The effect of high commercial buildings on microclimate for hot climate cities

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Abstract. Last decades cities were rapidly growing and continuously changes, the growth of population was increased and life conditions changes. Urban formation for cities changes accordingly, which includes land uses, the geometry of buildings, the heights and density for the built area changes. There is a research gap in studying the effect of high commercial buildings on microclimate for hot climate cities, which represented the research problem. To solve this problem research studied the effect of high commercial buildings on microclimate for Baghdad city, as an example for hot climate city comparing to original residential buildings land use, by using ENVI MET 4.4.2 software and analyze results. The result showed that high commercial buildings contributed in rising average air temperature as compared to residential buildings especially at night time. Also it decreased relative humidity during the day and night periods. While the wind speed increased its rates and the average mean radiant temperatures at night decreased.

1. Introduction
Cities had witnessed changes and transformations in their urban fabric with the evolving human needs [1]. Urban lands were expand and growth continuously, especially in developing countries, that experienced more rapid urbanization [2]. It is one of the most common symptoms in the development of the city, which occurred within the city or outside its borders, and the change of land use in the main streets of the cities from residential to commercial or mixed use [3]. This included changed of buildings types, as well as height, density, and formal properties for it [4]. These changes played an important role in creating small urban climates, which affected on microclimate for the cities [5]. The microclimate is defined as the characteristic climate of a small urban area, which may be a single location for a particular building or several buildings, extending from several square meters and sometimes up to square kilometers, and differs in its characteristics and rates from the general climate of the region, depending on: Topography, the location, the surface of the earth (whether natural or man-made), and its characteristics such as reflection, permeability and quality, the shape of the third dimension of the area, which includes natural elements (such as trees) and structural elements (such as buildings, walls and fences) [6]. While urban street canyon refers to the space, which consists of two parallel rows of buildings separated by a street, and the aspect ratio is the most important characteristic of urban architecture of the street, the ratio of street width to the height of buildings on both sides of the street as an example, where it has a complex impact on the microclimate, including The streets cover about a
quarter of urban areas, so street design is a major problem in the world, where the microclimate within the urban street canyon is influenced by its morphological nature, geometric pattern, orientation, built density, and available green space, air and access to solar energy in the urban street canyon and therefore thermal comfort at the level of pedestrians in the urban street, where the climatic conditions in the street are linked to the urban canopy layer, which is limited to the height of buildings, and is directly affected by the physical characteristics of specific area, such as urban formation of the street canyon. The height of the building is an independent design feature that can affect urban density as well as urban climate in several ways, as the unplanned rise of the building can cause discomfort in the city [7]. This was accompanied with the raised of global temperatures at the recent years that create the phenomenon of the global warming [8]. Several studies in climatology had examined the impact of urban fabric formation on micro-urban climate in diverse climates and different locations and focused on many aspects of the impact of different urban morphology parameters of the urban street canyon on the minor climatic conditions of the street and the thermal comfort of pedestrians. [9] Examined the thermal comfort in street valley for moderate climate through studied the morphological factors like sky view factor, shadow factor, height to width value than defined thermal comfort. Examples were examined and analyzed. The result of this study showed that there were reverse relation between sky view and shadow factors. Thermal comfort was obtained for a street width twice than buildings heights. While [5] studied the effect of street design on urban climate, and analysis the effects of street geometry on air flow and access to solar energy in urban valleys, the research found that increases of the ratio of the street width to buildings height, provides a better air flow than narrow valleys where the proportion of supply For lower altitude, with regard to the height of buildings, the lower proportion of e H/W ratio, would increase the solar energy received from street surfaces, as the earth receives more solar radiation compared to the vertical surfaces (walls) in the street valley itself, where the ratio of H/W affects the earth more than the walls. [10] Explored the relation between urban geometry and thermal comfort in morocco, by measurements of daily temperatures in hot and cool seasons for street canyons. The results showed that deep streets were cooler in summer season than Shallow Street. In reverse to winter season the shallow streets were better than deep one cause of the reach of solar radiant. [11] Pointed out the importance of housing buildings clusters arrangements on microclimate and thermal comfort in Baghdad hot climate. The results indicate that the optimum housings clusters were low and mid-rise types, with liner and U-shapes formations.

2. Methodology
The research studied urban land uses changes from residential to high commercial buildings in the same district for Baghdad city capital of Al-Iraq, as an example for hot climate cities. The selected case model was in Al-Adhamiya city. That witnessed changes in urban land uses for buildings recent decades, where the owners of the buildings property on the main street Al-Asmaey for both sides changed types from simple two story residential to multi-story commercial or mixed used buildings, as shown in Figure (1), therefore, the study was conducted, the status of the modern urban commercial land uses of the street, compare it with old residential types of buildings, through the study of an old aerial image for the street in the program (Google Earth Pro), and studied the changes in types of buildings. The selected program to compare and analysis these effects on microclimate and thermal comfort is Envi-met V4 is a 3D computer program that
simulates small climatic conditions in urban environments and can be used to evaluate several aspects. For the purpose of conducting environmental simulation, to predict the climate changes within the urban environment, total study area (41600 m²), and the street direction was (Northeast - Southwest), length 260 m and width 25 m, as in Figure (2). Difference of the H/W ratio, building coverage ratios, and number of floors for both case models are shown in Table (1). Where the old model for the urban residential land uses of the street was characterized by a low density and a smaller percentage of buildings with open and green spaces within residential blocks overlooking the street, and the buildings did not exceed three floors, while the modern commercial of the street is characterized by change of use and increase density, led to increase the proportions of construction and the decline of areas Open and green, where the geometry of the valley had changed (H / W ratios), where the H / W ratio in the old fabric was smaller than 0.5 because Height of buildings did not exceed half of the width of the street, but with the change of the street and the emergence of high-rise buildings up to 8 floors, the ratio of H / W changed, buildings height equal to the width of the street, which is called unified street canyon when this ratio equal (1). The two models were simulated in the program, and then environmentally analysis, in summer of 2019, meteorological data were as follows: Maximum temperature 45 °C and minimum 26 °C and the direction of the wind northwest (315 Degree of north), wind speed 2.5 m / s, simulation was conducted for two times of the day for an hour in the day (12-1 noon) and an hour at night (9-10 at night) for both modern models (A) and old (B), where each scenario is designed from the two models in a grid dimensions (160 * 260 * 30), and accuracy (1m * 1m * 1m), the model rotates from the north of the network 38.20 degrees, and was selected asphalt material for the course of the street. Buildings materials were chosen as typical materials in Baghdad buildings.

3. Results and discussion

3.1 Air Temperature
The simulation results in Appendix A showed that the mean air temperature in the old case model (B) during the day at 12-1 noon was (35.73min - 40.17max) °C, while the average air temperature in the same climatic conditions at the same time in the modern case model was (35.31 min - 40.45 max) °C, while inside the street canyon the air temperature ranged in the old case model (B) (36.62-39.28) °C, while in model (A) ranged (37.88-39.43) °C, where the difference was The average air temperature inside the street between the old and the new formation is (0.70) °C during the afternoon.

At night, at hour (9-10) in the old case model of the study area the average air temperature in (29.79min - 36.10 max) °C, while it was the modern case model (32.43 min - 36.20 max) °C, the air temperature in the old case model ranged from (32.95 -35.47) °C in the street canyon, and in the modern model (A) ranged from (34.32-35.83)°C, the difference between the two models in the average air temperature inside street canyon was 1.5 °C.
Fig 1. The selected case models in Al-Asmaey street (A) modern model type (B) old model type

Table 1. Difference of the H/W, Coverage ratios, and number of floors for both case models

| H/W               | Coverage ratios of the total area | Coverage ratios of the total built area | Building height |
|-------------------|----------------------------------|----------------------------------------|-----------------|
| A                 | Building 90%                     | Building 65%                          | 4 – 25 m        |
|                   | Open spaces and Grass 10%        | Open spaces and Grass 9%              | 1 – 7 stories   |
|                   | Road asphalt 16%                 |                                        |                 |
|                   | Basalt sidewalk 9%               |                                        |                 |
| B                 | Building 77%                     | Building 57%                          | 4 – 12.5 m      |
| H/W < 0.5         | Open spaces and Grass 23%        | Open spaces and Grass 17%             | 1 – 3 stories   |
|                   | Road asphalt 16%                 |                                        |                 |
|                   | Basalt sidewalk 9%               |                                        |                 |
3.2 Relative Humidity
The relative humidity results in Appendix A for the urban street canyon during the day showed that the average relative humidity during the afternoon of the day at (12-1) hour for the old model (B) of the street was (48.87% min - 59.55% max). The modern case model (A) of the street was (49.33% min - 56.61% max). During the night at (9-10) the simulation results of the old case model (B) of the street showed that the average relative humidity was (59.33% min-69.58% max), while the modern case model was (56 % min - 64.20 % max).

3.3 Wind speed
The simulation results in Appendix A showed that the average wind speed of the model (B) in the study area was 2.44 m/s, while inside the street canyon the wind speed ranged (0.24-1.71) m / s, while the rate increased Wind speed in the study area in general for model (A) during the day to 0.34-2 m/s, and during the night at the chosen time also the same rates of wind speed were recorded in the day time of the model (A). However, the average wind speed recorded for model (B) overnight was 2.35 m/s.

3.4 Mean radiant temperature ($T_{mrt}$)
Within the urban street canyon the simulation results in Appendix A showed that the average mean radiant temperature ($T_{mrt}$) during the selected hour during the day time of model (B) was (47.61 min - 65.88 max) °C, while model (A) in the same conditions and time was (47.28 min - 67.10 max) °C. During the selected time at night, the mean radiated temperature of model (B) was (19.81 min -26 max) °C, and in model (A) was (19 min- 25.92 max) °C.

4. Conclusions
According to the results of the environmental simulation in a comparison between old residential type and modern commercial buildings case land uses model that: the air temperature was similar in both models during the day time of the selected study area in general, but inside the street canyon there was an increased in the average temperature by 0.7 degrees Celsius in the modern model (A), but at night has increased rates of degrees Air temperature of 1.4 ° C in the area generally measured in Form A and 1.5 ° C within the street canyon.
Relative humidity rates decreased in model (A) during the measured times during the day and night periods, by 1% at (12-1) noon and 4% at (9-10) hours at night. While the wind speed inside...
the study area has increased its rates in the modern formation (A), by 0.94 m/s during the measured hour in the day, and 1 m/s during the measured hour at night, while the rate of wind speed in particular in the urban valley for the same model by 0.2 m/s at night and day periods. While the mean radiant temperatures inside the urban street canyon were close during the daytime measured for both models, but at night the average temperature within the modern model (A) decreased by 1.4°C. The change of urban formation from residential buildings type to commercial buildings affected on the geometry of the urban formation and street canyon in particular H / W ratios, coverage ratios, the density of buildings, and building heights of the street, affected the change of parameters of the urban climate in the small urban microclimate, where temperatures increased during the night and day in the commercial buildings model, while the average wind speed in the region during the night in the modern formation slightly, with a slight increase in wind speed. The radiated temperature inside the street canyon had decreased slightly in the modern commercial buildings model during the night. The increase in the building density, the increase in the height of the buildings, number of floors, and ratios of land coverage for high commercial buildings as compare to residential buildings, increased the intensity of heat trapped inside the street canyon. That affected negatively on microclimate for hot climate cities.

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Appendix A

| Figure 1: Residualization | Figure 2: Residualization |
|---------------------------|---------------------------|

Air temperatures in old case residential buildings | Air temperatures in modern case commercial buildings
Relative humidity in old case residential buildings
Relative humidity in modern case commercial buildings
Wind speed in old case residential buildings
Wind speed in modern case commercial buildings
Mean radiant temp. in old case residential buildings

Mean radiant temp. in modern case commercial buildings