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Climatic and thermal comfort research orientations in outdoor spaces: From 1999 to 2017 in Iran

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ABSTRACT: The satisfaction level with an environment differs among individuals caused by social, psychological and physical factors. One of the environmental factors affecting physical and mental satisfaction is the space thermal condition. In recent years, the importance of thermal comfort has been accentuated due to the climate change and global warming. The objective of the present study is to identify the main concepts raised in Iran outdoor thermal comfort by studying and classifying the studies in this field to identify the characteristics of each category. Thus, this study reviews 142 papers written in Iran published in the period between 1999 and 2017. The papers are first classified into two main categories (including fundamental studies on thermal comfort and practical studies) and three secondary categories that are subsets of the second main category (macroscale, mesoscale, and microscale studies). Each category is then studied and analyzed in more details according to the regions and climates considered, methodology and research means, effective factors and thermal indices used for evaluation. Accordingly, strengths and weaknesses of previous studies are identified and suggestions for future studies on the microclimate scale have been made. Eventually, the conceptual model of thermal comfort studies is presented in different climatic scales.

Keywords: Climate, Macroscale, Mesoscale, Microscale, Outdoor thermal comfort.

INTRODUCTION

Research approaches in the studies of urban open spaces can be discussed from different points of view. In one classification, climatic-environmental approach, sanitary-health approach, protective-ecological approach and managerial-planning approach are recognizable in contemporary studies (Mozzaffar et al., 2013). The present study considers evaluation of thermal comfort in different environmental scales with a focus on the climatic-environmental approach. The state of thermal comfort is the condition in which a person feels thermally neutral and perceives satisfaction. It is a mental state that is affected by air temperature, humidity, air velocity, and the amount of solar radiation (Givoni et al., 2003; Nikolopoulou & Lykoudis, 2006). It is obvious that this type of satisfaction or dissatisfaction is different among people. However, since thermal comfort is considered a subjective issue, it can change under the influence of mental conditions, expectations and experiences, which mean that different individuals may have different preferences under the same thermal conditions. According to Shooshtarian & Rajagopalan (2017), personal, social, physical and environmental, psychological and economic factors along with standards and criteria can affect the perception of thermal comfort. The importance of open spaces with acceptable thermal conditions leads to the enhancement of comfort in indoor spaces and reduction of energy use in buildings. It also prevents the formation of heat islands in a larger scale (Li et al., 2014). There are two main points to be considered when comparing thermal comfort in indoor and outdoor spaces. Firstly, outdoor spaces are subject to changing conditions but people do not have the ability to control environmental

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conditions in such spaces. This forces individuals to tolerate a wider range of thermal conditions. Secondly, people often spend most of their time indoors (Salata et al., 2016). However, in recent years, there has been an increase in using open spaces in cities, which make thermal comfort a determining factor in people's choice of urban spaces (Toner, 2015).

The main questions of the present study are: What approaches have been used in previous researches to study thermal comfort in Iran? If previous studies are presented in a conceptual model, to what extent is it possible to generalize their results? What directions should the future fundamental and practical studies adapt?

Accordingly, 142 papers from the period 1999 to 2017 were considered after searching domestic and foreign databases. For papers in Persian, the data bases used include the Scientific Information Database (SID), Noor specialized magazines (noormags), Islamic world science citation center (ISC), the University of Tehran's scientific journals database, Civilica science reference and comprehensive portal of humanities can be mentioned. For the papers in English, search was performed in Google Scholar, ScienceDirect, and Springer databases. The keywords used in the search include: thermal comfort, climate, different thermal comfort indices such as PMV, PET, ET, UTCI that were used with professional techniques of Mixed-method research. As can be seen from Table 1, 67.60 percent of the papers in the field, were published in the past five years. Classification of the papers will be discussed in the following sections.

MATERIALS AND METHODS

A large number of review papers have been published internationally both on indoor and outdoor thermal comfort. The works on outdoor thermal comfort can be classified into two main categories; first, some studies focus on the research processes including research methods, measurement tools and indices for calculation of thermal comfort (Johansson et al., 2014; Coccolo et al., 2016). These have the objective to calibrate the research process and demonstrate the functions and generalizability of thermal comfort indices and results of previous studies, enabling the comparison of results in similar or differing climatic contexts. Second, some other studies work on the factors that influence thermal comfort. These studies have a one-dimensional look, focusing on the effect of urban geometry (Jamei et al., 2016), vegetations (Nikolopoulou & Lykoudis, 2006), behavioral factors (Chen & Ng, 2012), and age groups (Vanos, 2015). Also, some have also focused on a specific type of outdoor space, such as central courtyards in traditional buildings (Taleghani et al., 2012), which investigates the effect of different factors on thermal comfort of occupants.

In the present study, however, reviewing 142 papers in Persian revealed that they can be classified into two main categories; first, fundamental studies in the field of thermal comfort (FSoTC) and second, Practical Studies on the application of thermal comfort in different climate scales (PSoTC)s, and another three secondary classes that are subsets of the second main category including macroscale, mesoscale and microscale studies. The method used for classifying the papers is in accordance with the climate scales, which include global macroclimate, regional macroclimate, mesoclimate and microclimate (Pourdehimi, 2011). Although according to Oke, there is a local climate in-between the mesoclimate and microclimate, we have presented both the local scale studies and microscale studies in one category (Pourdehimi, 2011).

1st category- FSoTC

One example of FSoTC studies is presented by (majidi & Peeravi, 2015) which focuses on the terminology of the field of thermal comfort. It seeks the historic origins of the application of the words energy and comfort in mechanics, physics, philosophy and architecture using semantic analysis. Thus, by identifying conceptual and content-related definitions of these two words, it expresses the semantic relation between these two from heat and warmth points of view and provides the basis for connecting these two fields. Some review studies can also be found that work exclusively on introducing thermal comfort indices and parameters and describe fundamental concepts, terms, classification of factors and thermal comfort models including thermal equilibrium and thermal adaptation models (Moalemi Khiavi & Maarefat, 2014). Ghiabaklou (2001) studied the methods of estimating and specifying the thermal comfort range by expressing the most important factors affecting thermal comfort. Heat exchange mechanism

Table 1: Article reviewed

Type	Classification of articles based on language		Classification of articles based on articles credit score			
	Persian	English	ISI	ISC	Conference proceeding	Journal articles
Number	102	40	32	75	26	9
Years	1999-2017	2005-2017	2005-2017	1999-2017	2007-2017	1999-2015
Frequency in last 5 years	Years		2012-2017			
	Number		23	48	19	6

and some thermal comfort indices are introduced in this paper. Tahbaz & Beheshti (2010) try to introduce an index that can be used in outdoor spaces by considering the existing set of factors and indices. In their opinion, for interior spaces, thermal comfort index has to describe the ideal thermal conditions but for exterior spaces, the tolerable conditions define the comfort range. Thus, they study the commonly used indices and apply them on the psychometric chart to provide the basis for introducing a new comfort range for outdoor spaces. Thus, the similarities and differences of the majority of indices are mentioned in the study.

Correction of thermal comfort ranges in accordance with the native conditions of each country especially Iran is accentuated in the study by Omidvar et al. (2007). Two related studies conducted by (Heidari, 2009) in Tehran and Tabriz (Heidari & Ghafari jabari, 2010) also suggest that the comfort range can be wider in Iran compared to the comfort range suggested by the ASHRAE.

In the majority of fundamental thermal comfort studies, the emphasis is on the factors that affect thermal comfort and its quantitative calculation. Some papers that aim to identify and prioritize these factors were found; a macroscale study tried to identify the factors that affect thermal comfort to choose a suitable index based on the consensus of professionals and by means of Delphi analysis methods (Asghari et al., 2017). Among different criteria that were considered, simplicity was found to be the most important and received the most points in Delphi method followed by credibility and reliability, cheapness, comprehensiveness and precision of the index, non-interference with the ongoing activity, handiness, being unaffected by other factors and being standard. In a smaller scale, reviewing different studies reveals a focus on personal factors such as the effect of gender. From this point of view, men have a slightly different perception of thermal comfort compared to women due to their higher metabolism rate (Mokhtari & Kordjamshidi, 2015). Regarding personal factors, weight, height, gender and the effect of body mass index were considered in a study (Davoodi et al., 2016). In this study, it is tried to use the temperature of the covered and uncovered parts of the body in calculation formulas, to estimate the thermal sensation of individuals with a higher precision. The importance of cloth is discussed in the study by (Omidvar & Afra, 2014), which tries to improve the Gagge model. This study calculates the effect of humidity and heat on the cloth value with higher accuracy. Such studies have considered the subject of thermal comfort in general, and the researchers did not mean the practical separation of subjects or local situations. In some cases, however, climatic thermal comfort models and indices in a certain scope such as tourism have been the subject of study. For instance, Zolfaghari (2002) has provided the time-based classification of the types of climatic studies and classified both the generally used thermal comfort indices and the comfort indices used specifically for tourism. Such indices, which aim to determine the tourism climate comfort, will be discussed in the next sections.

2nd category- PSoTC- macroscale

The papers in the second category are practical studies on the application of climatic factors and thermal comfort indices, which itself includes several different fields of study, such as the studies on climatic zoning, adjusting temperature map patterns and heat island in the macroscale.

The climatic zoning in the country has been conducted with varied number of weather stations in different studies. heidari & Alijani (1999) divided Iran into 6 climates and 12 sub-climates based on the data from 43 weather stations and statistical analyses. In this study, the fundamental factors affecting the climate were first identified by means of factor analysis and cluster analysis methods to present the climatic classification. Kaviani et al. (2006) worked on determining the thermal comfort conditions based on the effective temperature index by using data from 130 weather stations in the country. The analysis and calculations are performed for a period of 5 years by designing a software named Salaamat (Payandeh & Zaki, 2006). In another study (Hajarizadeh & Karbalaie, 2015), the data from 139 weather stations were considered to calculate thermal comfort temperature based on the effective temperature index and the percentage of time in each season that thermal comfort conditions were met. Daneshvar et al. (2013) identified 48 synoptic stations around the country and performed a thermal comfort classification based on Physiological Equivalent Temperature (PET) index. According to their study, in the altitude range between 1000m and 2000m, the highest changes in PET are witnessed in the temperature range between 12˚ and 20˚. In this context, the coldest value of PET belongs to Khorasan-e-razavi and Azerbayjan-e-gharbi and its warmest value is seen in Sistan-va-baluchestan. Such studies that consider zoning have been conducted in different climates with different objectives; in Tehran, by assuming a relation between the comfort temperature and the mean monthly temperature (heidari, 2009), climate data was recorded using the experimental method. The regression analysis of the neutral temperature and the mean monthly temperature shows a direct relation between the two. On the other hand, a significant difference from the anticipation made by the ASHRAE standard can be seen in this regard, because comparing the results of the PMV and AMV comfort indices for Tehran, shows a wider comfort range than predicted by ASHRAE standard. This wider range would lead to 40 percent saving in energy consumption if used in the environment design calculations. The approach in studies that tries to present a climatic classification has been seen on the province scale as well (khoshhal et al., 2006). Other cases can be seen in Table 2. In this regard, using effective Temperature index (ET) (Hajarizadeh & Karbalaie, 2015; Kaviani et al., 2006; Payandeh & Zaki, 2006) Physiological Equivalent Temperature index (PET) (Daneshvar et al., 2013; Farajzadeh & Ahmadabadi, 2010; Roshan et al., 2016) and Tourism Climate Index (TCI) (Esmaili & Fallah Ghalhari, 2014b; Roshan et al., 2016) have been the basis for calculations. The outputs of such studies are

Table 2: Classification of macroscale studies in Iran

Ref.	Type/Number Of Station		Research Period	Index	Data Collection Scale	Result
	Synoptic	climatology				
(payandeh & Zaki, 2006)	130	-	1997-2000	ET	Monthly	5 Climate Zone Classification in Iran
(Kaviani et al., 2006)	130	-	1996-2000		Hourly/Daily	-
(Hajarizadeh & Karb-alaie, 2015)	139		2005		Monthly	Thermal comfort period in June & October
(Daneshvar et al., 2013)	48	-	1990-2003	PET	Monthly	Temperature in different altitude
(Farajzadeh & Ahmad-abadi, 2010)	144	-	1960-2009	TCI	Monthly	6 Climate Zone Classification in Iran Thermal comfort period & Location: Spring- North. Summer: south & west- north. Autumn & Winter- South
(Roshan et al., 2016)	40	-	1975-2005	PET	Monthly	PET Changes in last 49 years
(Esmaili & Fallah Ghalhari, 2014a)	101	-	1961-2010		Monthly	Climate classification map Best thermal comfort period: Spring
(Roshan et al., 2016)	40	-	1988-2007	TCI	Monthly	TCI Changes in last 50 years

presented as zoning maps or location-time tables of the comfort condition. Thus, Iran is divided into five and six climate parts based on the ET (Kaviani et al., 2006) and TCI (Roshan et al., 2018), respectively. A degradation in the thermal comfort conditions and a change in the thermal comfort period into early spring and late autumn was reported to have occurred in the macroscale of the country in the period between 1961 and 2010 based on the PET index (Roshan et al., 2018). In this period, the most changes in the comfort conditions based on TCI are seen in June (Roshan et al., 2016).

It is notable that among the studies in this category, no example was found to directly work on thermal comfort or the application of its indices. However, such studies consider related issues such as thermal patterns and temperature changes in cities (Ahmadi et al., 2012, 2015; Ahmadi & Narangifard, 2015) in the macroscale or under the effect of reduced vegetation area (Amiri et al., 2015; Mazidi & Narangi Fard, 2016) and assessment of the heat island effect (Alavaipanah et al., 2015; Ranjbar Saadatabadi et al., 2005; Shahmohamadi et al., 2009), which provide the fundamental information required to make decisions in the microclimate studies and evaluating thermal comfort conditions

2nd category- PSoTC- mesoscale

In the mesoscale, the objectives of the assessed studies were set for tourism capabilities and the period of thermal comfort for different cities of the country was examined using different indices (mostly TCI). In this regard, 25 provinces of the country have been assessed on the province or city scale by different methods in the studies (see Table 3). These studies were performed with their focus on a city or a province but in some cases, the objective was to compare different cities in different climates (Akbarian Ronizi et al., 2016; Barimani & Esmaeelnezhad, 2001; Esmaeili et al., 2001; Farajzadeh & Matzarakis, 2009; Farajzadeh et al., 2015; khademolhoseini et al., 2010; Mokhtari & Anvari, 2015; Nazomolsadat & Majnoni, 2008). As seen in Table 3, there have been studies for determining the tourism thermal comfort range in about 75 percent of the provinces. However, comparing table 3 with the tourism map of Iran reveals that many parts of the country have not been studied thoroughly yet and that in different studies, the general data from one weather station has been generalized to the entire province. In table 3, the studies are listed according to the index used and the climate of study. In addition to the indices present in table 3, some other indices such as Terjung, Beaker, Neurotic Pressure, Chell wind and Mahoney and CTIS and UTCI have also been considered in some studies for determining the comfort range. Due to the fact that studies in the mesoscale focus on the tourism climate, the TCI has been the most used index. Here the point is to realize which index describes the climatic conditions of a region more accurately. Besides, comparing and presenting a seamless time-chart at the country level requires one of the indices to become the

Table 3: Classification of mesoscale studies based on climate group & indices

Köppen-Geiger climate group		Thermal Comfort Index			
		TCI	PET	ET	PMV
Group B: Dry (arid and semiarid) climates	BSK (Cold semi-arid climate)	East Azerbaijan, Tabriz (Hoseni, et.al, 2017; Yazanpanah, et.al, 2013) Maragheh (SariSaraf et.al, 2011) Fars (Babzadeh & Nargeszar, 2011; Safeepoor et al., 2013); Hamedan, Nahavand (Jaafari et al., 2014) Hormozgan (Rezazadeh et al., 2014); Kohgiluyeh and Boyer-Ahmad, Yasuj (Mohammadi et.al, 2010	East Azerbaijan, Tabriz (Zolfaghari, 2006, 2007); Khorasan-e-Razavi, Mashhad (Esmaili & Fallah Ghalhari, 2014a; Arvin & Shojaeezadeh, 2014) Golestan(Nadim et al., 2016) Tehran (Abbasnia et al., 2014)	Kohgiluyeh and Boyer-Ahmad (Lashkari et al., 2014); Khorasan-e-Razavi, Mashhad(Shams et al., 2012);	East Azarbaijan, Tabriz (Heidar & Ghafari jabari, 2010; Qvidel Rahimi & Ahmadi, 2013; Zolfaghari, 2006, 2007) Tehran(s. heidari, 2009); Golestan(Nadim et al., 2016)
	BWH (Hot desert climate)	Hormozgan, Qeshm (Enayati, 2011;)	Khuzestan, Ahvaz (Ataei & Hasheminasab, 2013);	Khuzestan,Ahvaz (Hoveizavi & Morshedi, 2016); Sistan & Baluchestan(K. Omidvar et al., 2013);	-
	BWK (Cold desert climate)	Isfahan(Ataee & Hasheminasab, 2012; Gandomkar, 2012, 2014; Halabian & Pooreedivand, 2014; Khorasanizadeh et al., 2011) Isfahan, Na ‘ in (Gandomkar, 2011) Kerman(Abdollahi, 2015; Hanafi et al., 2015)	Isfahan(Yazdanpanah et al., 2016); Semnan(Ataee & Hasheminasab, 2010);	-	Khorasan-e-Razavi, Sabzevar(Ahmadi, Asadi, & Dadashi Roodbari, 2016);
	BSH (Hot semi-arid climate)	Kohgiluyeh and Boyer-Ahmad, Gachsaran (Mohammadi et.al, 2010)	-	-	-
Group C: Temperate (mesothermal) climates	CSA (Mediterranean hot summer climates)	Ilam(Baratian & Rezaee, 2012; Jaafari & Jaafari, 2016); Golestan, Gorgan (Nadim et al., 2016); Lorestan (Hasanvand et al., 2011); Mazandaran (Ezatian & Momenzadeh, 2011; Ramazanipour & Ramazanipour, 2013) Isfahan, semirom(Gandomkar, 2010)		Qazvin(Inanloo & Mohammadi, 2014)	
	CFA (Humid subtropical climates)	-	-	Gilan, Bandar-e Anzali (Ramezani et al., 2013)	-
Group D: Continental (microthermal) climates	DSA (Mediterranean-influenced hot-summer humid)	Kurdistan (Javan et al., 2014)	West Azerbaijan, Urmia (Farajzadeh & Matzarakis, 2009) Kurdistan (Ataee et al., 2014)	Kurdistan(Javan et al., 2014; P. Mahmoodi, 2007)	Kurdistan (Saeedi & Toolabinezhad, 2014)
	DSB (Mediterranean-influenced warm-summer humid)	East Azerbaijan, Sarab (Saligheh et al., 2013)	-	-	-

Table 4: A suitable travel calendar for 21 provinces in Iran based on thermal comfort index

Location/ Time		Bushehr	Chaharmah & bakhtiari	Esfahan	East Azarbaijan	Fars	Gilan	Golestan	Hamedan	Hormozgan	Ilam	Kerman	Kordestan	Khorasan-e-eRazavi	Khozestan	Lorestan	Markazi	Mazandaran	Semnan	Sistan & Baluchestan	West Azarbaijan
Spring	April		■								■	■		■						■	
	May		■	■		■		■			■	■		■		■		■	■	■	
	June		■		■	■	■	■	■		■	■	■	■		■	■	■			
Summer	July		■		■		■	■					■	■			■	■			■
	August				■		■						■	■			■	■			■
	September				■		■		■					■			■	■		■	■
Autumn	October			■		■	■	■			■							■	■	■	
	November		■					■			■	■				■		■	■	■	
	December		■									■				■		■			
Winter	January									■					■						

reference. Investigating studies from worldwide to evaluate the credibility of the indices showed that in the majority of studies on determining the tourism climate potential, the TCI has been used for decision-making, because this index evaluates a wider range of factors as a hybrid index and determines the best time for travel for domestic and foreign tourists. In a general approach, by considering the provinces that the comfort period is determined for them using at least one index, the time-chart of traveling to 20 provinces of the country can be presented as Table 4. This time-graph is drawn according to the average comfort condition reported by studies that are listed in Table 3. Some points can be made about this graph: firstly, it provides a general idea about the climatic conditions of some parts of the country and the possibility for planning in different areas of economy, transportation, traffic, and for determining the type of tourism and related facilities. Besides, travel agencies and domestic and foreign tourists will have the decision basis for planning travel tours. This time-graph also has some weaknesses along with its primitive advantages that necessitate more profound studies. Firstly, several thermal comfort indices were involved in preparing this graph, which may lead to time errors. In addition, a large portion of the country including some provinces, cities, counties etc. have not been studied. Since in different parts of Iran, there is a diversity in climate even in small localities or time ranges, the studies that were performed in the province-scale cannot be easily generalized to all the cities and villages of that province. It should be noted that comparing the basic zones of the Köppen-Geiger classification with Table 3 shows that the provinces that are in the same climate zone (for instance Azarbayjan-e-sharghi and Isfahan are both in the B climate zone) do not have the same comfort periods as seen from Table 4. Thus, paying attention to the regional and local scales is important.

2 nd category- PSoTC- microscale

The studies in the microscale work on microclimates, investigating and evaluating thermal comfort conditions in urban open spaces (private and public). These studies make up 25.5 percent of all the studies that were considered in our study. These studies were all performed in areas that belong to the B climate zone of the Köppen-Geiger classification, which is the hot and dry climate, including the cities of Tehran, Shiraz, Yazd, Isfahan, Ahvaz, Bandar-Abbas, Arak, Torbat-e-Heydarie and Bandar-e-Imam-Khomeini. In the following, 36 articles focusing on the microclimate scale will be discussed based on their field of subject, research method, studied indices and method of analysis.

Thematic classification of microscale studies

Beside the role of the macroclimate of a region, microclimate and its specific physical characteristics are also important for assessing thermal comfort in outdoor spaces, because there is a diverse range of urban spaces that can be studied. In order to classify the studies, the present study has found

three approaches towards this topic: first, in some studies, a wide outlook towards the city was considered aiming to improve the design characteristics of the city or the impacts of urban development or to compare different urban fabrics (from the viewpoint of density or the separation of modern and traditional). Secondly, there are more detailed studies that focus on a certain type of open spaces such as streets, squares, parks and the spaces between the buildings where they are studied alone or in comparison with other studies. In such cases, we often face studies of real cases. Thirdly, there are some studies in which parametric simulation is used as the basis. Thus, previous studies that were performed in a wide variety of spaces can be classified into three categories:

1) Studies performed in public open spaces including streets, parks, bazaars, squares and urban fabrics.

2) Studies performed in semi-private-semi-public spaces that include the spaces between buildings of different functions (most studies in this category are field studies based on questionnaires and interviews).

3) Studies performed in private open spaces including central courtyards in traditional houses.

Studies performed in public open spaces

Examples of two different research methods were found for studies performed in the street level. In a field study in Valiasr Street of Tehran (Amindeldar et al., 2017) thermal sensation of people and climatic data were recorded using questionnaires and measurement appliances. The neutral temperature and the acceptable thermal comfort range were determined. It was also found that in achieving thermal adaptation, climatic parameters and expectations of individuals are quite determinative.

By choosing Ecotect for simulating the condition of pathways, Hoseni et al. (2014) and Monshizadeh et al. (2012) studied the effect of humidity, wind and solar radiation in a one-month period with the objective to determine critical areas and present solutions. In this process, in addition to identifying the critical areas in summer and winter, some requirements were reported to be effective for enhancing the thermal condition including the use of shading, fountain, vegetation, type and color of the materials and the ratio of the buildings height to the street's width (aspect ratio). Mazloomi et al. (2010) studied the solar radiation intensity under the effect of geometry (depth) and street orientation in two critical days of the year using the Ecotect software. In this study, simulations were two-dimensional. It was observed that shading is inversely related to the street geometry (depth), and for orientation, increasing the deviation of the street from the east-west direction towards the north-south direction leads to increases in the shadow intensity in summer and its decreases in winter in the warm and arid climate of Yazd.

Different scenarios resulting from altering vegetation's altitude and density and their effect on thermal comfort were considered for the city of Isfahan using the PMV index and simulations in the Envi-met software (Naslollahi & Kolivand, 2016). In this study, the effect of vegetation was described as very high because the study was performed in a hot summer day. It was also reported that higher areas and densities of vegetation lead to better thermal conditions, but the effect of lawn and trees were found to be different from each other.

About the studies in parks, the study by Heidar & Monam (2013) can be mentioned which assesses five different parks in Tehran using the field study method and specifies and compares the thermal comfort range based on PMV, SET, and PET indices. In their study, the PET index described a better climatic condition for Tehran compared to the other indices and showed a wider range of thermal comfort. The set of studies by Kariminia et al. (2016b) about the Imam Square and the Jolfa Square in Isfahan had various objectives. In their studies, determining the thermal sensation of people using the ASHRAE standard questionnaire and recording the climatic data of the microclimate using measurement appliances were considered. It was reported that individuals felt comfortable in the Imam Square in winter despite the diversity in their behavior and that only a few cases preferred increases in the level of humidity and decreases in the wind flow (Kariminia et al., 2010). In addition, it was demonstrated that people felt more comfortable in winter than in summer and experienced thermal comfort in the range between 12.3˚ and 30.9˚ in these two squares based on the PET index (Kariminia et al., 2011). The Imam Square has been studied based on some other criteria as well, such as the impact of environmental factors including vegetation and fountain (Kariminia & Ahmad, 2013; Kariminia et al., 2013) which showed the significant role of air flow and evaporative cooling from water surfaces in thermal comfort in summer. In addition to data extraction in field, software simulation has also been used to assess different scenarios of orientation and aspect ratio in this square (Kariminia et al., 2015). This study describes the effect of increasing the aspect ratio as positive in summer. Next, Kariminia et al. (2016a) used predicting models such as NN-ARX and ARXa, which use personal and climatic information as inputs to calculate outputs as PMV, TSV, SET and PET indices. The factors with the highest influence on thermal comfort were identified and used as inputs in the software to have outputs that are more accurate. According to this study, air temperature and relative humidity are the factors with the greatest influence on determining thermal comfort. These results have been evaluated and compared using some other algorithms such as ABC in different studies (Kariminia et al., 2015; Kariminia et al., 2016a; Kariminia et al., 2016b; Kariminia et al., 2016c). Penwarden, Boufort and Wind Chill indices were used in the urban fabrics of Isfahan to investigate positive and negative effects of the wind velocity on thermal comfort. This has shown that only in month December, the wind flow disturbs the comfort of individuals (Rozati & Qanbaean, 2014). In addition, the aspect ratio of different urban canyons in Isfahan were compared in Envi-met software and the results show that in the warmest day of the year, canyons with higher ratios provide better comfort conditions based on the PMV index due to higher levels of shading (Rozati & Qanbaean, 2014)

In some studies in the field, two different types of public spaces (e.g., parks and streets) were considered in a study performed in Ahvaz (Tahbaz et al., 2011). In this study, the THI and PT indices showed high thermal stress levels in summer, but solutions such as increasing vegetation, providing shading for surfaces and using light colored materials were found effective in improving the situation. In Bandar-Abbas, the traditional parts of the city were reported to have a better comfort situation due to their higher aspect ratio. In this study, the presence of vegetation was also reported to causes a positive effect on the environment due to the effect of evaporative cooling. Comparing three indices of PMV, PET, and SET also showed that using Passive design methods alone is not possible due to high thermal stress in summer (Dalman et al., 2013; Dalman et al., 2011).

Studies performed in semi-private-semi-public spaces

Examples of studies in semi-public-semi-private open spaces in residential complexes and University campuses are found. Mahmoodi et al. (2017) calculated the mean radiant temperature (Tmrt) and the physiological equivalent temperature (PET) by assessing different factors such as the sky view factor (SVF), shading, vegetation, and temperature changes in the middle day of every season in Envi-met and Rayman softwares. The results of this study which was performed in Ekbatan complex in Tehran emphasizes the importance of the capability of reflecting solar radiation towards the sky and thus the need for sufficient openness between the buildings. Thus, it is suggested to create a diverse condition by using different shading, material type and surface textures in the area. Using a similar method in Chahaarsad-vahedi residential complex in Bandar-e-Imam-khomeini and considering 12 different scenarios of vegetation density, building density and using water in Envi-met software led to the conclusion that in the month Khordad (May), the presence of water would lead to decreases in the air temperature and increases in the level of humidity. On the other hand, increases in the building density and vegetation density showed a positive effect on the PMV index due to higher levels of shading (Kolivand & Kolivand, 2015). Maqsoodi & Kordjamshidi (2014) have presented the typology of open spaces in residential complexes and described the factors affecting thermal comfort in open spaces including vegetation, water, material, orientation and climatic parameters. Kherodin & Zabetian (2016) used a similar method to review previous studies with the aim to identify the factors affecting thermal comfort and emphasized on the effect of the sense of belonging on psychological adaptation. Azizi & Javanmardi (2017) also point out that the most important factors affecting the wind intensity in urban fabrics are height and depth of pathways after simulating the Sanayi neighborhood of Tehran and investigating 15 different urban forms. Although in this study, thermal comfort was not directly mentioned, the effect of wind flow, which is one of the fundamental factors in calculating thermal comfort, is assessed. Also in Ahvaz, the thermal comfort conditions in relation with solar radiation is studied for open spaces of residential complexes using solar plot and shadow mask and the Penwarden graph. Thus, the best comfort condition is determined based on building form, location of blocks, transition of wind flow and shading (Shojaee & Moameni, 2016). Most of the studies on the spaces between buildings were performed for residential buildings and there is only one case of studies in non-residential open spaces where the University of Science and Technology campus (having extensive vegetation) and Amirkabir University campus (without extensive shading) were compared based on the UTCI index in 10 different points of each campus site (Ojaghlou & Khakzand, 2017). The results of this study show a 1.28˚C difference between the two campuses, which was caused by their different shading patterns (based on the sky view factor). Focusing on the central courtyards as common feature in Iranian architecture is of great importance. Accordingly, some studies have been performed to determine comfort conditions in such spaces in the cities of Yazd (Baqaee et al., 2015), Shiraz (Nasrollahi et al., 2017), Isfahan, Kerman, Kashan and Semnan (Soflaei et al., 2016; Soflaei et al., 2017) based on different indices.

Studies performed in private open spaces

Although central courtyard is not considered as an urban space, it is important due to its impact on its surrounding area in an urban fabric. In the study in Yazd, a dry-bulb temperature of 25˚ was found satisfactory for people. Nasrollahi et al. (2017) assessed the impact of orientation and proportions on the changes in the comfort condition in Shiraz based on the PMV and UTCI indices using the parametric method and the Envi-met software and described the dimensional proportions of 2:1 and 3:1 as reasonable for a central courtyard. Determining the optimal central courtyard model was considered for Kashan, Semnan and Yazd with the assumption that central courtyard is good choice in these climates.

A notable point in these studies is that the objective is sometimes bidirectional; in other words, in some cases the thermal comfort is studied in a certain space with the objective to improve the situation, while in some others, the objective was merely to study the thermal sensation of people and to determine the comfort range. Thus, the type of analysis used and the solutions or models proposed are different among studies. It is notable that often, there are some factors that need to be considered in introducing the studied area. These factors, which can differ among different space types (private, semi-private-semi-public and public) include information such as geographic location including longitude and latitude, climate and average weather conditions, physical characteristics including geographic position relative to the studied city, information regarding the function of the site, adjacencies, different urban densities (Stewart & Oke, 2012), or the aspect ratio of pathways, sky view factor and orientation and environmental characteristics including the type of flooring materials in different places, the percentage of each type of vegetation from the total and the amount of shading. The WMO standard will be helpful as well

in this regard, because it provides some suggestions regarding the classification of urban forms based on density, the aspect ratio and the percentage of hard surfaces (Jarraud, 2008). These studies were performed using three different methods including the field study, simulation research, or mixed-method research. In the field study method, which is used in 58.43 percent of the articles, the thermal perception of individuals were assessed using questionnaires along with the measurements performed in the studied area. 17.94 percent of the studies lean on the analyses provided by softwares such as Envi-met, Eco-tect and Rayman. In cases where the integration of the two methods was considered, validating the results and increasing their precision were possible.

RESULTS AND DISCUSSION

Among the published papers, the highest percentage of the total studies, which is equal to 53.9 percent, belongs to the studies on the application of thermal comfort indices in determining the tourism climate potential. Next, 27.65 percent of the studies was microscale and considered the application of (thermal comfort) indices in determining comfort in urban open spaces. These studies can be in turn divided into three sub-categories including studies in public (17.02 % of all studies), semi-public-semi-private (7.09%) and private (3.54%) spaces. Thermal comfort studies often extract and analyze a part of the data they use from weather stations. These stations were found by this study to have two types, namely synoptic and climatology. Synoptic stations usually possess the most complete set of meteorological equipment and measure data including the temperature, humidity, air pressure, horizontal visibility, wind direction and velocity, level of cloudiness and types of clouds, sunshine duration, level of ground reflection, temperature of earth in different depths and the amount of evaporation in 24 hours on an hourly basis. In climatology stations, the essential data including the temperature, humidity, wind direction and velocity and the amount of precipitation is collected every three hours. Thus, the climatology station does not measure the upper-air parameters at all, and does not possess the regular and hourly online reporting systems unlike synoptic stations. Among the macroscale and mesoscale studies, 43 instances presented the thermal comfort period based on the data from synoptic stations, 4 instances based on the data from climatology stations and 12 instances based on the data from both of them. Choice of the station type is determined based on two criteria: one, the type of index used and the input data it requires and the other, the available stations around the studied area. In addition to the diversity of weather station types, climatic classifications used in such studies are also based on different methods. The present study has seen cases using Köppen, De Martonne and Emberger classifications. Since the climatic classification expresses the dominant weather conditions, it plays a determining role in decision making at different climatic levels. However due to the deficiencies in these classification methods such as being very general and lacking enough subdivisions, the present study uses the Köppen -Geiger classification which offers its classification in a more detailed scale. Another point about these studies is the extensive scope of knowledge that relate to the topic, which engages different specializations in the way that professionals from the fields of geography, architecture, climatology, urban design, tourism planning, ecology, mechanical engineering, civil engineering, remote sensing, earth science, occupational safety and health and computer sciences (in order of frequency) have presented the results of their studies. The important point is the collaboration of different specialists in this field, which provides the basis for presenting more accurate and more practical results. In the fundamental studies of thermal comfort, the collaboration of mechanical engineers and architecture professionals is witnessed. In regional macroscale studies, the scientific fields of geography, remote sensing, earth science, climatology and ecology have had research collaboration. In urban microclimate (microscale), the role of urban designers and urban planners has become more considerable along with the role of architects. In thermal comfort studies, the period considered in the study is considered important from different points of view. We have faced two types of time period selection in our investigations; the first type is dedicated to the macroscale and mesoscale studies, which often have a broader period, and the second type is used in microscale studies. Regarding the first type, our classification of studies based on their period revealed that 30.43 percent of the studies considered a 20 to 40 year period, while 14.13 percent and 28.26 percent based their studies on 40 to 60 and 10 to 20 year periods respectively. In microscale studies, the periods considered were smaller and only include the warmest and coldest days of the year. The longest period considered in these studies is one week (in summer and winter). On the regional and local macro view, using the long-term data from weather stations becomes the priority and generalizing the results and forecasting the weather changes for future planning will be possible, if enough attention is paid to the numbers, the methods of creating interpolated surface map based on point climate database (such as the point interpolation method) are used and data errors are recognized. In microscale studies, it will be enough to consider critical conditions and credible results will be generated by selecting a few days of different months, because these studies consider evaluating thermal sensation of people and using field study methods. In such studies, the data of the closest weather station is often used in addition to the climatic data recorded at the site to approve and validate the results. Studying the time period considered in different studies is important because it makes it possible to compare their period and thermal comfort range. Regarding macroscale studies, the climatic zoning of the country according to the effective temperature, physiological equivalent temperature and tourism climate index are presented in Table 3. In mesoscale studies, the abundance of indices makes it hard to conclude, but with a broad perspective, the period of comfort for different provinces can be expressed (see Table 3). In the microscale studies, two approaches were found.

In some cases, thermal comfort range was mentioned for different seasons and in others, the impact of environmental or personal parameters on thermal comfort was evaluated and described based on the changes in thermal comfort indices. Studying the thermal comfort range in previous studies reveals that this range can be considered wider in open spaces. For instance, the temperature ranges of 12.3 to 30.9 and 9.4 to 19.1 were reported to be tolerable in the Imam Square of Isfahan in summer and winter, respectively, while the comfort range was reported to be between 24.23 and 25.42 in central courtyards of houses in Yazd. There can be a number of different reasons for such a difference when these two cities belong to nearly similar climatic classes. In other words, the impact of other parameters in analyzing the results of the field study has become significant and needs to be thought over. For example, the differences in mental background of individuals from the viewpoint of culture, emotions and emotional feelings, social position, clothing type, activity type, environmental quality, expectations and experiences regarding open and closed spaces lead to receiving multiple different results which in turn show the complexities of urban microscale studies. Thus, studying the parameters affecting thermal comfort in any level of urban open spaces (from public to private) will be important for reaching a comprehensive vision in urban planning and design. In the studies performed in Iran, this issue has received less attention, or field study methods were completely neglected and only studies with software simulation were performed. Reviewing the studies in this paper presents a conceptual model of the studies of thermal comfort in open spaces in Iran. The aim of presenting this model is to depict the rout for future studies in the field and guide their orientation. Accordingly, the presented model shows the classification of studies, their borders and the way they relate to each other. Besides, the means and data used in the studies are presented for each distinct category of studies. One of the major points about this model is that it demonstrates the similarities, differences, relations and discontinuities that exist among the studies. This model also sums up a large portion of the information presented in previous sections of this study, which facilitates the comparison of the characteristics of the studies. As stated before, the studies performed in Iran can be classified into two main categories including fundamental and practical studies. Fundamental studies often try to define the basic concepts and components that form the perception of thermal comfort and to calibrate the rout that other studies take. Thus, they discuss different factors, indices and computational formulas. However, the model (see Fig.1) focuses on the practical studies for two main reasons. Firstly, many fundamental studies in the country have not yet been evaluated and their strengths and weakness are not clear. Secondly, based on the studies from worldwide and the experience of the authors, field studies (studies that consider real situations and not merely experimental samples) are a better option and provide more credible results. However, there is a need to shed more light on the processes used in the field studies because they have a more complex scope and consider a large number of influential factors. Thus, the conceptual model of studies is presented here by focusing on the practical studies in the macroscale, mesoscale and microscale.

In the macroscale, we face studies that try to provide a zoning of the country. The researchers in this field use the data from weather stations (daily, monthly and annual data), validate them and provide a climatic zoning of the country based on the thermal comfort indices. On the other hand, due to the climate

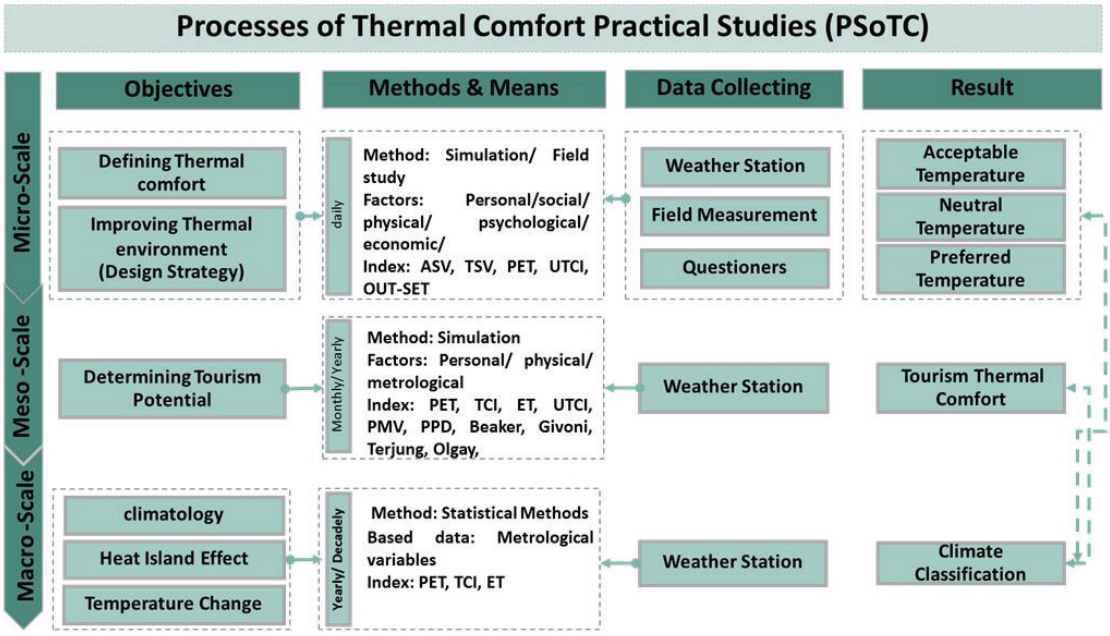

Fig.1: The trihedral conceptual model of the studies on thermal comfort in outdoor space

change issue, a portion of the studies in this scope, focuses on the temperature changes of the earth surface in long periods and its causes (such as changes in site use, vegetation, etc.) and the heat island effect. Such studies often use statistical methods and data from weather stations to break the country into different zones in the macroscale.

In the mesoscale, the studies were found to often study thermal comfort in monthly/annual periods with the objective to determine the proper time-location conditions for tourism around the country. Such studies are quite similar to macroscale studies with minor differences in the indices they use. Personal, climatic and physical factors are often considered in this scale based on the used thermal comfort index.

The microscale studies, focus on urban fabrics (from public to private) and evaluate the effect of different factors on the perception of thermal comfort and present the acceptable thermal range for different regions. Obviously, these studies include several steps and consider a wider range of factors. They use daily assessments of thermal comfort conditions in different seasons but their results can be generalized to the whole year or month for the location if a large statistical population is considered.

In the conceptual model in Fig.1, it is tried to present the research process of the three scales discussed, in the form of their objectives, means and methods and results. It is notable that microscale studies form the basis for the two other scales, but on the other hand, the results of microscale and mesoscale studies can be used to assess the credibility of the climatic classifications and thus for calibrating them. Therefore, we are facing a cycle between the studies of different scales, which necessitates engagement of professionals from different fields. Another point to be mentioned is that the indices that are mentioned in the conceptual model are only those that were seen in the studies reviewed in this paper, while there are more than 100 different indices in this scope according to our investigation. However, different factors that are considered in studies and their effects also need to be selected and evaluated based on the scale of the study and the social, economic, cultural and political conditions of the context. This model provides the basis for future studies, which will be further discussed in the next section.

CONCLUSION

This study tried to prepare the ground for future studies on thermal comfort in Iran by reviewing the current state of the literature. In order to identify the strengths and weaknesses of the previous studies, a set of comprehensive researches and assessments were performed to collect, evaluate and classify the studies on this topic. This process will provide the basis for planning and designing future researches. This research has tried to identify study approaches in the field and presented a classification that categorizes studies into three scales as a primary step for enhancing climatic conditions of open spaces in the country. The key points resulted from this manuscript and suggestions for future researches are mentioned bellow to help eliminate the current defects.

Climatic classification of the country has been performed in different studies based on different indices. This subject requires revision and calibration due to climate changes in order to provide the basis for appropriate design. There are different methods that can be used for climate classification in large scales. A common method that is used by many thermal comfort standards is the ASHRAE Climate Zone, which proposes eight different climate classes based on heating and cooling degree days. Due to the large number of weather stations available in Iran, it is possible to calculate the heating and cooling degree days for different parts of the country and use the ASHRAE classification method as a common basis for future studies. However, it may be also needed to use more detailed classification methods in some cases to include the economic, social and environmental factors based on the requirements of the studies.

Tourism attractions in Iran are quite widespread and can provide the basis for social and economic development of urban and rural areas. This requires devising a time-location schedule to present to tourists, travel agencies and urban planners. In the present study, an example of such schedules was presented and prepared based on a variety of thermal comfort indices. Unifying and integrating the timetables require an appropriate index to be selected and become the basis for evaluation and analysis. These indices may be selected and calibrated from the extensive list of available international indices or a new index may be introduced that is correspondent with the native context of Iran, which would consider the cultural parameters (clothing type, lifestyle. Experiences and environmental expectations, etc.) as well, in addition to the climatic parameters. It is evident that many parts of Iran are not yet studied thoroughly, and this subject requires on the one hand identifying tourism attraction points and studying their climates on the other hand, which creates extensive needs for research.

About thermal comfort indices, considering the variety of the indices in the investigated studies, it is necessary to point out that the indices have been classified into three categories of direct, logical and analytic. Direct indices have a one-dimensional look into the subject and use only one climatic parameter as the basis for decision. Logic indices are closer to reality and consider a mixture of components simultaneously. Analytical indices need to be interpreted by the researcher in addition to providing some quantitative results. Among the latter, those, which require field studies in the microscale, are being commonly used in recent years, because the subject of thermal adaptation of people has received attention from different physical, psychological and cultural points of view. This is exactly the subject neglected in most of the studies that we found, which regarded humankind as a static but not dynamic being. Thus, the present study suggests that future researches should lean on field studies along with simulations in software and laboratories. Nevertheless, the macroscale and mesoscale studies are usually considered a prerequisite for microscale studies, because climatic classification leads to

determination of climatic potential of an urban region; in other words, macro-information are investigated more deeply and in more details in the microscale. However, this will be possible only if different parameters (social, psychological, cultural and personal) be considered along with climatic parameters. The inevitable factor in determining the index used to describe the thermal comfort condition in microclimate is its ability to consider the thermal adaptation in people. Therefore, it is not enough to merely consider the climatic factors.

Another issue is to update weather data recording systems and to increase the number of weather stations. New stations, which can record a wider range of parameters and are located closer to the studied locations are needed to provide more accuracy in analyzing and generalizing the results. Even though in microscale studies, measuring weather data during the period of study is needed and it has to be performed at the same time as field measurements.

The findings of this study emphasize the importance of the interdisciplinary structure of environmental studies in open spaces. Examples of engagement of professional fields of engineering sciences, ecology, geography and earth science were witnessed while the need for environmental psychology and cognitive and behavioral science to play a role is strongly felt especially in microscale studies.

It should be noted that the disparities in the location and climate of the studies as well as in their theoretic bases makes it hard to arrive at a rigid conclusion. Thus, the following research steps are proposed here in order to cope with the current deficiencies in the thermal comfort studies in the country:

Choosing or proposing a climate classification method

Identifying the factors that affect thermal comfort in mesoscale and microscale.

Prioritizing the importance of these factors based on statistical methods or predictor algorithms.

Providing a thermal comfort index based on the affecting factors.

Preparing design models to help design open spaces in different scales according to the comfort needs of the users.

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The findings of this study are also used in researches on preparing assessment models and green design guidelines of the Taraz-e-Sabz research group of Shiraz University, which will be presented as new articles.

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