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A Comparison of thermal comfort in traditional and modern Bazaar from direct solar radiation perspective, Using questionnaire and Ecotect simulation – A case of Shiraz in Iran

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Abstract

Since the energy consumption has become one of the crisis of modern buildings, modeling the Iranian past architecture patterns could be helpful. The shopping streets as one of the main sectors consuming energy locate near the open spaces; it seems, therefore, they need more thermal comfort. However, using passive techniques, the Iranian traditional bazaars architecture solved the problems regarding thermal comfort. The present inquiry aimed at investigating thermal comfort of traditional and modern commercial buildings from the perspective of solar radiation to compare traditional structures (with traditional design and materials) with modern ones (with modern design and materials). Therefore, Vakil (traditional) and Mollasadra (modern) Bazaars (with the same orientation), located in Shiraz with a semi-arid climate, have been chosen. Vakil bazaar situated in historical context of city and Mollasadra situated in the first modern part built in 1980. A naturalistic approach was applied to investigate the relation between shadow on surfaces, shopping load and cooling needed in summer and the relation between the solar radiation on surfaces, shopping load and heating load in winter; first, a number of questionnaires were used to survey 120 samples including both customers and shopkeepers to show the relation between shopping load and cooling or heating need; second, Ecotect Analysis 2011 was employed to simulate surfaces with shadow and solar direct radiation in winter and summer to evaluate the relation between the surfaces received shadow and heating or cooling need. The results showed that along with a full shade in summer, the customers of Vakil Bazaar are interested to do shopping almost in all hours since there is no obtrusive solar radiation; in contrast, customers of Mollasadra Street experienced a shadow from sunrise to 11:00 in summer morning; thus 73.3% of customers in Mollasadra made complaints about the existing shadow since there is no shade in crowded shopping hours and points especially in summer afternoon; furthermore, 93.3% of shopkeepers in Mollasadra used cooling and heating equipment which demonstrate congruently of orientation and quality in sunshades with climate. At the end, some suggestions regarding the mentioned problem in Mollasadra have been proposed.

Keywords:Thermal Comfort, Solar Radiation, Urban Spaces, Commercial building, Shiraz.

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1.Introduction

A desirable combination of air temperature, relative humidity, air movement, and the average radiant temperature distinguishes a zone in which the majority of people feel comfortable; it is called thermal zone (Ghiabaklo 2002, 68). American Society of Heating, Refrigerating and Air-Conditioning Engineers) ASHRAE 2011, 29) believes thermal comfort is affected by air temperature, humidity, air velocity, and mean radiant temperature (MRT), as well as non-environmental factors such as clothing, gender, age, and physical activity. The combination of all these factors, undoubtedly, affect human beings and concerns with his/her physical and psychological ease.

Henson, as one of the pioneer expert in the realm of thermal comfort researches, suggests precious remarks. He (1990, 309) generally defines thermal comfort as a condition of mind which expresses satisfaction with the thermal environment; he also points out, from earlier research, reported by Fanger, Ipsen, Langkide, Olesen, Christensen and Tanabe (1985), McIntyre (1982), and Gagge (in 1986), thermal comfort is strongly related to the thermal balance of the body; it is influenced by 1) environmental parameters like: air temperature and mean radiant temperature, relative air velocity and relative humidity; 2) personal parameters like: activity level or metabolic rate and clothing thermal resistance. He also put forward some points about man's thermoregulatory system to show the interaction between humans, buildings and HVAC system[1]. Thermal comfort is a key factor towards design of energy efficient buildings, disregarding that causes an increase in energy consumption, results to an irreparable loss to country's economy, and lays the groundwork for environmental degradation definitely (Heidari 2011, 6).

This paper aims at examining the difference between thermal comfort of traditional bazaars (with traditional design and materials) and modern ones (with modern design and materials) from the perspective of direct solar radiation absorption in summer and winter. To this end, Vakil and Mollasadra Bazaars, placed in Shiraz, with the same orientation and the same approximate area were chosen. The satisfaction of samples have been assessed by employing the questionnaires. In order to simulate the shadow of buildings envelopes, Ecotect 2011 has been applied to distinguish the points where the shade is needed for providing the individuals' thermal comfort.

1.1. Thermal Comfort

As it was mentioned earlier, thermal comfort is the condition in which the environment provides thermal satisfaction (Ghiabaklo 2002, 69). A great volume of research, investigations, and experiments have been devoted to thermal comfort in diverse fields such as architecture, geography, mechanic, energy, etc. Another pioneers in this subject, in the architecture, are Fanger, Ipsen, Langkide, Olesen, Christensen and Tanabe (1985) who have presented the thermal comfort zone based on measuring the heat exchanges between the body and environment (Nicol and Humphreys 2002). Henson was another researcher who examined thermal comfort from the perspective of environmental parameters. As he believes, the human body produces heat principally by metabolism, exchanges this heat with the environment, and loses it by evaporation of body fluids (Henson 1990, 2).

Different experiments have been conducted on man's responses to environmental comfort. From Henson's point of view, distinc-

1. Heating, Ventilating, and Air Conditioning system

tion should be made between investigations on thermoregulatory system on the one hand and the establishment of thermal acceptable and comfortable conditions on the other hand (Henson 1990,5). The second type is of his interest. Nicol and Humphreys also have considered the adaptive thermal comfort and sustainable thermal standards for buildings and compared it with rational indicators; they found out using rational indicators to be difficult in real situations (Nicol and Humphreys 2002, 571).

A large number of investigations also have been conducted in Iran which indicates the high and important reputation of this subject in the realm of architecture and urban design. Ghiabaklo (2002) devoted his paper to examine the methods for estimating thermal comfort zone, and the main factors affecting the man's physical comfort regarding his/her environment. Like Heijs (1993), she also expresses, despite current view, factors such as age, sex, colors, and climate condition do not inform thermal comfort. Others such as Fanger, Ipsen, Langkide, Olesen, Christensen and Tanabe (1985), Henson (1990), Sadeghi Ravesh and Tabatabaei (2009), and Barzegar and Mofidi Shemirani (2010) believe, human factors and climate conditions have a significant impact on thermal comfort, man's physiological and psychological ease.

In order to measure the thermal comfort, different approaches have been applied thus far; among them Nicol and Humphreys (2002), Ghiabaklo (2002), Heidari (2011), Sadeghi Ravesh and Tabatabaei (2009), Heidari and Ghafari Jabari (2010), Hashemi and Heidari (2011), Monshizadeh (2012), Afshari and Taghvai (2014), Barzegar and Heidari (2013) can be mentioned. Each of them investigates the most effective method to measure thermal comfort in different climatic zones of Iran, since examining the climate changes and sensitivity, and determining the type of architecture in each zone seems necessary to reach ultimate comfort.

It is worth noting that the research, conducted in this area, can be divided into two groups, those using statistics and those using software. From among the works related to the former are: using effective temperature, determining thermal comfort temperature based on the mean ambient temperature, defining thermal comfort zone on the Psychrometric charts and assessing it based on the Predicted Mean Vote (PMV) (Ghiabaklo 2002, 74); using ASHRAE RP-884 adaptive model project which as Heidari believes is more close to the Iranian's standards (Heidari 2011); using Olgyay's approach and modifying the boundary of its thermal comfort (Sadeghi Ravesh and Tabatabaei 2009); using Olgyay's approach in order to draw the sun chart needed in Shiraz (Barzegar and Mirshamsi 2014); using cooling techniques in regard to the Köppen climate classification (Barzegar and Mofidi Shemirani 2010); determining building characteristics using Givoni and Mahani's method (Afshari and Taghvai 2014); using physiological equivalent temperature, according to Heidari and Manam is more accurate to predict mean thermal comfort, and have a higher correlation with outdoor thermal sensation (Heidari and Manam 2013).

The second group, namely those applying software, includes: using Comfort Ashrae which comprises variables influencing thermal comfort such as temperature, relative humidity, activity, clothing, and air velocity; it can specify the thermal status, and the required amount of heating, cooling and humidity (Heidari and Ghafari Jabari 2010); and using Ecotect and Vasari in order to explore the critical zones from the perspective of micro-climate (Monshizadeh 2012). Hashemi and Heidari (2011) applied both statistical procedure and software simulation. By modeling the greenhouses, using Energy plus software, Olgyay's bioclimatic charts examined air temperature effecting individual's comfort.

The important point to consider is that providing comfortable situation in open spaces needs more acquaintance with climate and environmental conditions than close spaces, since in indoor spaces the comfort can artificially be reached by cooling and heating equipment even though more energy and cost will be spent, while in outdoor there is not such a possibility (Tahbaz 2007, 28). Therefore, it can be said that creating shade in outdoor spaces can greatly impact on the man's thermal comfort using these spaces in hot seasons.

1.2. Shading Device in Building

Shadow is the space behind an opaque object which is an obstacle for light and heat from a given source (Tahbaz 2007, 30). Examining the shade lines of buildings, trees, and other artificial and non-artificial elements around a building and drawing it is of paramount information in designing buildings for different climates (Ghibklo 2003, 59). The kind of shadow depends largely upon topography, the slope degree and its direction (Ghibklo 2003, 68).

Using Olgyay's shadow mask (Olgyay 1987), using shadow of one building by applying topography (Ghibklo 2003), using mathematical modelling and numerical simulating (Mahdavinezhad and Javanmardi 2011), using Duffy's calculating method to draw the shades creating by veranda to assess the effect of it on the building envelopes receiving solar radiation (Habib and Barzegar 2014), are among the works concerned with the shade, its creation and its effect in Iran.

2.Case Study

Shiraz, the capital of Fars Province, is built in a green plain nearly 1491 meters (4891.7 feet) above sea level, at 29°32′N 52°35′E (Kasmai 2008, 276). With respect to Köppen climate classification, this city is located in a semi-arid climate (Barzegar and Mirshamsi 2014). Table 1 reports the average rainfall, maximum daily rainfall, and average numbers of frost days reported according to the 25-year GPA Statistics (1951-1975). Considering tables provided by the Iran Meteorological Organization (between the years 1999 to 2009), the mean maximum temperature of Shiraz is 38.53°C in June or July and the minimum is nearly 0.43°C in December or January.

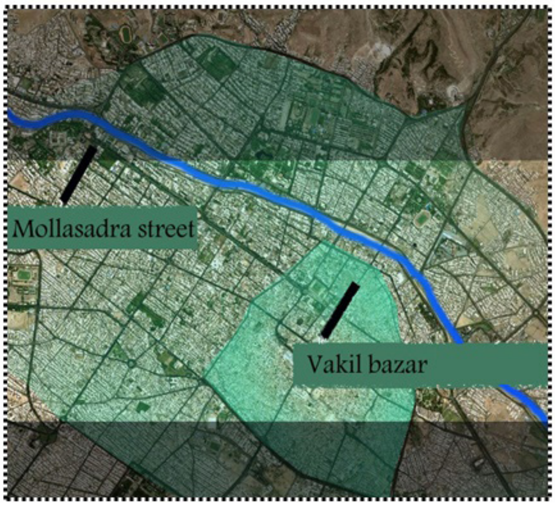
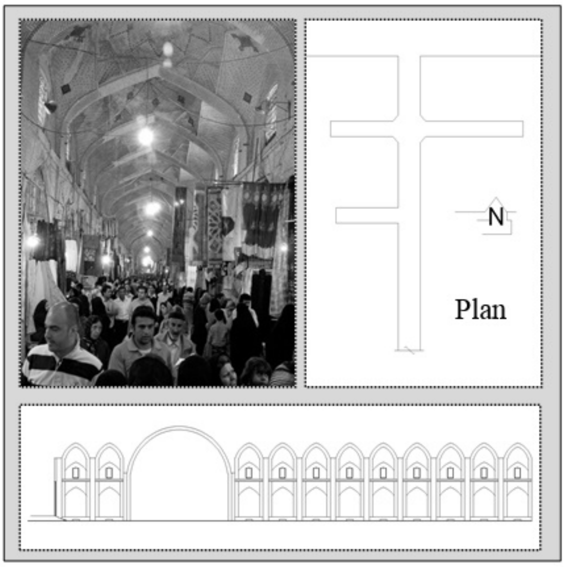


Fig. 1 Upper: the position of case studies in Shiraz; middle: the plan, elevation and pictures of Mollasadra Street; lower: the plan, elevation and pictures of Vakil Bazaar.



The first case study was Vakil Bazaar, located in the historical center of Shiraz and lies near the Vakil Mosque. It was built in 1187 A.H commissioned by Karim Khan[1] , and covers an area of 31840 m2 and is up to 23960 m2 (considering Inns) (Nasr 2008, 19).This bazaar has 74 arch vaults with a height of over 11 meters which now they have been reduced to 10 meters (See Fig. 1). This market contains three spaces for pedestrians, open space shop vitrine, and shop interior. Its orientation is NS-EW (Nasr 2008, 61). Ventilation has been conducted by simple wind catchers. Some windows also had been embedded under the roof; however, after restoration, they were closed; instead, today there are some small holes in the roof to ventilate and to inter light into the structure (Nasr 2008, 62) (See Fig. 1).

The other case to study was Mollasadra commercial street, located in the south corner of Namazi square, built in 1981. According to Shiraz Municipality official website, it has a 30 meters wide and 760 meters long. It also has north-south direction; Fig. 1 displays the direction of both cases. In this study, about 60 meters of Vakil and Mollasadra Bazaars were chosen to evaluate their thermal comfort.

Table 1 The amount of rainfall and frost days of Shiraz (Kasmai 2008).

Order	Parameters (units)	measurement
1	average rainfall (m.m)	343.2
2	maximum daily rainfall (m.m)	128
3	average numbers of frost days	56.6

3.Methodology

Since a long time ago, two chief methods have been common in the realm of thermal comfort: experimental studies and field studies. In the former, the participants have been put under certain and controlled conditions and were asked some questioned. In the latter, the participants observed in the real world without changing the environmental conditions (Heidari 2011, 7). In this paper, a combination of two methods was used. First, the surfaces with shadow and direct solar radiation have been simulated, using Ecotect 2011 software (See Fig. 3); second, the questionnaires were

1. The founder of Zand Dynasty

administered to the shopkeepers and customers to assess the times when there is sunshine and shade on the pavements and shop's vitrine, the best time for doing shopping from customers' point of view, the common ways shopkeepers employed to create shade, and the times when they use cooling or heating equipment; then, the collected data were analyzed to investigate the relationship between times when there is sunshine or shade on the surfaces and times the customers prefer to do shopping.

It is worth noting that to do this research, the hottest summer day in Shiraz (6th of July) was chosen based on the weather reports of Meteorological Organization for the last ten years; the 5th of January in winter also was considered as the coldest day of the year. The process of this study is presented in Fig. 2.

4.Discussion

4.1. The shadow and direct solar radiation simulation using Ecotect

During normal rest the body temperature is 37°C. The body's temperature control system tries to maintain this temperature when thermal disturbance occur (Henson 1990, 2). Important in this respect is if the body goes to a warmer environment it starts to absorb heat, and if it goes to a colder place it dissipate heat (Kasmai 2008). The current paper evaluates individuals' thermal comfort in the two case studies, mentioned below, in the summer and winter.

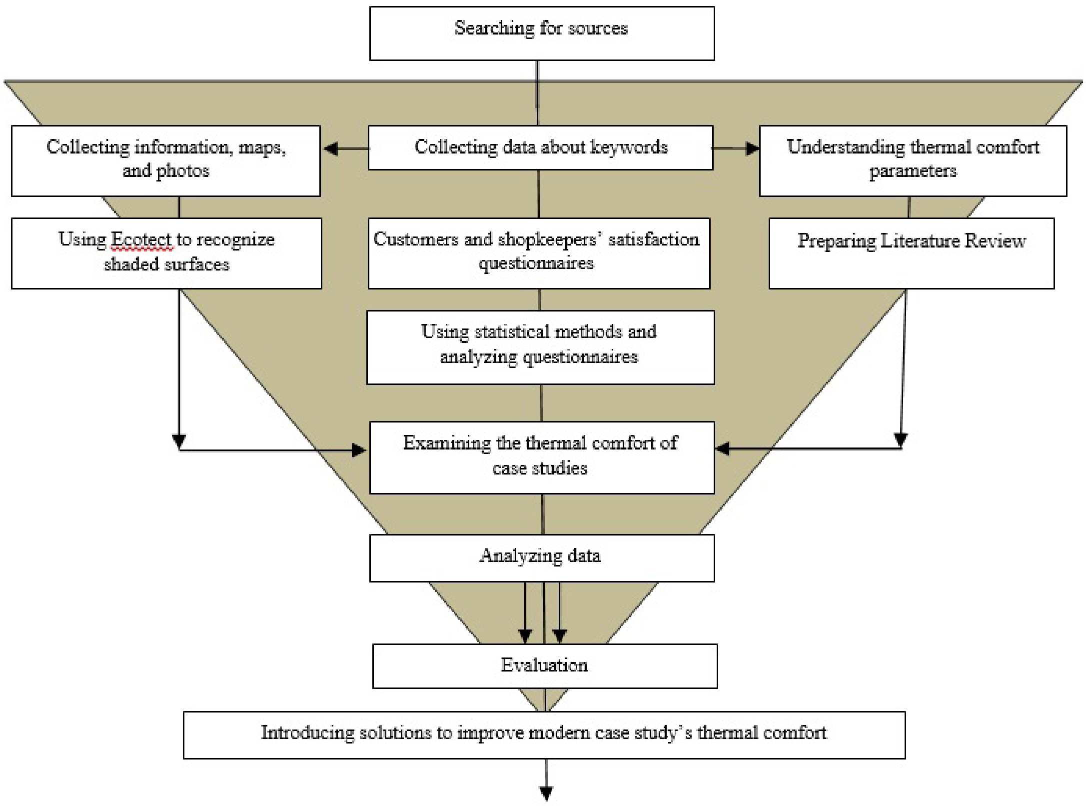


Fig. 2: Research executive process diagram.

4.1.1. Simulation of direct solar radiation and the shadow area in winter

The first case to study is Vakil Bazaar, which is located in the Shiraz historical center. Due to the presence of roof in this bazaar, the space achieved shade in all seasons. However, the important point is that as the bazaar is to some extent underground (approximate 1 meter), the floor gains the heat produced by the earth; and at the same time, by using heat gain and time lag technique, the solar is achieved in its roof and envelopes.

The second case to study, Mollasadra bazaar, which situated in the new texture of the city, obtained the solar radiation directly. Using Ecotect 2011, the area of direct solar radiation absorption on the envelopes and pavement was evaluated from 09:00 to the 19:00 in January.

The simulation results reported that in the east part of Mollasadra bazaar, the shops' envelops and pavement were completely in the shadow between 06:00 and 11:00 in the winter morning. However, from 11:00 until about noon, only shop's envelopes were in shade, and sunshine covered the pavement. After this time, the shops exposed to the solar radiation completely. Fig. 3 shows the result plan presenting the shade in the street and pavement, which was only happen from 06:00 to the 14:00.

4.1.2. Simulation of receiving solar radiation and the shade in summer

As it was mentioned before, because of existing roof and wind catcher in Vakil Bazaar, the sun cannot affect it directly. The main advantage of these wind catchers is to cool the air without using any kind of active equipments (Mazidi and Mazidi 2008, 39).

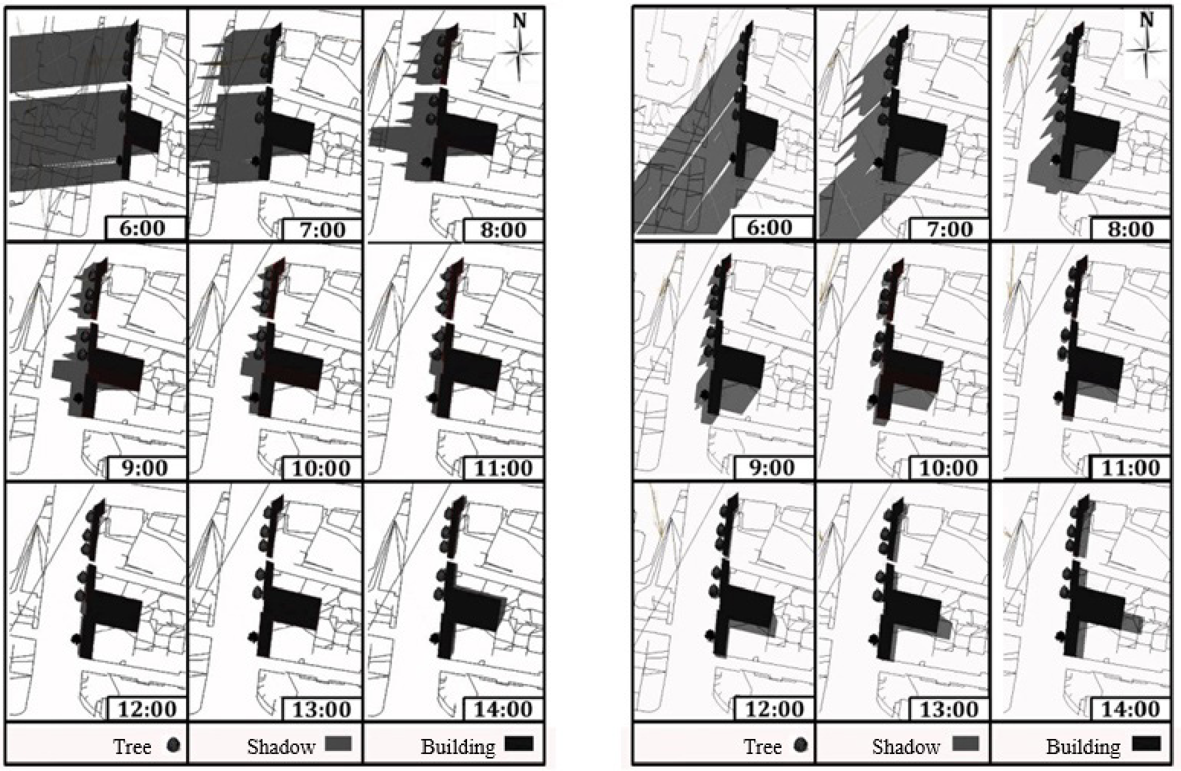


Fig. 3: Ecotect 2011 results for the east part of Mollasadra Street in 5th of January (left) and in 6th of July (right).

Regarding Mollasadra bazaar, Ecotect 2011 presented envelopes shadow area and direct solar radiation area in the hottest day of the year from sunrise to the sunset (See Fig. 3). The results demonstrated that the shadow can be seen in the pavement between 08:00 and 10:00 in the morning, but then direct solar radiation covered all the pavement and building body, and this process continues until 19:00.

4.2. The Sample's Satisfaction Level

The questionnaires, developed for winter and summer separately, were administered to survey 120 samples including 30 customers and 30 shopkeepers of Mollasadra, 30 customers and 30 shopkeepers of Vakil Bazaar. Tables 2 and 3 devoted to the results of questionnaires for winter and summer, respectively.

4.2.1. Winter Results

The results of Mollasadra's questionnaires indicated that the shopkeepers stated the best time to sell is between 11:00 and 13:00 in the morning and between 17:00 to the 19:00 in the afternoon (93.3%). Since direct solar radiation received on the pavement in these periods and the simulation results, it is obvious that the customers preferred these hours to do shopping due to the presence of sunshine and its winter heat.

70% of Mollasadra's shopkeepers expressed that in winter morning, there is no sunshine in the shop's vitrine and they experienced it only between 13:00 and 15:00.The questionnaires related to the received direct solar radiation on the pavement also demonstrated, all shopkeepers believed between 11:00-13:00 and between 13:00-15:00 the direct radiation are felt on the pavement. All shopkeepers of this street used heating equipment between 09:00 and 11:00 and 83.33 % between 17:00 and 19:00. The relation between direct solar radiation and winter heating load was reversing, which showed when direct solar radiation achieved on the building envelopes (Fig. 4). The results of customers' questionnaires from Mollasadra also show 86.6 % of them introduced the best time to do their shopping between 11:00-13:00, and between 17:00-19:00. The sell time and shopping time was to some extend the same (Fig. 4).

80% shopkeepers of Vakil Bazaar also knew the best time to sell between 11:00-13:00, and 70 % knew it between 17:00-19:00. Since, it is an indoor bazaar and the solar radiation cannot felt the pavement or shops' vitrine, the questions related to the direct solar radiation times omitted. Sixty six percent of shopkeepers announced they did not use any heating equipment. It can be considered as an important advantage in a public building. It derives from the fact that the structure had built by traditional materials and design, and passive technique such as being underground and having roof. Only about 33.3 % of shopkeepers stated they use heater between 09:00-11:00, and 30 % of them use it between 17:00-19:00 (See Table 2). The relation among the heating load and shopping time were direct and with the same slope. The only difference was on the amount, which the heating was less (Fig. 4). The 73.3 % customer of this bazaar also preferred to do their shopping between 11:00 and 13:00, and 70 % prefer the hours between 15:00 and 17:00. The curves of selling and shopping time were the same to some extent (Fig. 4).

Table 2: Winter questionnaire results.

Case study	samples	questions	7-9	9-11	11-13	13-15	15-17	17-19
Molla-sadra Bazaar	shop-keepers	The best time to sell	0	60	90	0	43.3	93.3
		The time of direct solar radiation on the pavement	0	0	100	100	30	0
		The time of direct solar radiation on the shop's vitrine	0	0	30	100	26.6	0
		The time of the heating load	0	100	56.6	0	53.3	83.3
	custom-ers	The best time to do shopping	0	40	86.6	0	40	86.6
Vakil Bazar	shop-keepers	The best time to sell	10	60	80	10	70	56.6
		The time of heating load	0	30	26	0	16.6	33.3
	custom-ers	The best time to do shopping	0	73.3	66.6	13.3	70	53.3

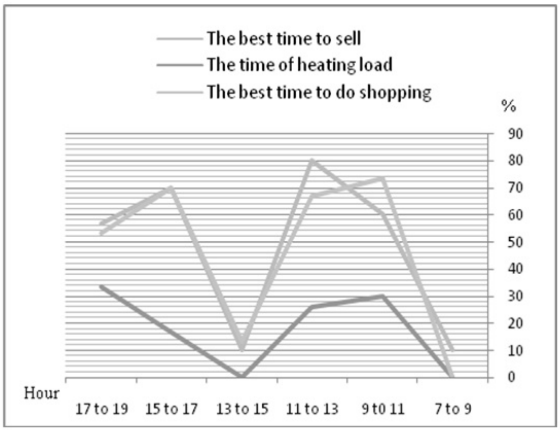


Fig. 4: The comparison of Mollasadra (left) and Vakil (right) Bazaar winter questionnaire results

4.2.2. Summer Results

The results of shopkeepers' summer questionnaires in Mollasadra indicated that the best time for selling was between 09:00 and 11:00 (83.3 %) and 17:00 to 19:00 (100%). Regarding the existence of shadow in the shops' vitrine, all shopkeepers claimed, the direct solar radiation hilted the vitrines between 11:00-13:00 and 13:00-19:00, (See Fig. 3). According to the survey and simulation results, it could be concluded that because of shadow in these hours, they were considered as the best times. The relation between direct solar radiation on vitrines and selling times was inverse (also shopping time), thus, the disturbing direct solar radiation did not causes the customers thermal comfort for shopping (Fig. 5). In order to omitting this radiation and providing shadow in summer, the shopkeepers used different techniques such as canopies in front

of their shops (60 %), veranda above vitrine (33.3 %), urban trees (66.6 %) and other traditional ways (10 %).
These shopkeepers also stated that sunshine can be seen on the pavement between 11:00-13:00 and 15:00-19:00. Furthermore, 73.3 % of customers of this commercial street preferred the best time to do shopping between 09:00 and 11:00 since no sunshine can be felt; and all expressed, 17:00 to 19:00 considered as the best shopping time in the afternoon. The relation between direct solar radiation on the pavement and shopping times was reversing (Fig. 5).
In addition, 93.3 % of shopkeepers use cooling equipment between 11:00 and 13:00, and between 17:00 and 19:00. It is worth noting that due to the existing of sunshine and lack of customer, the shops are closed before the time mentioned in the afternoon; they are opened after 17:00. As mentioned before, the relation between cooling load and pavement solar radiation absorption is direct with a bite difference in slope (Fig. 5).
Regarding the results obtained from the questionnaires of Vakil Bazaar, the researchers noticed that 86.6 % of shopkeepers believed the best time of selling is between 09:00 and 11:00 and 96.6 % of them knew the best time as 17:00 until 19:00 in the afternoon. 76.6 % of customers stated, they preferred to do their shopping from11:00 to 13:00, also, they preferred shopping from 17:00 to 19:00 in the afternoon. It should be mentioned that as it is an indoor bazaar, the cool air blows in the summer, and it also enjoys a hot air in the winter; and that is why the customers could be found all the time (See Table 3). The curve of selling and shopping times was exactly the same (Fig. 5).
In this bazaar, 56.6 % shopkeepers used cooling equipment between 11:00 and 13:00 in the morning and 63.3 % used it from 15:00 to 17:00 in the afternoon. As one of the best advantages, 23.3 % of shopkeepers claimed, they have no use for the equipment. Comparing these results with those of Mollasadra, one recognizes as Vakil Bazaar benefits from Traditional materials and architecture, using cooling and heating equipment, or in other words, the energy consumption is not as much as Mollasadra.

Table 2: Winter questionnaire results.

Case study	samples	questions	7-9	9-11	11-13	13-15	15-17	17-19
Mollasadra Bazaar	shopkeepers	The best time to sell	0	60	90	0	43.3	93.3
		The time of direct solar radiation on the pavement	0	0	100	100	30	0
		The time of direct solar radiation on the shop's vitrine	0	0	30	100	26.6	0
		The time of the heating load	0	100	56.6	0	53.3	83.3
	customers	The best time to do shopping	0	40	86.6	0	40	86.6
Vakil Bazar	shopkeepers	The best time to sell	10	60	80	10	70	56.6
		The time of heating load	0	30	26	0	16.6	33.3
	customers	The best time to do shopping	0	73.3	66.6	13.3	70	53.3

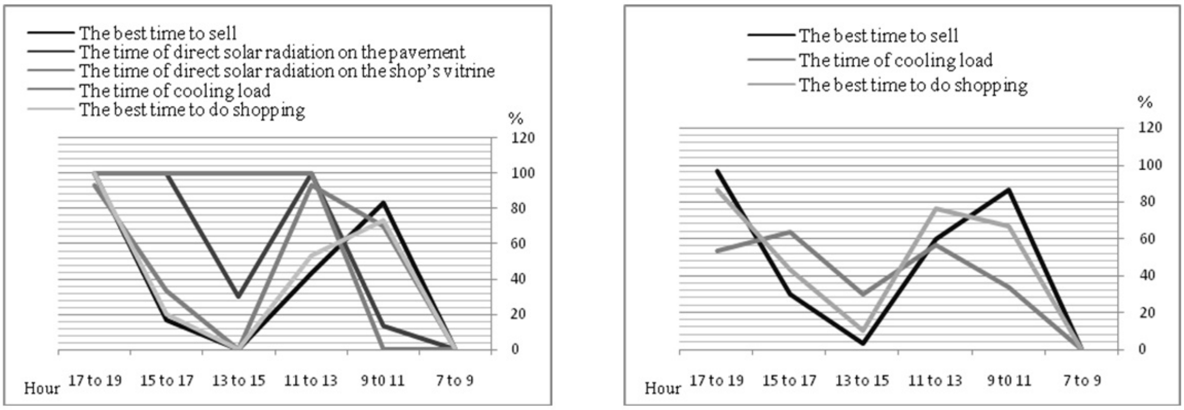


Fig. 5: The comparison of Mollasadra (left) and Vakil (right) Bazzar summer questionnaire results.

5.Conclusion

One of the most basic dimensions of comfort is thermal comfort (Barzegar and Mofidi Shemirani 2010). This paper made an attempt to compare traditional and modern architecture using two case studies–Vakil Bazaar and Mollasadra Commercial Street. The obtained results showed, Mollasadra cannot content a high percentage of customers with surfaces not having shade, especially in summer and in the rush hours. The pavement was exposed to solar radiation, and the existing trees cannot meet the needs of proper shading. On the contrary, the other case study–Vakil Bazaar, an indoor bazaar which was built with traditional materials, have a cool air in the summer, and only the overcrowding may cause excessive heat. Thus, the shopkeepers have to use cooling equipment. During winter, there is a desirable heat since this bazaar is an underground one.

In the winter morning, because of not receiving enough sunshine, shopkeepers have to use heating equipment. However, when sun hilted (in 11:00) on the shops, there is a reduction (nearly 43.3 %) in using heating equipment. Since the shops are closed between 13:00 and 15:00, using heating equipment is zero; but after they are opened using the equipment increases and resulted in raising energy consumption. But in Vakil Bazaar, with respect to its unique architecture, its roof and its underground position, there is no need to use heating equipment, and as the results show, its energy consumption is low in general. By comparing data obtained from customers' satisfaction in both cases, it could be concluded that people tend to go to this bazaar at all open times, since they are not exposed to the rain, snow, sunshine, cold and wind.

Considering Table 2 and obtained data from Ecotect, it could be inferred that in the summer crowded shopping hours, direct solar radiation can be felt in the pavement and shops' vitrine of Mollasadra. The people, therefore, are not interested to do shopping in these times (as the table show, a high percentage of people prefer to do shopping between 17:00 and 19:00 when the intensity of the heat reduces). The percentage of using cooling devices is high, either in the morning or in the afternoon, due to the intense sunshine and lack of desirable shadow. This cause wasting energy in the hours when the bazaar meets people doing their shopping. In Vakil Bazaar, however, it is quite different. The people easily do their shopping at all times. In this bazaar, the amount of energy consumption, in contrast to Mollasadra, built using modern materials and architecture, is lower (Fig. 6).

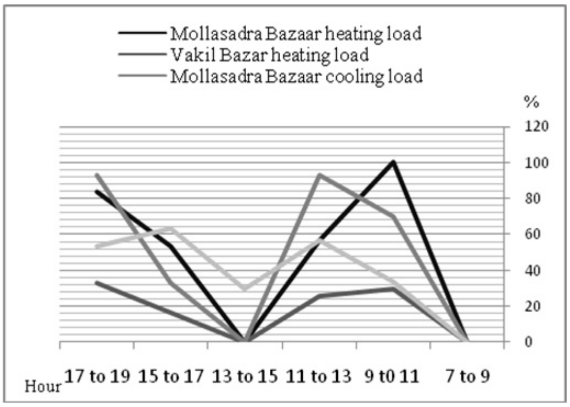


Fig. 6: The comparison of Mollasadra and Vakil Bazzar heating and cooling load.

To create shadow in Mollasadra, planting more shade trees can be considered as the best solution, since they can blot out some of the summer solar radiation and create shade with their full dense green foliage. In the winter, the sunrays can move across the foliage, feel the pavement and produce heat. Furthermore, applying a fountain in front of Denasa Commercial Building can help to produce a cooling environment using the wind in summer. Additionally, the buildings' horizontal veranda cannot help in creating shadow in this street because of western radiation. therefore, using vertical shading device is suggested for shops. Now, only 16 shops out of 28 apply them.

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