

Effect of Aspect Ratio and Symmetrical Distribution on Urban Design in Baghdad City, and the Impact of Greenery Strategies on improving Outdoor Thermal Comfort

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Abstract. The concept of thermal comfort relies on the knowledge and content of the pedestrians, particularly in an arid climate. This work concentrates on the possible methods to improve the pedestrian thermal comfort. There are inadequate investigations researches carried out on the outdoor thermal comfort in a desert climate. The researches on enhancing outdoor thermal comfort are nearly nonexistent in cities like Baghdad. Baghdad has a sophisticated urban fabric with contemporary buildings, traditional houses. This work aims at investigating possible strategies to verify how pedestrian comfort is influenced by the constructions design choices, and how vegetation contributes to enhancing the outdoor thermal comfort. The evaluation was performed by using ENVI-met on the hottest day in summer. ENVI-met represents buildings design and calculates the impact on the vegetation on outdoor thermal comfort. We adopted PMV indices to evaluate the outdoor thermal comfort. This work aims to design cities in an arid climate and to maintain a convenient level of thermal comfort. Also, how to perform a proper climate of pedestrians during the daytime beneath the burning sun, particularly in cities with an extreme rise in summer temperatures and for numerous months, as in Baghdad. The research exhibits a proposal area design in an arid climate based on the architectural and implementation standards to increase the pedestrians thermal comfort requirements and how the urban factors such as the aspect ratio, symmetrical distribution, and the green strategies are essential factors that urban designer may be taken into account, mostly for design new urban area in an arid climate.

1. Introduction

Thermal comfort had been discussed since 1930 [1]. In dry climates, there are three crucial parameters influence the canopy layer climate: cooling methods, ventilation, evaporation and solar sheltering [2]. Solar access is a significant requirement for the effect of solar heating on the buildings. The exposure of solar radiation path is one of the fundamental control factors which effects microclimate condition in urban design. Open spaces such as parks are ordinarily more exposed to the solar radiation than the roads and semi-enclosed areas. Controlling on solar access could be defined summarily in two various elements as, solar access for buildings and solar access for pedestrians. The amount of solar radiation could directly influence the solar access. Consequently, have an influence on the outdoor thermal comfort. Hence, the effect of solar access in urban design canyon is needed to enhance urban microclimate [3]. Pedestrians are maintained from the direct impact of sunlight by buildings components such as arcades, overhangs, canopies or frameworks, also by trees and vegetation. Strategies for providing shade by limiting the width of the street, shade may also be produced by applying trees along the pavements or by using pedestrians arcades connected at the street level of the adjacent buildings [4]. Several investigations verify how the green impacts have a



significant role in the method of sustainable cooling of the urban planning and in keeping energy and developing human thermal comfort. A study was conducted out in Cairo. There were satisfactory comfort levels and cooling reasonable for some orientations for the urban area due to the clustered form with cool green islands and the wind flow through the main canyons [5]. Shading surfaces contribute to reducing temperature and mean radiant temperature that are affecting the thermal comfort at any given moment in time. Shading surfaces can release the saved energy at night so that could be contributing to producing thermal comfort for the pedestrians in the next day [6]

1.1. Effect of Aspect Ratio and Sky View Factor

Urban canyon geometry described by Erell et al., [4] as the aspect ratio, also identified as height-width. Aspect ratio is determined as the proportion of the average height of neighbouring perpendicular parts like building facades and the average width of the space. As explain in Fig. (1). Bakarman and Chang [7] illustrated the superficial canyons that included $H/W = 0.42$ encounter higher ambient temperatures through the daytime when contrasted to the deep traditional aspect ratio $H/W = 2.2$. An investigation research in Morocco conducted by Alaoui et al., [8], the results confirmed that the aspect ratio more than 2 leads to growing the energy cooling demand due to the influence of low ventilation and the high thermal of the recession.

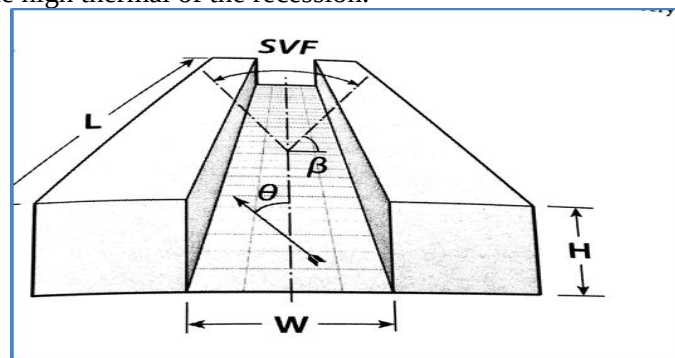


Figure 1. Cross-section of a symmetrical pattern of canyon [4].

Sky view factor (SVF) is almost correlated to its aspect ratio (H/W), as well represents the cross-sectional ratio of the canyon. Figure 2 presents the sky view factor as a function of canyon aspect ratio (H/W) [4]. Brown et al., [9], indicated that for the case where buildings cover 50% of the area of the sky, the sky view factor would be more significant than 5% because sky view factor is measured by the prevalence of the solar radiation overhead the surface of the area.

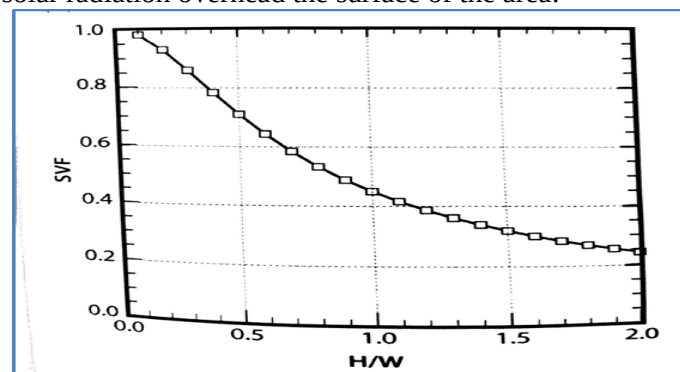


Figure 2. SVF as a function of (H/W) [4].

There is a correlation between the efficacious emissivity and SVF. The high amount of the buildings in the urban area meant that there is a small SVF and increased trapping of radiance [10]. According to a comparison study of the environmental circumstances of urban street canyons in the conventional area and other one contemporary neighbourhoods of Aleppo, Syria the study showed that the effect of shading on the T_{mrt} decreases significantly with the solar radiation decrease in canyons with low SVF (high aspect ratio) [11].

1.2. Effect of Orientation

Street oriented to [NE-SW] or [NW-SE] in an arid climates means that the shading impacts on the fences and walls are more effective than for an E-W orientation, accordingly, the deficiency of the direct exposure to sunlight due to the availability of shade leads to better comfort conditions [12]. According to Polservice [13], the typical street trend in Hot-Zone should be revolved towards the axis [Northeast-Southwest] and [Northwest - Southeast] to obtain the better insulation in the winter and insignificant heat and adequate shading in the summer season. Figure (3) depicts the buildings orientations and ideal streets in the hot climate in Baghdad.

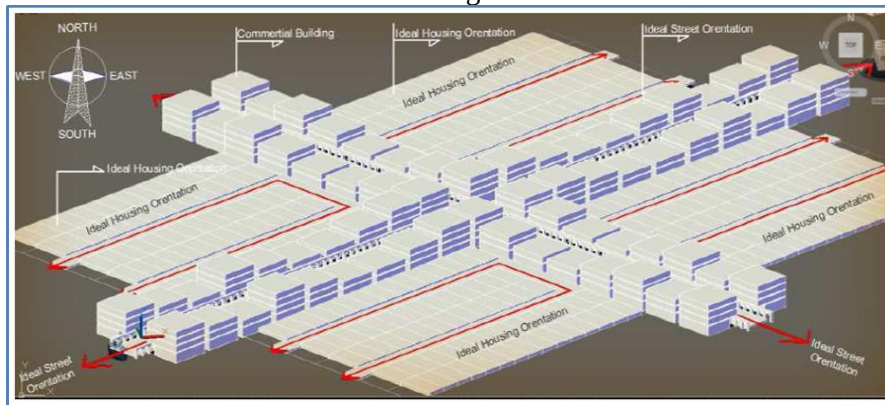


Figure 3. Typical streets and buildings orientation in arid climates [14].

1.3. Effect of Vegetation

Numerous investigations show how the greenery impacts have a significant role in the method of sustainable cooling of the urban planning and in keeping energy and enhancing human thermal comfort. A research was conducted in Egypt; Cairo explained that the satisfactory comfort levels and mitigating reasonable for some orientations for the urban area due to the collected form with cool green islands and wind flow through the main canyons [5]. In an investigation study on the effect of greenery strategies in an arid climate in Dubai, Rajabi and Hijleh [15] confirmed that green rooftop contributed to performing inadequately in decreasing the surface temperatures in urban areas; this is because of the cooling impacts of green roofs lessen by distance and consequently this influence is negligible on the overall temperature decrease in urban areas. Also, concerning the distribution of greenery, trees have the best participation to the decrease in surface temperatures.

2. Methodology

2.1. Study Area

Baghdad is positioned in the middle portion of Iraq on both sides of Tigris River Fig (4). It lies on latitude 33° north and longitude 44° east. The climate of the Baghdad region is described as a semi-arid, with hot dry in summer, and cold winter. Baghdad area comprises 4555 Km^2 , which described 1.047% of the whole area of Iraq.



Figure 4. location of Baghdad-Iraq Map (www.googlemap.com).

2.2. Micro-Scale Numerical Modeling ENVI-met

ENVI-met software simulates micro scale interplays urban surfaces, the atmosphere, and vegetation. The reliability of ENVI-met results for simulating the outdoor thermal spaces validated in many investigations. These investigations showed that the data measured at local meteorological locations seemed to accord with the simulated results [16]. Monam and Ruckert [17] validated that concerning to several investigations [18], [19] and [20] ENVI-met results could be recognized as accurate and reliable.

2.3. Data for the Proposed Model

Data adopted to simulate the proposed model was presented by Iraqi Meteorological Organization and Seismology. The microclimate features describe weather conditions of the hottest day of summer in Baghdad that was 12th of July in 2010 [21]. Accordingly, the original climatology environments for the primary conditions were 315 deg. for wind direction and 5 m/s for wind speed. Simple forcing for relative humidity and air temperature were applied along one day, which explains that the maximum temperature was 50 °C at 4 pm, and the minimum air temperature was 35 °C at 6 am. The minimum relative humidity at 4 pm was 24 %; the maximum relative humidity at 7 am was 36%. Simulation period is 24 hours. The assumed area has the model dimensions (180 × 180). The area for the mode has been performed with grid size $x = 60$, $y = 60$ and $z = 20$, this grid size is represented in a grid cell, the size of the grid cell is $dx = 3$ m, $dy = 3$ m and $dz = 5$ m. The model has been rotated of 45° depending on the buildings orientations and ideal streets in an arid climate [14].

2.4. Model Configuration

The work focuses on imposing an area 32400 m^2 to represent the specific urban area in Baghdad city. This area is an approach to an area that was adopted by the researcher in a previous study 48750 m^2 on improving the thermal comfort in Baghdad, where the area was taken from the real district in Baghdad city. The researcher relied on the recommendations and results for the previous researches and studies, which were listed in this work to design the area that has been imposed in Baghdad in order to improve the outdoor thermal comfort for the pedestrians at the hottest day in summer. Also, depended on the specifications of building and the construction requirements from the Ministry of Construction, Housing and Public Works in Iraq. The principles adopted to construct the proposed model for the suggested urban area are as follows:

1. The height of the residential buildings is 15 m (the new requirements of design the residential buildings in Baghdad), see Fig (5).
2. Spacing between the buildings based on the typical Aspect Ratio in an arid climate is ($H/W \geq 1$), so we choose $H/W = 2.5$.
3. Depending on the Standards of Housing Technical and the Code of Practice of Iraq prepared by (PolSERVICE) in 1982, also the outcome in this work, the orientation is (NW-SE).
4. The research focuses on the concept of courtyard design within the building to give proper ventilation within the courtyard of one building as shown in Fig (6), thereby contributing to adequate ventilation of the outer perimeter, and therefore creating appropriate thermal comfort for pedestrians between the corridors.
5. Concerning the role of albedo for enhancing the outdoor comfort, we choose light concrete pavement for the entrance and for the main street grey concrete pavement, see Fig (7).
6. To heighten the function of vegetation in outdoor comfort, we concentrate on utilizing trees and grass. Also, the role of afforestation and ventilation within the courtyards was also enhanced through the use of evergreen and shady trees (Sophora tree) see Fig (8), Thick tree branches contribute to obstructing the sunlight and reducing, and reduce its impact on the surfaces thus contributing to the enhancement of thermal comfort.
7. To enhance the active role of shading, which mainly affects the thermal comfort of the pedestrians, it has been proposed to design the buildings symmetrically in order to take advantage of the amount of shade contributed by the buildings each to other to protect pedestrian.

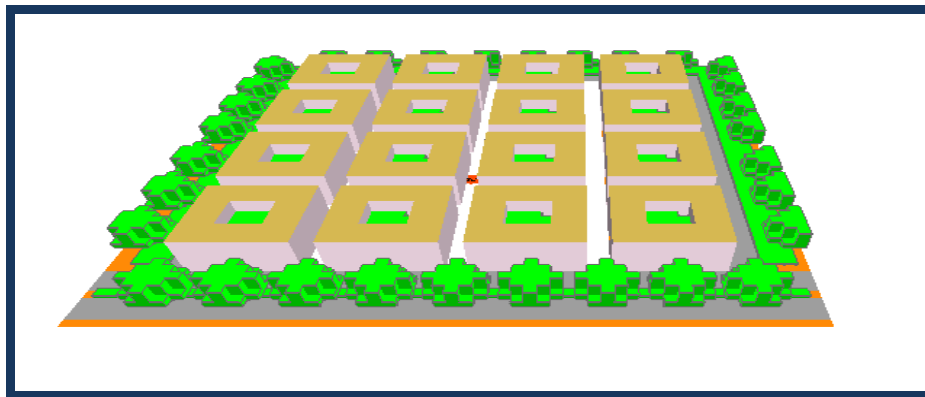


Figure 5. Perspective view of the proposed urban design simulated by ENVI-met.

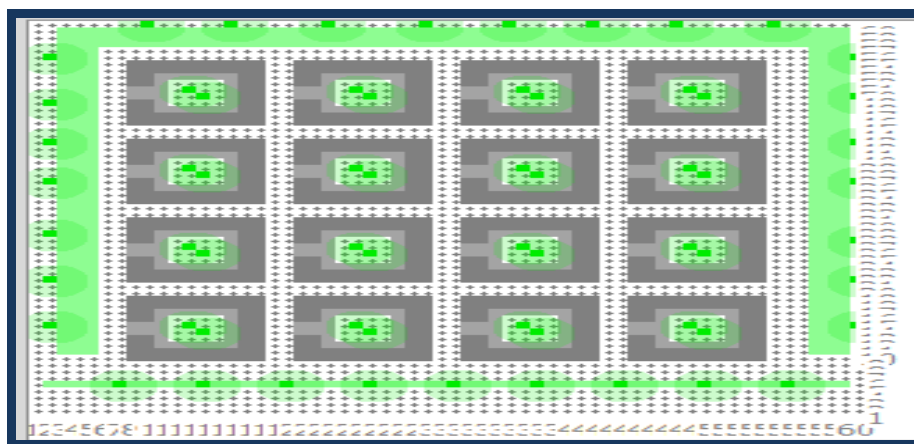


Figure 6. Top view of the proposed urban design simulated by ENVI-met.

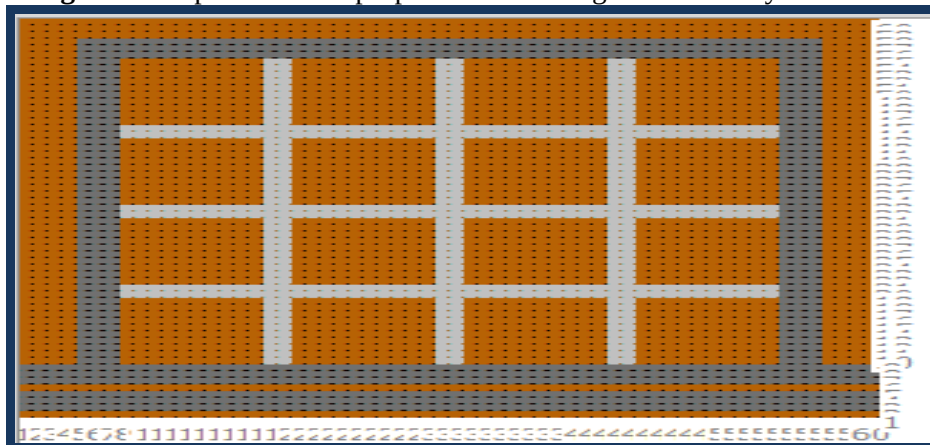


Figure 7. Distribution of roads and the main streets of the proposed urban design simulated by ENVI-met.



Figure 8. Sophora tree (<https://www.pinterest.com/>).

3. Results Analysis

The real temperature at noon time was measured 47°C according to the Iraqi Meteorological Organization and Seismology. We observe a decrease 2 °C in air temperature, the concentrated air temperature in the simulated urban area ranges between 43°C and 45 °C, as shown in Fig (9). Figure (10) depicts the distribution of temperature at height 1.5 m over the ground; this level indicates the human thermal sensation. We observe that the minimum air temperatures are recorded in the courtyards because the courtyards play an essential role in the cooling system in the simulated urban area. The existences of courtyards contribute to minimizing air temperature.

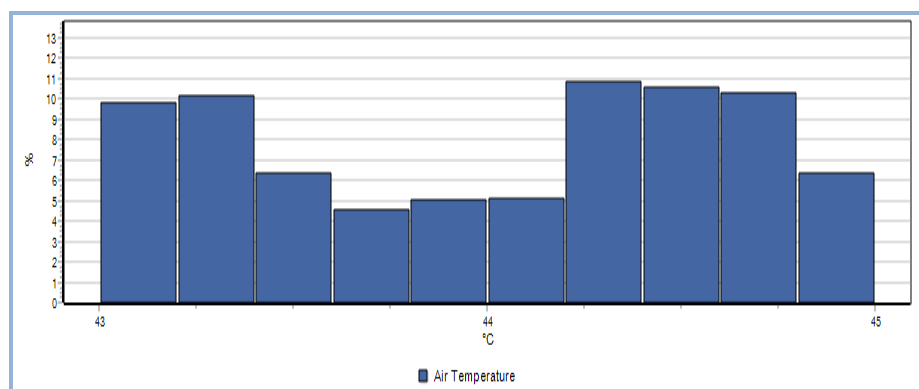


Figure 9. Percentage value of air temperature for the simulated urban area.

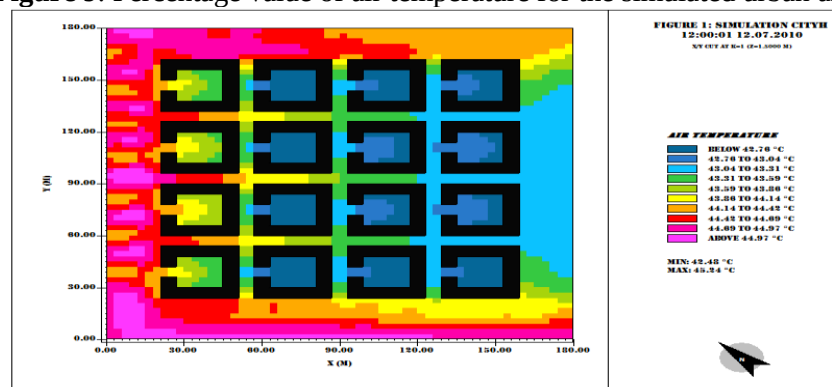


Figure 10. Air temperature distribution for the simulated urban area.

The real wind speed that was used in the simulation work was 5 m/s, we observe from Fig. (11) that the wind speed is around (0-4), this is attributed to the existence of vegetation, which leads to blocking the air flow.

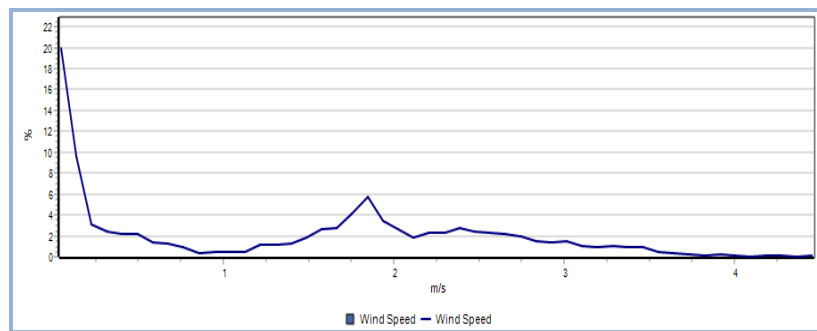


Figure 11. Wind speed Percentage value for the proposed design at midday noon.

Sky view factor also decreased, the existence of vegetation minimizes the open spacing in the urban area, Fig. (12) clarifies that the minimum values of sky view factor concentrated in the courtyards which are around (0.19-0.28), while the maximum values 0.65 and above are concentrated outside the distribution of the buildings.

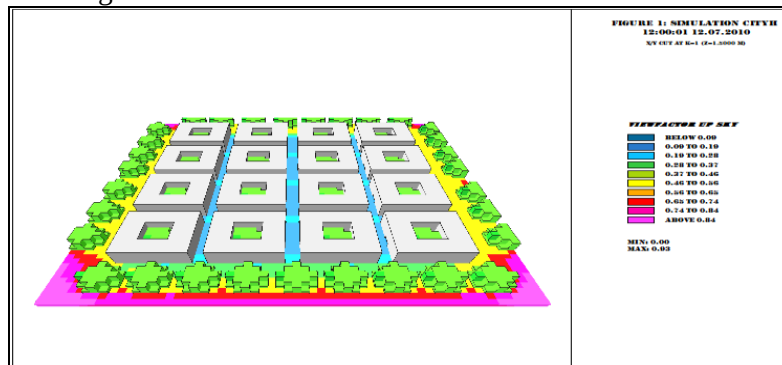


Figure 12. Three-dimension distribution of Sky view factor.

Typically, PMV range is described within [-4] very cool and [+4] very hot, 0 is the thermal comfort value (neutral), see Fig (13). Although PMV values are the mathematical function of the local environment, in most utilization, it can also give values above [-4] or below [+4]. Implementing of PMV equation to the outdoor circumstances in summer temperature stress conditions can efficiently provide values of PMV high over +4 [+8 and more]. While these results are mathematically accurate, it infringes the scale of the actual PMV method (www.ENVI-met.com). Figure (14) depicts the percentage value of PMV at noon; we observe that the proposed design achieves an improvement in the thermal comfort PMV values range (5 - 6.5). The distribution of PMV for the proposed urban design at noon illustrated in Fig (15).

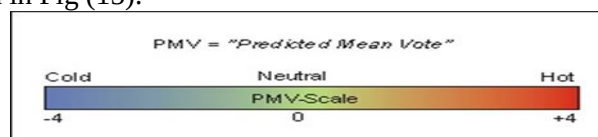


Figure 13. PMV scale ([www.ENVI-met. com](http://www.ENVI-met.com)).

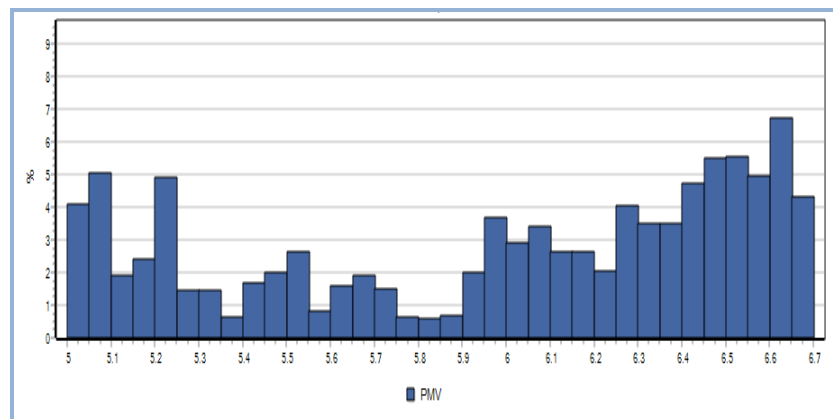


Figure 14. PMV percentage value for the proposed design at midday noon.

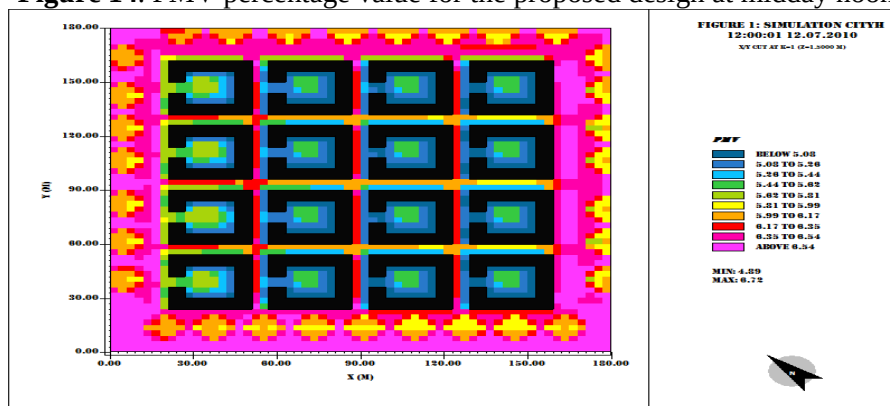


Figure 15. Distribution of PMV for the proposed urban design at noon.

4. Conclusion

The increase in desertification in the hot and dry areas in recent years, especially in Baghdad city, and lack of interest in the optimal design of cities, which simulates the environment and improves the pedestrians thermal comfort all these factors have motivated the researcher to do this research to achieving the urban environmental design under increasingly changing climate conditions. The results showed a decrease in temperature more than 2 °C. Concerning PMV outcomes in hottest circumstances day, the outcomes showed that the proposed design had adequate hot conditions. The characteristics of vegetation covering influence the results of thermal sensation directly such the leaves absorb and convey solar radiation and evapotranspiration provides for improving thermal sensation. The results of this work may help for enhancing cities design in an arid climate.

5. References

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