seasons and in the afternoon during cold seasons. Definitely, the former is more related to Yazd houses, which is why orientation in most houses in Yazd is northeast-southwest.

The open spaces contain the favorable shade and sun during the year if they are sunny during cold times hence open spaces should be wide during cold times. But open spaces should provide shade during hot times. Consequently, open spaces should be deep during hot times. Regarding the level of solar radiation, it could be concluded that either during cold times or hot times, the walls in deep open spaces and the floor in wide open spaces have the most share of receiving the solar heat. Regarding Yazd in which most yards are wide open spaces, the floor has the highest energy absorption and is the most effective in increasing the surroundings heat in both cold and warm times[18]. (Figure 6)

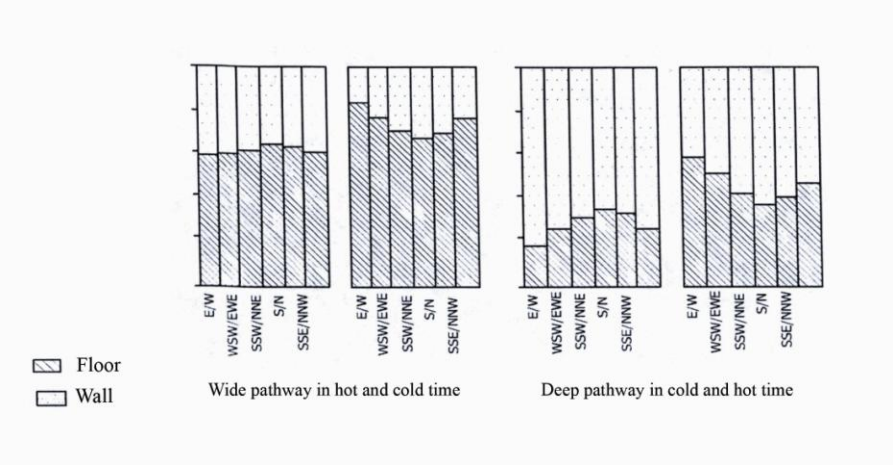


Figure 6 –Solar energy received by floors and walls

Maybe it is assumed that these yards should have been designed wide, but by considering the heat absorption by open space walls during hot times and the importance of open space floors in receiving heat during cold times, the best conditions is to make wide open spaces and the shade be provided by various shades and small leaf trees during hot times. Based on shade and sun mask in Yazd's traditional houses', designing deep open spaces deteriorates the situation and while it provides shade during summer, it does not provide a favorable situation for winters.

The existence of a fixed shade and deep dimensions does not help the shade, the sun and thermal comfort. Therefore, arrangements to use natural mobile vertical shades such as trees and plants on the surface and roof top sounds more logical for arranging the proportion of width to height (figure 7).

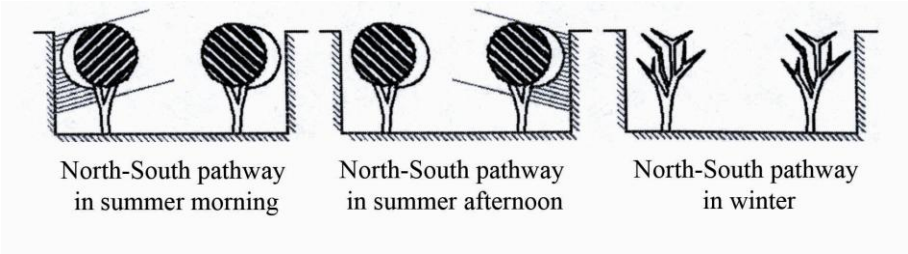


Figure 7- Mobile shade to fix H : W proportion

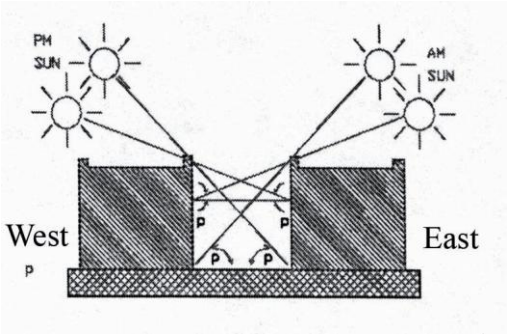


Figure 8- The impact of H : W dimensions on shade and sun in open spaces, [19]

Using trailing plants as a cover and temporary roof can improve the space quality in addition to providing comfort (figure 9) and (figure 10).

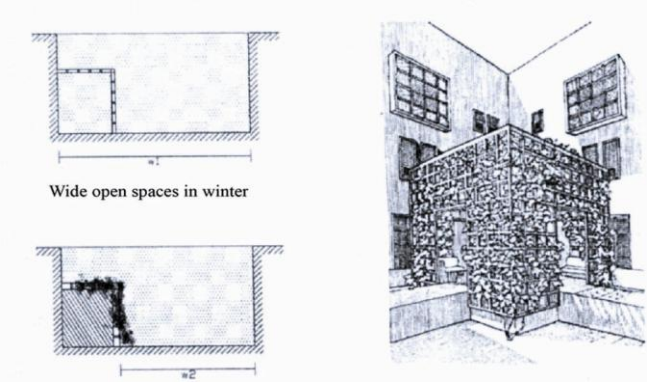


Figure 9- The arrangement of open space dimensions in winter and summer using trailing plants, [20]

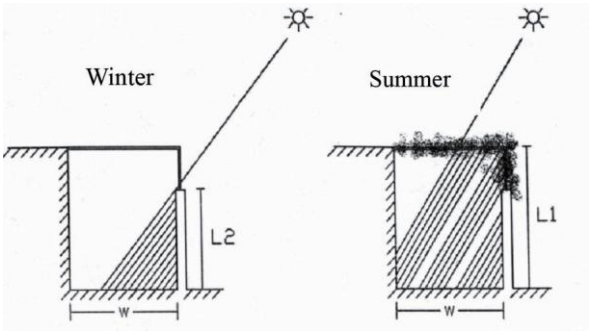


Figure 10- Using trailing plants as a temporary horizontal shade (L1<L2)
(Rafi far, V., Architecture Master's Thesis, Supervisor: Razjouyan, M.)

Creating a transparent layer like a porch or portico in open spaces can also be effective in reducing the solar radiation and providing the required shade for people (Figure 11). Since in traditional houses in Yazd, this possibility is considered for the adjustment of width to height proportion and we see the design of a half-open porch of 3 m deep for each floor so that provides the favorable shadow and sunlight at hot and cold times.

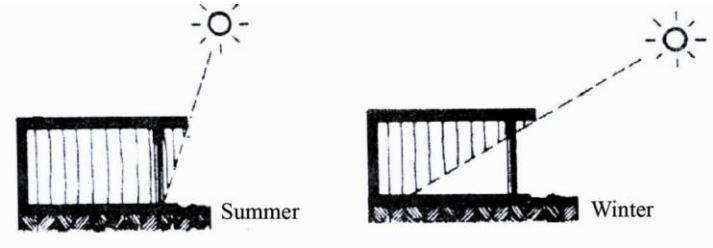
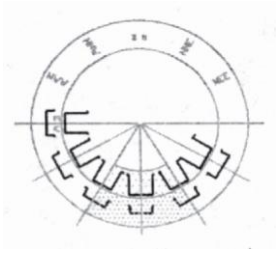
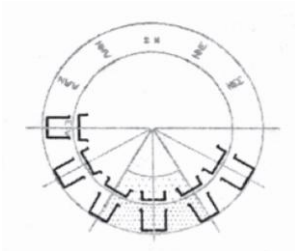


Figure 11- Porch as a fix shade toward south front, [21]

The most important point regarding all the traditional houses of Yazd is that these open spaces are sunny with any type of orientation, dimension and proportion, in direct sun radiation during summer afternoons regardless of the ideal situation and the only solution is to use horizontal shades in open spaces and yards. In the past, trees were used instead of pergolas to function as horizontal shades and provided the maximum shade. The information regarding the orientation of open spaces, the ideal situation and the previous studies on shade, sun and the intensity of solar radiation in yards can be summarized in table 4.

Table 4: Orientation and proportions in streets and open spaces

<table>
<tr><th>Orientation</th><th>Hot seasons</th><th>Cold seasons</th></tr>
<tr><td rowspan="2">Radiation and Temperature</td><td>  </td><td>  </td></tr>
<tr><td colspan="2">Consider north – south orientation up to 30 degrees deviation for open spaces on condition that:

Open spaces be deep in hot seasons open spaces be wide in cold seasons</td></tr>
</table>

The ideal design of open spaces should be provided by considering the right proportions and orientations, sun and shade masks of the walls and with the help of ideal green spaces so that it would be useful in creating thermal comfort and health of people in open spaces.

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