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Determining new threshold temperatures for cooling and heating degree day index of different climatic zones of Iran

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ABSTRACT

Iran is a country with a variety of different climates. Determining the threshold temperatures suitable for providing thermal and climatic comfort is necessary and vital to its population well-being. This research presents new threshold temperatures in order to calculate the degree day index required for heating and cooling by taking advantage of the 12 stations that are representative of the diversity of Iran's climate. Using Olgyay diagram, different bioclimatic ranges of 12 weather stations and their frequencies were compiled, processes and analysed. Mean daily data of temperature and relative humidity were used for the period of 1950–2010. Based on the frequencies of temperature readings falling in Olgyay's diagram comfort zone, representive temperature thresholds were selected based on 40 to 60 percentiles or (P20), 25–75% percentile (P50) and the threshold of 10–90% percentile. The findings of this study shows that Mashhad with 29.6% and Anzali with 2.33% of frequencies, have experienced the maximum and minimum days of comfort. After analyzing various percentiles to determine the threshold temperatures, it was observed that there is a little difference among the stations for determining the minimum threshold for the comfort. Differences are more obvious in the maximum thresholds. In total, minimum base temperatures (HDD) belonged to Ardabil stations that were 20.50, 20.90 and 20 deg C for P20, P50 and P80 respectively. The maximum temperature for calculating CDD with values of (P20 = 25 °C; P50 = 26.25 °C; P80 = 27.50 °C) is dedicated to Zabol station. The findings present more reasonable thermal comfort thresholds that can be used by architects, engineers and policy makers to achieve, in turn, more energy efficient homes and high quality indoor and outdoor living environments.

1. Introduction

Climate change is one of the major challenges of the 21st century requiring global strategies for efficient energy supply, sustainable use of resources and the reduction of greenhouse gas (GHG) emissions [1]. The massive population growth in the urban centers of Iran faces the affected regions with major challenges regarding energy supply and energy use as well as in the adaptation to climate change. These regions also offer enormous potentials in heading towards sustainable, climatically adapted urban development. There is a demand to the construction 1.5 million new housing units per year in Iran. With the construction of new settlements, consumption of energy, commodities and resources there is a serious need to develop solutions and strategies for energy efficient, comfortable and resilient urban development. There is therefore a need for specifying criteria for the indoor and outdoor environment for design, energy calculations, performance and operation of buildings.

The degree day index as could be seen as one of the most practical and simple indices in determining required energy for providing comfort climate is. The total mean deviation of daily temperature of human comfort temperature is called threshold degree day temperature. In temperatures higher than threshold temperature, there is a need to cool the environment and in temperatures lower than it, there is a need to heat the environment which are called cooling and heating requirements respectively [2]. Heating degree days (HDD) and cooling degree days (CDD) in different aspects, are considered an important and effective indicators. The measure of heating and cooling degree-days can provide a clear and accurate picture of the thermal needs of the building, the city and the region, it also play a positive role in

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providing thermal comfort and improving energy consumption patterns [3]. Estimating and calculating average value of degree-day requirement for heating and cooling as basic information to estimate the amount of energy needed for heating the building in winter and cooling it in the hot season is a result of energy consumption planning.

To date, a variety of HDD and CDD data are available in the literature and standardization for varies cities worldwide. However, in the case of Iran most HDD and CDD thresholds classifications are generic and there is no specific data for specific locations. Especially that Iran is a country with extreme climate and topographic variability. For instance during extreme winter in the North, many parts of the South experience very thermally comfort climate conditions, including cities such as Chabahar, southern coast islands and some coastal cities in the Persian Gulf and the Oman Sea. On the other hand, in hot summers, cities such as Ardabil, Khalkhal and some highlands experience cool weather accompanied with pleasant thermal comfort. The presence of Iranian cities in different geographical areas such as forests, deserts, beaches and mountain regions influence the climate variability strongly. The combination of different weather systems and atmospheric mass over the years with local topography agents causes great disparities between cities. Even cities, which are relatively close to each other, experience differences in climatic conditions. Therefore, the is a serious necessity to conduct a fundamental review of climate in different Iranian cities and more important set up new thresholds temperature to support designers and city planners with validated information that can help them to implement energy efficient strategies in each location independently in order to achieve maximum thermal comfort inside and outside buildings.

The percentile method is applied frequently in the environmental sciences, such as climatology and biometeorology; and according to the data frequencies, it aims to identify upper and lower thresholds. The idea of using the percentile method in this study was based on this fact that in some valid studies, the 90th and 10th percentile of the maximum and minimum temperature of the stations were used to identify the bioclimatic indexes such as heat and cold waves, respectively [4,5]. Hence, based on this method, thermal thresholds identifying the heat and cold waves are different for different stations. According to what is mentioned above, it can be concluded that thermal comfort zones of each area needs to be identified according to the climate pattern of that area. We believe that the local people of each area can adapt themselves to their surrounding climate; therefore their tolerance and biocomfort is different in different climates. On the other hand, considering the huge climate variability in Iran, identifying a fixed base temperature of 18–24 °C for monitoring the demand in cooling and heating energy, cannot justify an appropriate threshold for this climate variability. Therefore, in this study we aimed to identify the dominant possibilities in comfort of each station according to its behavior and thermal pattern, based on the identifying the thermal thresholds of P20 as representative for the ideal comfort zone, P50 as favorable comfort zone and P80 as appropriate comfort zone. According to their applications and aspects, these three different thermal bases can be used in different ways. For example, considering the global warming and increase in the maximum temperature records, making use of P80 thermal threshold for CDD can be an appropriate thermal base for stations having experienced temperature increase in the recent years. Eventually, it must be mentioned that in this study some new based temperature thresholds have been introduced, but it must be considered that these new based temperatures have been chosen in the comfort zone which was proposed by Olgyay before. In the present study, we just suggest some new threshold temperatures based on the data frequencies in the comfort zone.

In this context, this study focuses on the determination of new threshold temperatures for cooling and heating degree day index of different climatic zones of Iran. The new threshold temperatures for cooling and heating degree day index has been proposed as providing designers and facilities managers with the opportunity of reducing energy consumption yet ensure that thermal comfort is maintained by allowing buildings to operate in free-running mode rather than use mechanical systems for cooling and/or heating. This arises as a consequence of the fact whilst mechanical systems require energy for their operation, buildings in free-running mode, where occupants can freely adapt their local/personal environment by opening/closing windows, altering dress etc, largely do not. Whilst buildings which use mechanical cooling or heating systems customarily use broadly fixed temperature limits which are independent of outdoor air temperature to define the upper and lower boundaries of the zone of thermal comfort1, the fluid temperature limits of the new threshold temperatures for cooling and heating degree day index are set in relation to the variant outside air temperature [6,7]. Also from the viewpoint of the land use planning and long-term and mid-term planning of Iran, the results of this study can have a determinant role on climate change, energy consumption, housing, urban development, economic development and some other social and economic arenas. The importance of the present study lays its ability to provide a finer classification that would facilitate the implementation of environmental strategies that are tailored to the local context. Therefore, the results of this study are considered as guidelines for architects and civil engineers in Iran. The accurate and specific determination of bioclimatic characteristics of a location or city, can help designer to select environmental urban patterns and construction techniques that achieve thermal comfort, occupants well beings and reduce the depends on fossil fuels. On the long term this will lead to decreasing cooling and heating loads and consequently the cost pressure on inhabitant's budget and government's energy supply.

This paper is organized into six sections. The first section identifies the context of the research and its importance. The second section reviews different thermal comfort models and establishes an understanding of Iran's climatic situation. The third and fourth section identifies the research methods, used materials and studied weather stations. The demonstration and processing of the results are presented in section five. The final section discusses the research findings and limitations along with the implications for the design practice community and future research.

2. Climate and human comfort

One of the most important issues in applied climatology is the branch of bioclimatology, which is presented as an independent branch in climatology. Various scholars have written numerous books and articles on the subject and they have also devised methods [8–13]. In fact, bioclimate, investigates the weather conditions in relation to organism and in particular to human [14]. Considering climatic parameters of human comfort, outdoors and indoors, is an important field in climatology studies. These are part of a larger topic in applied climatology entitled climates and built environments or bioclimatic architecture and climate adapted built environment.

Generally there are two general methods for monitoring and analyzing bioclimatic conditions. The first method can be called the indices method that is based on empirical measurement and computational calculation covering a range of simple to complex indices. For example, humidex is an example for simple indices that although various methods have been proposed to calculate this index but in most of them, two parameters of temperature and relative humidity are used [15–17]. Wind chill index is another