1.0 Introduction

1.1 Background to the research

Sustainable development is defined as a development which seeks to balance the needs of the present with the future viability of natural resources and the plant's ecology. The term sustainable development first appeared in 1981 in the World Conservation Strategy conference (WCS). (National Strategy for sustainable development, 2007). Brown (1981) presented a more comprehensive definition of sustainability, He defines the sustainable society in terms of population stabilization, the preservation of the earth's renewable natural resource base, the prudent use of land (urban, farm and wilderness), the protection of biological systems (including fisheries, grasslands and forests and the conservation of energy resources through the shift to renewable sources of energy. Sustainability was raise on the public agenda during 1980s due to the following reasons:

In the 1970s for the first time the oil price reached the highest rate in their history due to an OPEC embargo of oil in response to support of Israel by western nations during the war between Israel and the neighboring countries. This was the first time the world started to think about alternative natural resources and the proper usage of all natural resources and to look into a way of life less tied to oil consumption. Several studies in the mid-1970s showed global warming as a result of industrial years from 1950 onwards. One of the first studies conducted in this field was by Bryson and Dittbernerr (1976) who revealed the carbon dioxide (CO_2) augmentation and causes.

According to Yeang (2005), contribution of energy to global warming is around 57% which is the most influencing sector. One of the major growing industries is construction which is known as a signifier of economic. This industry globally uses 60% of the produced material, 60% of the timber products, 50% of the water and 50% of all the generated energy (Yeang, 2005). Therefore, any approach towards a sustainable built environment results in a significant impact on the energy reduction, consequently global warming and a reduction of CO_2 emissions.

Sustainability in the built environment deals with the urban fabric from a macro scale point of view and individual buildings from a micro-scale point of view. Shore (2006) noted the sustainability issues in the urban scale. He mentioned that the traditional urban pattern was a cluster of people activities which was surrounded by the residential district which could minimize the land use and transportation. Buildings have an enormous impact on the environment, both direct and indirect. Not only do they use resources such as energy, water, and raw materials, but they generate vast amounts of waste and emissions during their lifetime. There are several strategies to achieve a sustainable built environment including passive, active, renewable energies, renewable and non-renewable materials, efficient building management system, and water and waste management.

Passive strategies are the primary approaches. A Passive solution starts from the site selection to the proper facade design. Several studies have been conducted in this area for instance, Shashua-Bar and Hoffmana (2003) studied the passive cooling impact of trees in the urban fabric. Santamouris and Asimakopoulos (2001) gathered the passive cooling strategies from several studies conducted by different researchers. Givoni (1994) provided a guide for architects and other building-design practitioners who are engaged in designing buildings in hot regions in order to incorporate the various passive cooling systems in their design.

Meadows and Spiegel (1999) presented the way to select green building materials such as certified timber (FSC, PEFC). It was also recommended in their research to use recyclable material and also local materials in order to reduce the consumed energy involved in transportation. Active strategies consist of efficient building services and building management systems. They include efficient lighting systems, efficient cooling and heating systems such as radiant cooling or solar cooling, efficient vertical transportation and intelligent building management systems to improve energy efficiency through monitoring the performance of systems. Smith (2003) explored in his research the different varieties of renewable energy in detail including solar thermal power, geothermal energy, wind power, photovoltaic cells, fuel cells, small-scale hydro, and wave and tide. Waste and water management can also provide a possibility to minimize and conserve the natural resources.

1.2 Middle East

According to the latest statistical report by British Petroleum (2007), more than 60% of the total oil and 40% of the total gas reserves are based on the Middle East .The figures demonstrate the large concentration of fossil fuel in this region. However, the potential of the other renewable energies such as solar energy has been assessed as being as important as fossil fuel or even much better. Although the Middle East has enormous energy reserves in the form of gas and oil, it is also using these natural resources at a rate that is not sustainable.

The large amount of energy consumption by the Middle Eastern countries in the world, and the fact two of them are ranked as the top three countries in the highest ecological footprint ranking (Global Footprint Network, 2007), the opportunities to optimize future design with higher level of sustainability can lead to a preservation of the natural resources. With reference to the booming development in the Middle

Eastern countries, the sustainable design approach is even more crucial and of the highest importance on the development agenda.

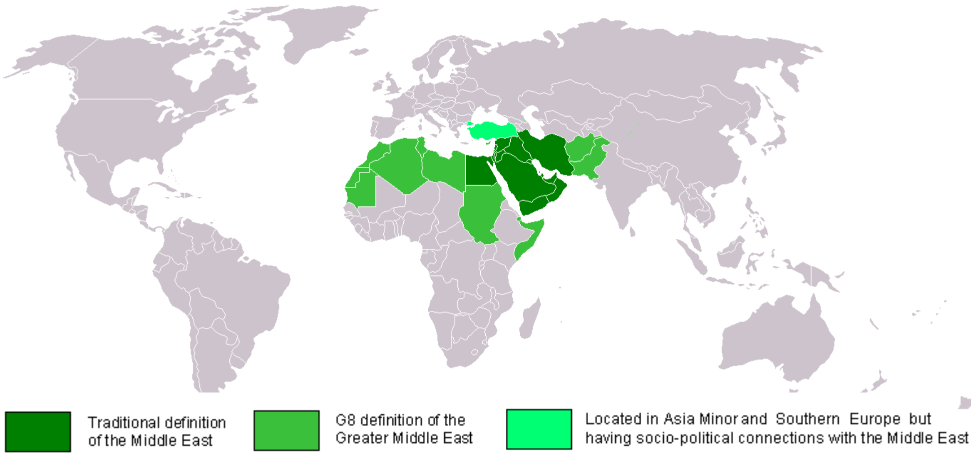


Figure 1.2.1 Middle East countries (Wikipedia, 2007)

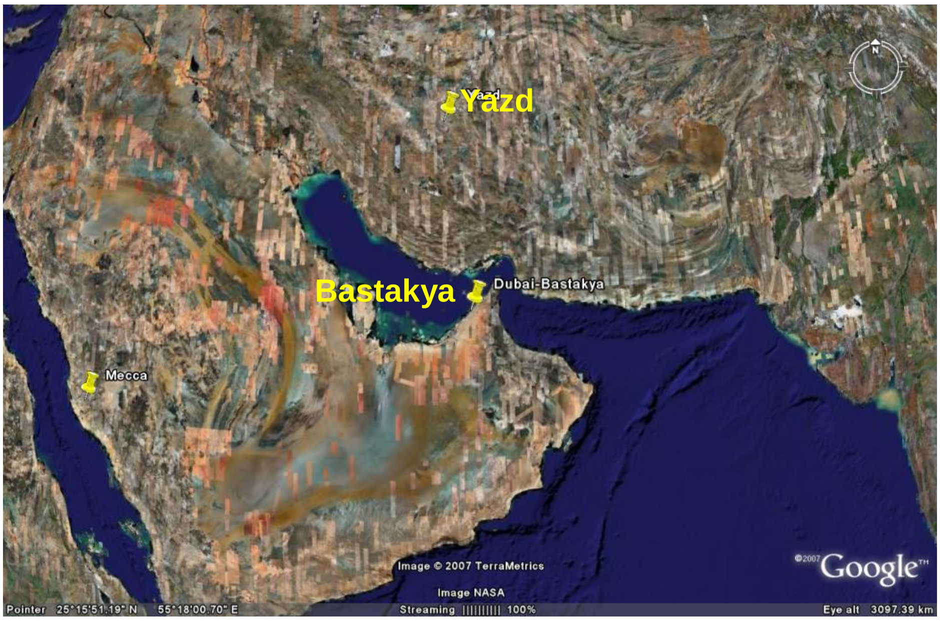


Figure 1.2.2 Yazd and Bastakya in the world map (Google Earth, 2007)

But sustainability can play a main role in preserving the natural resources and environment in the Middle East. The sustainable built environment can be achieved by understanding the principles and proper response to the climate, culture and social aspects of the society. Passive strategies are the main and first step toward a sustainable built environment. In the Middle East countries, the passive solutions most likely need to deal with extreme heat. In the following section the major passive solutions in this region are explored.

1.3 Traditional passive strategies

Passive cooling in hot climate has been investigated as one of the most effective strategies that provided comfortable indoor conditions in ancient Egypt and Persia hundreds of years ago (Cook, 1985). At that time, the lack of technology forced humans to use in passive cooling strategies. But passive strategies are again high on the agenda for different reasons. In recent years, the energy crisis and oil prices are the main issues which have resulted in people bringing back the traditional solutions.

Badgir (wind tower or wind catcher) is probably the most famous known approach to cooling down the indoor environment in the hot region of the Middle East. This solution directed the prevailing wind into the indoor spaces however, in some cases it could also draw the hot air out (A’zami, 2005). Thermal mass strategy was also integrated into the building to keep the indoor air cool for a longer period of the time and prevent the quick heat exchange in the building skins. People in some parts of Iran escaped from the harsh sunlight and benefited from the ground cooling effect. Usually in every house in the hot and arid regions, there was a room more than four meters lower than ground level. Food was kept there and the occupants moved there when it was unbearable to stay in both indoor and outdoor spaces in the summer time (Memarian, 1995).

Shading is another passive solution which has advantages at the time when solar radiation was the main threat to human comfort. It can be seen that in the urban scale, the narrow streets employed shading to provide a cool path way for pedestrian thousands years ago.

The strategies mentioned were introduced into the traditional built environment mainly due to high solar gain. The solar radiation was the major source of heat in both urban and individual buildings. Therefore, they struggled to deal with it in a way to improve the comfort level for the occupants.

A few studies have investigated the shading impacts in the built environment from energy and thermal aspects. Bourbia and Awbi (2004) explored relationships between urban geometry and urban temperature through several shading simulations. Lam (2000) investigated the effect of overshadowing on the building energy demand in 120 towers in Hong Kong. Muhaisen (2006) carried out research on the courtyard geometry effects on the shading pattern in different locations such as, Rome, Kuala Lumpur and Stockholm. Tzempelikos and Athienitis (2005) conducted research on the impact of shading devices on the building cooling load. Since there is a lack of research into the effects of shading on human comfort in the hot regions of the Middle East, in this research the role of shading on human comfort level is investigated in the traditional built fabric of two cities, Yazd and Dubai.

1.4 The aim and objectives

The principle aim of this research is to explore the shading impacts in the traditional built environment in order to learn from the local strategies for more appropriate future development and to integrate such robust and rich solutions into the design of the urban fabric.

The main objectives of this research are on the one hand to introduce shading as a solution to prevent solar gain, and on the other hand to investigate the shading impacts from different aspects and in different case studies. This is necessary in order to demonstrate the role and the effects of shading which can result in a sustainable and efficient future development.

The Middle Eastern countries have their own traditional built environment which worked very well for hundreds years. Moreover, there are several passive cooling strategies which have been introduced for the first time in this region. The proper studies on those built environment can reveal the strategies and solutions which they were not only cheap and simple but they also had harmony with culture and climate.

Case study is the selected methodology in this research which aims to investigate the shading effect on two rich locations in the region in terms of passive solutions. Yazd is a famous city particularly for the natural cooling system of the *Badgir* throughout the world however, there are few other passive strategies which will be discussed later. Bastakya is the main traditional built environment in the UAE which benefits from several passive solutions. Both locations have a similar cultural pattern which affected the urban form. In addition, the hot summer is the similar climatolgical condition which is the major factor which led to a similar architectural style in Yazd and Bastakya.

In order to present a comprehensive understanding of the different aspects of shading in the built environments, field measurement, simulation and research base studies are combined. Every approach assesses and supports the findings from the other methods.

1.5 Case studies

1.5.1 Yazd

Yazd has been ranked as one of the oldest city in the world with over 3000 years history (Iran Chamber Society, 2007). It is located in the middle of a deserts area on the central part of Iranian plateau. The lack of rainfall gives a dry climate to the city. The sand storm is the main climatological character in Yazd. The temperature varies between 40 °C in summer and -20°C in winter which reflects the different climates throughout the year. Due to its distance from important capitals in the different dynasties it remained partially isolated and therefore the urban form and architectural style today demonstrate a rich history.

1.5.2 Dubai (Bastakya)

Dubai is located along the south part of the Persian Gulf in UAE. Dubai is known as the fastest growing city in the world. The rapid urban development started from 13 years ago. The temperature usually exceeds 40°C in summer and humidity sometimes reach 90% in the nighttime. The extreme climatic condition made people to integrate passive solutions years ago. Bastakya is the one the oldest traditional built environment. This area is rich in terms of the passive solution to deal with extreme heat (Kay and Zandi, 1991).

1.6 Passive solutions in the case studies

In the Yazd and Bastakya urban built environments, several passive solutions were integrated into the urban fabric in order to improve the human comfort level in the extreme climatic conditions. Yazd is the city of the *Badgir* (traditional wind catchers or wind towers) in Iran. The wind tower was a solution to enable people to benefit from the prevailing wind to cool down the space and extract the hot air. It was also initially used in *ab-anbars* (underground water-houses or water storage) to cool the stored water and also feed oxygen into it to keep it always fresh. *Qanats* (underground water tunnels) was another solution to tap the underground water and channel it to the ground levels in the region where the average rainfall was too low (Bahadori, 1976).

In addition, the mud-brick wall worked as a thermal mass to separate the indoor environment from the outdoor environment. In hot summers, it reduced the heat conduction through the walls to keep the indoor area cool and the opposite in the winter time.

Since the first people who came to Bastakya were Iranian from Bastak city in the southern part of Iran, a typical Iranian architecture style for hot and humid climates was introduced into the Bastakya (Damluji, 2006). The wind tower-building type can also be seen in Bastakya as a main passive solution to the hot climate in Dubai. Despite the fact that the wall material in Bastakya was different to Yazd it worked as a thermal mass. Air puller was another passive solution for the people who slept on the roof in summer. It was integrated into the roof parapet to pull in cool air from the outdoors over the roof level where people slept at that level in summer.

1.7 Importance of shading in Case studies

Shading is considered as a natural cooling strategy in a hot climate. In the traditional built environment, shading devices were created. In Yazd and Bastakya, it can be seen that the courtyard housing had integrated a few shading devices in order to improve the comfort level for the people who lived there. In addition, the buildings geometry and form in the both urban fabrics created a unique shading pattern which benefited the people in the hot summer. However, there are other examples revealing that sometimes shading has been made without any earlier decisions. For instance, the courtyard form and orientation independently provided well shaded areas in the Yazd and Bastakya courtyards which can improve the outdoor comfort level of the occupants and enabled them to use this space for the period of the time when the occupants were not able to stand under the harsh sunlight.

1.8 Scope and methodology of this research

Shading impacts on the built environment are explored through assessing the different effects of shading. The shading impacts are categorized into the two major categories: an urban and an individual building. The urban effects include the shading intensity in the urban streets and the urban forms which affect the solar radiation exchange between the urban surfaces and it has an impact on the average urban temperature in comparison to the rural area. In addition, the overshadowing in the urban scale can modify the thermal loads of the individual building.

The courtyard housing in the traditional built environment of Yazd and Bastakya demonstrates a unique shading pattern in the courtyard. This shading affects the outdoor thermal comfort of the occupants. It also influences the visual comfort.

For the individual building within the urban fabric, different shading structures were integrated into the courtyard in order to provide protection against the harsh sunlight either visually or thermally or both. They also act as the outdoor comfort modifier in the courtyard. The main advantages of these structures are investigated in the hot summer. The discussion of the shading impacts is elaborated in further detail in the following section.

This research consists of the introduction which gives a clear idea of the different shading impacts in the built environment through exploring the relevant studies in the same area. The methodology includes a variety of approaches to assess the shading impacts in the case studies. Every approach is explained in details and the background of the approach is also elaborated in order to establish the elected method. The results of the analysis are compared with the findings from other studies. The comparison proves the validity of the results.

The discussion section presents a comprehensive understanding of the results in Yazd and Bastakya through explanation of the causes which led to the final results. The findings in the two case studies are compared to demonstrate the different effective factors in two locations.

The learned lessons from the discussion section can provide an exclusive guideline for the future developments which are described in the conclusion. The strengths which can give benefits to the coming projects in the region or any location with a similar climatic and cultural pattern are presented in the outlook. The weaknesses of the shading impacts are also discussed in this section.

2.0 Analysis and Results

The methodology of this research consists of different sections. It starts by explaining why certain housings were chosen as the selected building type in this research. Then the introduction elaborates more details of the two case studies including location, climate, historical background of the locations, historical background and description of two houses and the courtyard function in both locations.

The shading impact is assessed from the macro scale to the micro scale. The simulation method is incorporated in order to assess the shading intensity within the urban fabrics of Yazd and Bastakya. The urban form impacts on the urban temperature in the two compact urban fabrics are studied by employing the findings of the other researchers.

After assessing the urban fabric, each building is examined individually which is the major part of the methodology section. The shading intensity in the courtyards is analyzed through the similar method which was used for the urban analysis. The sunlight hours study is also carried out for the courtyards to demonstrate the sunlight hours distribution within the courtyards in the different seasons.

The shading impact on the occupancy pattern of both houses is explored through relevant research and finding from the sunlight hours simulation. The integrated shading strategies in the courtyard are explained in detail. A simulation study is also incorporated to examine the visual performance of the shading devices for the indoor spaces.

In order to investigate the shading impacts on the outdoor comfort level in the courtyards, other relevant studies, simulation and field measurements are combined. Then according to the finding from the courtyard shading intensity, the impact of the shading on the outdoor comfort at the peak time and during a sample year is explored. Finally, the effect of the overshadowing of the neighboring buildings on the façade solar incidence and the building heat gain are discovered through the simulation method.

2.1 Housing

The house is the selected building type to be assessed in this research. The importance of housing is not only because of its quantitative significance in the built environment but also because it is the most complex component of the urban form which supports the principle of social interaction. Fathy (1961) elaborated the house function:

> "If the family is the fundamental social group the interpreter and buffer between the individual and society- then the house has an analogous function as between the individual and the world of things. It is the objective and tangible projection of the family, and the most important thing in a family's or an individual's life."

In Arabic,'' Sakan'' means house which is mentioned more than forty-five times in the Quran (Mortada, 2003). According to the Quranic verses, the house is a place of peace and rest for the body and mind: It is Allah who made your habitations homes of rest and quiet (16:80)

2.2 Selection of the case studies

The Lari House in Yazd and Building 69 in Bastakya are selected to be studied in this research. Both buildings are single-storey. The main physical characteristics of the selected buildings are that both are courtyard-type, with similar geometric ratios. The *Lari* house consists of the more spaces and occupies a bigger area of land. The function of both houses is residential. They were built in the same period of time. They benefit from a central courtyard as a typical Muslim house in the hot region in the Middle East (Bianca, 2000).

2.3 Bastakya

2.3.1 Location

Dubai is located in 25.1° latitude and 55.2° longitude. Bastakya is tin one of the oldest area in Dubai which is located on the southern side of the creek in Bur Dubai. The total area of Al Bastakya is 38000 m^2 which expands 300 m parallel to the creek and 200 meters towards the south (see photos 2.3.1 and 2.3.2).

Photo 2.3.1 Bastakya site plan (Google Earth, 2007)

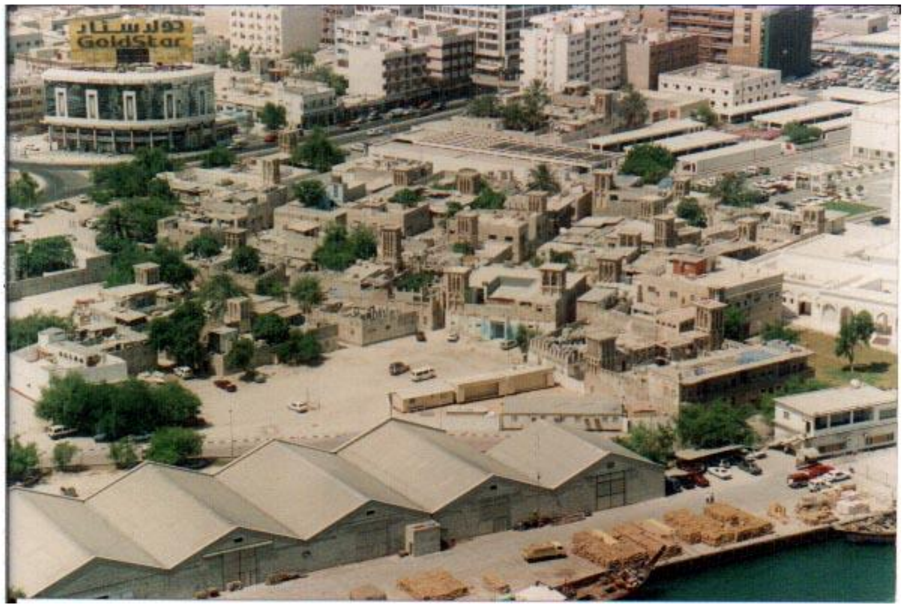


Photo 2.3.2- Bastakya-1993 (Dubai Architectural Heritage Society)

2.3.2 Historical Background

Bastakya is a residential district which was built as a supplementary storage for the rich merchants who mainly had shops close to the Abra (Textile and Spice) Souq. The houses were built in 1902 by Iranian merchants who had left Bastak and Lingah in the northern coast of Persian Gulf due to the high customs for the imported goods. In 1936, because of the legislation of the Shah of Iran abolishing the use of the veil, a further number of families joined the old group from Bastak and Lingah (Darke, 1998). As result, a number of wind tower-houses were added to the original fabric at this time.

2.3.3 Climate

Dubai is a desert land which is supposed to have a hot and dry climate but due to its location along the Persian Gulf, the climate is hot and humid. The average temperature varies between 12°C and 40°C. However, the maximum temperature usually exceeds 47°C. The average humidity fluctuates between 40% and 60%. The prevailing wind direction is north-west. The sand storm is a typical characteristic of the desert type land which occurred regularly before the booming urban development in Dubai (see figures 2.3.1 and 2.3.2).

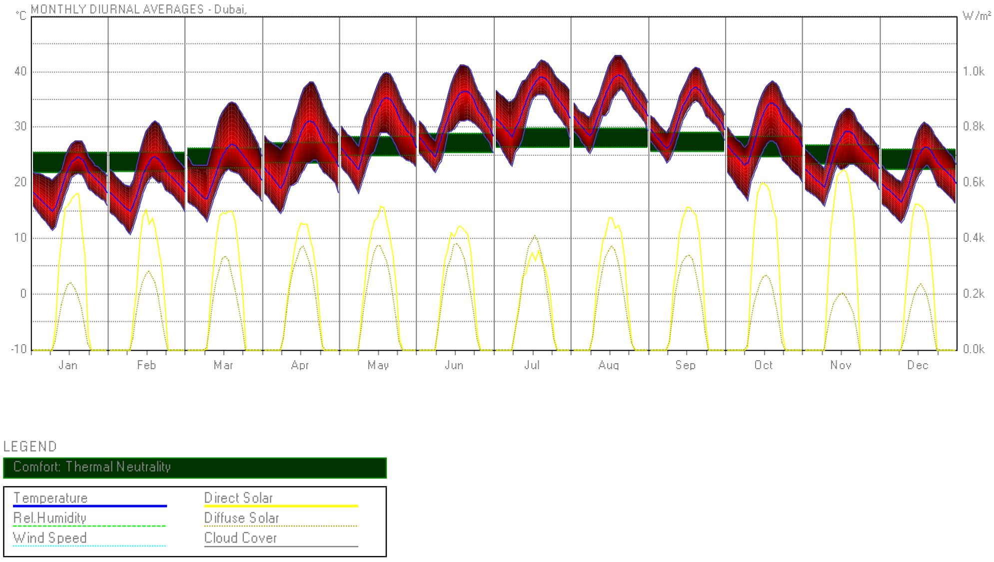


Figure 2.3.1 Monthly weather data –Dubai

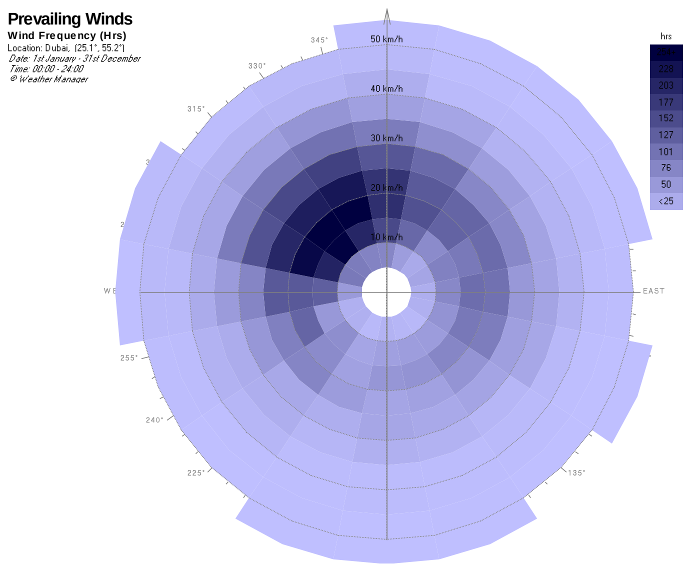


Figure 2.3.2 Wind rose- Dubai

2.3.4 Overview of Houses

Although, a few modern houses and temporary structures have been added to the Al Bastakya area, the courtyard houses are the major house type in the existing fabric. The houses size and shape varies according to the individual needs of the owner, the plot size and location. In addition, the existing building may be not the original one because of some modifications which have been carried out to respond to the different needs of the generations through years. Damluji (2006) mentioned the purpose of the courtyard housing in Bastakya:

‘’The defining architectural concept behind all these houses is one of providing maximum privacy for the family from the outside world.’’

2.3.5 Building 69

According to the Dubai architectural heritage society document, the original building was built around 1890. The building form changed throughout several years as it was used by the different generations of one family. The current building structure was constructed in 1940 (Dubai architectural heritage society).

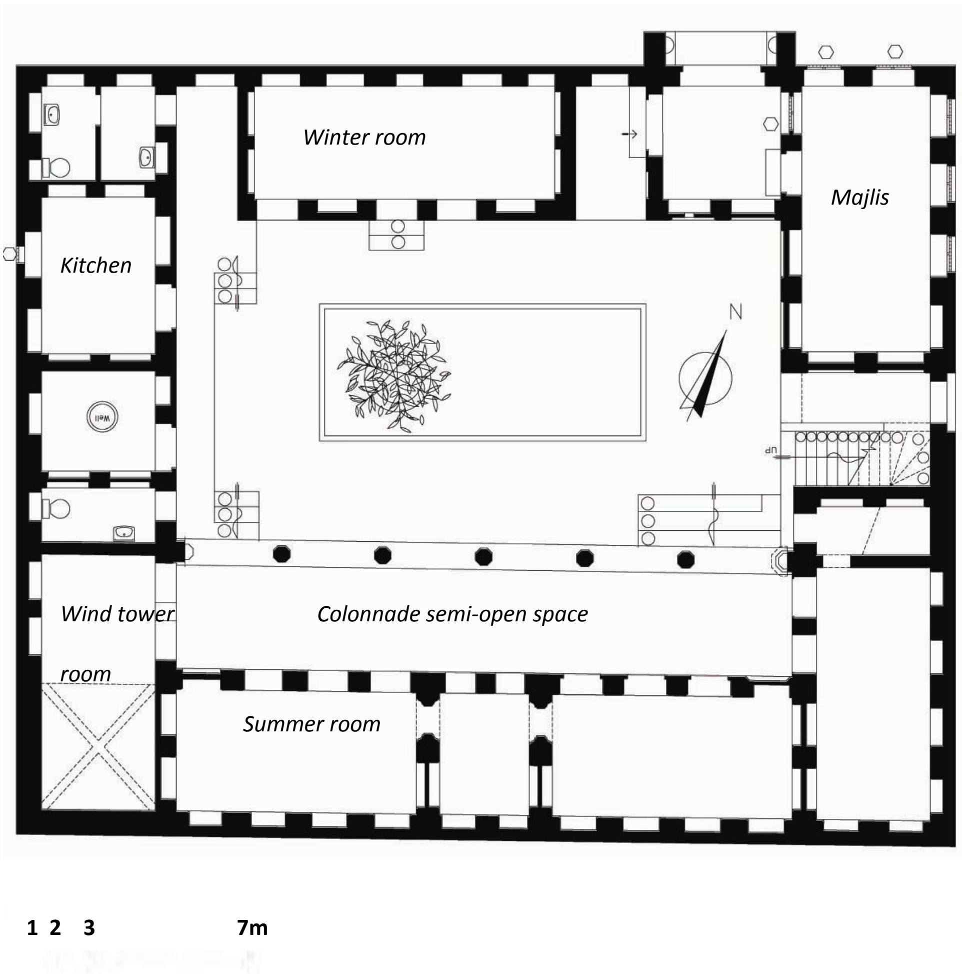


Figure 2.3.5.1 Drawing plan- Bastakya house

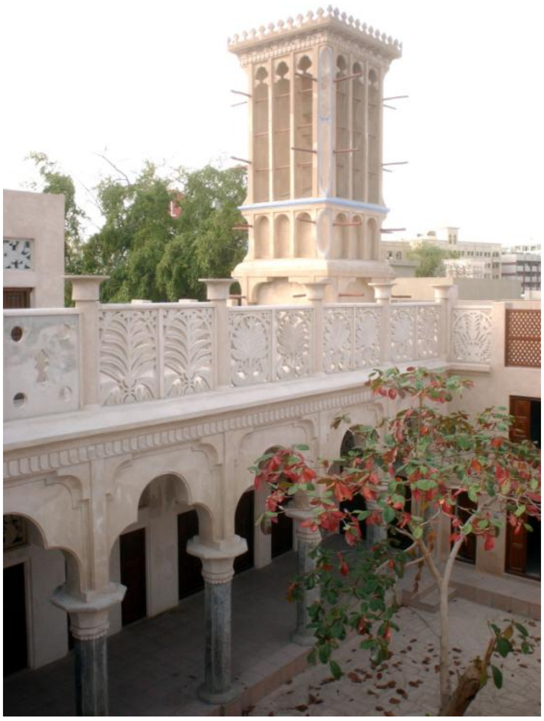


Photo 2.3.5.1 Bastakya wind tower (Dubai architectural heritage society)

The *Majlis* (guestroom) is located in the north-east of the courtyard which is the only space in the house with an opening to outside. There is one room in the north-west side and two rooms in the south-east side which are the multi-functional spaces in the house used depending on the seasons. A room in the corner of the south-west wing of the courtyard directly under a wind tower was used only in the summer time. In addition, the house consists of a storage room, two bathrooms and one kitchen in the south-west wing of the courtyard. A colonnaded structure was integrated into the courtyard which provided a shaded area for the outdoor usage of the occupants. The main landscape feature of the courtyard was almond Indian tree due to low rainfall (Damluji, 2006). In addition, the roof could be used in the summer time since the roof benefited from air pullers.

2.3.6 Building Material

The main building materials used in Bastakya was coral stone which is found in the original structure but after several modifications sea-sand lime stone was also used in the structure of the house. These materials were taken along the creek area in Dubai (Damluji, 2006).

2.3.7 Courtyard function

The main element of the courtyard in the Bastakya house is a central tree. This tree provides a private garden for the occupants. But, since the central area of the courtyard served as a link to the different spaces and according to the shading intensity in summer the courtyard was not well shaded, it was not used as an outdoor sitting space. The semi-attached area on the south-east part of the courtyard was used for the purpose of outdoor sitting space. This area was shaded most of the time, especially in summer. Not only the flooring was shaded but the surrounding walls were also shaded. According to the Givoni (1996) research, radiant heat is an effective factor therefore, the shaded surrounding walls could help to improve the outdoor comfort level in the colonnade space (see photos 2.3.7.1 and 2.3.7.2).

Photo 2.3.7.1 Semi-attached space in the Bastakya courtyard (Dubai architectural heritage society)

Photo 2.3.7.2 The Bastakya courtyard (Dubai architectural heritage society)

2.4 Yazd

2.4.1 Yazd Location

The city of Yazd is located in the central part of Iran at 31.5° latitude and 54.3° longitutde. Yazd consists of a modern and the traditional urban fabric which is predominantly untouched.

Photo 2.4.1 Yazd urban form (Google Earth, 2007)

Photo 2.4.2 Yazd landscape view (A'Azami, 2005)

2.4.2 Historical background

This city is known as one of the ancient land with bright culture and civilization in the different eras of the Persian history. The age of city goes back to 3000 years ago. The word Yazd also means worship in the Old Persian (Wikipedia, 2007). The urban form and the traditional structure of Yazd have been unchanged due to the far distance from the Persian capitals throughout hundred years. In addition, the harsh climate and the isolation by the neighboring mountains in the middle of the desert were the other factors in conserving the urban fabric. .

2.4.3 Climate

The Yazd altitude is 850 m above the sea level. The average rainfall varies between 50 and 100 mm. The temperatures fluctuation is significant between day and night regardless of the seasons. The maximum temperature reaches to 45 °C and the minimum recorded temperature is -20°C. The following diagrams present the climatic data for Yazd. The prevailing wind direction is the south-east direction however, the north-west winds is also significant (see figures 2.4.3.1 and 2.4.3.2).

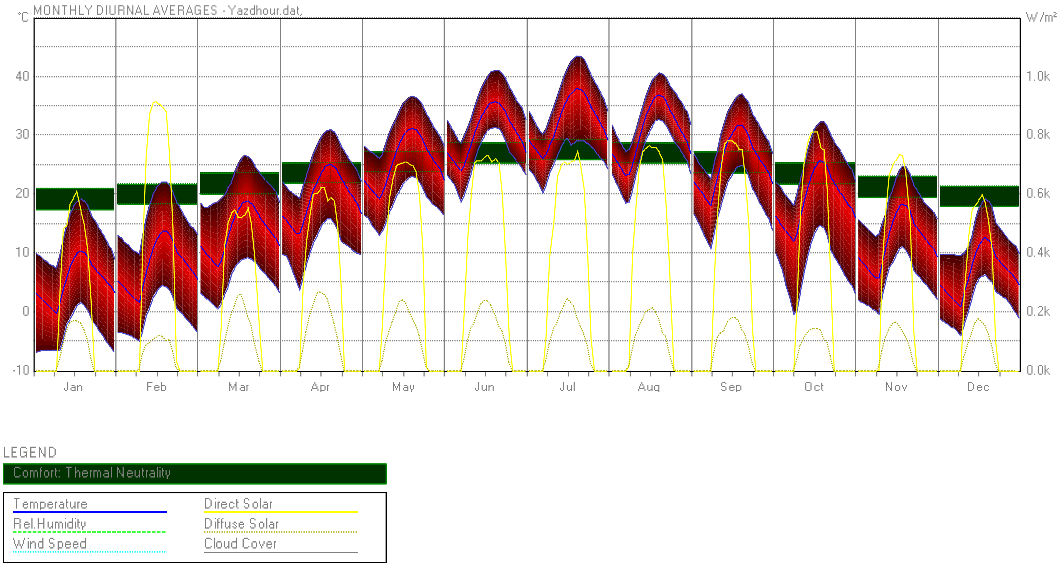


Figure 2.4.3.1 Monthly weather data- Yazd

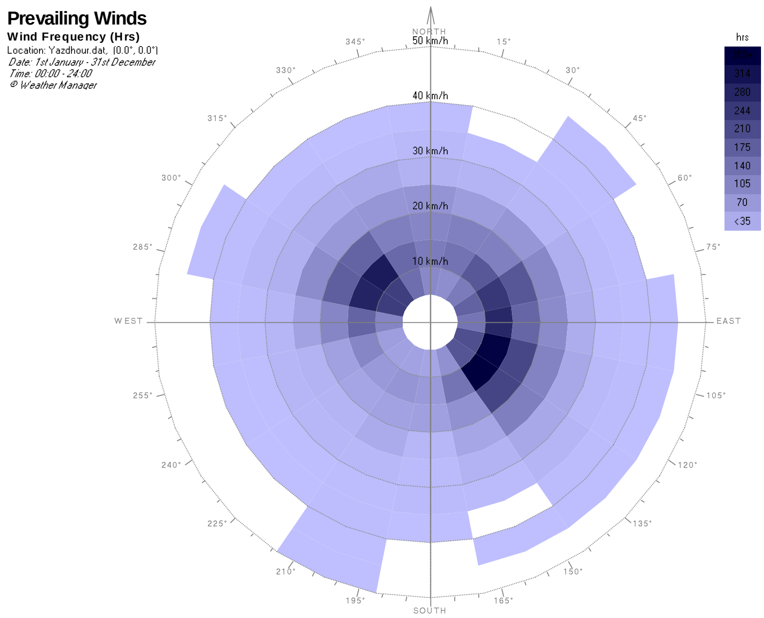


Figure 2.4.3.2 Wind rose- Yazd

2.4.4 Overview of Houses

The courtyard housing without any opening to the outside is the main house type in Yazd. Most of the people in Yazd have seen the harsh sand storm at least once in their life and therefore they knew that the only opening for the house must be the entrance. The dry outdoor environment encouraged people to make the green courtyard which could provide the inner pleasant view for the habitant in absence of any opening to the outside.

2.4.5 Selected building: Lary House

The original structure of the house was built around 130 years ago by the grandfather of Laryha in Yazd (laryha were people from the Lar city in southern part of Iran). Similar to Bastakya, the current building is a modified version of the old house which have several additional space (Ganjaname, 2005) The major components of Lary house include a large courtyard, along with a collection of *Eivans* (semi-open indoor space), rooms, a portico and an entrance vestibule.

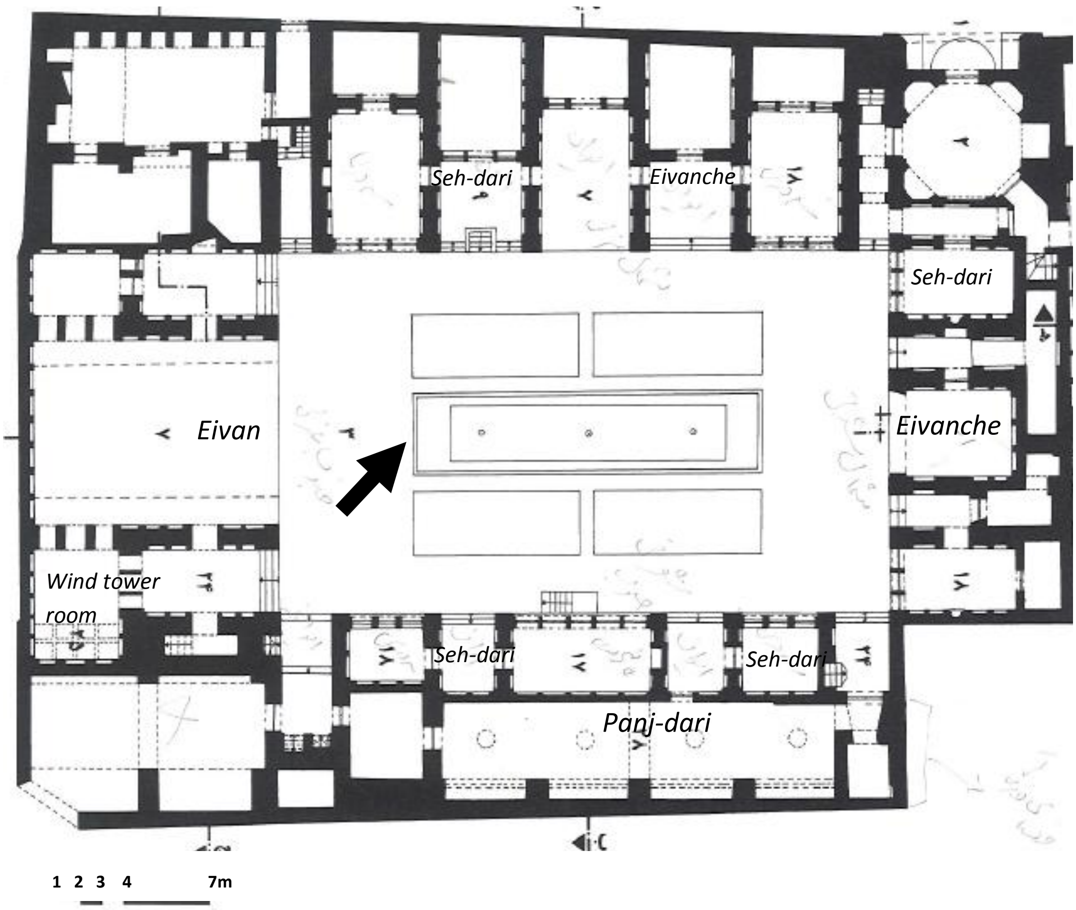


Figure 2.4.5.1- Lari house Plan (Ganjnmaeh, 2005)

Photo 2.4.5.1 Lari house in Yazd (Tehrani, 2007)

The eivans and the main rooms surround and overlook the main courtyard. But the service area is essentially located in the corners, behind the rooms facing the courtyard. The courtyard is rectangular and its longitudinal axis lies in an approximately northeast-southwest direction. The main rooms include a *panj-dari* (a room with five doors) and two *seh-dari* (a room with three doors) in the south-east wing of the courtyard and four more sh-dari on the other wings of the courtyard. There are two main *eivans* on the south-west and north-west wings of the courtyard. In addition, there are several *eivanche*s (mini Eivan) all around the courtyard wings. A wind tower room is connected to the main south-west eivan. In summer, the occupants stayed there to benefit from cool air coming from the wind tower. All the service spaces including the kitchen, storage room and toilet are located in the north-west wing of the courtyard. *Sardab* (a room in the basement level) and main storage are 8 m lower than the courtyard level. The green landscape and the central pond in the middle of the courtyard are the main and unique characteristics of the courtyard in Yazd which benefited from the winter and autumn rainfalls. (see figure 2.4.5.1 and photo 2.4.5.1).

2.4.6 Building material

The main material which was used in Yazd was mud due to the climate, technical aspect and availability. Therefore, the mud components can be seen in the different applications in the house. In the traditional construction method, basically they used excavated materials mostly mud was available in-site for the building construction.

In the harsh sunlight in summer time, the only available material which had a high thermal capacity and could act as an insulation layer was mud. However, the brick has been rarely used in Yazd, mud shows lower thermal conductivity in comparison to brick (Thermal conductivity- Brick: 0.85 W/mK, Mud: 0.75 W/mK). Mud is the most basic building material. Through several experimentations the best combination of sand, loam, clay, and water resulted in the best recipe for mud constructions which is adapted to the availability of materials and climatic conditions (Ragette, 2003).

2.4.7 Courtyard functions

The courtyard in *Lari* house performs different functions. A small garden incorporated with a pond in the middle of the court yard is an abstract of Muslim interpretation of heaven (see photos 2.4.7.1 and 2.4.7.2). The plants and pond can act as the passive cooling strategies for the courtyard in the hot summer days (Memarian & Brown, 2006). This environment provides the indoor looking space for the occupants and also it enables privacy for the Muslim users. In addition, the psychological impact of the courtyard can soften the tough building form and make the harsh summer climate more acceptable.

Photos 2.4.7.1 and 2.4.7.2 The courtyard in Yazd (Tehrani, 2007)

2.5 Urban shading intensity

Several studies have dealt with the shading intensity in the urban fabric and the courtyard buildings. Awbi and Bourbia (2003) employed a simulation and field measurement methods to assess the solar shading and urban microclimate for a hot dry climate. Muhaisen (2006) explored the shading pattern in the courtyard in the different climates. Muhaisen and Gadi (2004) conducted another study to present a mathematical model to calculate the sunlit areas and the shading patterns in the circular geometric courtyard. All the researchers tried to explore the shading impacts either within the urban fabric or the courtyards in order to understand how shading can influence human comfort.

The compacted urban form in Yazd and Bastakya is known as a typical Islamic urban form in the hot region (Bianca, 2000). In order to assess the shading density in the urban fabric including the two case studies, a portion of the urban fabric where the selected houses are located, were chosen. The urban fabrics are similar in size. 3D models of these are made in ECOTECT program (Ecotect, 2005). The models were analyzed on June 21st (to present summer), September 21st (to present mid-season) and December 21st (to present winter).

June 21st and December 21st are the solstice days at which time the sun is located at the minimum and maximum angle to the earth (see figures 2.5.1 and 2.5.2). September 22nd is the equinox which means the sun shines at a mid-angle toward earth at which, the daytime and nighttime are equal. There is a day's difference in September in comparison to the others but in order to have a homogenous result, the 21st is selected in this research.

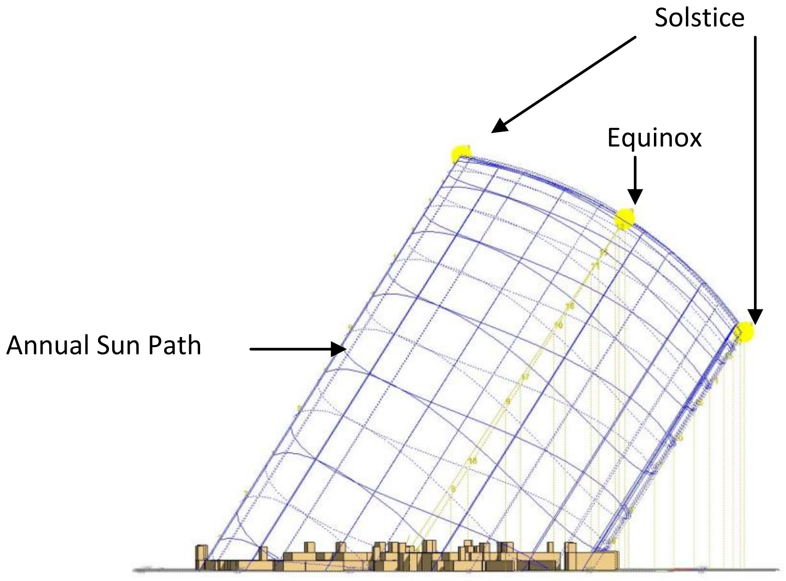


Figure 2.5.1 **West elevation of Bastakya-annual sun path**

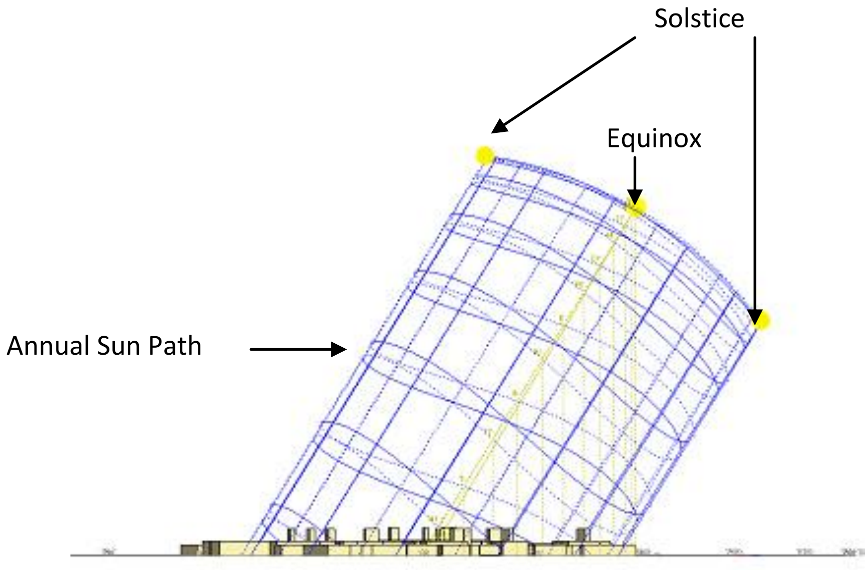


Figure 2.5.2 **West elevation of Yazd-annual sun path**

Bastakya

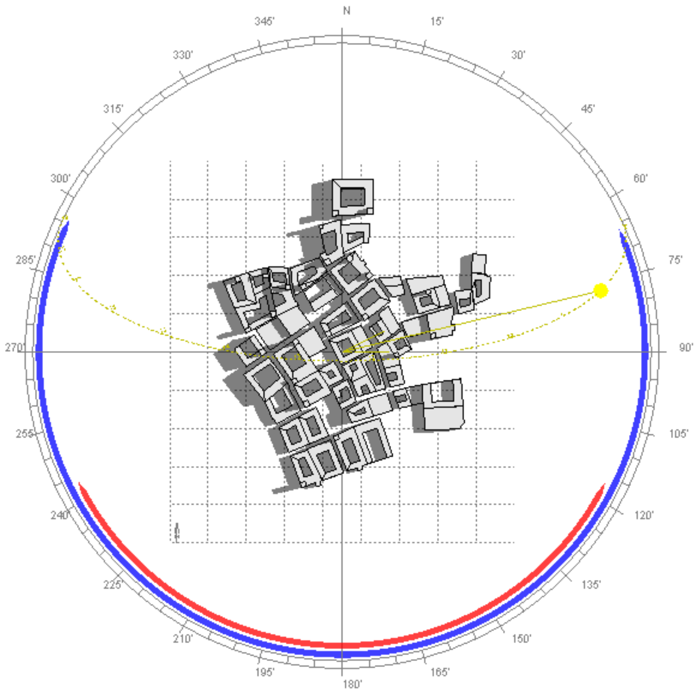
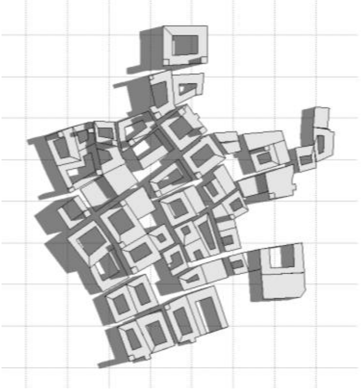
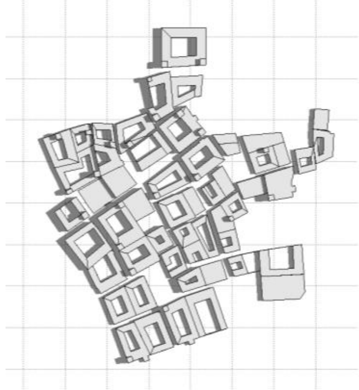
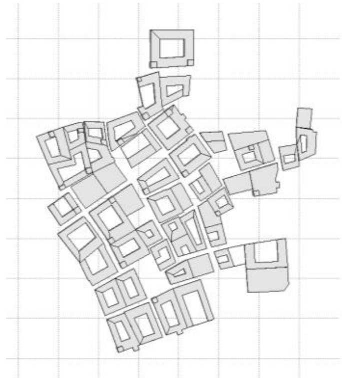
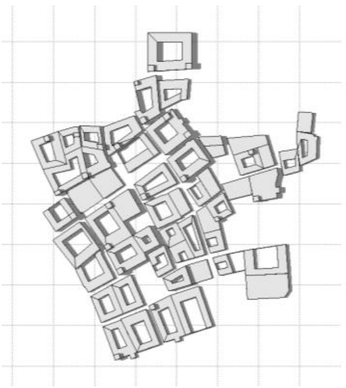
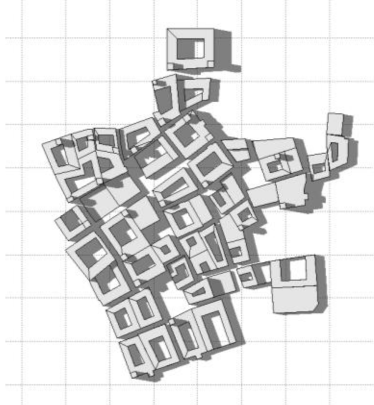
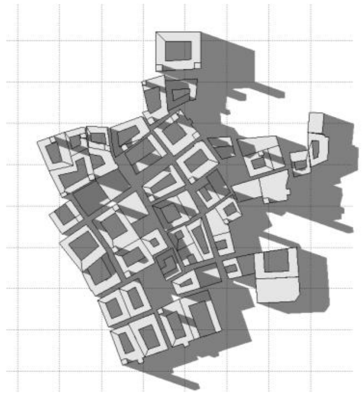


Figure 2.5.3 Sun path diagram June 21st -Bastakya

Summer

In the summer time, in the morning, the *sikkas* (alleys) are very well shaded between 8:00 and 11:00. From 11:00 to 14:00 due to the high sun angle in summer the *sikkas* are almost exposed to the sun. However, after 14:00 the efficient shading can be seen (see Table 2.5.1).

Table 2.5.1 Urban Shading analysis-June

June 21st		
		
8:00	10:00	12:00
		
14:00	16:00	18:00

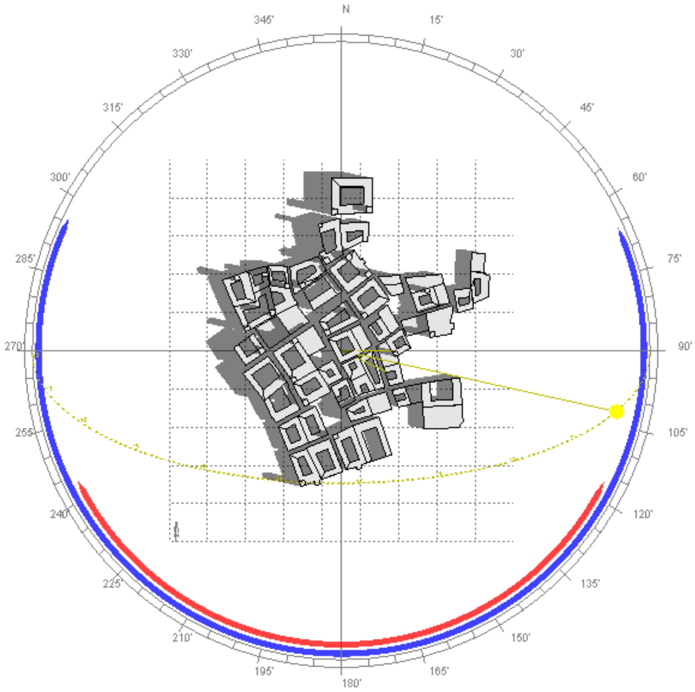


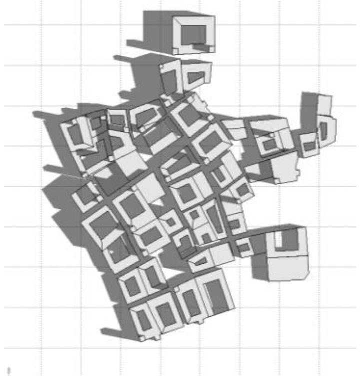
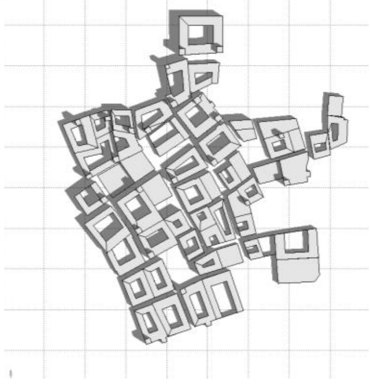
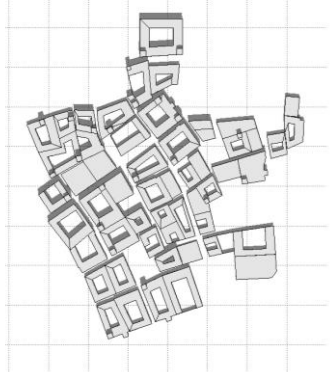
Figure 2.5.4 Sun path diagram September 21st –Bastakya

Mid-season

In the mid-season time, the mid-day is the time at which the *sikkas* are not shaded but, in the rest of the day shading is spread over on the *sikkas* (see Table 2.5.2).

The shaded *sikkas* in the time which average temperature still varies between 27°C and 37°C can affect the outdoor thermal comfort.

Table 2.5.2 Urban shading analysis- September

<table>
<tr><td colspan="3">September 21st</td></tr>
<tr><td></td><td></td><td></td></tr>
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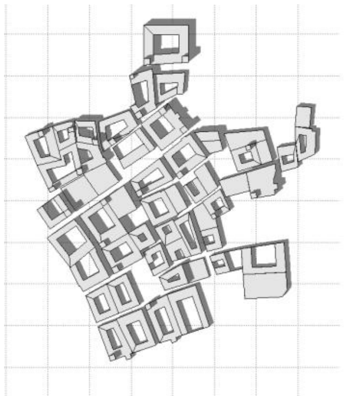
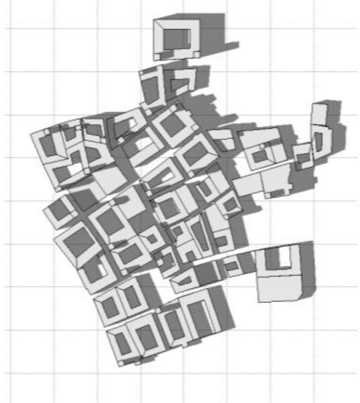
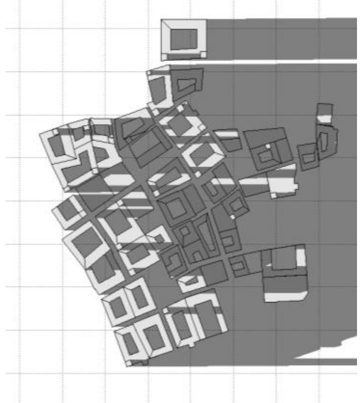
<tr><td></td><td></td><td></td></tr>
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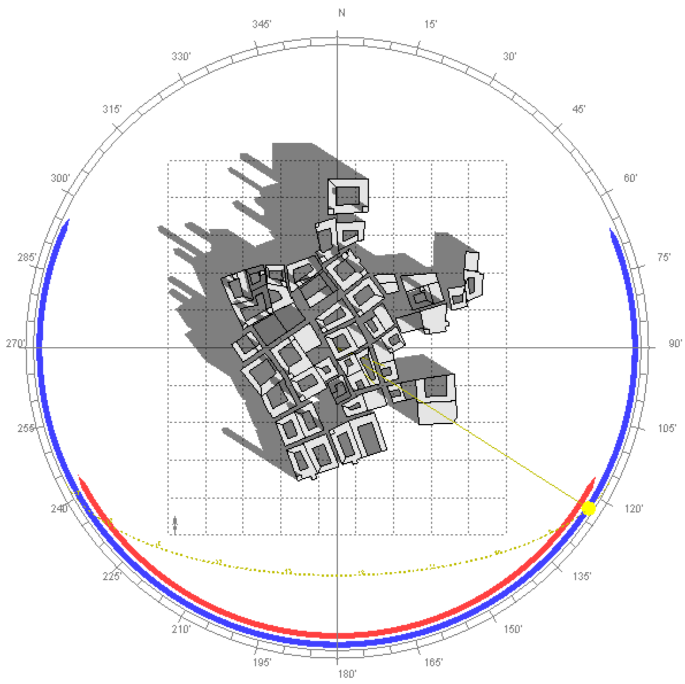
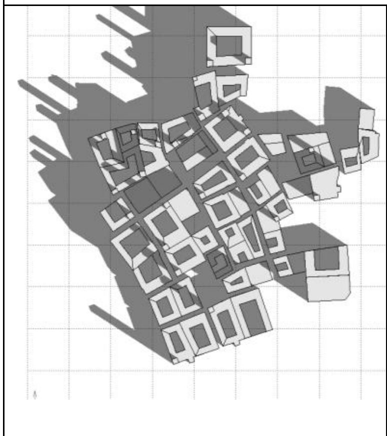
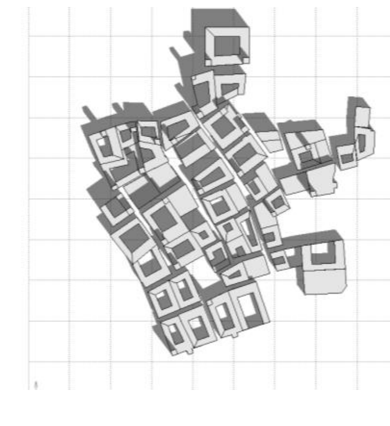
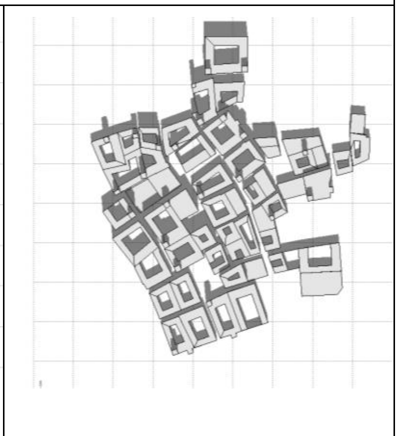


Figure 2.5.5 Sun path diagram December 21st -Bastakya

Winter

The *sikkas* are shaded the whole day in the winter time due to the low sun angle. Although the shading in the winter time is not desirable, in mid-day it can be effective to reduce solar radiation and provide more comfortable environment.

Table 2.5.3 Urban shading analysis - December

December 21st		
		
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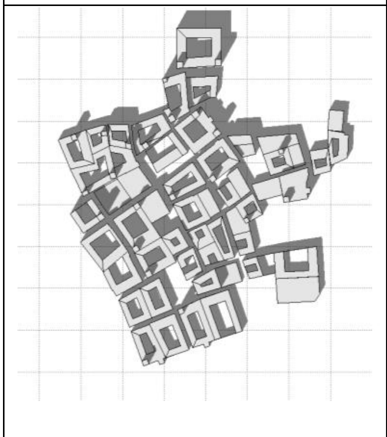
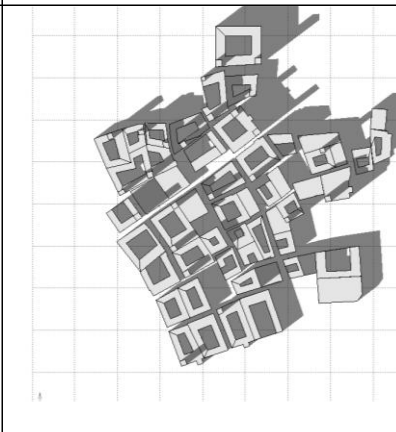
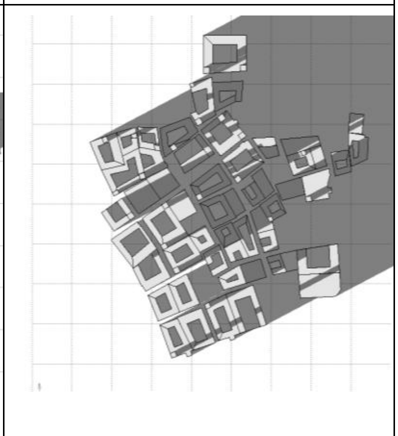
		
14:00	16:00	17:15

Yazd

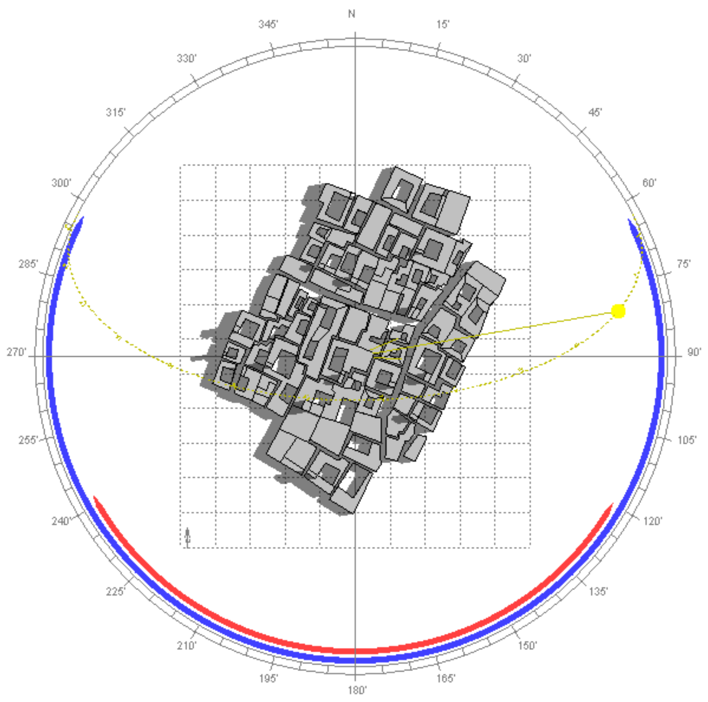
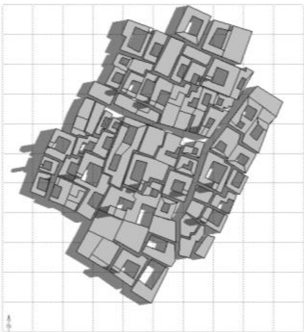
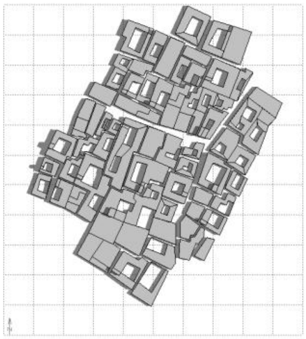
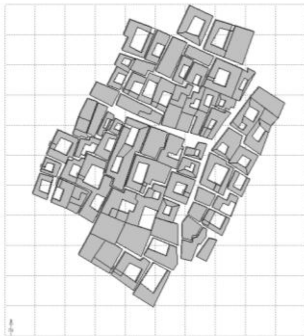


Figure 2.5.6 Sun path diagram June 21st -Yazd

Summer

Apart from the main east-west street in Yazd, the other streets are well shaded in the early morning and the late afternoon in the summer day.

Table 2.5.4 Urban shading analysis – June

June 21st		
		
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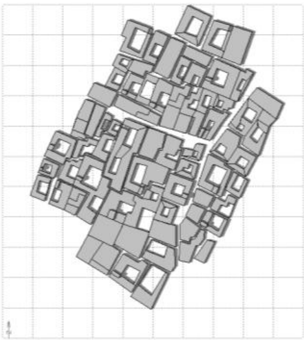	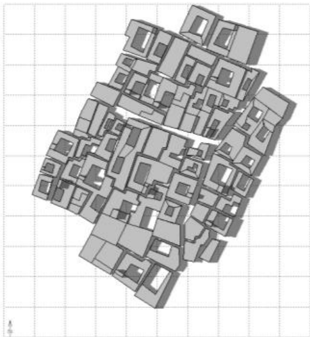	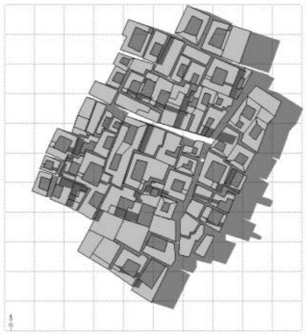
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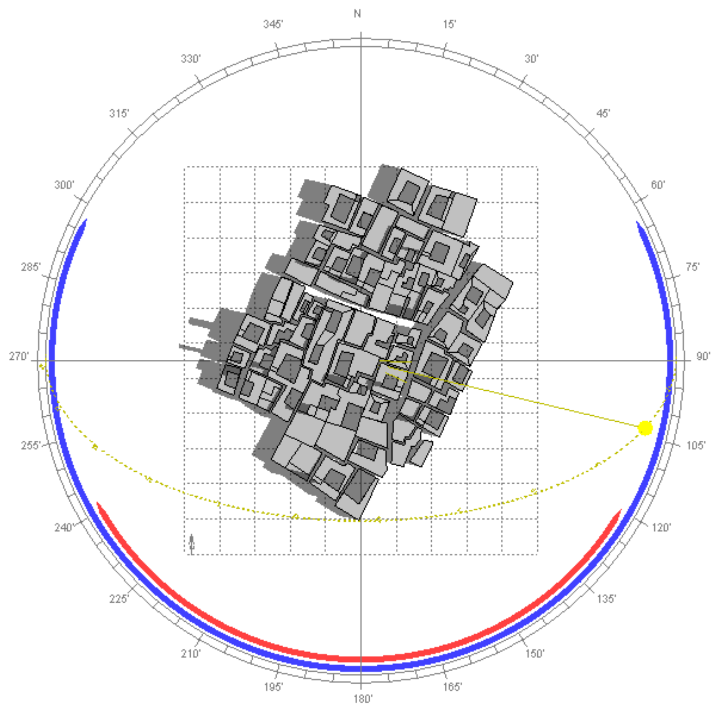
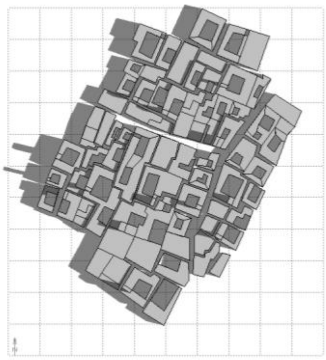
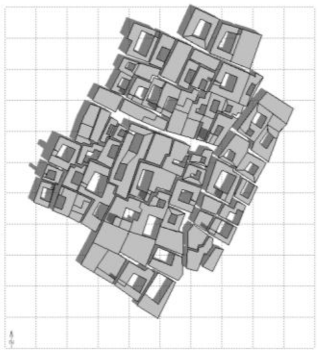
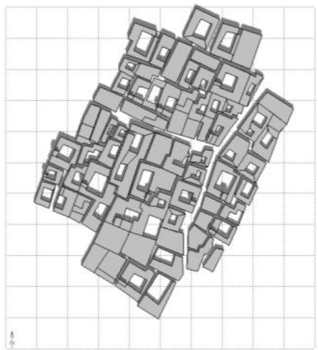


Figure 2.5.7 Sun path diagram September 21st -Yazd

Mid-season

The urban form provides well shading throughout the day however, similar to Bastakya the streets are exposed to sunlight in the midday time.

Table 2.5.5 Urban shading analysis - September

September 21st		
		
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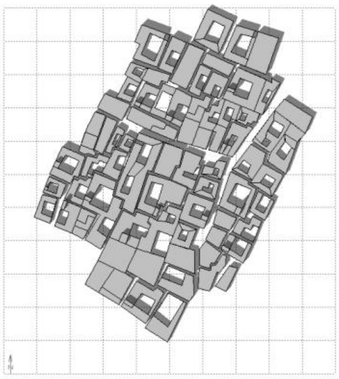	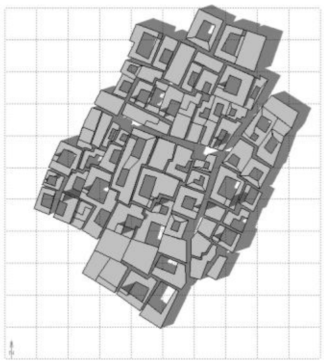	
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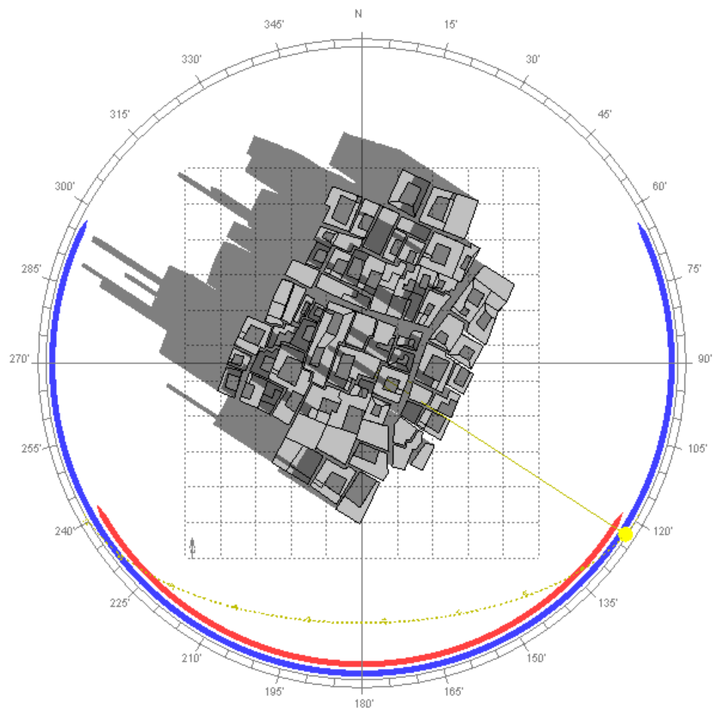
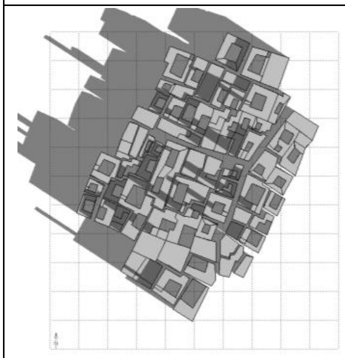
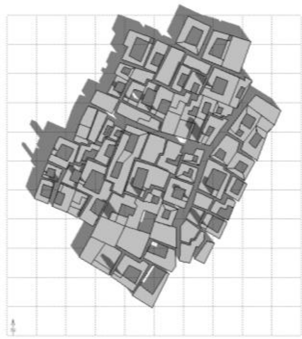
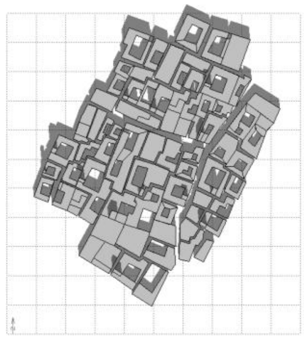
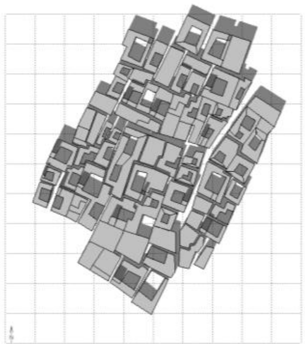
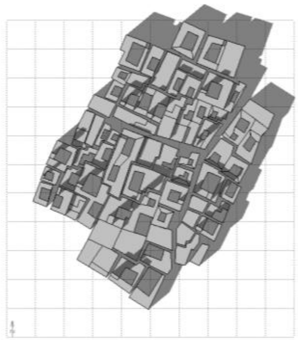
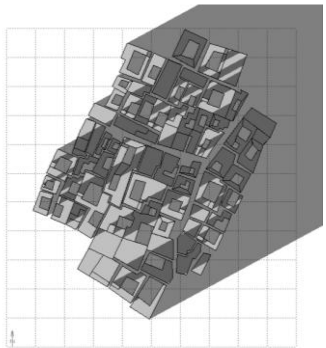


Figure 2.5.8 Sun path diagram December 21st -Yazd

Winter

Table 2.5.6 below shows very dense shading over the streets in winter. The thorough shading is not desirable in Yazd when the temperature falls down to -5C.

Table 2.5.6 Urban shading analysis - December

December 21st		
		
8:00	10:00	12:00
		
14:00	16:00	17:15

Urban Shading Intensity

According to the above diagrams, the calculated shading intensity based on the calculated shaded areas in the selected urban fabrics is summarized in the tables below.

Table 2.5.7 Urban shading intensity- Bastakya

Bastakya	08:00	10:00	12:00	14:00	16:00	18:00
Summer	100%	50%	0%	30%	**90%**	100%
Mid-season	100%	70%	25%	70%	100%	100%
Winter	100%	100%	**90%**	100%	100%	100%

Table 2.5.8 Urban shading intensity- Yazd

Yazd	08:00	10:00	12:00	14:00	16:00	18:00
Summer	95%	60%	0%	40%	90%	95%
Mid-season	95%	90%	70%	80%	98%	100%
Winter	100%	100%	100%	95%	100%	100%

Results

Bastakya

Table 2.5.7 reveals the influence of the Bastakya urban form, including the *sikkas* width, buildings form and orientations, on the shading intensity of the outdoor spaces throughout the year. As it was mentioned before, in summer and mid-season shading is more preferable since, the other thermal comfort parameters reach to the peak rates. In the overall evaluation, at the only short period of the summer time *sikkas* are exposed to sun. In order to understand the outdoor occupancy pattern in sixty years ago there more studies should be conducted in future. In that time, after the *Zohr* (noon) pray, all the outdoor activities were closed for 3 hours which means by the time when they were back to work, the shaded sikkas were ready to be used.

Yazd

In Yazd, similar to Bastakya, the minimum shading intensity occurs at the summer midday. In the period of 4 hours, sun penetrates directly into the streets and the urban form and geometry can not be effective factors in providing shading (see table 2.5.8). The intense shading in mid-season in Yazd can be effective in improving thermal comfort level. However the maximum shading intensity in the all seasons is seen in winter, it is not desirable for the occupants in the very cold winter in Yazd.

2.6 Urban form and temperature

In order to understand the effect of the compact urban fabric in both Yazd and Bastakya on the urban average temperature the SVF is explained below.

Introduction to the Sky View Factor

If we look out toward sky from a point on the ground with 180° horizontal and 180° vertical angles (fish eye view) then the ratio between the visible sky and the total view is the SVF (sky view factor). The SVF presents a value to measure the compact level of the urban fabric.

For instance, for a roof which has a full view of the sky the SVF would be 1 but for the street located between towers, it would be less than the roof SVF depending on the amonut of obstructions.

In addition, heat island phenomenon, which is the increase in temperature within an urban context in comparison to the rural area, can also be determined by the SVF (Steemers and Steane, 2004). According to the Oke's research (1981), research, lower SVF results in higher urban temperature in comparison to the rural areas He presented the equation below:

$$\Delta T \text{ max urban-rural} = 15.27 - 13.88 SVF$$

In the above equation, ΔT is the maximum temperature difference between the urban and rural context and SVF is sky view factor.

In order to undertake a SVF analysis, Ecotect program is used to make the models of two urban fabrics. Ecotect program has an option to display a fish eye-view for a mid-point on every selected sufface. Since the SVF is presented for a single point, the more divisions on the selected surface, the more accurate the results achieved are. Therefore, as it is shown in figure 2.6.1 for a point in Bastakya, the fish eye view consists of the visible and obstructed areas. In figure

200, 200 points are displayed within the diagram, and every point represents 0.5% of the daylight illuminance based on the CIE Uniform Sky, in which all areas are equally weighted (Ecotect Help Desk). In the case of urban study, the context should be divided in to smaller sections and then every section is studied individually and then the result is an average of every section.

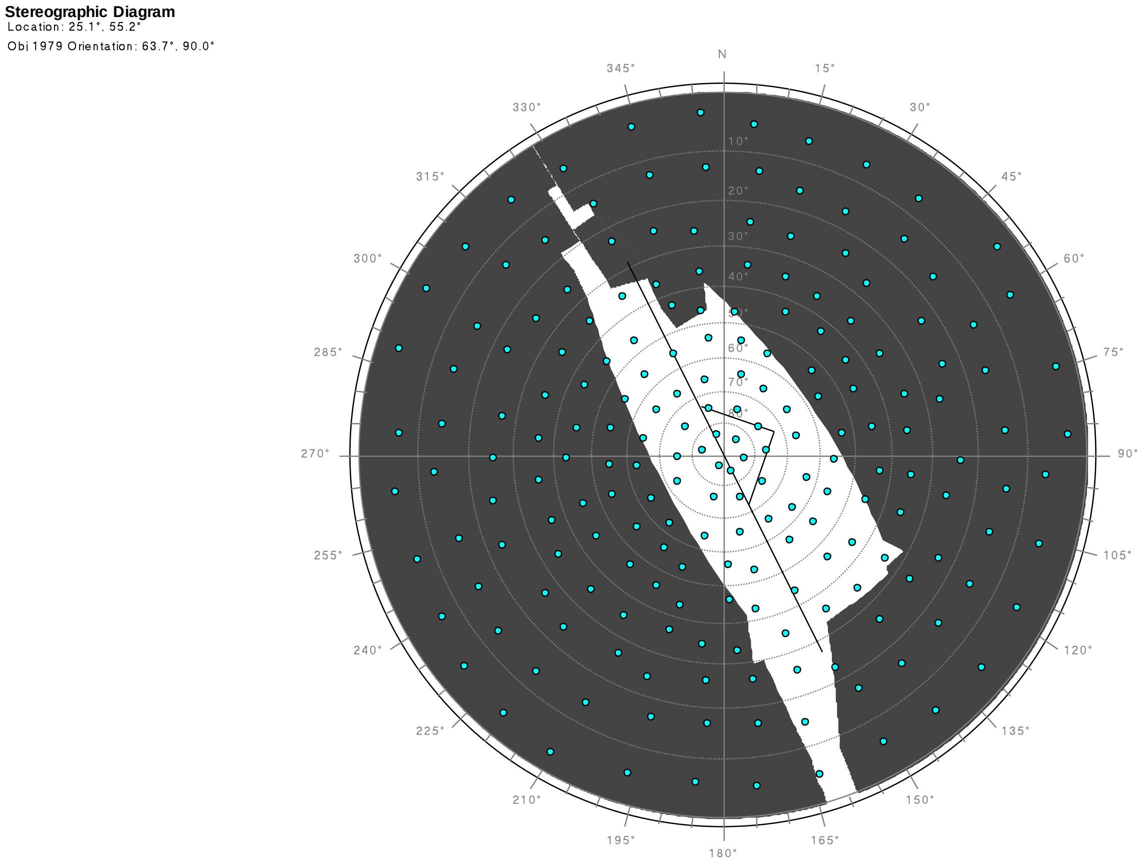


Figure 2.6.1 ECOTECT SVF result

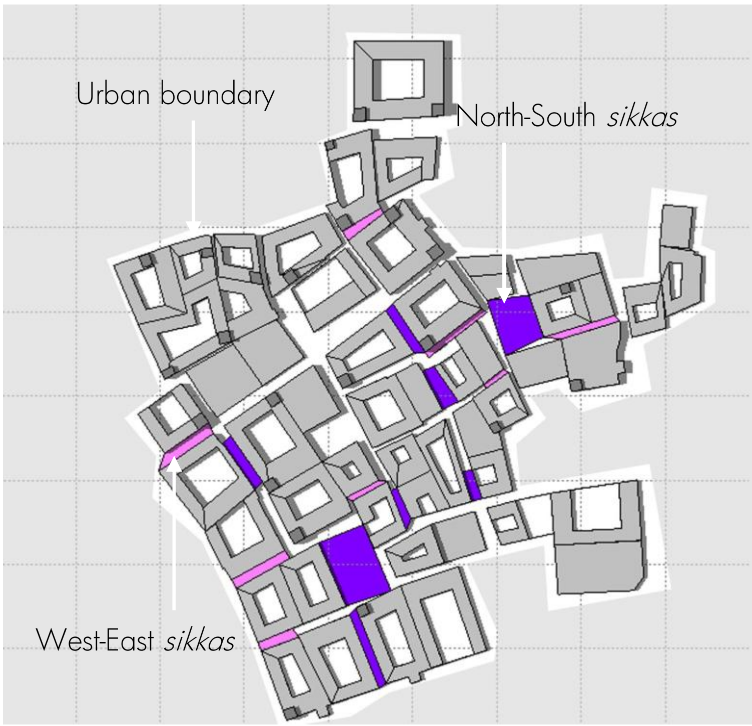


Figure 2.6.2 The SVF divisions distributions- Bastakya

Figure 2.6.3 the SVF divisions distributions- Yazd

Results

To analyze the Bastakya and Yazd urban fabrics, seven streets on north-south and seven streets on the west-east directons were selected. Every street was divided in three sub-divisions (Figure 2.6.2 and 2.6.3). Thus, SVF for every street is an average of the all three sections. In Table5, the calculated SVFs for the all streets are presented. However the total average of SVFs can not be absolutley accurate , the findings from this methods is very close to the total SVF because it includes the average maximum and minimum SVF within the urban boundary.

According to the Oke equation, the difference temperatures of the urban fabrics in Yazd and Bastakya to the rural areas are presented in the tables below:

Table 2.6.1 The Average SVF and ∆T –Bastakya

Sikkas divisions	*Sikkas*						
	Avg-1	Avg-2	Avg-3	Avg-4	Avg-5	Avg-6	Avg-7
North-South*sikkas*	0.265	0.25	0.16	0.14	0.32	0.155	0-15
West-East *sikkas*	0.125	0.52	0.105	0.075	0.2	0.21	0.525
Total Avg SVF	0.2285						
∆T	12.09 °C						

Table 2.6.2 The Average SVF and ∆T –Yazd

Yazd divisions	*strreets*						
	Avg-1	Avg-2	Avg-3	Avg-4	Avg-5	Avg-6	Avg-7
North-South*sikkas*	0.095	0.135	0.11	0.055	0.24	0.055	0.095
West-East *sikkas*	0.075	0.225	0.325	0.105	0.08	0.07	0.075
Total Avg SVF	0.130833						
∆T	13.45 °C						

Results

The reuslts of the Oke equation deals with the urban form regardless of the surface absorption or reflectance or temperature because it solely workds with the sky view factor. The results of this method present the urban fabric effect on the radiation exchange between sky and the urban surfaces.

Bastakya

In the Bastakya urban fabric, the results present the high temperature difference in the *sikkas.* It means that the urban fabric temperature is 12.09 °C cooler than the rural area. The results illustrated the effect of the urban form and geometry on the urban temperature.

Yazd

The denser urban fabirc in Yazd in comparison to Bastakya results in higher SVF value. According to the Oke equation in Yazd and the calculate average SVF, ΔT is 13.05°C.

2.7 Shading Intensity analysis

Building

The selected buildings in Bastakya and Yazd have been studied individually to assess the shading intensity within the courtyard. The models of two houses are made in Ecotect based on the CAD drawings. The models are analyzed on the typical summer, mid-season and winter days which mentioned earlier (see the urban shading intensity analysis).

Bastakya

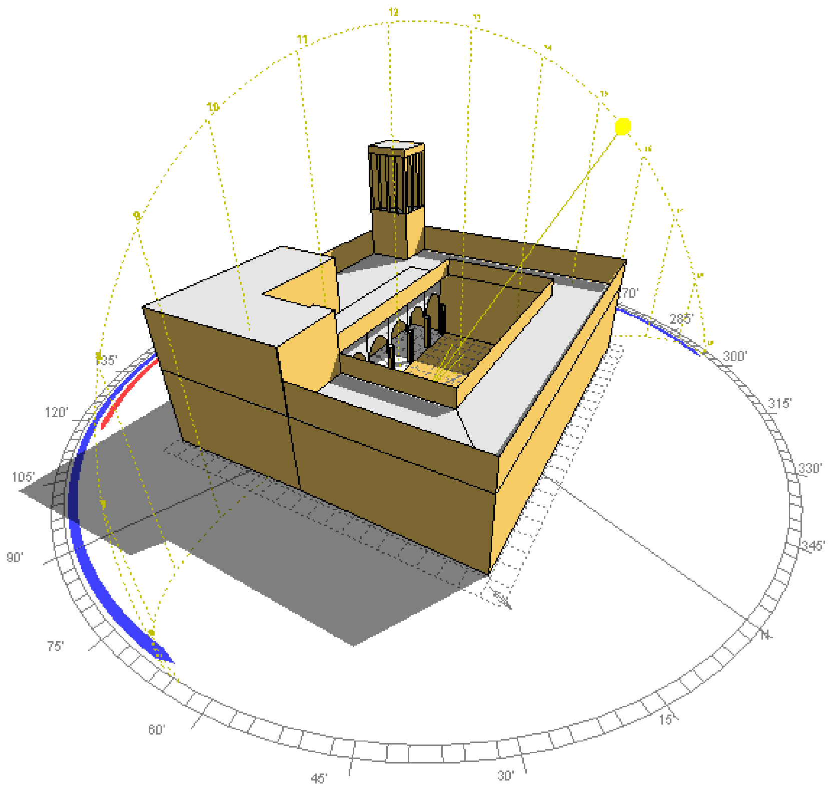


Figure 2.7.1 Sun-path diagram on the perspective of the building in Bastakya

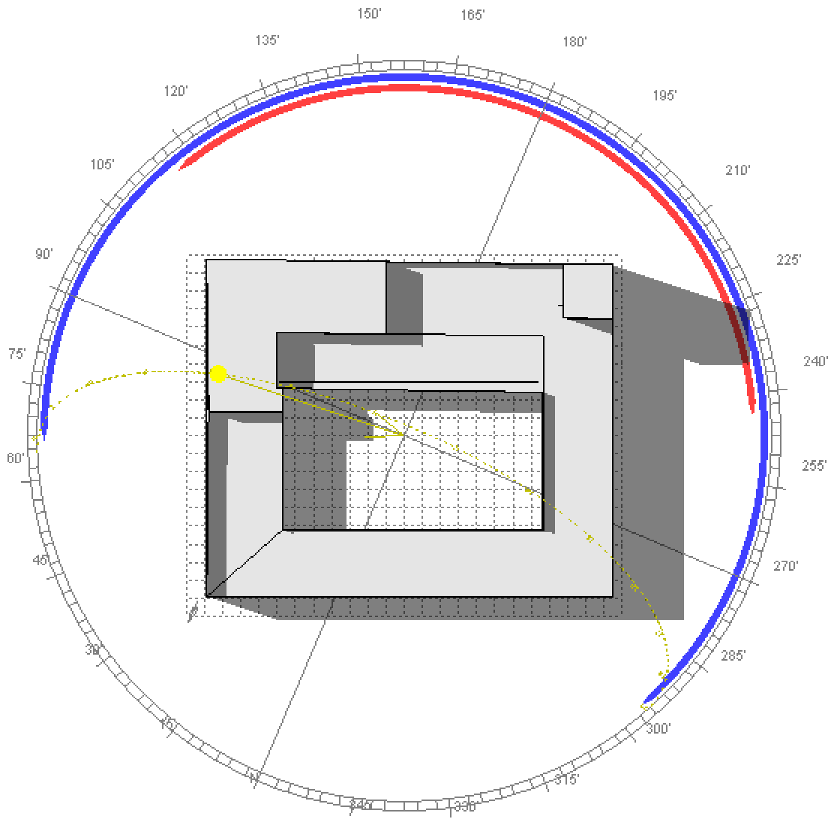
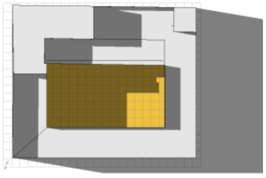
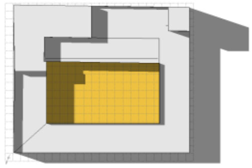
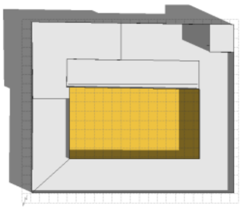
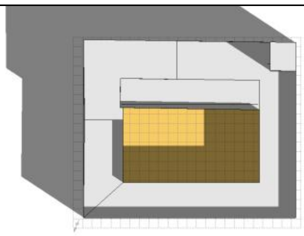
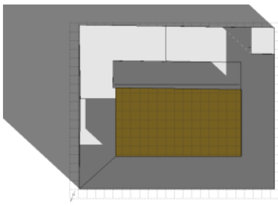


Figure 2.7.2 **Sun-path diagram on the plan of the building in Bastakya**

Summer

In the summer time, in the early morning and the late afternoon the courtyard is well shaded, for period of 4 hours, between 10:00 and 14:00, the minimum shading is seen.

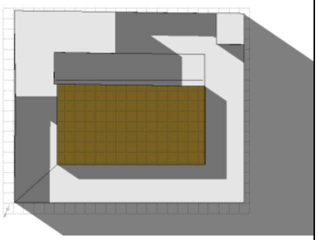
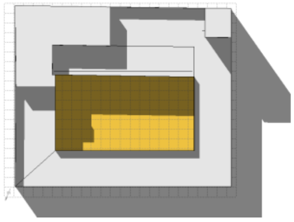
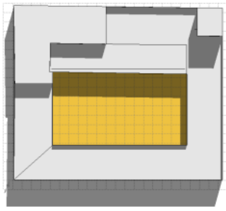
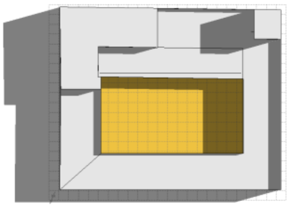
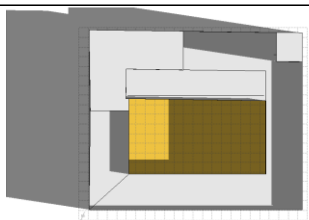
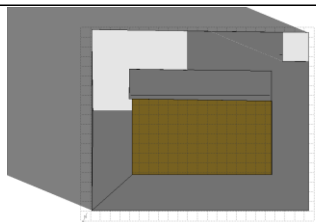
Table 2.7.1 Building shading analysis- June

June 21st		
		
8:00	10:00	12:00
		
14:00	16:00	18:00

Mid-season

The minimum shading in the courtyard is shown at mid-day which is still 25%. In the hottest period of the day, between 12:00 and 17:00 when the average temperature fluctuates between 35°C and 38°C, the shading increases from 25% at 12:00 to 60% at 16:00.

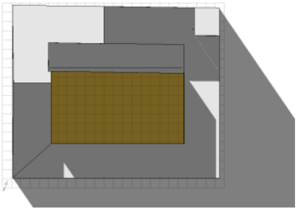
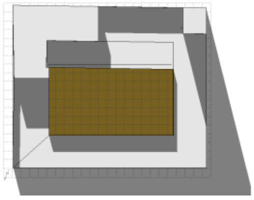
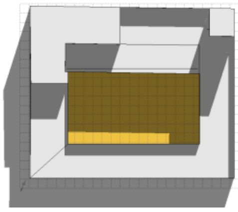
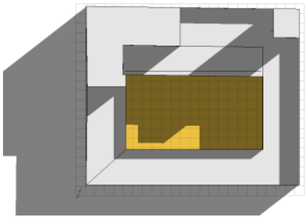
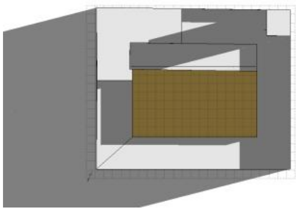
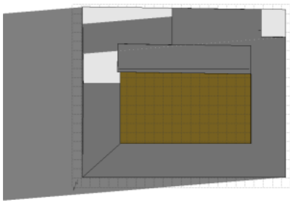
Table 2.7.2 Building shading analysis- September

September 21st		
		
8:00	10:00	12:00
		
14:00	16:00	18:00

Winter

In the wintertime, like the *sikkas*, the shading completely covers the courtyard throughout the day.

Table 2.7.3 Building shading analysis- December

December 21st		
		
8:00	10:00	12:00
		
14:00	16:00	17:15

Yazd

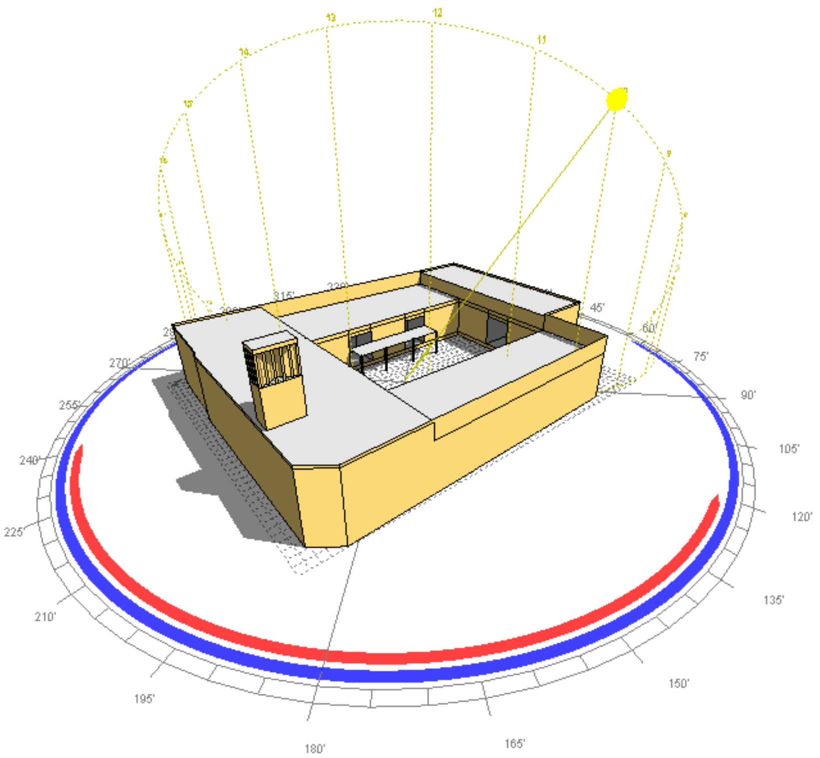


Figure 2.7.3 Sun-path diagram on the perspective of the building in Yazd

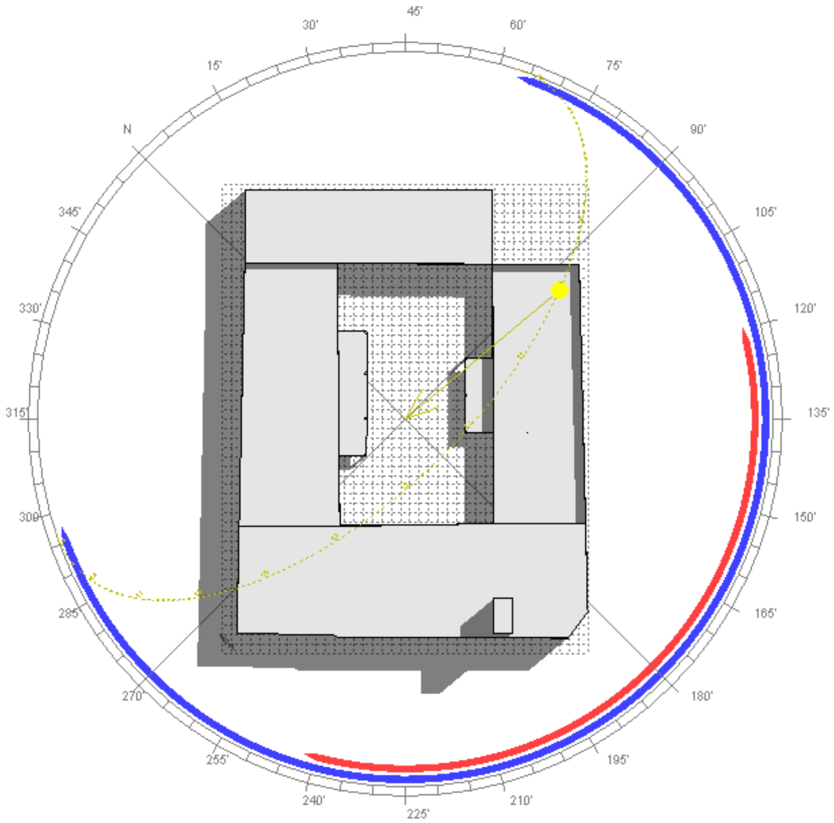
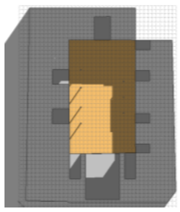
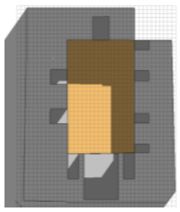
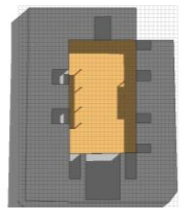
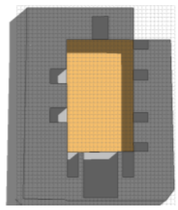
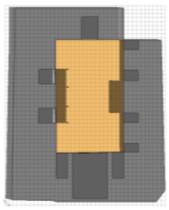
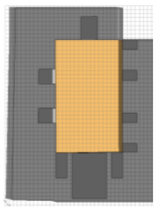
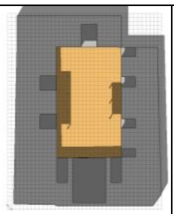
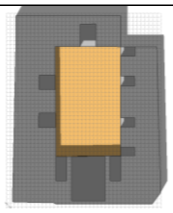
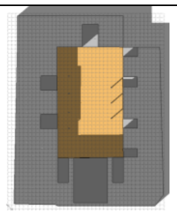
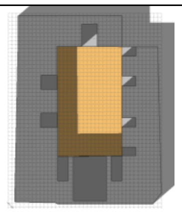
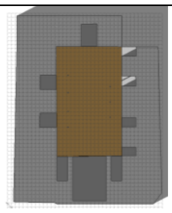
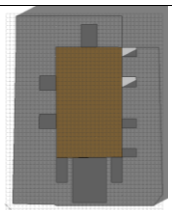


Figure 2.7.4 Sun-path diagram on the plan of the building in Yazd

Summer

As it is shown in the table below, the maximum shading is seen between 8:00 and 10:00, and 16:00 afterward. However, when the sunlight penetrates directly to courtyard the shading has the minimum intensity, the vine shading device helps significantly in providing shaded areas in the front of the main rooms.

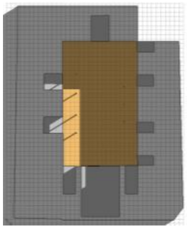
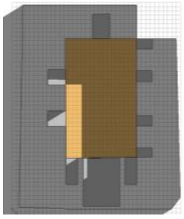
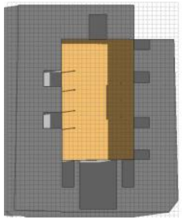
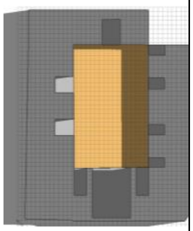
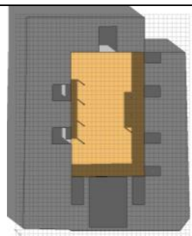
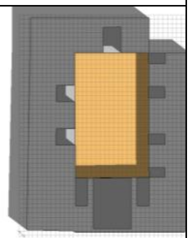
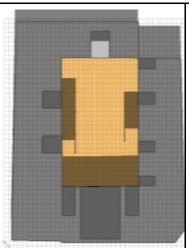
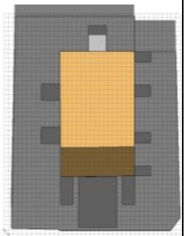
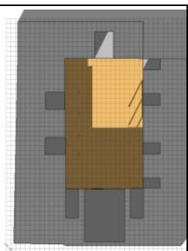
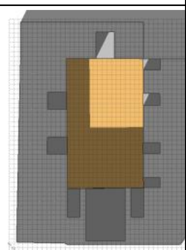
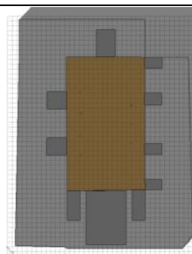
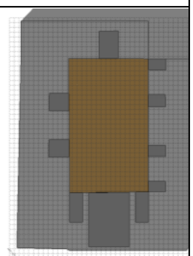
Table 2.7.4 Building shading analysis- June

June 21st					
					
Vine shading	Non-Vine shading	Vine shading	Non-Vine shading	Vine shading	Non-Vine shading
8:00		10:00		12:00	
					
Vine shading	Non-Vine shading	Vine shading	Non-Vine shading	Vine shading	Non-Vine shading
14:00		16:00		18:00	

Mid-season

The shading intensity varies from the maximum in the morning time to the minimum 30% in mid-day and again it increases to the maximum 75% at 16:00. The vine shading device works properly in the hottest time of the mid-season day.

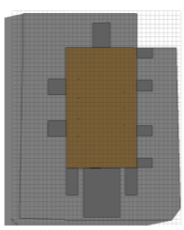
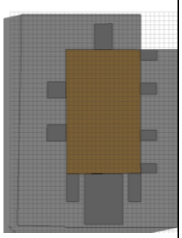
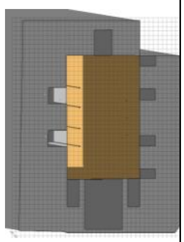
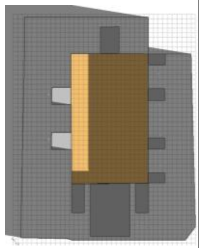
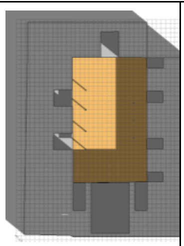
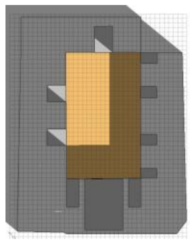
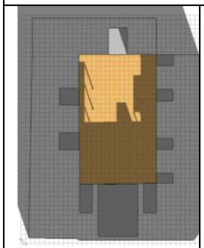
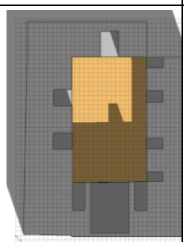
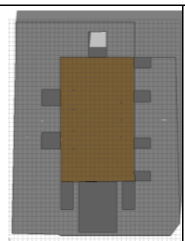
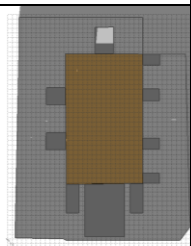
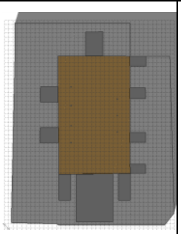
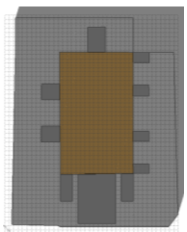
Table 2.7.5 Building shading analysis- September

September 21st					
					
Vine shading	Non-Vine shading	Vine shading	Non-Vine shading	Vine shading	Non-Vine shading
8:00		10:00		12:00	
					
Vine shading	Non-Vine shading	Vine shading	Non-Vine shading	Vine shading	Non-Vine shading
14:00		16:00		18:00	

Winter

When the sun is desirable in Yazd in the cold wintertime, the shading intensity is quite effective and only for the midday time partially the sunlight is available. In this period of the year, the minimum shading intensity is 55%.

Table 2.7.6 Building shading analysis- December

December 21st					
					
Vine shading	Non-Vine shading	Vine shading	Non-Vine shading	Vine shading	Non-Vine shading
8:00		10:00		12:00	
					
Vine shading	Non-Vine shading	Vine shading	Non-Vine shading	Vine shading	Non-Vine shading
14:00		16:00		17:15	

Shading intensity in the courtyard

The results of the above diagrams have been summarized in tables 2.7.7 and 2.7.8 which present the shading intensity in the courtyards throughout the year.

Table 2.7.7 Shading Intensity in the courtyard - Bastakya

Bastakya	08:00	10:00	12:00	14:00	16:00	18:00
Summer	80%	40%	5%	40%	75%	**100%**
Mid-season	**100%**	60%	25%	45%	80%	**100%**
Winter	**100%**	**100%**	**90%**	**90%**	**100%**	**100%**

Table 2.7.8 Shading Intensity in the courtyard - Yazd

Yazd		08:00	10:00	12:00	14:00	16:00	18:00
Summer	**With Vine shading**	60%	30%	15%	25%	45%	**100%**
	Without Vine shading		15%	0	10%		
Mid-season	**With vine shading**	**80%**	40%	30%	40%	70%	**100%**
	Without Vine shading			15%	20%		
Winter		**100%**	**80%**	**55%**	**75%**	**100%**	**100%**

Results

Bastakya

Table 2.7.7 reveals the efficiency of the traditional building form in Bastakya in providing shading within the house. However, it should be mentioned that the building orientation is the other major factor which had a significant effect on the shading pattern. As presented in table 2.7.7, 5% is the minimum shading in the whole year and it occurs at midday in the summertime. According to the shading intensity growth and decline, it is understood that in a period of two hours, between 11:00 and 13:00, the shading does not exceed 25% which is very low for in 11 hours sunlight per day on June. In mid-season, the shading is quite homogenous and effective. Even, at midday 25% shading helps reduce received solar radiation by the courtyard. In the wintertime, although 10% direct solar radiation is received at midday, the shading intensity in the courtyard is quite high which is not desirable in the wintertime.

Yazd

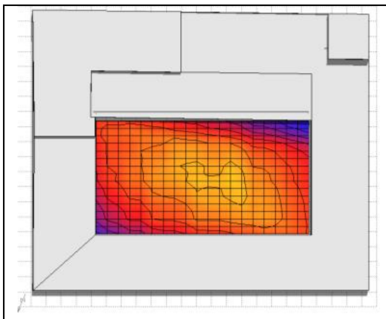
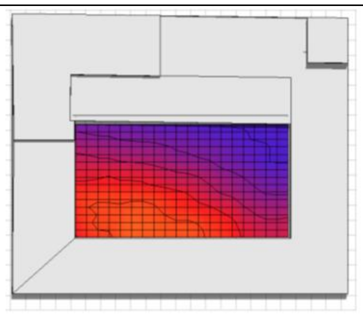
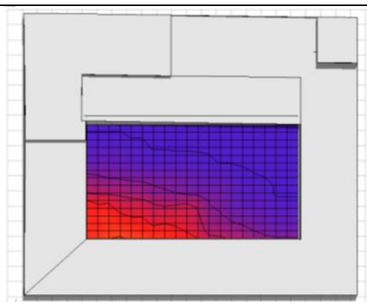
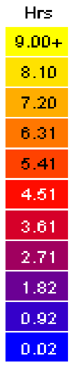
In Yazd, by integrating the vine shading structure into the courtyard, the minimum shading intensity increases from 0% to 15% in the summer mid-day time. This is an efficient solution to provide shaded outdoor areas at the hottest period of the year. The homogenous shading is seen during most of the time in mid-season. In the cold winter when the temperature decreases to 4°C, the sunlit area does not exceed 45%of the courtyard.

2.8 Sunlight Hours in the courtyard

The sunlight hours study is carried out for the same Ecotect models. The daily average sunlight hours in the courtyard are calculated in summer, mid-season and winter (in representative days) using ECOTECT program for the Bastakya and Yazd courtyards.

Bastakya

Table 2.8.1 The sunlight hours in the courtyard -Bastakya

			
Summer- Sun hours- Daily Avg	Mid-season Sun hours- Daily Avg	Winter- Sun hours- Daily Avg	

Summer

In the summer time, the south and north corners of the courtyard receive less than an hour's sunlight. However the maximum sunlight hours is seen in the middle of the courtyard (10% of the courtyard area) for 7 hours, the average of the sunlight hours does not exceed 4.5 hours per day.

Mid-season

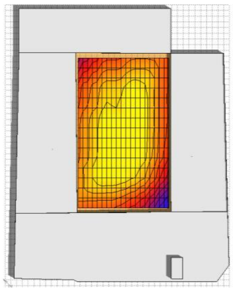
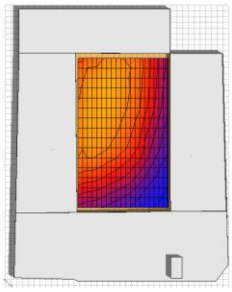
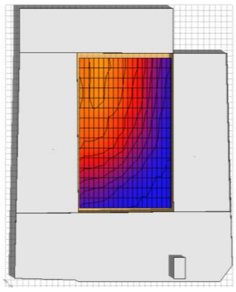
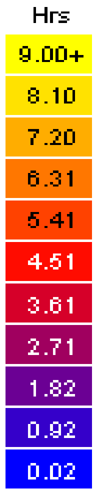
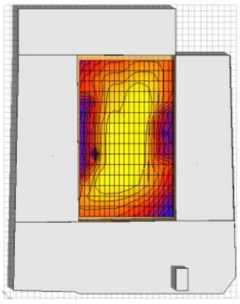
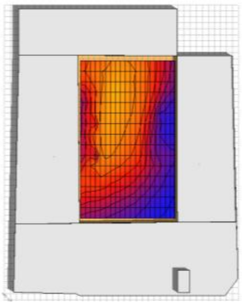
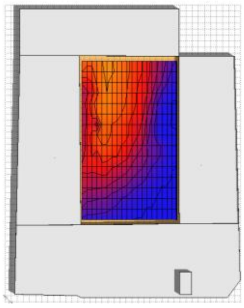
The courtyard can be divided into the southern and northern zones due to the distribution of sunlight hours. The southern zone does not receive more than an hour's sunlight but the northern zone gets an average of 5 hours per day.

Winter

Only a tiny northern part of the courtyard receives direct sunlight for an average of 4 hours.

Yazd

Table 2.8.2 Average sunlight hours in Lari house

Without shading Device				
Vine Shading Integrated				
	Summer- Sun hours- Daily Avg	Mid-season Sun hours- Daily Avg	Winter- Sun hours- Daily Avg	

Summer

The south corner of the courtyard demonstrates the lowest sunlight hours which does not exceed an hour. But the majority of the courtyard receives more than 9 hours sunlight in the summer time.

Mid-season

In mid-season, the south corner of the courtyard in the summer time which has the minimum sunlight hours is extended to a-third of the courtyard. The diagrams do not show more than an hour of sunlight in this area. In two-thirds of the courtyard, the average sunlight hours reaches 6.31 hours per day.

Winter

The east and west-north areas of the courtyard show five hours sunlight on average. In winter, half of the court yard is almost completely shaded.

2.9 Building occupancy pattern

The occupancy pattern of the housing is a unique feature of the traditional courtyard housing in the Islamic countries (Bianca, 2000). This enables the occupant to use a room for different functions in respect to the seasonal changes. People tried to be in the colder place in summer and in the hotter place in winter. Memarian (2006) mentioned in his research about courtyard housing that:

“A sample of 45 houses in Shiraz (Iran) revealed various different patterns of occupation and movement within the house. The main winter rooms might be on north-east or north-west, and the summer rooms could be on south-east or south - west of the courtyard. “

He also pointed out the vertical movement in the houses which occurred in the Iranian courtyard housings in hot climate. Pirnya (1981) also explored this feature in his study on the Iranian buildings in the hot climate. There is a lack of research to illustrate the differences between the summer and winter spaces in terms of the thermal comfort. In this study, the vertical movements in both case studies are assessed based on the sunlight and shading in the courtyard. The vertical movement in Yazd is assessed by the field measurement method.

Bastakya

The occupancy pattern in Bastakya was tin response to the extreme heat. The occupants wanted to be in the shaded and cooler spaces in the hot period of the year. In the hot summer, the south part of the building is the shaded and cooler space. Due to the large concentration of the solar gain on the center part of the courtyard, two shaded parts are created on the south and north of the courtyard. The wind tower is a main reason for selecting the south corner of the house for the summer occupancy.

In winter, the north parts of the building, both the north-west and north-east were more appropriate for occupation staying in. Theses space benefited from the direct sunlight from the low sun angle in winter. Apart from the north corner of the courtyard, the rest of the area is extremely shaded and it is seen in table 2.8.1 that the average annual sunlight hours in the major area of the courtyard hardly reaches one hour. The seasonal movement in Bastakya was similar to Yazd but, in Bastakya the wind tower was a useful tool to cool down the summer spaces (see figure 2.9.1).

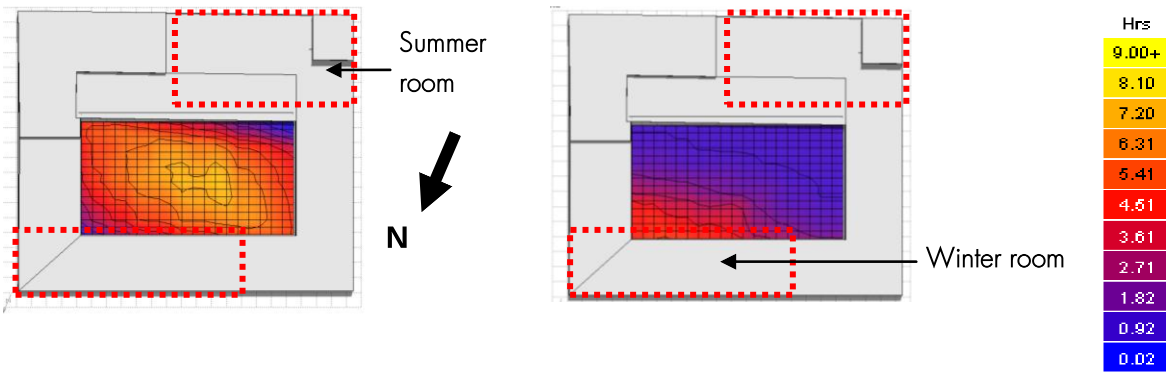


Figure 2.9.1 Occupancy pattern- Bastakya house

Yazd

Two types of movement in the Lari house took place: the vertical movement and horizontal movement. The horizontal movement was a response to the seasonal climate change. The occupants moved to be in the shaded spaces in summer and in the sunlit areas in the Yazd cold winter. The house benefited from the *Sardab* (basement space) which is 8560 millimeter lower than the courtyard ground level. This space was used in the summer afternoon (see figure 2.9.2). The sunlight did not reach the *Sardab* and it was always in shade. Ground cooling is a passive strategy which was used in *Sardab*. Therefore, the *Sardab* temperature was very close to the Yazd average temperature due to 8560 m distance from the ground level.

In order to understand the thermal comfort level in *Sardab*, the air temperature in July 28th was measured by the author. The results are shown in table 2.9.1

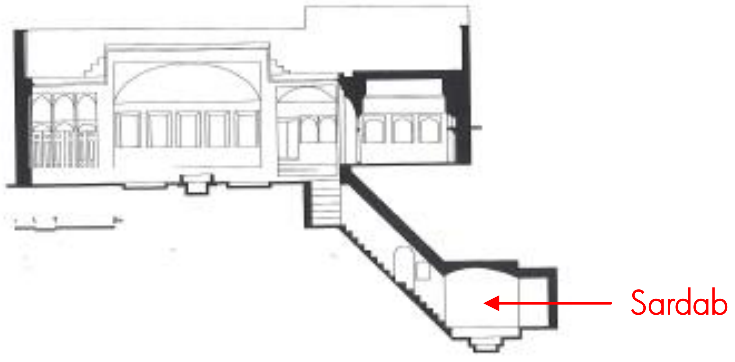


Figure 2.9.2 *Sardab* in Lari House in Yazd

Table 2.9.1 Sardab details and measured data

Date	Time	Probe Temperature	Sardab Temperature	Sardab Depth from the ground level
July 28th	12:40	35.8 C	16 C	8560 mm

The horizontal movement occurred in order to be the shaded spaces in summer and the sunlit spaces in winter. In the summer time, south-east was occupied and in the winter time, the north-west part was the ideal place to stay due to the high solar gain since the other parts were fully shaded (see figure 2.9.3).

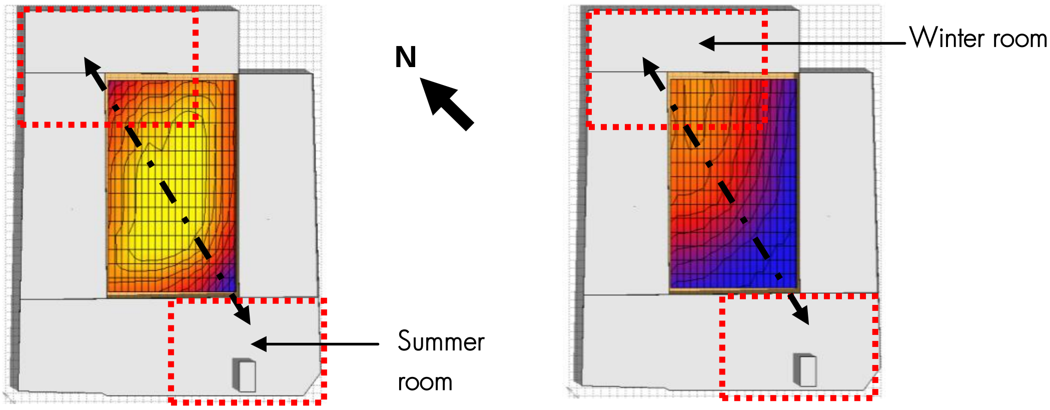
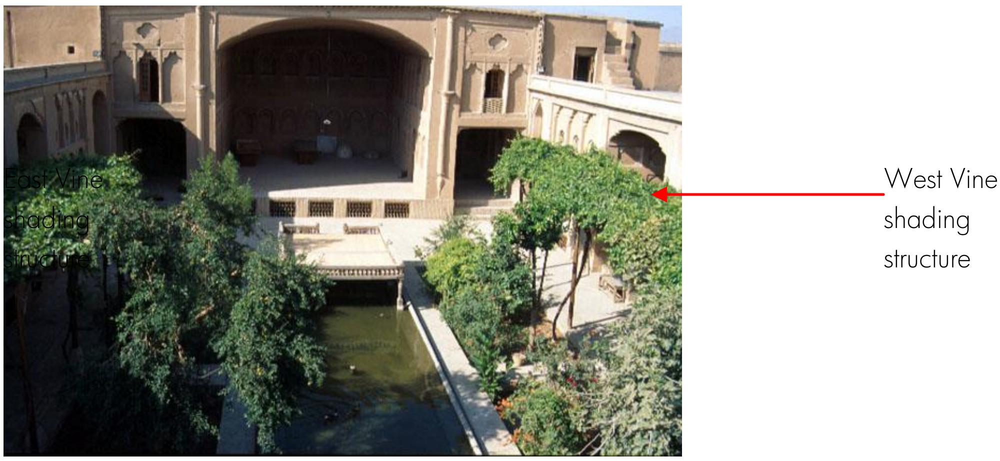


Figure 2.9.3 **Horizontal movement and occupancy pattern in Lari house**

2.10 Vine shading structure in courtyard

The vine shading structures was incorporated as an additional element into the courtyard in Yazd. This structures are located in the east and west side of the court yard (see photos 2.10.1 & 2). The vine shading structure in the courtyard would have the indoor and outdoor effects in the different aspects. The shading effects are categorized in respects to the indoor and outdoor and are discussed separately.



Photos 2.10.1 & 2.10.2 Vine shading structure – Lari House (Tehrani, 2007)

Indoor

The indoor effects of the shading include the thermal and visual comfort and psychological. The daylighting simulation reveals that in the summer time, the shading structure is quiet efficient in preventing the direct sunlight and glare. It also illustrates that this structure enables receiving enough light and at same time, preventing the undesirable solar gain. The shading structure does not influence on the light level in the room and only obstructs the direct light. In winter, since the sun angle is low, no major effect is seen. The high solar gain and daylight are received by the room and both are acceptable for that specific time of the year. The vine shading structure also provides a nice view for the interior which can be counted as an important psychological impact.

Outdoor

In the area directly beneath the vine shading device, the average sunlight hours in summer is reduced from 5 hours to less than 1 hour (see table 2.8.2). According to the findings in section 2.12, the sunlight hours reduction results in improving the outdoor thermal comfort in the courtyard. The outdoor condition improvement enabled the occupant to use it more often. In addition, the plants (vines) photosynthesis process has an effect on the microclimate. It increases the rate of evaporative cooling therefore, it influences the outdoor thermal conditions (Givoni, 1996). Since there was few green urban spaces in Yazd, bringing the greenery into the house through the vine integrated shading device helped in keeping the human and nature connection. This was a significant psychological impact in the lack of the greenery in the fully mud built environment.

Another effect of the vine shading device was explored in table 2.8.2. In summer, two shaded zones directly beneath the shading device are created. These zones have more than five hours sunlight in the option without the shading device since, the average sunlight hours reduces to one hour per day in the vine structure integrated option. In mid-season, the north-west shading structure cannot demonstrate a significant impact on the average sunlight hours and, in north-east there is a part which was already in shade by the surrounding walls. The winter diagrams do not show any difference in the sunlight hours. It means that the vine shading structure does not prevent the sunlight.

2.11 Visual impacts of shading

Integration of the shading devices in a building results in better thermal indoor and visual comfort. An efficient shading device can control the light level and prevent un-needed solar gain in the hot seasons. Several studies have been conducted in this field. The performance of typical shading devices on the daylight distribution has been presented to educate the designers (Chou, 2004). Tzempelikos and Athienitis(2005) demonstrated the shading device impact on the building thermal load for commercial and office buildings in their research. In the Yazd house, a vine shading device was added to the courtyard for both indoor and outdoor purposes. In the Bastakya house, a colonnade structure is a part of the courtyard which seems to be an additional space in the courtyard to control the sunlight. Relevant research was carried out by Sandifer and Givoni (2002) to reveal the effect of the vine structure in reducing the building thermal load.

The vine shading structure in Yazd and the colonnaded structure in Bastakya are analyzed in order to demonstrate the light level for assessing the visual comfort in the indoor spaces.

When assessing whether places are adequately lit by daylight for visual comfort, the practice in many parts of the world is to look at daylight levels under a heavily overcast sky (where the brightness is reduced for 85% of the time). This is a worst case scenario, and for the majority of the day / year the predicted daylight levels will be exceeded.

In Dubai and Yazd, however, the problem is not so much one of dark, overcast skies, as one of clear, sunny skies, or hazy skies reflecting light from all directions, causing excessive brightness. Therefore, daylight levels have been assessed for both a clear sky and a overcast sky (which follows a standard CIE distribution of brightness.)

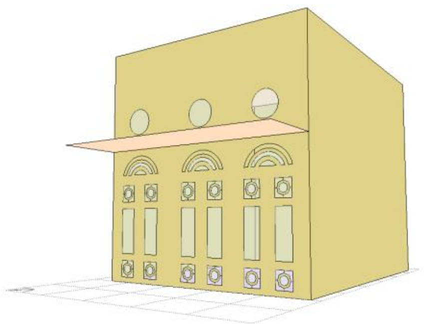
Results are presented as daylight factors with an equivalent value in Lux for the following:

- Overcast sky (worst case for darkness) – sky brightness of 10,000Lux
- Clear sunny sky – sky brightness of 20,000Lux and 100,000Lux in the sun

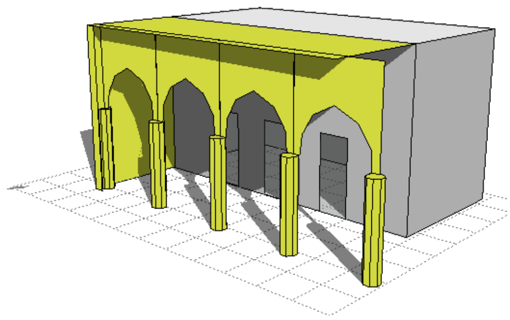
A daylight factor (%DF) is the proportion of daylight available outside that is achieved inside. For example, on a hazy day with a sky brightness of 50,000Lux, a daylight factor inside of 2% would be equivalent to 1,000Lux.)

The excessive brightness is also referred to as glare of which there are two types. The first is veiling, contrast, or disability glare, which is when there is a point of light in one's field of view that is several times brighter than the average brightness seen.

This other type is saturation glare, where excessive light reaches the eye and the pupil cannot close enough. This happens in bright sunshine, but also in lightly hazy conditions when light is reflected off dust in the air so that, no matter where you look, excessive light reaches your eyes.



Yazd room



Bastakya room

Figures 2.11.1 The Radiance models of the selected rooms-Yazd and Bastakya

In order to simulate the daylight level in the Yazd and Bastakya houses, one room in each house was selected as a representative of the whole house. The room was modeled using ECOTECT program and then it was imported into the RADIANCE program (Radiance, 2005). Several modifications were made on the imported model in RADICANCE. First, a proper sky for the analysis was generated. The sunny sky was defined based on the latitude, longitude, time and date. But overcast was introduced according to the RADIANCE manual description. Second, the reflectance ratios for the different surfaces were fed into the model. The reflection ratio for the floors, walls, and ceilings were: 0.3, 0.5, and 0.7. These figures are based on the RADIANCE recommendation for the white walls and ceilings which concurs with the houses in Yazd and Bastakya conditions.

Bastakya

In Bastakya, the rooms do not have any windows either opening on to the courtyard or outdoor apart from the guestroom. However, the guest room has five windows which opened to the outside. They were usually kept closed and used only for cooling purposes (Dalmuji, 2006).

The only openings to the outside are doors which were used instead of the windows. Whenever the occupants needed daylight, they had to open the doors (see photo 2.11.1). These doors were divided into the upper part and the lower part and depending on the occupants needs, each or both parts were opened or closed.

In order to assess the shading impact of the colonnade on the visual comfort in the indoor spaces, the main room was selected. This room is on the south-east wing of the courtyard. As it was discussed earlier, there is no window for this room and the doors were used to fulfill in the same function as windows. The selected room was modeled in the ECOTECT (see figures 2.11.1 and 2.11.3) and the modifications were applied to the model in RADIANCE. In the absence of the glazing, the clearest glazing was selected. The glazing light transmission was: 0.85. Table 2.11.1

presents the daylight level throughout the year in the afternoon when the sun hits the room and in the overcast sky conditions.

It should be noted that there were semi-open ornaments above the doors of some rooms which could be used for ventilation purposes but due to the very low percentage of opening in comparison to the opaque part, these could not have been used as a source of light. However, these very minor openings could be an indicator of the time of the day for the occupants (see figure 2.11.1).

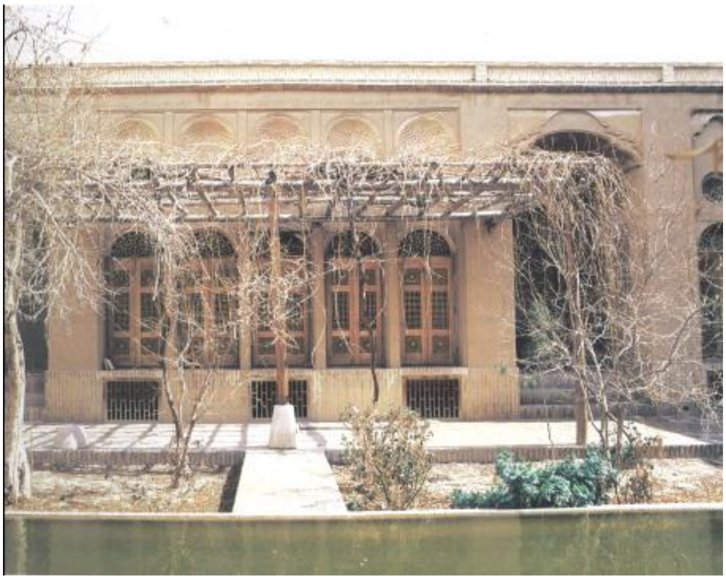
Photo 2.11.1 Bastakya room (*majlis*) - the openings (Dubai architectural heritage society)

Yazd

In the case of Yazd, the room is located on the west wing of the courtyard. Therefore, the direct sunlight only is available in the morning time till mid-day. The room consists of three traditional windows and three circular windows on the top of those. The windows include colored glasses (see figure 2.11.2).

Photo 2.11.2 The Lari house- the colored windows (Ganjname, 1999)

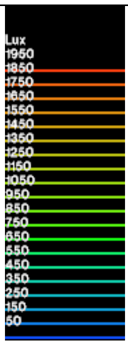
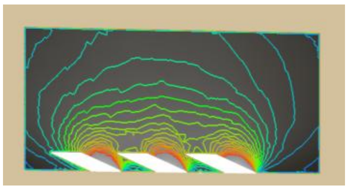
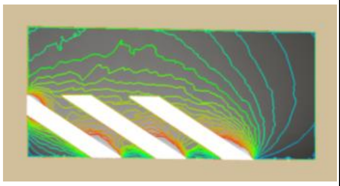
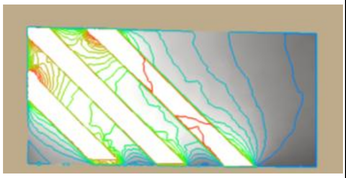
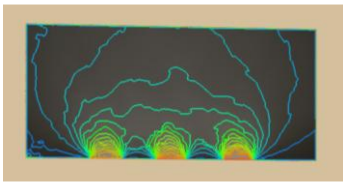
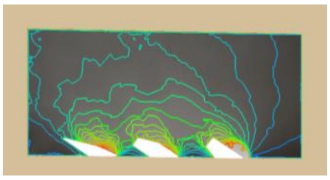
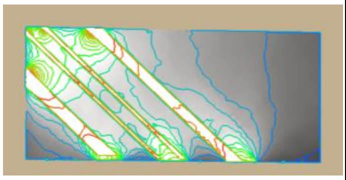
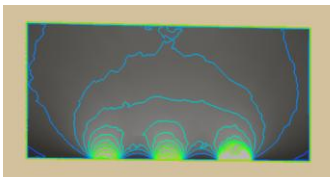
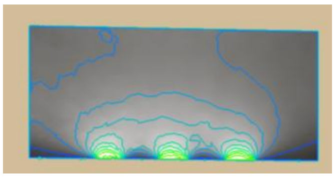
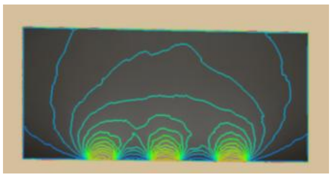
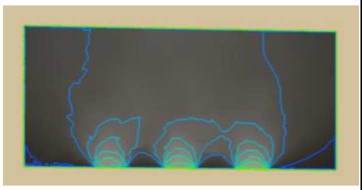
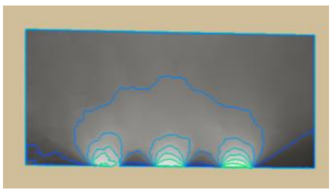
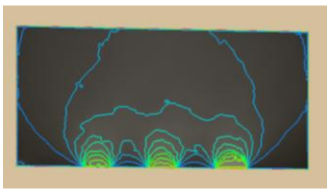
Photos 2.11.3 The openings in the Bastakya house (Dubai Architecture Heritage Society)



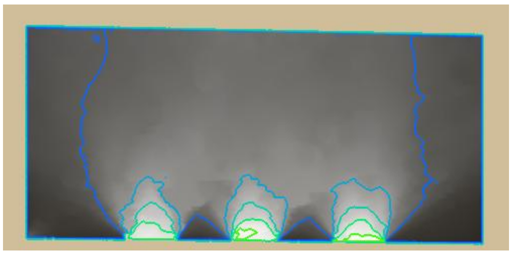
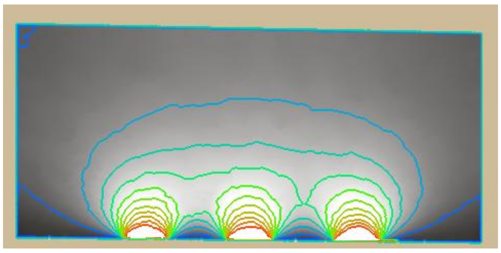
Photos 2.11.4 The openings in the Yazd house (Ganjnameh, 1999)

Bastakya

Table 2.11.1 The visual analysis- selected room in Bastakya (plan view)

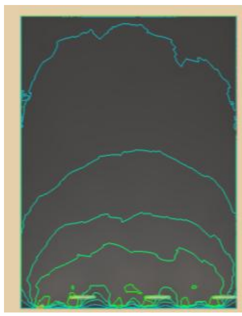
	14:00	16:00	18:00
Summer			
Summer - Shading Device integrated			
December			
December- Shading Device Integrated			

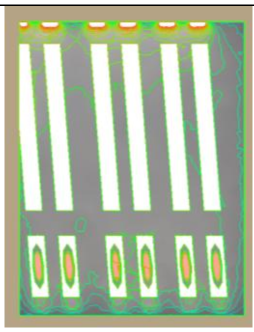
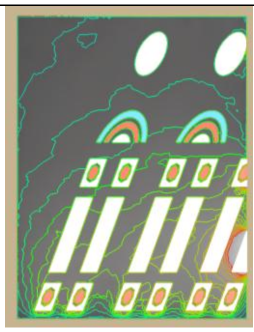
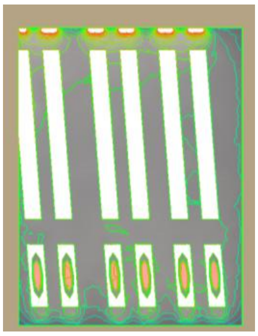
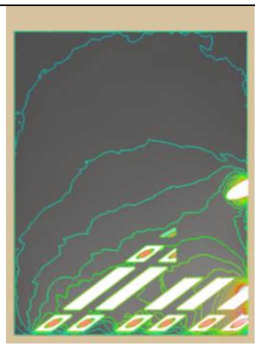
Overcast Sky 10000 Lux

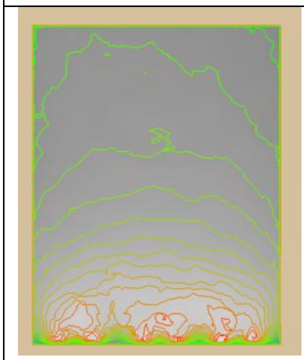
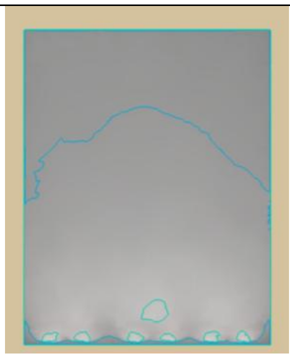
Plan -Colonnade Shading integrated	Plan- No-shading	Scale
		

Yazd

Table 2.11.2 The visual analysis- selected room in Yazd (plan view)

	8:00	10:00	12:00
Summer - Without vine structure			
Summer With Vine structure			

December Without vine structure			
December With vine structure			

Overcast Sky 10000 Lux		
Without vine structure	With vine structure	Scale
		

Results

Bastakya

In the Bastakya house, the minimum 250 Lux level is seen in the corner of the selected room in the summer diagrams but the average light level is around 550 Lux which is suitable in the residential building(Lighting Guide LG3, 2001).

In the summer late afternoon the direct sunlight penetrates more into the room and therefore, the larger area of the room is bright. In that area, the glare is the visual threat for the occupants. In the colonnade option which is the current building, the brightness is minimized due to the colonnade structure form. Since the sun angle in the winter time is low, the building form does not allow the direct sunlight to reach the room and the brightness disappears. The main source of the light in winter is the diffuse light. It can be seen that, the colonnade option does not demonstrate a significant difference in comparison to the other options. This is a positive advantage of the colonnade structure for the time when sunlight is desirable. In the overcast sky conditions, the large area of the room receives 500 Lux and the brightness is observed in a area near to the doors. The brightness level is reduced in the colonnade option however, the average daylight level in the room is also decreased to less than 300 Lux.

Yazd

As the daylight level is shown in the above tables, in the sunny sky in the summer time, the minimum daylight level is 350 Lux which is not ideal for the residential purposes. In winter, the daylight level increases due to the low sun angle which directly can reach the end of the room. In the overcast sky, the minimum daylight level is not less than 7% which is equal to 700 Lux. The light level in the overcast sky is almost twice more than the sunny sky.

2.12 Shading impacts on the outdoor comfort in the courtyards

The outdoor thermal comfort is a factor which influences the outdoor activities. It can encourage the people to do outdoor activities. As the outdoor discomfort is minimized, people like to be outside and use the outdoor spaces. For instance, in a sunny day, the more shaded outdoor spaces result in more usage of those spaces such as park.

Almost all of the research so far has dealt with indoor thermal comfort. The outdoor comfort involves different parameters which are not defined in the indoor evaluation such as: solar radiation. Generally the outdoor thermal comfort is defined by the following parameters: wind speed, ambient temperature, average surface temperature, relative humidity, solar radiation, people activity and people clothing.

The courtyard is known as an indoor open-space in the traditional built environment. Therefore the comfort level in the courtyard is in respect of the outdoor criteria. A few studies have been done to explore the role of the courtyard in providing indoor comfort but rarely any research dealt with the comfort level within the courtyard (Tablada, 2005).

In recent years few research dealt with the passive strategies in the court yard. A study by Muhaisen and Gadi (2006) explored the relation between shading patterns in the courtyard and the building form but did not explore how the shading could be useful for the occupants. In the other relevant studies, shading is always examined for the outdoor space but there is a lack of studies on the relation between the shading effects on the outdoor thermal comfort.

In a few research projects conducted on the outdoor comfort, different indicators to measure the outdoor comfort level have been introduced throughout the world. For instance, Givoni (2000) presented Thermal Sensation as an outdoor thermal indicator in his research. The thermal sensation is a parameter which he achieved through his research in Japan on a limited number of people. PET (Physiologically Equivalent Temperature) and SET (Standard Effective Temperature) are two other parameters which specify the thermal comfort level and these are used in RayMan program. This program has been developed for the urban climate analysis by Matzarakis (2001).

Other studies used the results of the two studies above in order to examine the outdoor comfort level in the different locations. Gaitani and Santamouris (2005) employed the Givoni research methods to educate the designer with different approaches to provide more comfortable outdoor space in Athens, Greece

The outdoor thermal comfort is a parameter which can indicate the comfort level in the courtyard. A few studies present the different approaches to calculate it, however there is not an exclusive way to measure the outdoor thermal comfort yet. The lack of studies in the outdoor comfort topic is obvious which should be investigated in the future research.

The main purpose of this section of the research is to present two approaches in order to define the outdoor thermal comfort and to examine the shading impact on the comfort level in the courtyard. The Givoni research has been successfully employed in the several studies (Givoni, 2000). The other chosen approach is Rayman program from University of Freiburg, Germany (Rayman, 2006). The Givoni research presents an equation. In order to define the all parameters for the whole year, the field measurement and several assumptions should be taken into consideration due to the lack of data. To minimize the influence of the assumptions, in this research, it is only used to understand the shading impact on the comfort level in the courtyard at the peak time (hottest period of the year).

The Rayman program needs only weather data (taken yearly) to calculate the comfort level since the other parameters are easily defined and the program is able to calculate the average surface temperature based on the weather data. This means that without any assumptions, the program is able to produce results for a long time. Thus, the overall impact of the shading on the comfort hours is assessed by this program. In the following section, the Rayman results are incorporated with the building shading intensity findings to explore the comfort level in the shaded and not-shaded part of the courtyard in both houses.

Field measurement

The field measurement was carried out in June, July and August, in order to investigate the effect of shading on the surfaces and temperatures and consequently the thermal comfort level to run the Givoni equation.

The infrared thermometer was used to record the surface temperatures, probe temperature and humidity in the hottest period of the year.

Device Description

The device used in this research is a Hygro-Thermometer + InfraRed Thermometer (model RH101). According to the device catalogue the range and resolution of this device is presented in the table below:

Table 2.12.1 Thermometer device description

Function	Range and Resolution	Accuracy
Humidity	10.0 to 95% RH	± 3.5% RH
Air Temperature	-20 to 60 Cº	± 2.0 ºC
IR temperature	-50 to -20 ºC	± 5ºC
	-20 to 93.3 ºC	± 2 º C
	93 to 204 ºC	
	204 to 500 ºC	± 3 ºC

The Outdoor Thermal Comfort

First Method

Nearly all of the research done to date on thermal comfort has been conducted in indoor conditions. The outdoor thermal comfort is defined by the several parameters which are not included in the indoor comfort such as, the variation of solar radiation, shading, wind speed and etc. In the Givoni (2003) research, the experimental study was carried out in Japan (1994-1995) in order to assess thermal sensation and overall comfort of subjects staying outside. The research has carried out with a group of six persons consisting of males and females from twelve to fifty years old from the summer of 1994 to the summer of 1995. The survey was on the thermal sensation on controlled conditions for solar radiation and wind speed. The group experienced three conditions including, direct sun exposure, being under a large tree (shaded) and being behind a wind break wall to controlling the effects of each factors. The analysis of the measured data enabled Givoni to develop a formula predicting the outdoor thermal sensation. He also mentioned that the formula obtained is based on a small group of people therefore it should be used as a thermal sensation indicator. The formula and parameters are presented below:

TS =1.7+0.118*Ta+0.0019*SR – 0.322*WS – 0.0073*RH+ 0.0054*ST

With an R^2 value of 0.8792

TS=thermal sensibility

Ta= air temperature (°C)

SR= solar radiation (W/m²)

WS= wind speed (m/s)

RH= relative humidity (%)

ST= surrounding surface temperature (°C)

According to the Givoni research, if proper parameters are fed into the formula, the thermal sensation varies from 0(very cold) to 8(very hot). The thermal sensation scale is shown in table below:

Table 2.12.2 Thermal sensation scale

Thermal sensation scale	
1	Very Cold
2	Quite Cold
3	Cold
4	Comfort
5	Hot
6	Quite Hot
7	Very Hot

Second Method

This method relies on RayMan 1.2 program which was developed in the Meteorological Institute of the University of Freiburg, Germany. This model is based on the German VDI-Guidelines 3789, Part II: Environmental Meteorology, Interactions between Atmosphere and Surfaces; Calculation of the short- and long wave radiation (VDI, VDI-3789, Part 2: Beuth, Berlin (1994).) The input data include human air temperature, relative humidity, wind speed, short-wave and long-wave radiation either from the 3D model or directly, clothing and human activity. Accordingly, the outputs will be the calculated mean radiant temperature, which will be the input for the other program output, Predicted Mean Vote (PMV), Physiologically Equivalent Temperature (PET) and Standard Effective Temperature (SET)(RayMan,2006).

The table below presents the PET index according to RayMan description:

Table 2.12.3 PET index

PET (°C)	**Thermal perception**
<4	Very cold
4-8	Cold
8-13	Cool
13-18	Slightly cool
18-23	Comfortable
23-29	Slightly warm
29-35	Warm
35-41	Hot
>41	Very hot

Ranges of physiologically equivalent temperature (PET in °C) for different grades of thermal perception by human beings according to [A. Matzarakis and A., Mayer, H., WHO Newsletter 18 (1996)]

Translating shading effect within the courtyard into the outdoor thermal comfort

In order to analyze on the shading impact for the outdoor thermal comfort in the Bastakya and Yazd courtyards based on the Givoni research and the RayMan Model, the peak and annual conditions were selected to be examined.

For the annual assessment, the RayMan was used to model both courtyards. The climatic data was imported from the METEONORM (1999). The results are presented through two parameters: SET (Standard Effective Temperature) and PET which are discussed in the following section. These two parameters present the outdoor comfort level in the different scale however, SET derived from the equation below:

$$SET=0.7PET-3.0$$

In the calculation procedure, it was assumed that the shaded area only receives diffuse radiation and the not-shaded area normally receives both direct and diffuse radiations and accordingly, data was imported into Rayman. The other assumption is that the albedo ratio for the flooring is 0.3. This figure represents the light colored stones.

The albedo and bowen ratios are described below:

Albedo: "The albedo of an object is the extent to which it reflects light, defined as the ratio of reflected to incident electromagnetic radiation (Wikipedia and Lechner, 2007)

A Bowen ratio is the ratio of energy fluxes from one medium to another by sensible and latent heating respectively (Wikipedia, 2007)

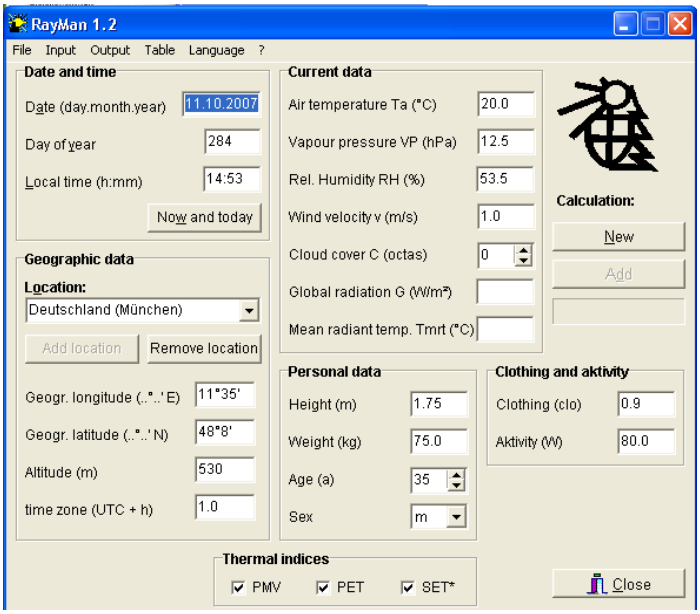


Figure 2.12.1 Rayman program interface

The total comfort hours based on the PET scale (see table 2.12.2) on the shaded and not-shaded area in the Bastakya and Yazd courtyards, are presented in table 2.12.4:

Table 2.12.4 Comfort hours in the courtyard

	Number of Hours of Comfort for Not-Shaded area	Number of Hours of comfort for Shaded area	Extra Hours of Comfort Due to Shading	Percentage of extra comfort hours
Bastakya	414	479	65	16%
Yazd	537	559	22	4%

Results

Table 2.12.4 demonstrates the effects of the shading for 9 hours a day throughout the year in both locations. The total comfort hours in the Yazd house increased from 537 to 559 hours and in the Bastakya house from 414 to 479 hours. In Bastakya, the overall improvement is 16% which is four times more than Yazd. The major increase in the comfort hours is seen first in autumn and second in spring. However, there is a low thermal comfort hours augment in winter in comparison to the other seasons.

The temperature drops down almost 20 degree but still the high humidity is a threat to the comfort level (see table 2.12.5).

Table 2.12.5 Outdoor thermal comfort hours- Bastakya

Seasons	Comfort Hours No-Shading	Comfort Hours With Shading	Percentage
Summer	29	44	52%
Winter	156	213	37%
Autumn	87	214	146%
Spring	148	234	58%

Table 2.12.6 shows that in Yazd, the major improvement occurs in spring in terms of hours from 205 to 284 whereas in winter the reverse happens when the shade is a factor in reducing the thermal comfort level due to the very low temperatures (see Yazd Climate Diagram in section 2.4.3).

Table 2.12.6 Outdoor thermal comfort hours- Yazd

Seasons	Comfort Hours No-Shading	Comfort Hours With Shading	Percentage
Summer	12	23	92%
Winter	89	10	-89%
Autumn	231	242	5%
Spring	205	284	39%

2.12.1 The comfort hours in the courtyard

In section 2.7, the shading analysis explored the shading intensity of the courtyards in the different seasons. In the RayMan approach, the comfort hours were obtained due to the shading for 9 hours a day throughout the year.

In this section, the shading impact on the comfort hours in the courtyard are revealed according to the results of two studies mentioned. Tables 2.7.7 and 2.7.8 demonstrate the shading intensity in the courtyard in the Yazd and Bastakya houses. In order to employ the findings from both tables, an average of the shading intensity of every season is calculated based on the hourly data. Taking an average of the results is one of the best approaches to find an indicator for the shaded and not-shaded areas of the courtyard however, the averages cannot present the real situation.

The Rayman study for the shaded and not shaded areas in Bastakya and Yazd presents the comfort hours throughout the year. Tables 2.12.5 and 2.12.6 illustrate the comfort hours in every season. According to the results of Rayman and shading intensity analysis, tables 2.12.1.1 and 2.12.1.2 relates the comfort hours to the shaded and not-shaded areas.

Table 2.12.1.1 The comfort hours of the courtyard-Bastakya

Bastakya		Average Area of the courtyard	Comfort Hours	Percentage of the comfort hours in each season
Summer	Shaded	57%	44	5%
	Not-Shaded	43%	29	4%
Spring	Shaded	68%	234	29%
	Not-Shaded	32%	148	18%
Winter	Shaded	97%	213	26%
	Not-Shaded	3%	156	19%

Table 2.12.1.2 The comfort hours of the courtyard-Yazd

Yazd		Average Area of the courtyard	Comfort Hours	Percentage of the comfort hours in every season
Summer	Shaded	48%	23	3%
	Not-Shaded	52%	12	1.5%
Spring	Shaded	60%	284	35%
	Not-Shaded	40%	205	25%
Winter	Shaded	85%	10	1%
	Not-Shaded	15%	89	11%

Results

Bastakya

In summer on average, 57% of the courtyard is shaded and in this area the comfort hours reach 44 hours in the summer time. The comfort hours in the other area of the courtyard make up 29 hours which is 35% less than the shaded area. The major impact of the shading is seen in spring when the comfort hours increased 58% from 148 to 213 hours. In this season, the temperature drop helps the shading to be an effective factor in increasing the comfort hours in 68% of the courtyard area. In winter, the smaller part of the courtyard is not-shaded and the shading can provide 35% augment in comfort hours for the 97% of the courtyard.

Yazd

The comfort hours are very few in summer due to the harsh sunlight and high temperature. Although the shading doubled the comfort hours, it did not exceed 3% of the 810 hours of the summer time. Similar to the Bastakya house, spring is the season at which the shading works very well to increase the comfort hours with the similar reasons. In winter, the shading has a negative impact on the comfort hours. Due to very cold winter in Yazd at when the temperature sometime reaches to -5 ^{o}C, the sunlight is extremely wanted in order to increase the comfort hours. Therefore, the only 15% of the courtyard is the pleasing place for the occupants in 11% of the winter time.

2.12.2 The comfort level at the peak time

The other analysis on the outdoor thermal comfort deals with a hot summer day in both locations. In this analysis, the required data for Givoni simulation was measured by the author during site visits. The measurement was carried out in two different times and was done in the hottest period of the time in year (late July in Yazd and early August in Bastakya). The surfaces temperature, air temperature and relative humidity in the summer time were measured by a thermo meter device which was introduced in the section 2.12.

The measured data in Yazd are show in the table below:

Table 2.12.2.1 The measured data- Yazd and Bastakya

	Yazd	**Bastakya**
Date	26/07/07	10/08/07
Time	12:25	12:50
Air Temperature	35.8°C	39°C
Relative Humidity	30%	55%
Ground Surface Temperature -Shaded	42°C	44°C
Ground Surface Temperature – Not-Shaded	52°C	55°C

In order to use Givoni equation the solar radiation and wind speed are also required. In the Givoni research, it is explained that in the shading, the solar radiation reduces to 10% to 30% of the solar radiation on the not-shade. The solar radiation varieties are reference to the intensity of the shading. Author used ECOTECT to also assess the Givoni recommendation. The results are illustrated in the table 2.12.2.2 which concurs with the Givoni findings. The other required parameter of the Givoni equation is wind speed. According to the Sharples and Bensalem (2001) research, it would be between 12. 6% to 17% of the urban wind speed for 0 to 45 degree wind orientation. The 17% and 12.6% both are taken into consideration in the calculation, and the results were same. The METEONORM is incorporated in this section for the weather data. The derived data from the simulations and weather data are demonstrated in the below table:

Table 2.12.2.2 Simulated data- Yazd and Bastakya

	Yazd	Bastakya
Solar radiation in no-Shade-ECOTECT results	636 Wh/m	524 Wh/m
Solar radiation in no-Shade- weather data	528 Wh/m	454 Wh/m
Solar radiation in shade –ECOTECT results	166 Wh/m	181 Wh/m
Wind speed in Courtyard (According to the Bensalem and Sharples (2001))	0.17*4.8m/s	0.17*5.4m/s

The thermal sensation results from the Givoni's research based on the above input data are shown in the below table:

Table 2.12.2.3 The comfort sensation results

	Yazd	**Bastakya**
Not-Shaded	Quiet Hot	Quiet Hot
Shaded	Hot	Hot

Results

Table 2.12.2.3 presents the thermal comfort sensation level on the two hottest times in the both locations. The shading has modified the Quite Hot comfort level to the hot comfort level which is a considerable impact given the harsh sun condition in the courtyards in summer. However, it's still not comfortable for the occupants to stay outside. The main reason that prevents a greater improvement in the comfort level is the high surface and air temperatures in the courtyards. The temperature difference between the shaded and not-shaded areas illustrates 10 °C which is a significant effect of shading on the ground temperature. This directly influences the thermal sensation level. It should be mentioned here that as it was discussed earlier the results were not changed with the different wind speed ratios and solar radiations.

2.13 The overshadowing impacts

In the traditional urban form in hot climates of the Middle East the urban fabric is very dense (Mortada, 2003).In this part of the world latitude varies between 10° and 40° which means that the sun angle is too high and there is a period of hot sunny days. The urban fabric response well to the climatic condition and as result the buildings are located too close to each other and the narrow streets are the major links between the buildings. In this type of urban fabric, the buildings form shades the streets and the facades of the neighboring buildings depending on the orientation, geometric properties of building and streets. The shaded streets were used in the hot, sunny days when walking under the direct sunlight was impossible.

The overshadowing had two major impacts in the traditional built environment: thermal and visual. The thermal aspects include the street and shaded building effects. Lam (2000) studied the effect of the overshadowing on the building loads in Hong Kong and he found that the overestimation design of plant size of 2% by neglecting the effects of overshadowing on 120 commercial buildings. However, Nagy and Anderson (2000) also investigated this effect on a residential building in the hot arid climate in Arizona. In this research, the overshadowing effects on the building are investigated in two steps. First, the building solar incidences in the selected case studies are examined by simulation method for two options, the building within the fabric and standalone buildings. In the second step, a room is selected in each case study with a shaded external wall with similar geometry and location characteristics in the both houses and then the effect of the shaded facade on the cooling load is assessed.

The main characteristic of the urban form in the hot climate of the Middle East is the high density pattern (Mortada, 2003). In the other words, due to climatic and cultural reasons the buildings are very close to each other and as a result, the narrow streets are created. This characteristic of Middle East cities in a hot climate can be seen in Bastakya and Yazd (see photos 2.13.1 and 2.13.2).

Photo 2.13.1 The original urban fabric of Bastakya-1930s (Dubai architectural heritage society)

Photo 2.13.2 The old urban fabric of Yazd- 2004 (Nicholls, 2004)

Due to this characteristic in Yazd and Bastakya, the building facades are shaded by the neighboring buildings. This effect benefits the building in terms of the surface temperatures. The measured surface temperatures of facade reveal a 10 degree difference between the shaded and not-shaded facades (see tables 2.13.2 and 2.13.3). On the cooler facades, the heat flux reduces and therefore the conduction heat loads are decreased. In several studies it has been mentioned that the roof is the main source of solar load for the single storey buildings (Nahar, 2000)

But in the Yazd and Bastakya courtyard housings the facades are more critical in terms of solar gain. Table 2.13.1 shows the ratio between the facades and roofs in Yazd and Bastakya. The R/F ratio in Bastakya is 0.64 which indicates that the facades are almost double the size of the roof and can be the major source of the heat conduction. In Yazd, the R/F ratio is 0.857, and it demonstrates that the façades area is still more exposed to the sunlight than the roofs.

Table 2.13.1 The F/R ratio in the Yazd and Bastakya Housings

	R/F Ratio	Facades Area (m²)	Roof Area (m²)	Building footprint (m²)	Courtyard Area (m²)
Yazd	0.857	1419	1217	1687	470
Bastakya	0.6400	548	351	459	108

The field measurement

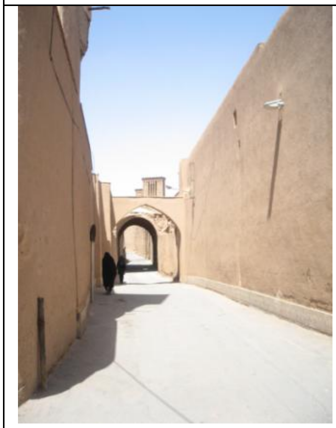
The field measurement is incorporated into this part of the research to observe the current situation in the case studies. The measurement was taken by the infrared thermometer (see device descriptions in section 2.12) in the hot period of the year in the both locations. However, the field study was done in the different months of summer 2007 by the author (tables 2.13.2 and 2.13.3). Since the measurement device shows the value instantly and there is a weakness in recording data, as every piece of recorded data is the result of the average of several time measurings. This procedure took less than a minute for every façade therefore the timing flaw for the measured value would be very minor.

Although in Bastakya all the facades were accessible, in Yazd only the façade temperatures for the south-east and north-west were measured.

Table 2.13.2 The measured façades temperatures- Bastakya

Bastakya			
14:00-14:04, August 8th			
North Elevation	West Elevation	South Elevation	East Elevation
			
46°C	52°C	45°C	43°C

Table 2.13.2 The measured façades temperatures- Yazd

Yazd	
15:15, Jun 1st	
South-east	North-west
	
47°C	57°C

Results

Bastakya

In Bastakya, the easy accessibility allowed the author to record the data in four minutes for all the facades. The West and East elevations demonstrate a temperature difference between the shaded and not-shaded condition. The North and South facades adapted to the situation thus, one got hotter and the other got colder. Both present 3 to 7 degree difference in the extreme conditions.

Yazd

The recorded data reveal that in Yazd, the shaded facade is almost ten degrees cooler than the un-shaded façade. However, it should be taken into consideration that both facades were almost in the same condition for 3 hours (south-east: Shaded and north-west: Not-shaded) and therefore the facades were in a stable condition.

2.13.1 The overshadowing impact on the façade solar incidence

In the Yazd and Bastakya urban fabric as was discussed earlier, the buildings are very close to each other. Therefore, for every building, the surrounding buildings act as a solar barrier. Moreover, every house is enclosed by the buffer layer of sikkas.

In this section in order to study the impact of the overshadowing of the neighboring buildings on solar incidence of the selected houses, the Bastakya and Yazd houses are analyzed twice in ECOTECT. Once within the urban fabric and the second time as a standalone building without any neighboring buildings (see tables 2.13.1.1 and 2.13.1.2).

Table 2.13.1.1 Solar incidence analysis- Bastakya

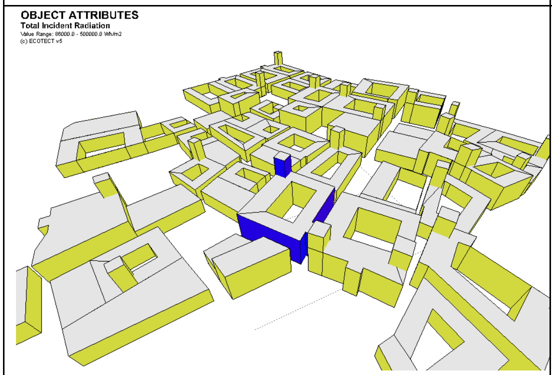
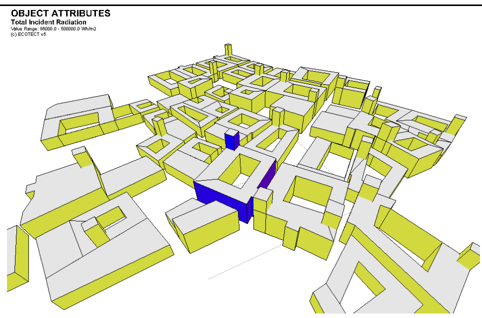
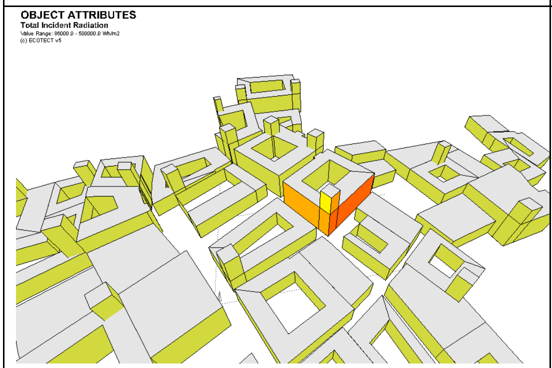
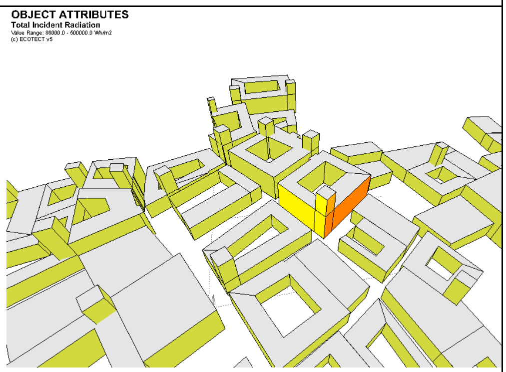
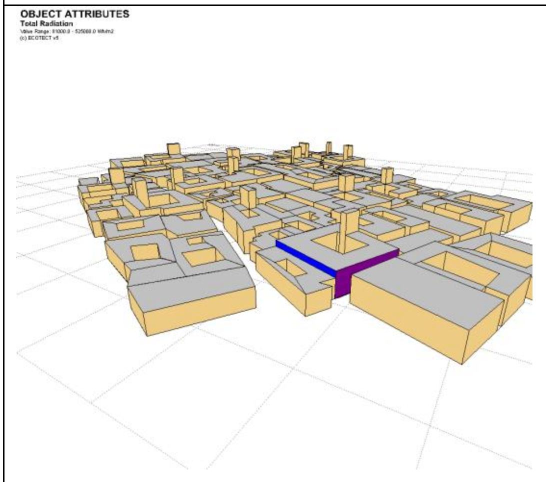
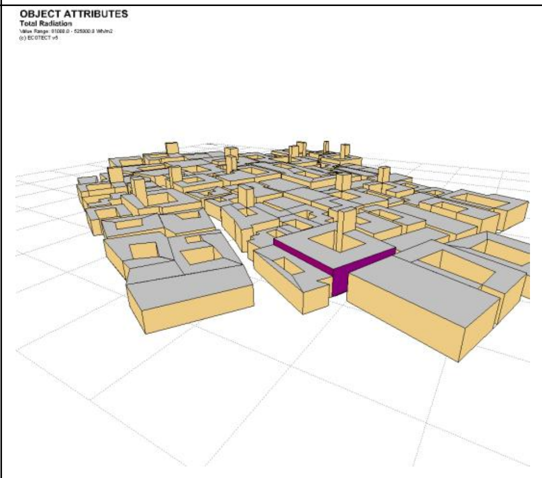
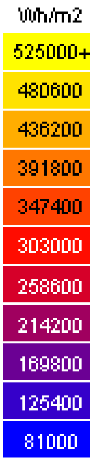
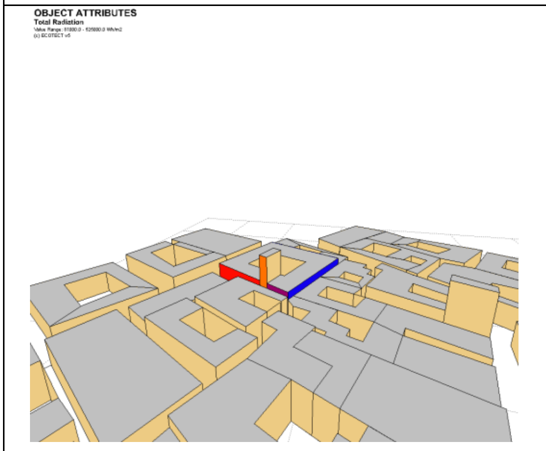
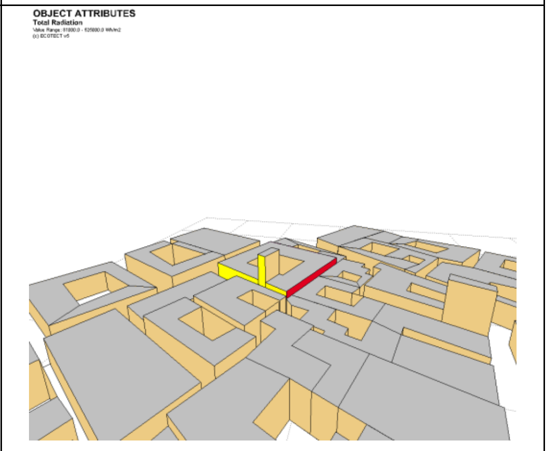
Annual Solar Incident- Bastakya		
Within the Urban Fabric	Standalone building	Scale
		
		

Table 2.13.1.2 Solar incidence analysis- Yazd

Annual Solar Incident- Yazd		
Within the Urban Fabric	Standalone building	Scale
		
		

Results

Bastakya

The comparisons of the results reveal that the solar incident on the west façade is reduced from 500000 Wh/m2 to 417200 Wh/m2. This means, there is a16% annual solar incident reduction on the west façade. On the south façade, the solar incidence reduction is 11%. In the standalone building option, the solar incident is 375800 Wh/m2 which reaches 334400 Wh/m2 in the other option. Since, in the traditional buildings, the major load is the solar load, the overshadowing has a significant impact on the heat gain. In the case of Bastakya, the 16% reduction on the west façade and 11% on the south façade can influence the fabric load.

Yazd

The major solar incidence reduction occurs on the north-east façade from 525000 Wh/m2 to 303000 Wh/m2 per annum. In the south-east façade, it is reduced from 258600 Wh/m2 to 125400 Wh/m2 which is a almost 52% reduction. Finally, the south-west façade also show 23% reduction. The urban fabric shows quite effective results in reducing the solar incidence in the very narrow streets.

2.13.2 Building heat gain

In order to examine the shading impact on the fabric load and consequently on the indoor comfort level, the west façade room in Bastakya and Yazd are modeled. It is assumed that the external facades of two rooms are fully shaded throughout the year. However this assumption is very close to reality, it is not 100% accurate. The main parameters for the thermal modeling analysis in ECOTECT were fed by the window presented in figure 2.13.2.1 for every thermal zone.

Material Thermal Properties

The thermal properties of the building skins are the other important parameters which are defined according to the available situation in both buildings. In ECOTECT, all the skins are introduced by the layers and the program would be able to estimate the U-Value of every skin.

In Yazd, the wall material is mud-brick. It is a traditional Iranian material in the hot climate area. The thermal conductivity of the mud-brick is 0.75 W/mK (CIBSE guideline, 1999) and since the wall thickness is 500 mm, the wall U-value is 1.5W/ m^2K. For the 200 mm roof with the similar material property, the u-value is 3.75 W/ m^2K. According to ECOTECT default material U-Value for the exposed ground is 3.5 W/ m^2K and for single timber glazing is 5.1 W/ m^2K which are same in two locations.

In Bastakya, the external wall thickness is 600 mm and roof thickness is 300mm which the major used material is coral stone, gypsum or sea-sand limestone. However, Damluji (2006) mentioned in her research that the coral stone was the original building material which later was replaced by sea-sand limestone. Since there is no data available for the R-Value of the coral stone in UAE, based on the Dalmuji (2006), the thermal properties of the sea-sand lime stone are taken into consideration. According to CIBSE, thermal conductivity of the sea-sand is 1.31 W/mK The U-Values for the external walls are 2.18 W/ m²K and for the roof is 4.36 W/ m²K.

Since, in both cases, there is only one zone thus, the data input procedure is only done once for each model (see figure 2.13.2.1).The main internal gain for the rooms is the occupants' loads. The sensible load per occupant is 90W and the latent is 60W, based on the ASHARAE Fundamental (2005). The infiltration rate for a space with the opening to the outside is 0.5 and wind sensitivity rate is 0.58 according to the ECOTECT tutorial for an urban study. The comfort band is assumed to be between 21C and 25C. The other parameter which should be defined is the HVAC system. Since, we are more interested in the heat gains and shading impact on the heat gain and the cooling load at the peak time therefore, a full air-conditioning system is selected. This option only gives the values for the cooling purpose. No time schedule is given to ECOTECT for the options, due to purpose of this study which is met with the default schedule occupancy pattern.

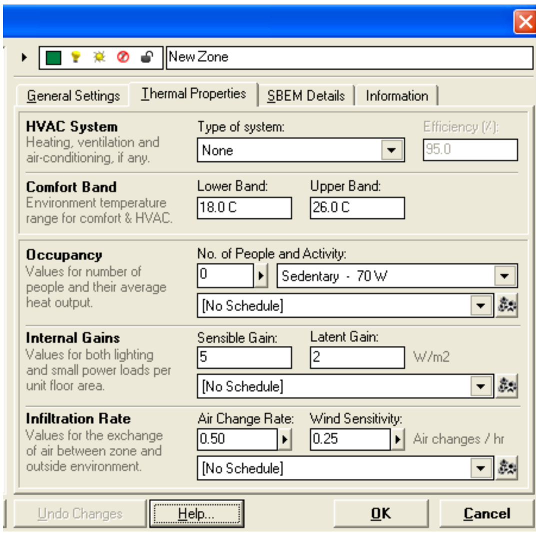
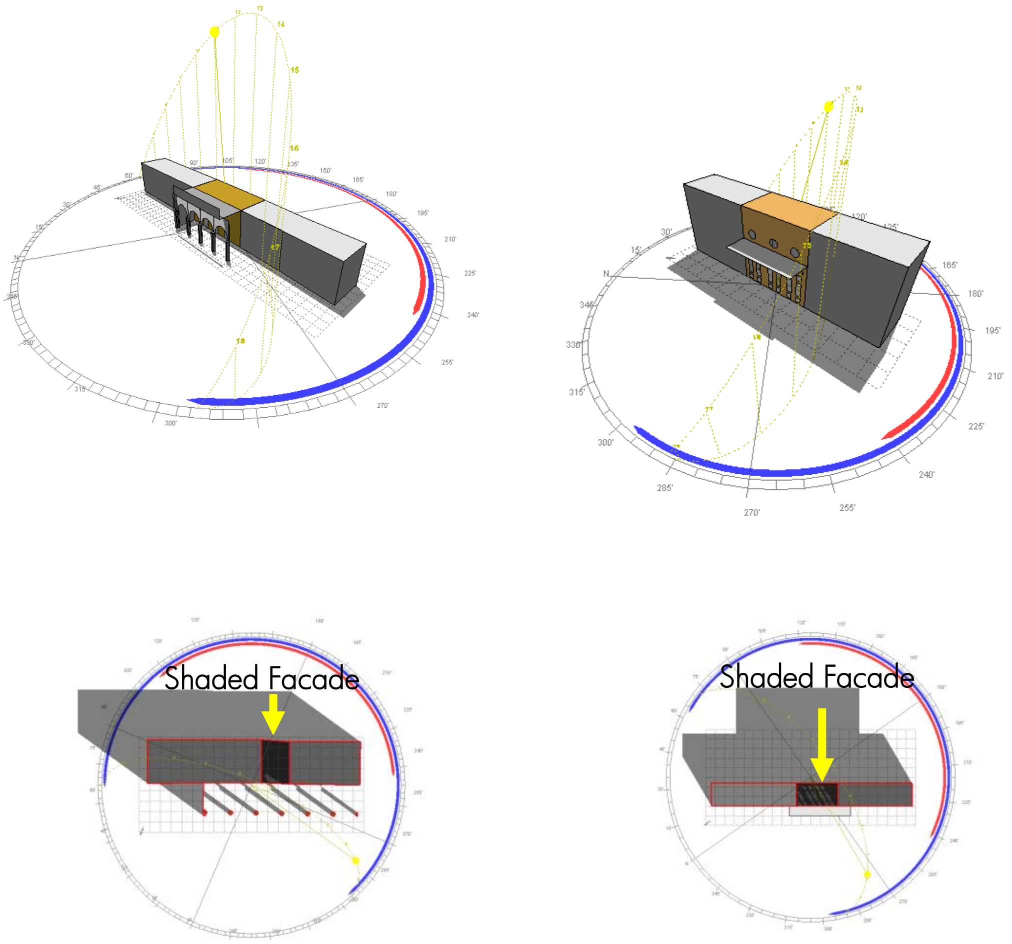


Figure 2.13.2.1 The typical input window for the thermal analysis.



Bastakya Yazd

Figure 2.13.2.2 Thermal Models- The selected rooms in Yazd and Bastakya

Table 2.13.2.1 The model input and output data -Bastakya

Bastakya	
With Shading effect on the outer wall	Without Shading effect on the outer wall
Floor Area: 10.53 m2	Floor Area: 10.53 m2
Room Height: 4800 mm	Room Height: 4800 mm
Max Cooling: 3135 W at 14:00 on 19th August	Max Cooling: 3135 W at 14:00 on 19th August
Annual Cooling Load: 812 Wh/m²	Annual Cooling Load:797 Wh/m²
Sensible:27 W/m2 Latent 18 W/m2	Sensible:27 W/m2 Latent 18 W/m2
Occupancy :3people	Occupancy :3 people

Table 2.13.2.2 The model input and output data -Yazd

Yazd	
With Shading effect on the outer wall	Without Shading effect on the outer wall
Floor Area: 10.35 m2	Floor Area: 10.35 m2
Room Height: 4800 mm	Room Height: 4800 mm
Max Cooling: 3135 W at 17:00 on 22nd July	Max Cooling: 3135 W at 17:00 on 22nd July
Annual Cooling Load: 436 kWh/m²	Annual Cooling Load:450 kWh/m²
Sensible:27 W/m2 Latent 18 W/m2	Sensible:27 W/m2 Latent 18 W/m2
Occupancy :3people	Occupancy :3 people

Table 2.13.2.3 The thermal study results- Bastakya and Yazd

	Max cooling load at peak time (W)			**Average load (kWh/m²)**		
	Not-shaded facade	Shaded Façade	Load Reduction	Not shaded Façade	Shaded Façade	Load reduction
Yazd	3135	3135	**0%**	450	436	**3.2%**
Bastakya	3204	3204	**0%**	812	796	**2%**

Results

Table 2.13.2.3 shows that there is no changing in the cooling load at peak time which means that the fabrics gain at the peak time does not significantly influence on the total load. But, the average load on the building with shaded façade is reduced. In Yazd, a 3.2% reduction is seen in the shaded option and a 2% reduction in Bastakya. The results present that the shading on the selected façade has a similar impact on the both building since both rooms are in same size. The difference between the reduction refers to the different climate and thermal properties of the used materials.

2.13.3 Orientation

The orientation of the urban fabric has its own impact on the individual building in the traditional urban form. The urban orientation is not a result of a simple reason but it is a consequence of several factors during a long period of time. Rapoport (1969) mentioned that the orientation of the traditional urban cannot simply relate to the climatic aspect, however sometime the easiest answer would be climate. Memarian (2006) mentioned that the orientation in the Islamic environment influenced by the Qibla direction (the direction of Mecca which Muslim prays towards). Memarian continues by saying the prominent urban direction in Yazd and Shiraz (a city in Iran) is south-west to north-west which also defines the seasonal spaces in the traditional buildings.

The effect of the current orientation in the two case studies is important since the urban is too dense and solar received amount by the façade is also low. In order to survey the urban orientation impact on the exposure of the building skins to the sunlight, the current orientation and the other critical possible options for the two case studies are analyzed.

The major buildings and urban orientation axis is north-east to south-west however few buildings follow it. This direction does not concur on the Qibla direction in Bastakya. The urban direction is effective in providing shaded sikkas. The sikkas comfort level changed due to the overshadowing. This effect was studied in the section 2.5.

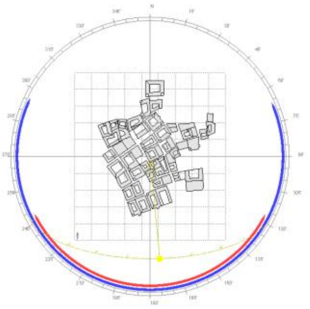
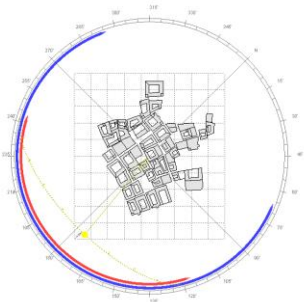
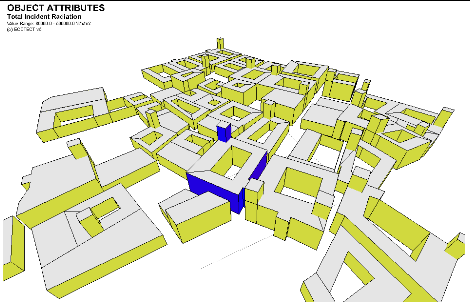
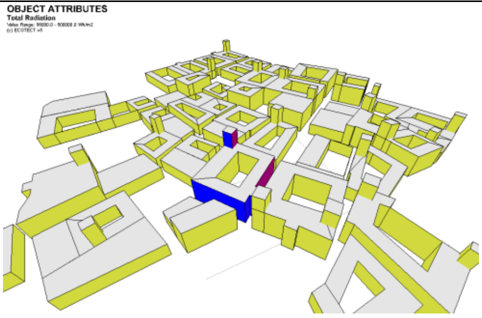
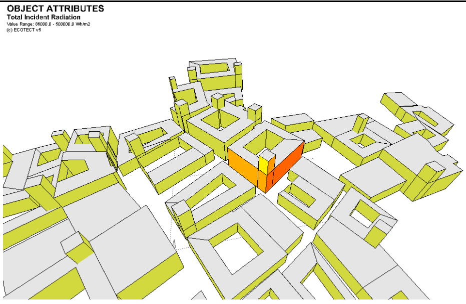
In order to assess the effect of the orientation on the building solar incidence, the critical alternative orientation was selected to study. In the critical option, the west and east façades were changed into the long axis facades. In the hot climate in Yazd and Bastakya, the major sources of solar gain in the building skins are from the east and west facades and in the selected orientation, they are located on the long axis facades.

Bastakya

The urban direction in this option was changed into so that the current south-west façade would be turned into the south façade. The results show that the north-east façade (in the actual orientation) solar incidence is kept at the same amount but a 50% increase can be seen on the north-west façade. The south-west façade receives 20% more on the proposed orientation since, there is a 30% reduction on the south-east façade (see table 2.13.3.1).

The results present a combination of the solar incidence increase and decrease on the different facades. In the overall evaluation, the proposed orientation receives more solar radiation due to the major augment on the north-east and south-west façades.

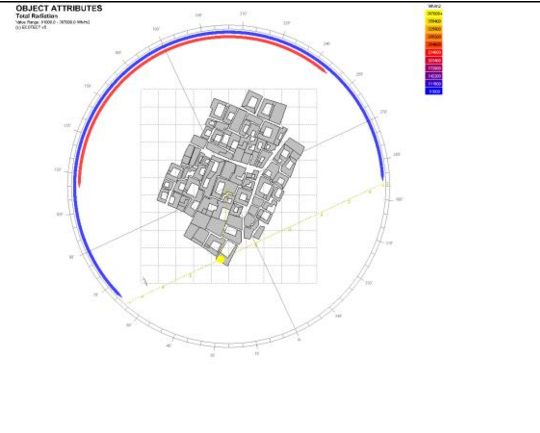
Table 2.13.3.1 The Bastakya building in the different orientation- façade solar incidence

Annual Solar Incident		
Actual Orientation	North-south orientation	
		
		
		

Yazd

The proposed urban orientation in Yazd makes all the facades exposed to the sunlight throughout the day but the solar incidence is on the minimum level for each. There is a slight solar incidence reduction on the north-east façade and at the same time, a similar increase can be seen on the north-west façade.

Table 2.13.3.2 The Yazd building in the different orientation- façade solar incidence

<table>
<tr><td colspan="3">Annual Solar Incident</td></tr>
<tr><td>Actual Orientation</td><td>North-south orientation</td><td></td></tr>
<tr><td>
</td><td>
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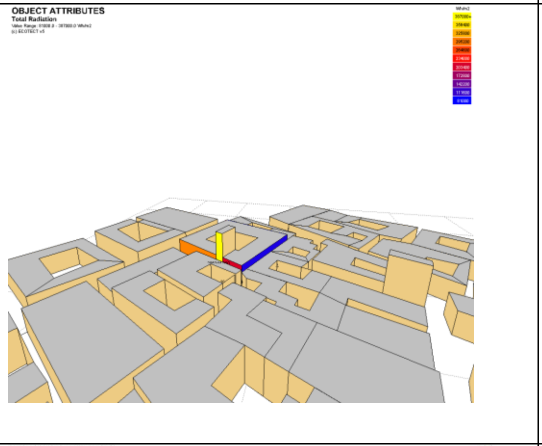
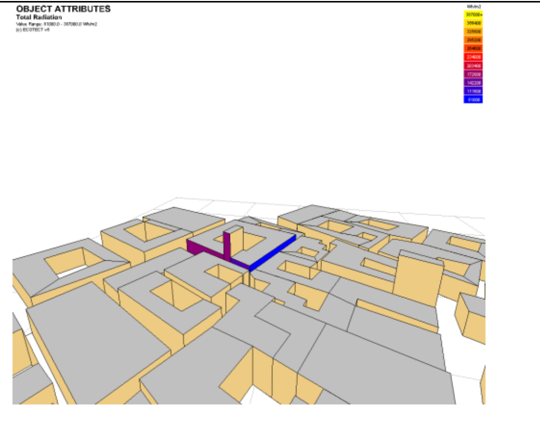
<tr><td>
</td><td>
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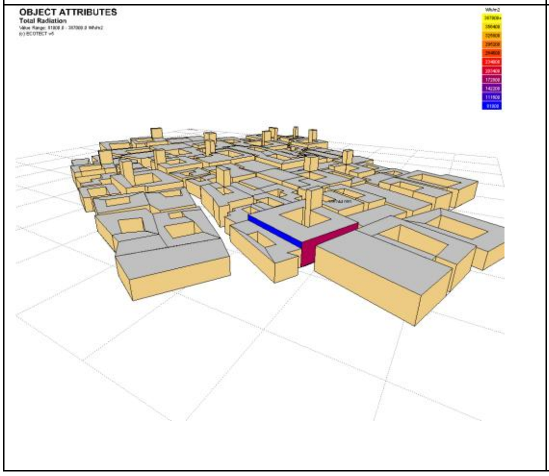
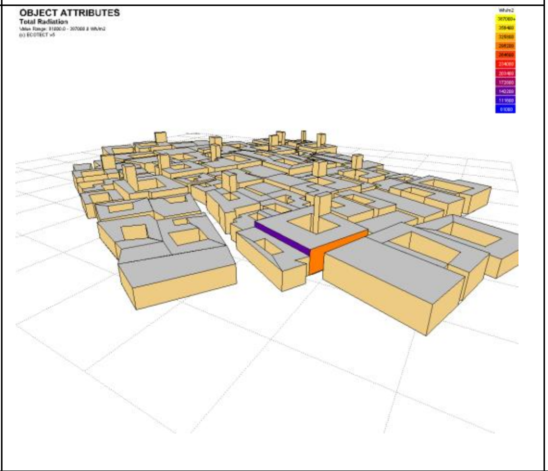
<tr><td>
</td><td>
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3.0 Discussion

3.1 Urban Shading Analysis

In the overall evaluation of the shading analysis, the Yazd streets are better shaded than the Bastakya streets due to the lower latitude, narrower streets, taller buildings and the more dense urban fabric. In summer, for a period of 4 hours at midday from 10:00 to 14:00, 10% more shading is seen in Yazd (see tables 2.5.6 and 2.5.7). For the same period of time during the day in mid-season, the shading intensity is increased but in winter both urban fabrics in Yazd and Bastakya provide the same shading level over the streets.

As it was mentioned earlier, the outdoor occupancy pattern should be considered in that time. Since both case studies are located in a similar location in terms of cultural and traditional aspects of life therefore, the occupancy patterns are very close to each other. However mid-day shows the lowest shading intensity throughout summer and mid-season and at that time all the outdoor activities were down in Yazd and Bastakya (see tables 2.5.2 and 2.5.4). Despite the fact that many things have changed since that time the people's behavior is still same. They stay at their home in the hottest period of the day. In winter, both urban streets are strongly shaded. In Bastakya, the shading intensity does not demonstrate a significant impact on the outdoor comfort level like Yazd due to the higher average temperature in Bastakya in comparison to Yazd. The Awbi and Bourbia (2003) presented same findings that the higher H/W (a ration between height to width of the urban street) results in denser shading which complies with the findings of the Yazd and Bastakya shading analysis.

3.2 Urban temperature analysis

According to the method used to calculate SVF, the SVFs vary between 0.105 and 0.525 in Bastakya and 0.055 and 0.325 in Yazd. They establish the fact that both urban fabrics are compacted. The results can also help to confirme the better shading intensity in Yazd with denser urban fabirc. The low SVFs in both locations demonstrate that urban form obstructs the street from the sky. In other words, the lower SVF results in the lower radition exchange thorugh the urab surfaces. Therfore, the urban fabric with the lower SVFs is cooler than the other urban form with similar properties.

The average SVFs in Yazd led to higher ΔT in comparison to Bastakya. Although the total average SVF in Bastakya is 75% more than Yazd due to the Oke equation since in using that formula SVF=0 and 1 result in ΔT=15.27°C and 1.37°C. The ΔT results concur with the findings from the shading anlaysis which showed more compacted urban and shading intensity in Yazd. Tsianaka (2006) conducted a field measurement research in order to assess the relation between the SVF and urban temperature. He also revealed that the lower SVF led to lower urban temperature.

3.3 Courtyard Shading Analysis

The impact of the building geometry and form on the courtyard shading intensity has been assessed in tables 2.7.7 and table 2.7.8.The shading is a significant factor which improves the human comfort level in the courtyard in hot seasons.

Table 3.3.1 presents the shading performance by the Bastakya and Yazd building form and geometry to provide shading in the courtyard. However, the orientation of both buildings is similar and the percentages of the courtyard area to the building footprint are also very close to each other. In addition, the sun angle in Bastakya is even higher than Yazd therefore, the courtyard should be more exposed to the sun and the less shading should have been seen but, table 3.3.2 demonstrates the opposite results. It is revealed that the higher height to width/length ratios result in better shading in the courtyard. The less shading in the winter and early spring in the Yazd house in comparison to the Bastakya house benefit the occupants in the period of the time at which temperature never rises above 20 C. Muhaisen (2006) has mentioned in his research that to achieve the optimum shading, the courtyard height should be three-storey in hot and humid climate and two-storey in hot and arid climate. However, the both Yazd and Bastakya courtyards are single-storey, they provide optimum shading.

Table 3.3.1 The average shaded area in the Yazd and Bastakya courtyards.

Average shaded area of the courtyard	**Yazd**	**Bastakya**
Summer	48%	57%
Spring	60%	68%
Winter	85%	97%

Table 3.3.2 The geometry analysis of the courtyards in the Bastakya and Yazd houses.

	Latitude	**Courtyard to Building footprint Ratio**	**Height (m)**	**Width (m)**	**Length (m)**	**Courtyard height to Width**	**Courtyard height to Length**
Yazd	25.1	28%	8.5	16.5	27.9	52%	30%
Bastakya	31.5	24%	6.7	7.8	14.5	86%	46%

3.4 Sunlight Hours in the courtyard

According to tables 2.8.1 and 2.8.2, the courtyard in Yazd receives more sunlight throughout the year. A large portion of the Yazd courtyard recieve more than 9 hours sunlight per day in summer. In Bastakya the sunlight hours never passes over 7.5 hours a day in summer. In the overall evaluation of the two courtyards, the Yazd one is more exposed to sun and therefore more sunlight hits the courtyard. The increased sunlight in summer equals less comfort however, whereas more sunlight in winter means more comfort for the occupants.

Table 3.4.1 presents the percentage of the area of the courtayrd which recieves less than an hour's sunlight in the different seasons based on the previous analysis. In other words, the table shows the courtyard area which is in shade for 90% of the sunlighit hours (the study was carried out for 10 hours of 24 per day). This is the part of the courtyard which was used permanently by the occupants during summer and mid-season. In winter, it would have been the opposite and people would have liked to be in the other part of the courtyard.

Table 3.4.1 The areas receiving less than hour sunlight in the courtyards

	Summer	**Mid-season**	**Winter**
Bastakya	20%	40%	70%
Yazd	10%	30%	60%

3.5 The Shading impacts on the visual comfort

The shading effects of the two noble ideas in both case studies have been investigated in tables 2.11.1 and 2.11.2. The results prove the efficiency of the shading structures in order to improve the visual comfort of the occupants.

3.5.1 Sunny Sky

Summer:

In the Bastakya house, the colonnade structure which is attached to the courtyard performs very well during the afternoon time when the sun's angle decreases, and obstructs the direct sunlight and prevents glare due to the direct radiation. During the time when there is no direct sunlight, the minimum 350 Lux is seen in a major part of the room. Similar to the Bastakya house, in the Yazd house the direct sunlight is obstructed and the light level is kept at the same level. The images also reveal that the glare threat is minimized.

Winter:

In Bastakya, the building form already obstructs the direct sunlight therefore, the colonnade structure only reduces slightly the light level in the room and it does not have a significant impact on the visual comfort. But in Yazd sunlight penetrates deeply into the room and the vine shading structure is not effective in preventing direct sunlight due to the low sun angle. Thus, the glare threat is present for the occupants. In case of the Yazd house, the shading structure does not perform well in terms of providing visual comfort but, it should not be forgotten that the sunlight was a major source for heating purposes in the cold winter. Thus, the visual comfort was sacrificed for the thermal comfort which was the first need. The light level in the

Bastakya house is similar to the summer levels but, in Yazd they increase though direct sunlight penetration.

3.5.2 Overcast sky

Although the brightness in the perimeter area is reduced by the colonnade structure, the light level also drops into the half and becomes less than 300 Lux in the Bastakya room. This also reveals that the people in the Bastakya house lived in the average of 300 Lux to 350 Lux regardless of the sky condition and seasons. In Yazd, the vine shading structure caused a large reduction only in the light level. The light level descends from 700 Lux into 300 Lux.

3.6 Occupancy patterns of the housings

In Yazd and Bastakya, the idea of multi-functionality of traditional housings has been examined by field measurement and simulation (Bianca, 2000). The results pointed out that in Yazd, the vertical movement of the habitants occurred due to the ground cooling effect and the occupant escaping from the sunlit space to cooler and shaded space. The temperature difference of 19.8°C between the ground level and *Sardab* could have been enough reasonable to make the occupants move despite the lack of visual comfort. In contrast, there was no vertical movement in the Bastakya house probably due to the low water level in that area since Bastakya is only 100 meters far from the Dubai creek. In addition, in Bastakya, there is not a huge difference between ground temperature and ambient temperature.

The horizontal movement in both case studies happened in a similar pattern. In summer, they used to stay in the south part of the house which was shaded and when the sun was not able to penetrate into it and in winter, they moved to the north part of the building which could get sunlight from the openings facing the courtyard.

3.7 Shading and courtyard thermal comfort

3.7.1 Annual Comfort hours in the courtyards

In the Bastakya and Yazd courtyards, summer is the time at when the sun angle is high and temperature reaches the maximum amount during the year. Therefore, the shading shows the minimum effect on improving the outdoor comfort level. The maximum comfort hours are seen in spring when temperature is decreased. During this period of the time, the shading increases the comfort hours to 30%-35% of the total studied time for the 60%-68% area of the courtyards in spring. In winter, the shading impact in Yazd is negative which means that it reduces the comfort hours in this season and in Bastakya, the effect includes only 3% of the courtyard. In the overall evaluation, spring and autumn are the best seasons to benefit from the shading effect and when the average comfort hours are increased.

3.7.2 Comfort level at summer peak time

According to the field measurements and simulations, the Givoni equation for thermal sensation reveals that there is a minor shading impact on the thermal sensation level in the courtyards in the hot summer days. The results concur with RayMan which showed only 1% to1.5% comfort hours improvement in summer.

It should be pointed out that although the humidity in the Bastakya is 20% more than Yazd, the other parameters are very close to each other. Logically there should be a difference between the results, but as earlier mentioned the Givoni results can only be used as an indicator since his research conducted for a very small number of subjects (Givoni, 2000).

3.8 Overshadowing effects

3.8.1 Solar incidence

Table 3.8.1.1 reveals the major impact of solar incidence on the building facades through the analysis. The results show that the solar incidence for the east and west façades is reduced between 11% and 16% in Bastakya due to the overshadowing of the neighboring buildings. The reduction of the solar incidence results in the building solar load reduction. This effect has been studied in the section 2.13.2.

The overshadowing analysis reveals the impact of the neighboring buildings in reducing the solar incidence in Yazd and Bastakya. The urban geometry and form in Yazd has a significant effect in solar incidence reduction. It can be seen a 43% reduction In the north-east façade and a 52% reduction in the south-east facade.

Table 3.8.1.1 The façades solar incidence in the standalone and within urban fabric options

	Facades	Standalone building (Wh/m²)	Within the urban fabric (Wh/m²)	**Reduction**
Bastakya	West	5,000,000	4,172,000	**16%**
	East	3,758,000	3,344,000	**11%**
Yazd	north-east	5,250,000	3,030,000	**43%**
	south-east	2,586,000	1,254,000	**52%**

3.8.2 Building heat gain

According to the thermal analysis for the both rooms, there is a minor reduction in the average cooling load. This means that the overcast shadowing was not a considerable factor in reducing the building load. The peak load never changed which means that the overshadowing effect on the fabric solar gain in the hottest period of the year is not considerable. There is a 3.2 % reduction in Yazd in the average load since in the Bastakya room, the load reduction does not exceed 2%. The difference between the load reductions goes back to the wall and roof thermal properties which are quite different in two case studies and the different climatic conditions in the wintertime. Lam (2000) found the overshadowing reduces the total building cooling load by 2% in Hong Kong. His findings is very close to the Yazd and Bastakya results.

3.8.3 Orientation

3.8.3.1 Bastakya

The urban direction in this option has been rotated so that the current south-west façade is turned into the south façade. The results show that the north-east façade (in the actual orientation) solar incidence will be kept at the same amount but a 50% increase can be seen on the north-west façade. The south-west façade receives 20% more on the proposed orientation since, there would be 30% reduction on the south-east façade (see 2.13.3.1). The results present a combination of the solar incidence increase and decrease on the different facades. In the overall evaluation, the proposed orientation receives more solar radiation due to the major augmentation on the north-east and south-west façade.

3.8.3.2 Yazd

The proposed urban orientation in Yazd exposes the all facades to the sunlight throughout the day but, the solar incidence is on the minimum level for each. There is a minor solar incidence reduction on the north-east façade and at the same time, a similar increase can be seen on the north-west façade.

According to the above discussions, in Yazd and Bastakya, the actual orientation of the selected buildings is at the optimum orientation to receive the minimum solar radiation.

4.0 Conclusion

In recent years, a large number of studies have dealt with passive cooling strategies in the traditional built environment to reveal the performance of these methods in order to employ them in the current built environment. In comparison to the active solutions they are cheaper and also their cooling performance is significant.

Since solar gain in a hot climate is the main source of heat for both urban and individual building, shading is a passive strategy solution with low cost but high effectiveness in preventing heat gain and at the same time having other visual advantages. A number of studies have been conducted on the cooling strategies in the hot regions of the Middle East due to the rich urban fabrics and unique integrated passive solutions. Yazd and Bastakya were selected as illustrative examples of this area with different backgrounds but similarities in terms of form, geometry and strategies.

In this research Yazd and Bastakya have been assessed to demonstrate the shading impact on both the visual and thermal comfort of the people in the traditional built environment. The impact of the shading on the traditional built environment was studied firstly within the urban fabric to give a clear understanding of the macro scale of the shading effects and then the research focused on the selected housings in both locations as the main body of this research.

4.1 Urban

Both urban fabrics of Yazd and Bastakya were modeled in ECOTECT in order to assess the shading intensity within the urban fabrics. Shading was an effective factor on the thermal comfort of people which means that better shading could provide a more acceptable environment for the hot period of the year. For the 4 hours mid-day in summer poor shading was seen in both case studies. However Yazd urban analysis revealed a slightly better performance. Apart from this short period of time, the results showed that strategies used in both case studies provided effective shading throughout the year.

Since the very dense urban fabric with narrow streets as the major links are the main characteristics of the urban fabric in Yazd and Bastakya, the effect of the urban geometry and forms on urban heat gain level through radiation were examined by employing the Oke(1981) research. This section of the urban analysis was carried out to complete the shading intensity assessment and explore the other effects resulting solely from the urban form. According to the calculated SVFs, the Yazd urban temperature in comparison to rural area was slightly cooler (1.36°C) than Bastakya due to the more compact fabric.

The other effective parameters on the urban temperature can be investigated in future research by the advance simulation modeling and field measurement in order to achieve a comprehensive urban design guideline in hot climate in the Middle East.

4.2 Building

The selected buildings were modeled in ECOTECT and the shading intensity within the courtyards was studied and the different shading patterns and intensities were explored for the two buildings. The shading intensity in the Bastakya courtyards showed 8-12% on average more than in Yazd one throughout the different seasons despite the higher sun angle in Bastakya but the greater height to width/length ratios played main role in increasing the shading intensity.

The sunlight hours in the courtyard were directly in relation to the shading intensity. Therefore according to the previous section, it was simulated in ECOTECT program. The sunlight hours analysis revealed different zones with different sunlight hours distribution in the courtyard in the different seasons. Since the shading intensity in Yazd was less than in Bastakya more sunlight was received in Yazd particularly in the summer time. It was also discovered that on average the Bastakya courtyard received less than 10% sunlight than the courtyard in Yazd.

Since the shading intensity and sunlight hours were studied, the previous analysis was translated into the outdoor human comfort level which can demonstrate the real impact of shading on human life. The shading impact on the outdoor comfort level was studied during a sample year and at the peak time by implementing the Givoni research and Rayman model. The two-month study showed that the shading had the minimum effect in the summer time. It could also be seen that the major shading effect on the outdoor comfort level was in spring and autumn and the shading had an opposite results in winter in Yazd since the temperature is very low and it was an effective factor tin decreasing the outdoor comfort level. The peak time study showed that based on the Givoni equation for both case studies, the thermal sensation level could be changed from Quite hot to Hot which was more acceptable for the occupants. It should be mentioned that the shading impact was achieved in the hash summer in Yazd and Bastakya therefore it is a significant result.

The visual comfort level of the occupant is as important as thermal comfort thus, this was studied for the indoor space in the courtyard housings. Both Yazd and Bastakya benefited from the unique shading device in the courtyard which affected the indoor and outdoor spaces. A typical room in both buildings was selected and modeled in Radiance. According to the results in summer both shading structures performed well to provide improved visual comfort level for the occupants and prevent solar gain. In the winter time the building form helped the shading device in Bastakya therefore the direct sunlight was blocked but in Yazd the shading device did not perform well however the uncomfortable visual aspect could be acceptable since the sunlight is desirable in the cold winter. Finally in overcast sky conditions in both locations the light level was decreased. In the overall evaluation the shading structures had an acceptable impact on the visual comfort in Yazd and Bastakya.

According to the shading intensity and the sunlight hours analysis and relevant research the occupancy pattern of the selected houses were assessed. In the Yazd and Bastakya there was a similar pattern of occupants' movement in the different seasons despite the fact that in Yazd there would have been an additional movement which was vertical movement and the all movements were the occupants response to the extreme heat and cold to be in a comfortable space. The traditional seasonal occupant movements suggest to use of the spaces for multi-functionality rather than them being specified for a particular function.

The compact urban fabric provides overshadowing from neighboring buildings over the selected buildings. The overshadowing directly reduces the façades sola incidence and indirectly the building heat gain. The Ecotect models of the buildings were simulated in the standalone option where there were not neighboring buildings and for the second time within the urban fabric. The overshadowing effect of reducing the building solar incidence in Yazd was four times more than Bastakya which only relates to the more compacted fabric. The results concur with the SVF findings and both illustrate that the Yazd urban is more compacted and as result less solar radiation was received by the building facades.

In order to assess the overshadowing effect on the building heat gain, two rooms with similar orientation and geometry were selected and thermal analyses were conducted using Ecotect program. The results showed that the overshadowing effect can not reduce the peak heat load, but in the annual evaluation the selected building in Yazd performs slightly better (1.2%). However, when the solar incidence is translated into the building load the effect is minor in both buildings (Yazd reduction: 3.2%, Bastakya: 2%).

In summary, it can be seen from this study that shading as passive cooling strategy is an effective approach to improve human comfort level in a hot climate. However, there are possibilities for the future studies to assess the other passive cooling strategies in traditional built environment such as: thermal mass, in order to educate designer and employ these strategies to achieve sustainability through simple and practical solutions.

5.0 Outlook

Due to the high cost of oil in the recent years, the urban development of the Middle Eastern countries has been rapid. It can be seen that both urban and individual building mainly from the different western built environment are imported which probably worked well in their original climate and culture but can not necessarily be adapted to the Middle East region. Therefore, the local research would help to learn lessons from the past to employ in the future.

The findings of this study can be implemented into the future development in Dubai and Yazd or any other cities in the Middle East with a similar climate since the cultural pattern are very close in all the countries in this region.

From the shading impact on the urban fabrics in the hot region of the Middle East, it can be learned that a compacted urban fabric will result in a greater outdoor comfort level for the occupants combined with denser shading intensity and lower urban temperature in comparison to the not-compacted one.

The courtyard building type not only has cultural value in the Middle Eastern countries but also works well environmentally. In this research only a few advantages have been revealed but there are others which have been explored beforehand and still more possibilities for the future research.

The result of the shading analysis presented the advantages of the shading provided by the building form on the outdoor comfort level in the courtyard housing. In addition, the effective performance of the integrated shading device on the visual and thermal comfort of the occupant in the courtyard is proved. This research revealed that building form has a significant impact on the courtyard shading intensity.

It has also been shown that although the building solar incidence in the compacted urban is largely reduced, it will not have a major impact on building heat gain. However, it should be mentioned that the results rely completely on the thermal properties of the building materials used and there is a possibility that the results would be modified by the different building materials.

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