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IMPROVING CLIMATIC COMFORT EMPHASIZING THE EFFECT OF SUNSHINE RADIATION ON THE PROPER ORIENTATION OF THE PHYSIC OF SQUARES IN YAZD

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ABSTRACT

The heat of the earth is provided by sunshine radiation. A change in the angle of sunshine radiation and the surface of Earth, the height and distance of the Sun from the Earth causes changes in ambient temperature. Sometimes these changes will reduce climatic comfort for human beings. Climatic comfort is established when there is a balance between excreted and absorbed temperature by the skin of the body. Orientation of the physic of the squares to geographic north causes changes in the received amount of direct sunshine radiation in different months. Thus the establishment is appropriate in some orientations and inappropriate in others. The inappropriate orientation of the physic in most squares of the city of Yazd reduces the climatic comfort of the citizens. In this study, the correlation coefficient was used and the difference between the different orientations regarding the amount of getting sunshine radiation was calculated using the software R. Calculations were based on a fixed rectangle in the eight cardinal and intercardinal orientations during the year and have been compared with each other in terms of climatic comfort. According to the results, north-south orientation is the most desirable orientation in the whole year for the physic of squares in Yazd. Getting close to the east-west orientation reduces the desirability. The difference in getting sunshine radiation between the orientations is quite significant. This study shows that using the north-south orientation or orientations near it for the physic of squares in Yazd, increases climatic comfort of the citizens.

Keywords: Orientation of the physic of squares; climatic comfort; shading of the physic; warm and dry climate.

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1. INTRODUCTION

Street and square are the two main elements of urban space. Square is the first device for people to use urban space. The square is made by the accumulation of houses and other urban elements around an open space [1]. Square is an area which is accumulative and integrated. It also brings social life for the citizens [2]. Unlike the street, square is a space is to stop rather than to pass. In fact, the main application of square in the city is a gathering place for residents and formation of communities [3]. Comfort is a prerequisite for a successful square. People in public spaces have five basic needs to be met: comfort, convenience, effective communication with the surroundings, active relationship with surroundings and revelation in the sense that most good places meet these expectations. Comfort is a prerequisite for a successful public spaces. The time that people stop in a public space is a sign of performance and convenience of that space [4]. Feeling of comfort includes 1- bioclimatic comfort 2- physical comfort and 3-social and psychological comfort [5]. In this research climatic comfort is explored [6].

Climatic comfort is generated when there is a balance between disposed and absorbed temperature of the skin. It causes body temperature to remain balanced at about 37° C [7]. Climatic comfort is affected by factors such as temperature, humidity, wind and clothing, among which temperature plays an important role. The temperature of earth is provided by the energy from sun received from sunshine radiation [8]. The amount of need to getting this energy, depending on the location and time, is not fixed. Thus in the hot and dry climate, existence of sunshine radiation on most days of the year is considered the main distortive factor of climatic comfort. Having shades in this climate is the first thermal modulation technique on most days of the year. There are many ways to create shades in urban spaces but proper orientation of their confining physic is the most cost-saving and effective way to control shades and sunshine radiation [9].

The proper orientation of the physic of city squares as public open spaces plays a decisive role in the climatic comfort of citizens. It improves the efficiency of urban spaces. The knowledge of urban designers results in designing of squares that are used in the most hours of the day by citizens. Yazd is located in the hot and dry climate [10]. However, researchers paid little attention to the orientation of the physic of open spaces in this city and they just paid attention to the orientation of the physic of the buildings. They achieved the northeastern-southwest orientation as the best orientation in terms of climate [6]. Lack of attention to the orientation of urban spaces has caused that urban spaces do not have suitable climatic conditions for being used by citizens and lose their position in the city. The orientation of the physic of urban squares as urban spaces, which is determined by the buildings around, is opposite to the orientation of the buildings. Is the orientation of the physic of squares in Yazd in terms of improving the climatic comfort of citizens or not? What is the best orientation of the physic of squares in terms of sunshine radiation?

The aim of this study was to find the most appropriate orientation of physic for squares in Yazd with an emphasis on increasing climatic comfort by controlling sunshine radiation (depending on the need for it in the squares). In this study, the correlation method is used. The data is collected through field and library surveys. Considering the importance of climatic comfort in the use of urban space by citizens and the role of physical orientation of urban space, the results of this research can make urban planners close to achieving their goal of creating convenient and comfortable spaces.

2. ORIENTATION OF BUILDINGS

Pirnia [6] has identified three dominant orientations for buildings in Iran according to the climate as following. Right orientation: in this orientation a rectangle is inside a hexagon. It has a northeast-southwest orientation. Iran's central cities like Tehran, Yazd, Jahrom and Tabriz are in the Right orientation. Isfahani orientation: this orientation is south-east to the northwest. This orientation is in Isfahan, Estakhr, Persepolis and Fars province. Kermani orientation: it has an eastern-western orientation and cities like Kerman and Hamedan, and villages in western Azerbaijan, Khoy and some other cities have been made based on this orientation (Fig. 1).

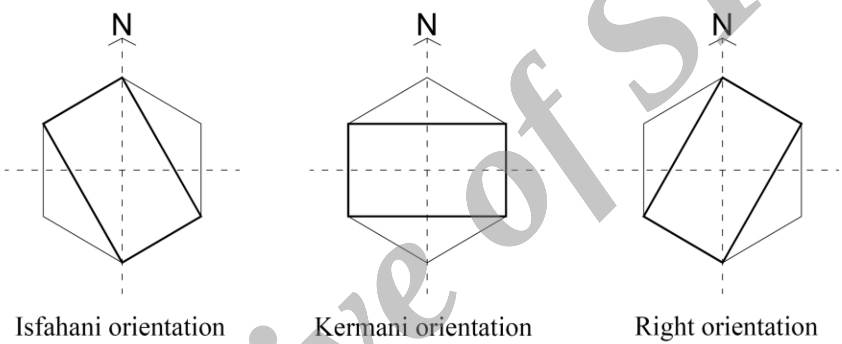

Figure 1. Orientations used in the buildings of Iran

Based on the findings of Pirnia [6], the buildings of Yazd are in line with Right orientation. Thus the physic of remaining spaces between buildings, which includes squares, have northwest-southeast orientation with 60º deviation from North to the West (Fig. 2).

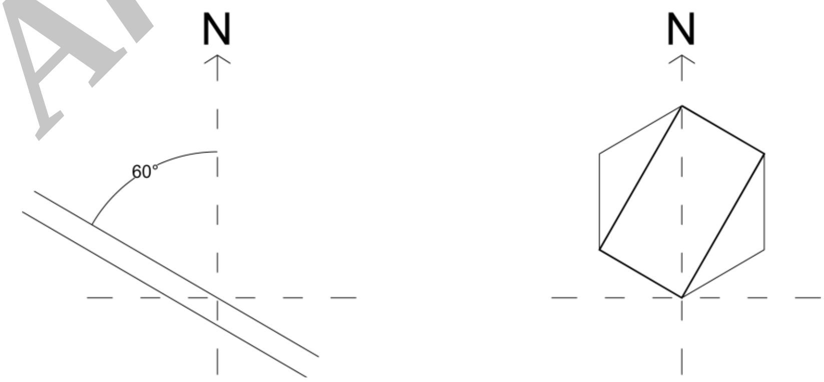

Figure 2. The orientations used in Yazd

It seems that the desirable orientation of the buildings in Yazd is merely in line with the climatic comfort of private spaces, so the public spaces between these buildings do not have the desired orientation. Because in the past, urban spaces were seen as the remaining spaces of buildings physic and buildings had the priority. In the case of providing climatic comfort conditions in urban spaces, many people's activities take place in the outdoor. Otherwise people prefer to take turn to the buildings to achieve thermal comfort. Thermal comfort means a range of temperature and humidity that the thermoregulatory mechanism of the body is doing the minimum activity [11].

Urban squares as a public territory have "physic" (space) and "social" (activity) dimensions. The physic of public territory means *spaces* or environments with private or public property that support and facilitate public life and social interaction. Activities and events that occur in these spaces and environments can be called as the public socio - cultural territory [4]. This study explores the orientation as a quantitative component of dimension of physic, due to its direct impact on the climatic comfort. The approach used in this study is deductive [12], therefore all of the studies and researches are from the whole to the components. Yazd is located in hot and dry and semi-hot and dry part of the northern hemisphere. The number of rainy days is 23 days, sunny hours on average is 3052 hours and non-sunny days on average are 60 days. The average daily temperature is variable between 11.9 and 20.7 degrees Celsius for the whole year [13].

In the hot and hot and dry climates, the first method for making climatic comfort on most days of the year is the use of shades. If there is not proper shading, people are exposed to direct sunshine radiation, reflections from sky and reflections from hot street and sidewalk floors. As a result, the heat load of short and long sunshine radiation waves would be unbearable and people will be forced to leave the urban spaces [9]. Many efforts have been made to calculate the range of thermal comfort, one of the first well-known methods is using equal comfort lines that reflect the effective temperature (shown by ET2). Then new effective temperature was introduced after some refinements [14]. Fanger [15] defined comfort range based on the calculations of the amount of heat exchange between human and the environment. United States national institute of standard in 1985, considered the moisture content caused by perspiration on the skin the best method for estimating the thermal discomfort. Thus it defined the skin temperature and its wetness as two important factors in the calculation of thermal comfort [16]. Then in 1987 Szokalay defined comfort temperature ranges by the average ambient temperature [17].

In this study, the basis for determining the need for sunshine radiation or shade in urban spaces for months of the year is applied as defined by the climatic comfort in open spaces in ASHRAE Handbook of Fundamentals Comfort Model. This model is applied on Geun psychrometric charts based on hourly data. It is used for the analysis of monthly, seasonal and 44-year period (1961-2004). This model, apart from being a good model to determine thermal comfort zones in open spaces, presents the most realistic results according to a study in Yazd in 2009 done by Sadeghi Ravesh and Tabatabaei.

3. PHYSIC OF SQUARES IN YAZD

With a field study, six main squares of the city of Yazd were studied as samples. Studies showed that the squares built in order to create a space for gathering of residents on a scale of city, have an elongated geometry close to rectangular. This is due to the need to achieve a large space for gatherings. Also reducing the surface of physic and sunny space of squares to enhance the climatic comfort of citizens in the hot and dry climate of this city is needed. Most of the physical orientation of these squares are northeast-southwest and northwest-southeast. The main characteristics of six squares is given in the following (Fig. 3).

Urban space	1-Vaghto-Saat Sq	2-Grand Mosque Yard	3-Shah Abolghasem Sq	4- Khaan Sq	5-Shah Tahmaseb Sq	6-Amir Chakhmaq Sq
Shape	square	Rectangular	rectangular	rectangular	rectangular	rectangular
operation level	local	Urban	local	urban	urban	urban
Area	159	1117	844	1658	6929	7923
Closeness ratio	1/9	1/4	1/6	1/4	1/12	1/9
Length to width ratio	1/1	1/2.5	1/2.5	1/4	1/1.5	1/3
elongation orientation	Northeast-southwest	Northeast-southwest	Northeast-southwest	Northeast-southwest	Northwest – southeast	Northwest - southeast
Angle to north	32°	41°	°52	°48	46°	47°
The average height of the wall	6	6	6	5	10	6

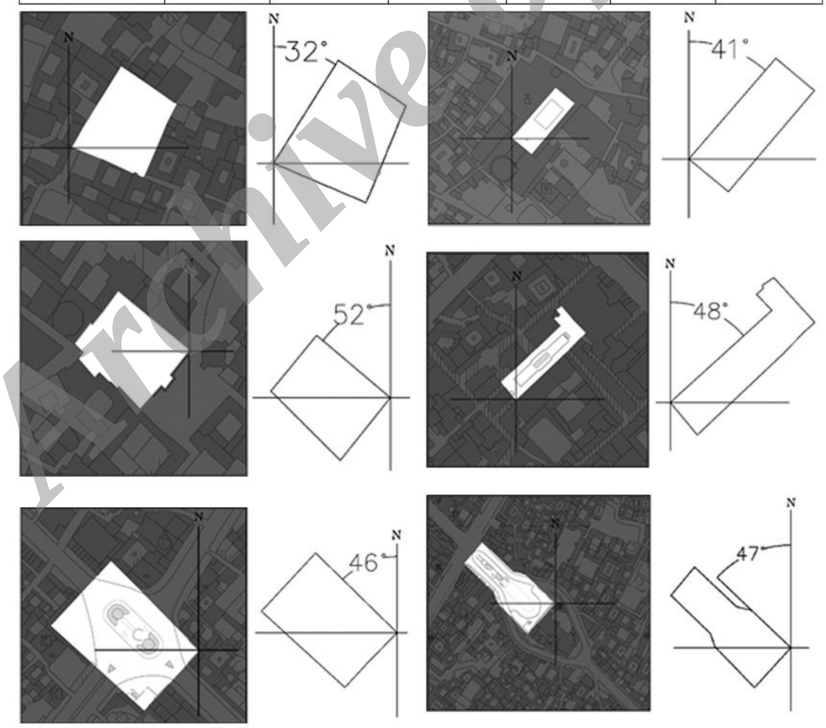

Figure 3. Six studied samples of urban spaces with the use of squares in Yazd

4. THE THEORETICAL MODEL OF STUDY

Given that the squares of Yazd and the studied samples have rectangular geometry, so to get the proper orientation of squares physics, at first a rectangular space with golden ratio (length = 1.63 × width) and closeness ratio of 1/2 (width = 2 × height of the wall) was simulated. Then this rectangular space was considered with eight different orientations (North-South, 22.5°, 45°, 67.5°, east-west, 112.5°, 135°, 157.5°), This calibration is started as clockwise from the north and 22.5° is added exponentially (Fig. 4) In each of these orientations sunshine radiation rate was calculated every 30 minutes for the entire year and the results were compared with each other. To determine the importance of their differences in different months, at first the significance of these differences should be approved by R software. Thus the analysis of variance (ANOVA) test was used.

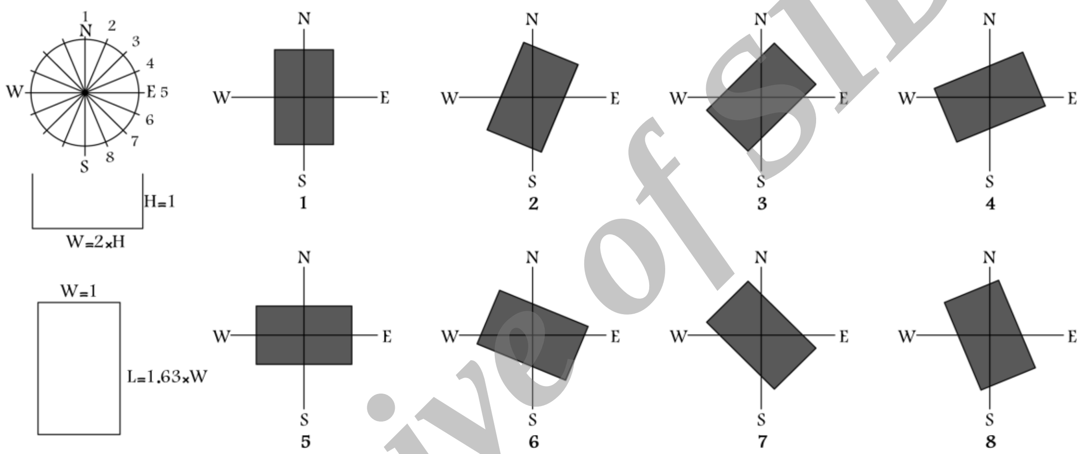

Figure 4. The characteristics of the studied orientations of the squares

4.1 Findings

In the first quarter of the year due to low air temperature, climatic comfort of citizens in urban areas during the day is naturally very low (Figs. 5, 6 and 7). To approach the conditions of climatic comfort in these months, the presence of sunshine radiation in the urban spaces is essential. Therefore, between different orientations in these months, the orientations which receive more sunshine radiation during the day are prior.

In the first month of the year, out of the eight considered orientations, the North-South orientation received 26% of sunshine radiation as the most, and East-West orientation received 16% of sunshine radiation as the least (Table 1). In the second month, North South orientation received 31% of sunshine radiation as the most, and the East-West orientation received 27% sunshine radiation at the least (Table 2). Also in the third month, the orientation 112.5° received 39% of sunshine radiation as the most, and the North - South orientation received 36% of sunshine radiation as the least (Table 3). The difference in percentages between the different orientations in the first month is highly significant ($P \leq 0.001$), but in the second and third months the difference was not statistically significant ($P \geq 0.05$). The results of the months with statistically significant differences is given in 10 days separately to be more accurate, but in other months the results are given in month (30 days).

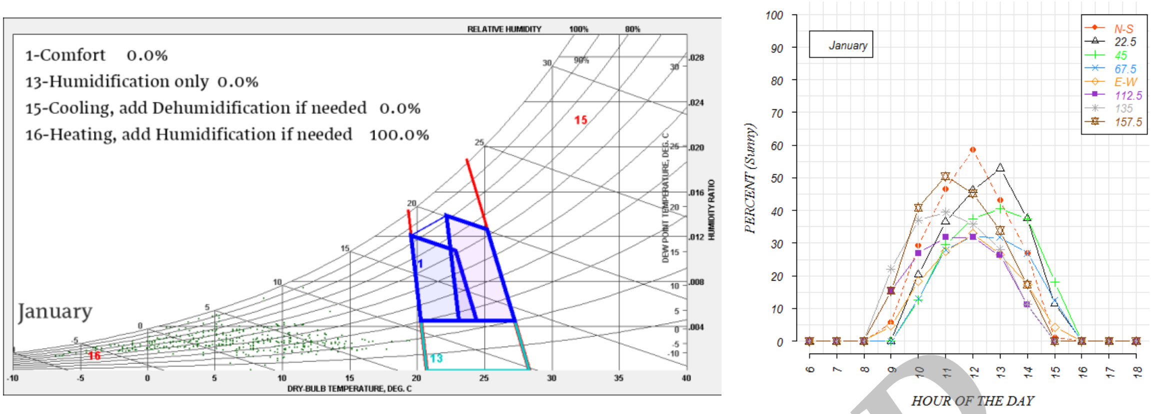

Figure 5. The figure of percentage of receiving sunshine radiation in different orientations in january (right) and Geun psychrometric charts of that month (left)

Table 1: Percentage of sunshine radiation of physical orientations in month by 10 days and ranking them based on the amount of sunshine radiation

	January	(1-10)		January	(10-20)		January	(20-30)	
	Orientation	means	M	Orientation	means	M	Orientation	means	M
1	N-S	23.9	a	N-S	25.1	a	N-S	25.5	a
2	°22.5	22.6	ab	°22.5	23.9	a	°22.5	24.8	a
3	°157.5	22.6	ab	°157.5	23.9	a	°157.5	24.7	a
4	°45	18.5	bc	°135	20.0	ab	°45	21.6	ab
5	°135	18.4	bc	°45	20.0	ab	°135	21.5	ab
6	°67.5	14.6	cd	°67.5	16.2	b	°67.5	18.2	b
7	°112.5	14.6	cd	°112.5	16.1	b	°112.5	18.2	b
8	E-W	13.0	d	E-W	14.9	b	E-W	17.2	b

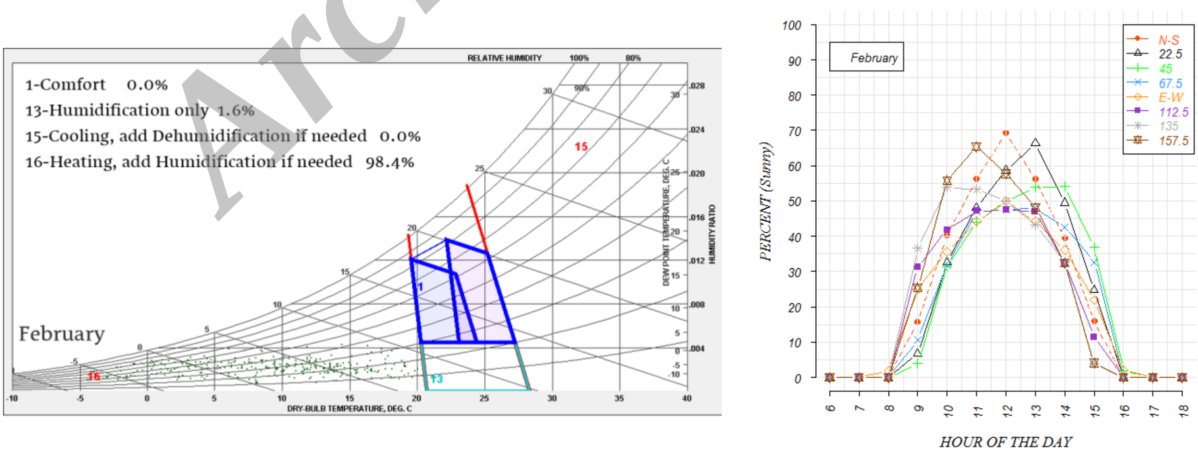

Figure 6. The figure of percentage of receiving sunshine radiation in different orientations in february (right) and Geun psychrometric charts of that month (left)

Table 2: Percentage of sunshine radiation of physical orientations per month in average

N-S	°157.5	°22.5	°135	°45	°67.5	°112.5	E-W
31.3	31.2	31.1	30.2	30.2	27.7	27.6	27.1

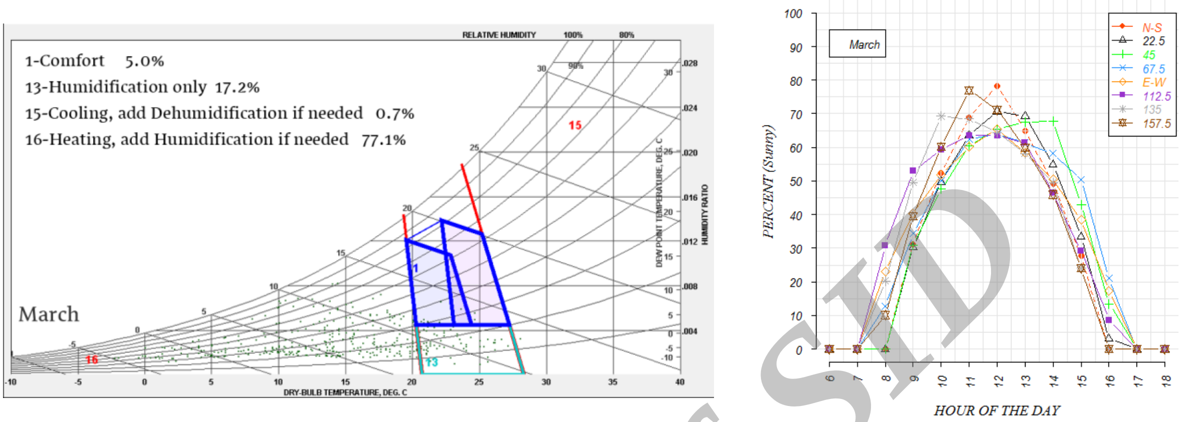

Figure 7. The figure of percentage of receiving sunshine radiation in different orientations in march (right) and Geun psychrometric charts of that month (left)

Table 3: Percentage of sunshine radiation of physical orientations per month in average

°112.5	°67.5	°135	°45	E-W	°22.5	°157.5	N-S
39.4	39.3	39.0	39.0	38.6	37.3	37.3	36.4

In next six months of the year, from the fourth to the ninth month, due to normal increase of temperature and overheating of weather, climatic comfort of users in urban spaces during the day is naturally very low (Figs. 8, 9, 10, 11, 12 and 13). So to get close to climatic comfort in these months, having sunshine radiation in space is unfavorable. Sunshine radiation have a high role in shading of space and balancing temperature. So the months which received the least sunshine radiation during the day are prior.

According to the results, out of eight orientations, the fourth month of the year receives 49% of sunshine radiation as the most in east-west orientation and 41% as the least in north-south orientation (Table 4), In the fifth month, east-west orientation received 56% of sunshine radiation as the most and north-south orientation with 44% as the least (Table 5), in the sixth month, the east-west orientation received 57% of sunshine radiation as the most and the north-south orientation, 157.5° and 22.5° with 46% as the least (Table 6), In the seventh month, the east-west orientation received 57% of sunshine radiation as the most and north-south orientation, 157.5° and 22.5° with 46% as the least (Table 7), in the eighth month, the east-west orientation received 56% of sunshine radiation as the most and north-south orientation with 45% as the least (Table 8), in the ninth month, the east-west orientation received 46% of sunshine radiation as the most and north-south orientation with 39% as the least (Table 9).

The difference between the different orientations of the fourth to eighth months was significant ($P \leq 0.001$), but not statistically significant in the last 10 days of the ninth month ($P \geq 0.05$).

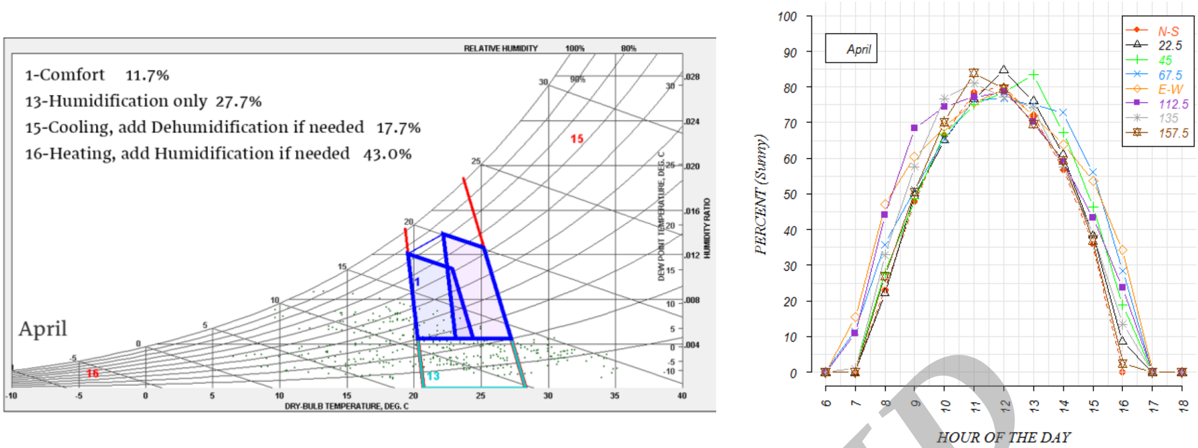

Figure 8. The figure of percentage of receiving sunshine radiation in different orientations in april (right) and Geun psychrometric charts of that month (left)

Table 4: Percentage of sunshine radiation of physical orientations in month by 10 days and ranking them based on the amount of sunshine radiation

	April	(1-10)		April	(10-20)		April	(20-30)	
	Orientation	means	M	Orientation	means	M	Orientation	means	M
1	E-W	45.7	a	E-W	45.6	a	E-W	51.9	a
2	°67.5	45.6	a	°112.5	45.0	ab	°112.5	50.1	a
3	°112.5	45.6	a	°67.5	44.9	ab	°67.5	50.1	a
4	°135	43.1	ab	°45	42.0	bc	°45	46.4	b
5	°45	43.0	ab	°135	42.0	bc	°135	46.3	b
6	°22.5	40.5	b	°22.5	39.4	cd	°157.5	43.6	bc
7	°157.5	40.5	b	°157.5	39.4	cd	°22.5	43.5	bc
8	N-S	39.3	b	N-S	38.3	d	N-S	42.4	c

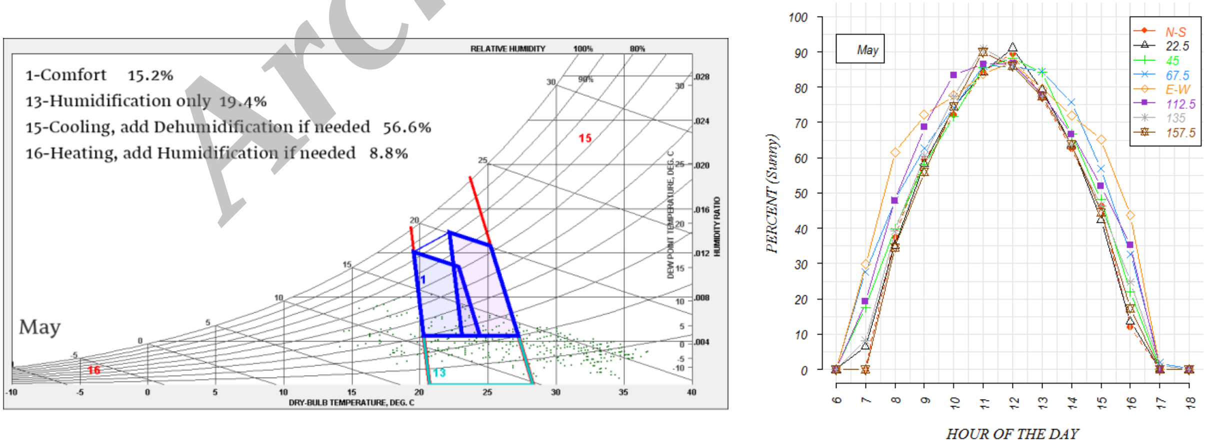

Figure 9. The Figure of percentage of receiving sunshine radiation in different orientations in May (right) and Geun psychrometric charts of that month (left)

Table 5: Percentage of sunshine radiation of physical orientations in month by 10 days and ranking them based on the amount of sunshine radiation

	May	(1-10)		May	(10-20)		May	(20-30)	
	Orientation	means	M	Orientation	means	M	Orientation	means	M
1	E-W	51.5	a	E-W	53.8	a	E-W	58.2	a
2	°67.5	48.9	a	°112.5	50.6	b	°67.5	54.4	b
3	°112.5	48.8	a	°67.5	50.6	b	°112.5	54.3	b
4	°45	44.9	b	°135	46.5	c	°45	49.9	c
5	°135	44.9	b	°45	46.4	cd	°135	49.8	c
6	°157.5	42.2	bc	°157.5	43.8	de	°157.5	47.0	d
7	°22.5	42.1	bc	°22.5	43.6	e	°22.5	46.9	d
8	N-S	41.5	c	N-S	43.1	e	N-S	46.5	d

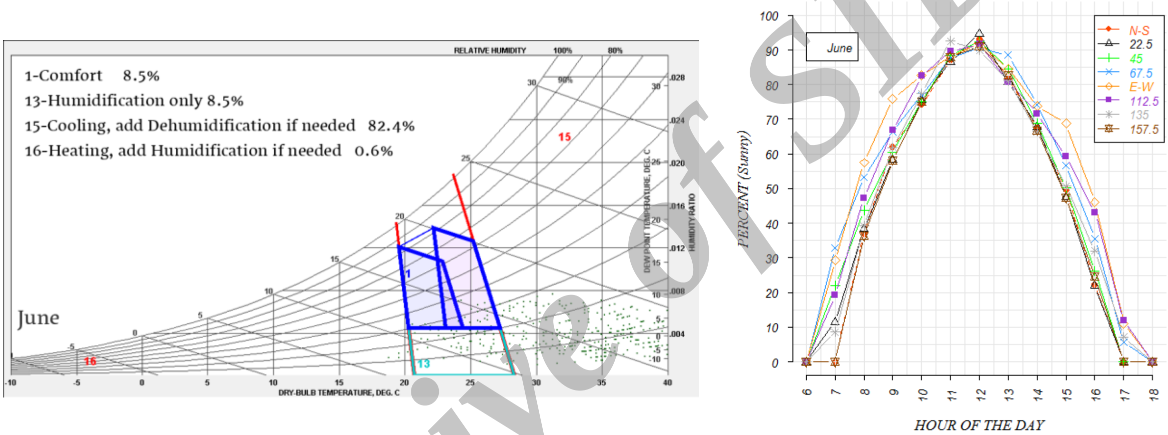

Figure 10. The figure of percentage of receiving sunshine radiation in different orientations in june (right) and Geun psychrometric charts of that month (left)

Table 6: Percentage of sunshine radiation of physical orientations in month by 10 days and ranking them based on the amount of sunshine radiation

	June	(1-10)		June	(10-20)		June	(20-30)	
	Orientation	means	M	Orientation	means	M	Orientation	means	M
1	E-W	57.3	a	E-W	57.9	a	E-W	58.2	a
2	°67.5	53.5	b	°67.5	54.1	b	°67.5	54.3	b
3	°112.5	53.5	b	°112.5	54.0	b	°112.5	54.2	b
4	°135	49.0	c	°135	49.5	c	°135	49.8	c
5	°45	49.0	c	°45	49.5	c	°45	49.7	c
6	°22.5	46.3	d	°22.5	46.8	d	°22.5	47.1	d
7	°157.5	46.2	d	°157.5	46.7	d	°157.5	47.0	d
8	N-S	46.0	d	N-S	46.6	d	N-S	46.9	d

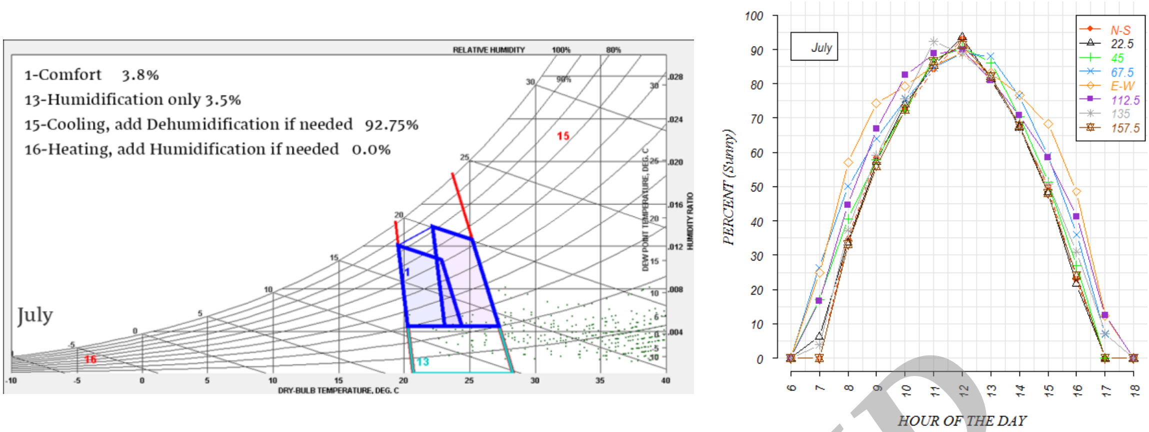

Figure 11. The figure of percentage of receiving sunshine radiation in different orientations in july (right) and Geun psychrometric charts of that month (left)

Table 7: Percentage of sunshine radiation of physical orientations in month by 10 days and ranking them based on the amount of sunshine radiation

	July	(1-10)		July	(10-20)		July	(20-30)	
	Orientation	means	M	Orientation	means	M	Orientation	means	M
1	E-W	58.0	a	E-W	57.5	a	E-W	56.4	a
2	°67.5	54.1	a	°67.5	53.6	b	°67.5	52.6	b
3	°112.5	54.0	b	°112.5	53.5	b	°112.5	52.6	b
4	°135	49.6	b	°45	49.2	c	°45	48.2	c
5	°45	49.5	c	°135	49.1	c	°135	48.2	c
6	°22.5	46.9	c	°22.5	46.4	d	°22.5	45.6	d
7	°157.5	46.9	d	°157.5	46.4	d	°157.5	45.5	d
8	N-S	46.8	d	N-S	46.3	d	N-S	45.4	d

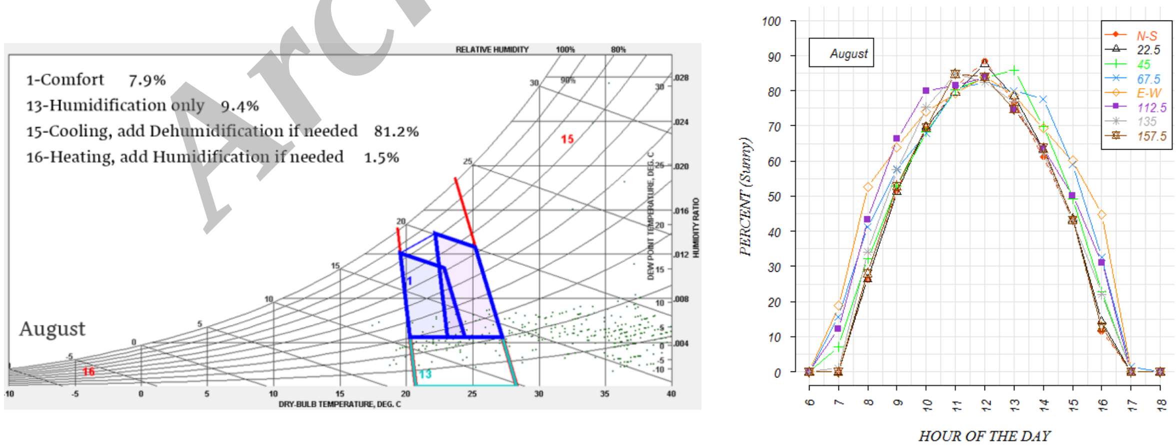

Figure 12. The figure of percentage of receiving sunshine radiation in different orientations in august (right) and Geun psychrometric charts of that month (left)

Table 8: Percentage of sunshine radiation of physical orientations in month by 10 days and ranking them based on the amount of sunshine radiation

	August (1-10)			August (10-20)			August (20-30)		
	Orientation	means	M	Orientation	means	M	Orientation	means	M
1	E-W	54.4	a	E-W	54.5	a	E-W	49.2	a
2	°67.5	50.9	b	°67.5	51.4	b	°67.5	47.2	a
3	°112.5	50.9	b	°112.5	51.4	b	°112.5	47.1	a
4	°45	46.7	c	°45	47.3	c	°45	43.4	b
5	°135	46.7	c	°135	47.2	c	°135	43.3	b
6	°22.5	44.1	cd	°157.5	44.5	cd	°22.5	40.8	bc
7	°157.5	44.1	cd	°22.5	44.5	cd	°157.5	40.8	bc
8	N-S	43.7	d	N-S	43.6	d	N-S	39.8	c

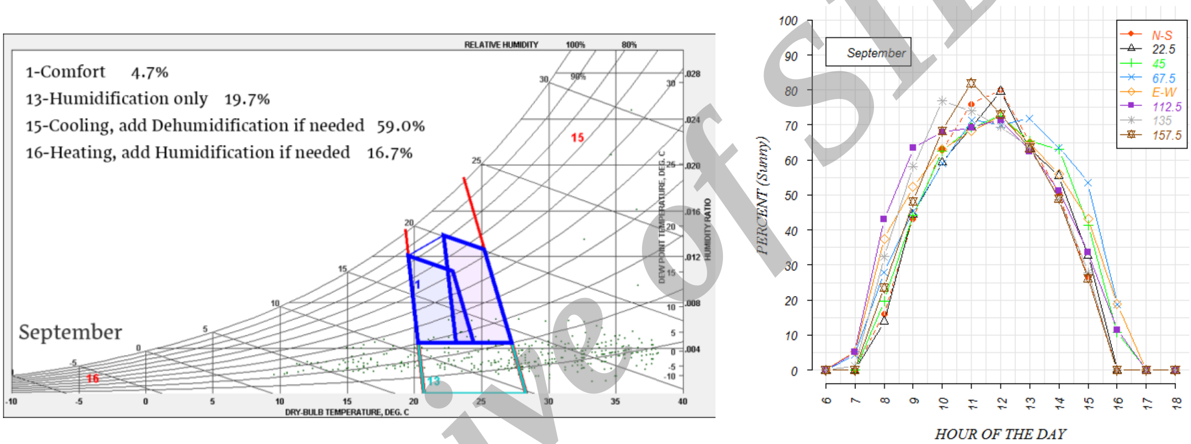

Figure 13. The figure of percentage of receiving sunshine radiation in different orientations in september (right) and Geun psychrometric charts of that month (left)

Table 9: Percentage of sunshine radiation of physical orientations in month by 10 days and ranking them based on the amount of sunshine radiation

	September (1-10)			September (10-20)			September (20-30)		
	Orientation	means	M	Orientation	means	M	Orientation	means	M
1	E-W	48.5	a	E-W	44.4	a	°112.5	42.2	a
2	°67.5	47.5	ab	°67.5	44.4	a	°67.5	42.2	a
3	°112.5	47.5	ab	°112.5	44.3	a	E-W	41.6	a
4	°45	44.3	bc	°45	41.8	ab	°45	40.4	a
5	°135	44.2	bc	°135	41.7	ab	°135	40.4	a
6	°22.5	41.6	cd	°22.5	39.3	bc	°22.5	38.2	a
7	°157.5	41.6	cd	°157.5	39.1	bc	°157.5	38.1	a
8	N-S	40.4	d	N-S	38.0	c	N-S	37.0	a

In the last quarter of the year, due to drop of temperature, climatic comfort of users in urban spaces is naturally very low during the day (Figs. 14, 15 and 16). To get closer to conditions of climatic comfort in these months, the presence of sunshine radiation is crucial. Thus the orientations which receive more sunshine radiation during the day are prior in these months.

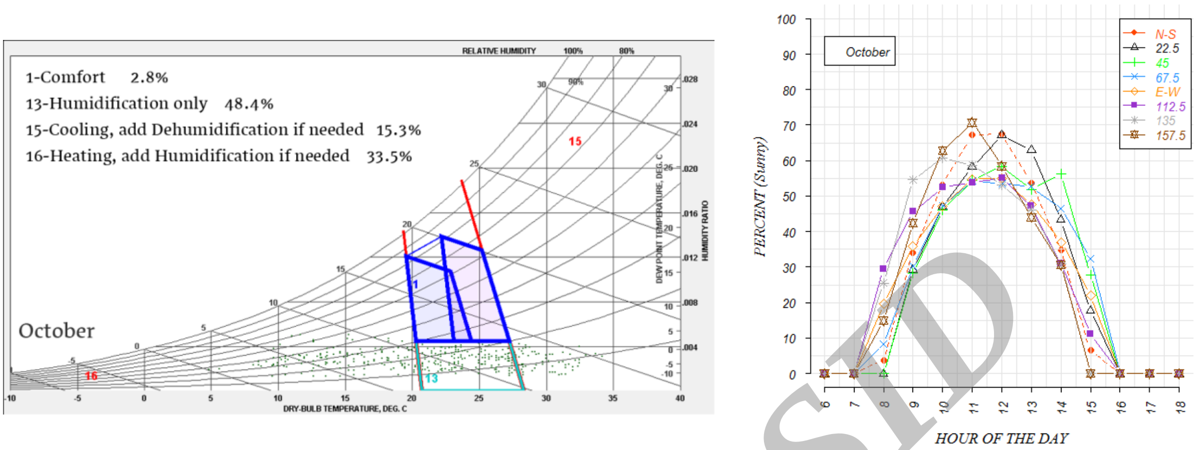

Figure 14. The figure of percentage of receiving sunshine radiation in different orientations in october (right) and Geun psychrometric charts of that month (left)

Table 10: Percentage of sunshine radiation of physical orientations per month in average

°135	°45	°112.5	°67.5	E-W	°22.5	°157.5	N-S
36.3	36.35	35.96	35.9	35.3	35.1	35.0	34.4

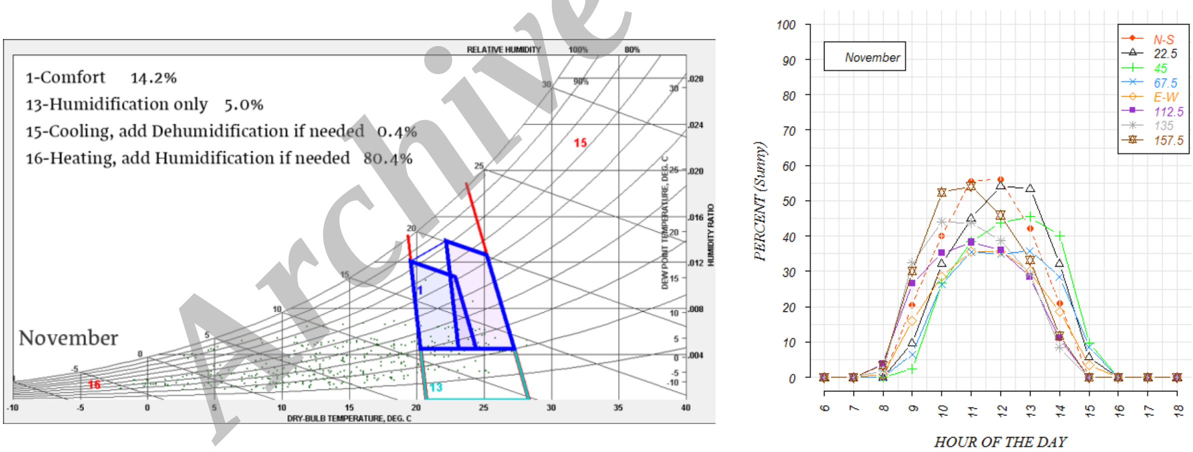

Figure 15. The figure of percentage of receiving sunshine radiation in different orientations in november (right) and Geun psychrometric charts of that month (left)

According to the results out of eight orientations in the tenth month of the year, the orientation 135° received 36% of sunshine radiation as the most and the north-south orientation with 34% as the least (Table 10), in the eleventh month the north-south orientation received 30% of sunshine radiation as the most and the east-west orientation with 23% as the least (Table 11) and also in the last month of the year the north-south orientation received 25% of sunshine radiation as the most and the east-west orientation with 14% as the least (Table 12).

The difference between the different orientations in the tenth month and the first 20 days of the eleventh month (November) was not significant ($P \geq 0.05$), but it was significant in the last 10 days of the eleventh month ($P \leq 0.01$) and in the twelfth month it is highly significant ($P \leq 0.001$).

Table 11: Percentage of sunshine radiation of physical orientations in month by 10 days and ranking them based on the amount of sunshine radiation

	November	(1-10)		November	(10-20)		November	(20-30)	
	Orientation	means	M	Orientation	means	M	Orientation	means	M
1	°157.5	31.3	a	N-S	27.1	a	N-S	27.6	a
2	N-S	31.2	a	°157.5	26.8	a	°22.5	26.9	a
3	°22.5	31.0	a	°22.5	26.7	a	°157.5	26.8	a
4	°135	30.2	a	°135	24.8	a	°45	23.8	ab
5	°45	30.1	a	°45	24.8	a	°135	23.7	ab
6	°67.5	27.6	a	°112.5	22.0	a	°67.5	20.3	b
7	°112.5	27.5	a	°67.5	21.9	a	112.5	20.2	b
8	E-W	27.0	a	E-W	21.4	a	E-W	19.2	b

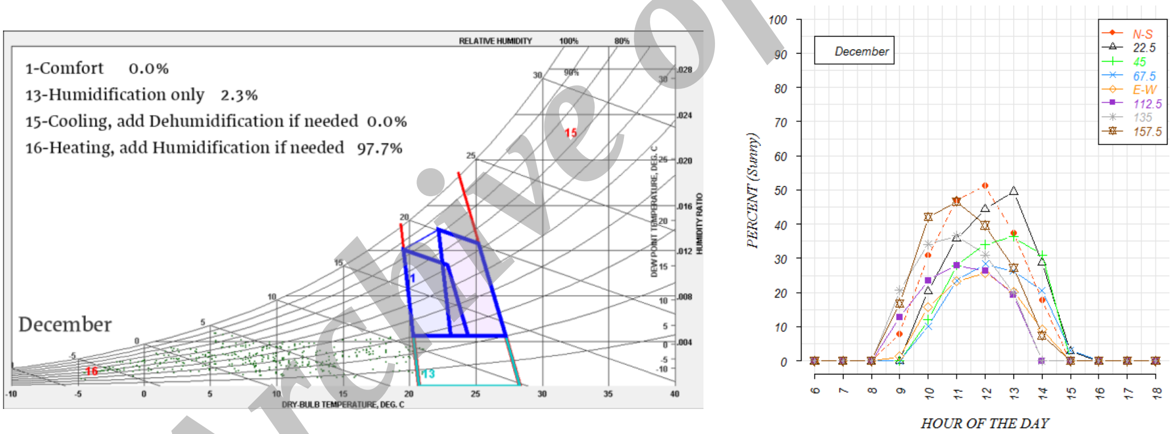

Figure 16. The figure of percentage of receiving sunshine radiation in different orientations in december (right) and Geun psychrometric charts of that month (left)

4.2 Analysis

Ranking of eight orientations is given in the tables below; the up section of table 13 includes warm months (months in which there is a need to shade to get closer to climatic comfort conditions of citizens in urban spaces), and the down section includes cold months (months in which there is a need to sunshine radiation to get closer to climatic comfort conditions of citizens in urban spaces). Only the months that different orientations had significant differences were mentioned in these tables. Accordingly ranking of warm months was based on the least amount of received sunshine radiation that provided the best conditions in terms of climatic comfort and the second table shows the rankings based on the most amount of received sunshine radiation.

Table 12: Percentage of sunshine radiation of physical orientations in month by 10 days and ranking them based on the amount of sunshine radiation

	December	(1-10)		December	(10-20)		December	(20-30)	
	Orientation	means	M	Orientation	means	M	Orientation	means	M
1	N-S	25.2	a	N-S	22.7	a	N-S	24.9	a
2	°157.5	24.2	a	°157.5	21.6	a	°22.5	23.5	ab
3	°22.5	24.2	a	°22.5	21.5	a	°157.5	23.5	ab
4	°45	20.5	ab	°135	17.6	ab	°45	19.0	bc
5	°135	20.5	ab	°45	17.6	ab	°135	18.8	bc
6	°112.5	16.8	b	°112.5	14.10	bc	°67.5	14.9	cd
7	°67.5	16.8	b	°67.5	14.0	bc	°112.5	14.8	cd
8	E-W	15.3	b	E-W	12.5	c	E-W	13.1	d

Table 13: Percentage of received sunshine radiation of different physical orientations and prioritizing them based on urban spaces need to sunshine radiation in warm months of the year

				Warm months				
Rankings	Orientation	Apr	May	Jun	Jul	Aug	Sep	Average
1	N-S	41.8	44.9	46.5	46.2	45.4	39.6	44.1
2	°157.5	43.0	45.5	46.68	46.3	46.28	40.8	44.7
3	°22.5	43.0	45.4	46.7	46.3	46.2	40.9	44.8
4	°135	45.7	48.4	49.47	49.0	49.1	43.4	47.5
5	°45	45.8	48.4	49.4	49.0	49.1	43.5	47.5
6	°112.5	49.0	52.6	53.9	53.4	53.4	46.1	51.4
7	°67.5	49.0	52.7	54.0	53.4	53.4	46.1	51.4
8	E-W	49.9	56.0	57.8	57.3	56.5	46.2	53.9
	P (>F)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
				Cold months				
Rankings	Orientation	Jan	Nov	Dec				Average
1	N-S	26.9	30.3	25.7	-	-	-	27.6
2	°157.5	25.7	30.0	24.5	-	-	-	26.7
3	°22.5	25.7	29.9	24.5	-	-	-	26.7
4	°45	21.7	27.8	20.2	-	-	-	23.2
5	°135	21.6	27.8	20.1	-	-	-	23.2
6	°67.5	17.7	24.7	16.2	-	-	-	19.5
7	°112.5	17.6	24.7	16.2	-	-	-	19.5
8	E-W	16.3	23.9	14.5	-	-	-	18.2
	P(>F)	0.0000	0.0014	0.0000	-	-	-	

Given that the city of Yazd is in the hot and dry climate [10] the results show a highly significant difference between the eight orientations in terms of received sunshine radiation in six warm months of the year (Table 13). Thus the importance of the difference between physical orientations for urban spaces, particularly urban squares is implied. This means that using the proper orientation for the physic of urban squares in this climate could do much to reduce the climatic risks which are more available in warm months and it provides the possibility of more use of the urban spaces for citizens.

Change in the angle of sunshine radiation and the height of the sun in different months causes change in the need for sunshine radiation and shade to achieve climatic comfort in urban spaces. This means that in cold seasons that the distance of sun from the earth gets more and the sun shines with a more oblique angle, urban spaces need sunshine radiation in the space to get close to climatic comfort while the reverse is true for warm seasons. As a result of the above analysis, the physic with the biggest obstacle to the sunshine from the East and the West (prevalent orientations of the sun in warm months) and the least obstacle to the south (prevalent orientation of sunshine in the cold months) has the most favorable conditions for all seasons in the city of Yazd. The orientations that are contrary to this have the most undesirable conditions, and the rest of the orientations lay in a range between the best and worst orientation.

The difference in the angle of sunshine radiation between warm and cold months, has caused the orientations that receive most sunshine radiation in the cold months, also have the biggest shade in warm months when there is an inevitable need to shade in urban spaces. In addition the orientations that make shade in cold months, and are inappropriate, are very sunny and inappropriate in warm months too (Fig. 17). So to choose the best orientation out of eight orientations, based on a significant amount of the difference between the different orientations in Yazd, we can prioritize as follows. The priority is according to meet the climatic conditions of both warm and cold seasons (Table 14).

Table 14: Ranking of eight main physic orientations of squares in Yazd based on the desirability of receiving sunshine radiation and making shades during the year

Rank	1	2	3	4	5	6	7	8
Direction	N-S	°157.5	°22.5	°135	°45	°112.5	°67.5	E-W

Charts of receiving sunshine radiation of the best orientation (north-south) and the worst orientation (east-west) for Yazd clearly shows how the difference between warm and cold seasons happen. In warm months that sunshine radiation reduces climatic comfort, north-south orientation with 2.5 hours of +80% sunshine radiation and 4 hours of +70% sunshine radiation has better climatic comfort conditions for citizens rather than the east-west orientation with 3.5 hours of +80% sunshine radiation and 6 hours of +70% sunshine radiation. In cold months that sunshine radiation increases climatic comfort, north-south orientation with 4.5 hours of +30% sunshine radiation is better in terms of climatic comfort conditions and increasing the sunny area of space rather than east-west orientation that doesn’t receive +30% sunshine radiation in any hour during the day (Fig. 17).

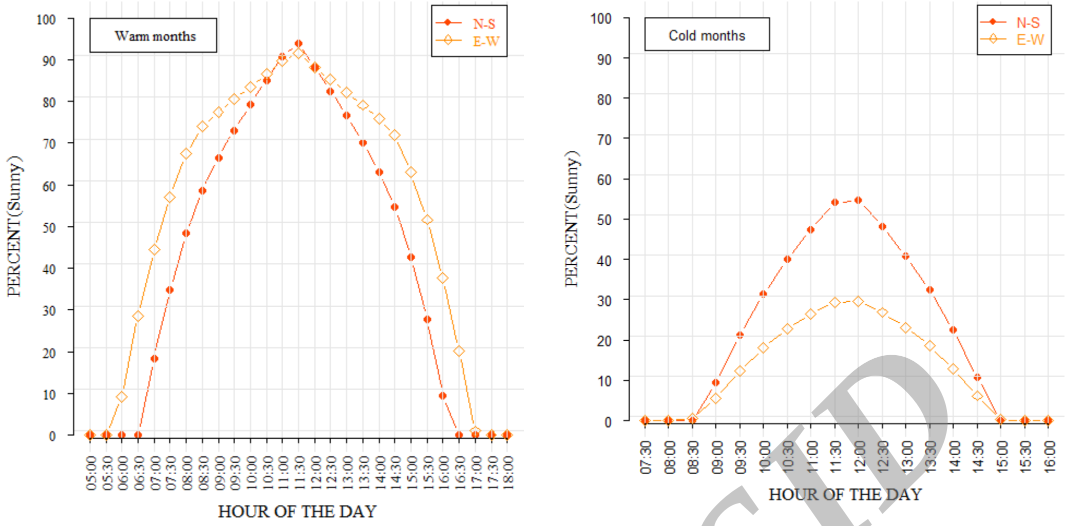

Figure 17. Chart of receiving sunshine radiation of the best (NS) and the worst (EW) and the orientations in the warm and cold months of the year

5. CONCLUSION

Monthly psychrometric chart of the hot and dry city of Yazd clearly indicates the theory of increasing the climatic comfort of citizens of this climate with making shade in space. Due to the high temperature as a result of sunshine radiation, the there is no climatic comfort for citizens during most of the year. So a decrease of sunshine radiation in space climatic comfort of citizens will increase. The results confirmed the significant difference between receiving sunshine radiation and shading in different orientations of physics of squares in Yazd ($P \leq 0.001$). The difference between different physical orientations and the effect of the presence or absence of sunshine radiation on the climatic comfort of the citizens, shows that the proper orientations of squares physic relative to The North can increase climatic comfort of citizens in the urban spaces significantly.

The most important factor that determines the climatic comfort of citizens in Yazd, a city in the hot and dry climate, is the presence or absence of sunshine radiation. It is the most effective and cost saving controlling factor of sunshine radiation in squares space is the proper orientation of the squares physic. In the past, proper orientations of buildings in this city was prior than its urban spaces and open spaces such as squares were less important. So the orientations of the city squares is determined by the orientations of the buildings enclosing it which were in line with climatic comfort of residents and users of buildings. This way of orientation of squares physic urban spaces of Yazd is a reason for the citizens of this city to take refuge in buildings and the least use of squares by citizens. It is clear that in emergency situations the squares were used forcibly and currently such situation is still continuing.

Out of eight studied orientations, the range of 45° NS (i.e., NS to 22.5° and NS to 157.5°), in Fig. 18, is the most favorable range for orientations of the physic of squares in

Yazd in terms of the importance of sunshine radiation to increase climatic comfort. The most unfavorable range is the range of 45° EW (i.e., EW to 112.5° and EW to 67.5°). As a consequence, NS and EW are the most favorable and unfavorable orientations, respectively. The orientations in the range of 22.5° to 67.5° and 112.5° to 157.5° are the moderate range (see Fig. 18). Of these two orientations 45° and 135° are the most moderate orientations; a range between favorable and unfavorable ranges. Among the squares examined in this study none of them have been in favorable or unfavorable range but all are in the moderate range. In the following table the deviation of orientation of the physic of each one of them, obtained relative to the most favorable orientation i.e. the NS orientation, is shown and ranked. Therefore, the less the physic orientations deviation is, the more favorable it is and with increasing distance from it the favorability of orientations of the squares physic is reduced (Table 15).

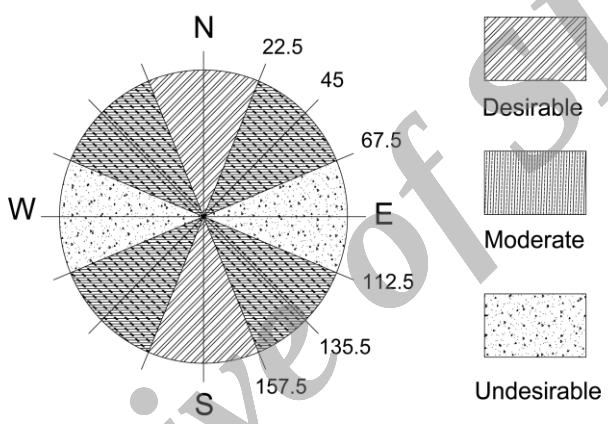

Figure 18. Status of favorable, moderate and unfavorable ranges of physical orientations of squares in Yazd

Table 15: Ranking the studied squares based on the favorability of orientations of squares physic relative to the most favorable orientation (NS)

Squares	Deviation from NS To the west	Deviation from NS To the east	rankings
Vaghto-saat	---------	32°	1
Grand Mosque yard	---------	41°	2
Shah Tahmaseb	46°	---------	3
Amir Chakhmaq	47°	---------	4
Khan	---------	48°	5
Shah Abolghasem	52°	---------	6

The difference between the amount of received sunshine radiation and shading in different orientations of the squares physic is such that the orientations which have the least sunshine radiation in their spaces in the warm months of the year are and the most favorable, have the most sunshine radiation in the cold months and are the most favorable orientations. This is also true in the case of unfavorable orientations and they are unfavorable in both warm and cold seasons. This is due to the change in the angle of sunshine radiation and height of sun relative to Yazd during the year.

The results mean that just paying attention to orientations of buildings and urban masses didn't cause proper orientation of the open spaces physic such as squares, but caused orientations close to unfavorable orientations. To create squares with higher climatic comfort, it is better to think of favorable physical orientations regarding this city. It should be noted that in this study, sunshine radiation is used as the main factor affecting physical orientations of urban squares in order to increase climatic comfort of citizens. So other climatic factors, including wind and so on have been neglected in this study. Other factors and variables must be considered in future researchs to study the climatic comfort of citizens comprehensively with the intervention of all variables.

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