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ORIGINAL ARTICLE

Urban design in favor of human thermal comfort for hot arid climate using advanced simulation methods

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KEYWORDS

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Abstract Improving outdoor human thermal comfort could be considered as one of the most important targets for achieving successful open space designs. In hot arid climate, residential neighborhoods are responsible for the high request of energy to provide cooling needs for the occupants' comfort. The main problem is the non-responsive contemporary urban design to human thermal comfort and energy. In this context, this paper aims at testing specific landscape parameters that could enhance outdoor human thermal comfort. The study is limited to the microclimate at urban open space and will be conducted in New Borg El-Arab (hot arid city according to Middleton and others [1], Alexandria, Egypt). The adopted methodology is based on the use of ENVI-met 4.0 software to measure four thermal indices (air temperature, relative humidity, MRT and PMV) and assess outdoor human thermal comfort in an existing neighborhood. In addition, different design scenarios that emphasize different landscape elements were also assessed. The results of this analysis depict changing street networks, landscape design and materials could enhance the level of thermal comfort in the urban open spaces.

1. Introduction

The increase in world population leads to an urgent need to diminish the energy footprint of humanity. In hot arid climate, residential neighborhoods are responsible for the high request of energy to provide cooling needs for the occupants' comfort [2]. The main problem is the non-responsive contemporary urban design to human thermal comfort and energy efficiency. Due to recent changes in the urban density and street networks of contemporary urban context, controlling micro-climate of neighborhoods imposes difficult challenges to achieve human thermal comfort. Randomized and careless urban design leads to developing uncomfortable areas between building blocks [3].

In this respect, several recent researches explored bioclimatic strategies that may enhance outdoor human thermal comfort. A recent research by Alireza Monam and Klaus Rückert [4] suggested strategies for the development of low carbon "energy-efficient" and resilient housing districts in semi-arid climates. This was achieved through the designing of 35 ha area of southern Hashtgerd new town using passive strategies for 8000 inhabitants in 2000 residential units. Other researchers attempted to adopt a retrofitting approach, such as

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Table 1 PMV ranges and physiological equivalent for different grades of thermal perception and physiological stress; internal heat production: 80 W, heat transfer resistance of the clothing: 0.9 clo [12].

PMV	Thermal perception	Grade of physiological stress
<-3	Very cold	Extreme cold stress
-3	Cold	Strong cold stress
-2	Cool	Moderate cold stress
-1	Slightly cool	Slight cold stress
0	Comfortable	No thermal stress
1	Slightly warm	Slight heat stress
2	Warm	Moderate heat stress
3	Hot	Strong heat stress
>3	Very hot	Extreme heat stress

Axarli and Teli [5], who redesigned an open space in a residential area in Thessaloniki Greece.

According to Middleton and others [1] Egypt is located in the hot arid climate zones. In this context, many planning projects have been produced and implemented to cope with population growth. In Egypt, the overwhelming rate of population growth did not allow time for full environmental studies for both the built and the natural environments where buildings and open spaces have to be adequately climatic responsive [6]. Urban design is strongly dependent on climate interactions which can improve or moderate impacts on human thermal comfort. This brings us to the must of a deep understanding of all the forces affecting the thermal comfort in the urban environment. Moving one step ahead, this knowledge is used to support urban designers and planners in decision making. Thus, their designs will ensure reduced energy consumption and improve human thermal comfort.

This study aims at testing specific landscape parameters that could enhance outdoor human thermal comfort in hot arid climate. In order to achieve this aim, the first part of this paper (theoretical study) investigates the literature review of the human thermal comfort in general. Particularly, this paper focuses on two thermal variables: air temperature and relative humidity. In addition, the thermal indices that could be used to evaluate both cold and hot outdoor conditions, such as Predicted Mean Vote (PMV) and Mean Radiant Temperature (MRT) were analyzed. The second part of this paper (Empirical study) discusses the adopted methodology which is based on proposing three different scenarios for existing urban area in New Borg El-Arab, Egypt. These scenarios assume preservation of existing buildings and changing street networks, landscape design and materials. ENVI-met 4.0 software is used to measure four thermal indices (air temperature, relative humidity, MRT and PMV) and assess outdoor human thermal comfort in the existing neighborhood and the three proposed scenarios. The results of this analysis depict changing street networks, landscape design and materials could enhance the level of thermal comfort in the urban open spaces.

2. Human thermal comfort

Achieving human thermal comfort is essential for hot arid regions. "Thermal comfort is generally defined as that condition of mind which expresses satisfaction with the thermal environment. Dissatisfaction may be caused by the body being too warm or cold as a whole, or by unwanted heating or cooling of a particular part of the body (local discomfort)" [7]. Air Temperature is the most common indicator of human thermal comfort. Nevertheless, air temperature alone is not an accurate indicator of thermal comfort. There are other environmental and personal parameters must be taken into account. According to ASHRAE Standard 55-2010, environmental parameters are air temperature, mean radiant temperature, wind speed and relative humidity. Personal parameters are activity level and clothing insulation. In general, outdoor thermal comfort is much more complex than indoor comfort. For example, the spatial and temporal microclimatic variations of meteorological variables are often very large. Other reasons for the difficulty include lack of climate control in outdoor spaces [8].

To help architects and urban designers for better design decisions, some thermal variable and indices are proposed

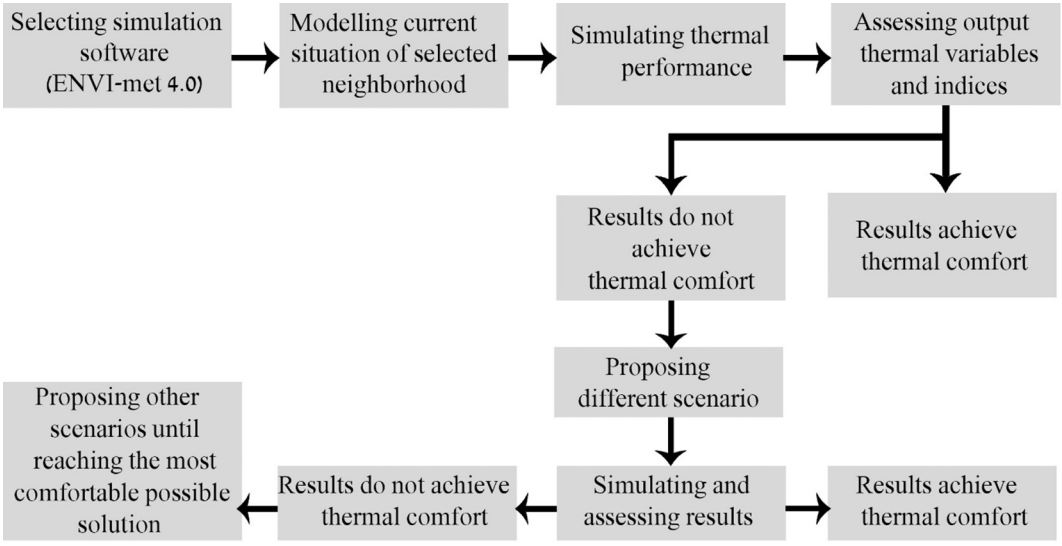

Figure 1 The adopted steps for this paper.