Kerbala Journal for Engineering Science

https://kjes.uokerbala.edu.iq/

The Effect of Different Urban Forms on Microclimate in Hot Arid Climates

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Received: 14 July 2021; Revised: 15 October 2021; Accepted: 18 January 2022; Published: 31 March 2022

Abstract:

Traditional cities are characterized by different urban forms. The transformations in urban formation came in response to human needs over time and technological developments. This research explores the relationship between urban forms and microclimate in hot aired climate cities. A comparative analysis for two selected urban forms patterns in Baghdad city as example of ancient cities in hot aired climate. The study investigates the influence of urban form on microclimate. The research relied on the ENVIMET 4.4.2 software simulation program to determine the microclimatic differences. The results showed that urban form in traditional areas achieved better results in microclimate (air temperatures, the average mean radiant temperature, relative humidity, and wind speed) as compared to modern urban form during daytime periods, especially in hot afternoon times, which may negatively affect the urban microclimate and the thermal comfort of pedestrians in the spaces of modern urban form.

Keywords: urban form, simulation, microclimate, hot arid climate.

1. Introduction

The urban form had an impact on microclimate. Old and traditional cities had different types of urban forms cause of the transformations and changes that relate to progressing in human needs. Changing street patterns were done to use vehicles, urban mass patterns, building heights, and building density [1]. The microclimate is defined as "the climate of a small area that may consist of several buildings, extending from a few square meters and sometimes reaching some square kilometres ". The rates and characteristics depend on the site and topography, whether man-

made or natural land and its different characteristics such as reflection and permeability and storage, in addition to the shape of the third dimension of the urban area, which includes the various structural elements built and natural elements [2]. The effect of urban forms on microclimate had been studied by many researchers in different climates types. Johansson (2006) studied the relationship between thermal comfort and urban form geometry in Morocco was found by recording the temperatures of street valleys in cold and hot seasons. The results showed that the traditional streets were cooler than the modern streets in the summer. The opposite occurs in winter, due to solar access [3]. In their research, Najeeb and Hassan (2019) compared the airflow speed for the traditional, and modern urban fabric in the canyon street for Baghdad city. CFD Software simulation was dependent on the calculations. The results determined that traditional urban fabric had increased the airflow speed in the street canyon as compared to modern urban fabric [4]. Also Hyader and Hassan (2020) compared changes in the microclimate of two types of urban forms, the traditional urban fabric and the modern urban fabric, using environmental simulation programs. The results showed that modern buildings contributed to an increase in the average radiant temperature and air temperature, especially in the afternoon and night hours. While the relative humidity decreased slightly during the day in the modern model and the wind speed increased slightly than the traditional model [5]. The research of Shishegar (2013) studied the effect of street design on the urban microclimate, and the effect of engineering changes for streets on access to solar energy and wind flow in urban valleys. The research found that the proportion of the street valley effect on the air- flow and solar radiation [6]. So this research aims to discover the relationship between urban forms with different urban architecture and the local climate in the city of Baghdad with a hot arid climate.

2. Methodology

The research studied models of different urban forms in Baghdad city in Iraq, as an example of hot and arid climatic cities. Samples were selected in the city of Kadhimiya, which is located in the northern region of Baghdad. It includes a variety of urban fabrics, such as the old traditional fabric with narrow winding alleys, resulting from the gradual accumulation of urban fabric in the historical center of the city in the areas surrounding the Imam Al-Kazim shrine, and The modern mesh fabric resulting from the urban expansion of the city in the surrounding modern areas, which is characterized by wide streets and large areas of built land overlooking it, as shown in Figure 1.

The chosen models, the traditional (T) part of sector 421 and the modern (M) part of sector 413 are shown in Figure 2. The study was done by analyzing and comparing the traditional

and modern models through an aerial city image in Arc GIS. Then their effect on the microclimate was tested using the program (Envi-met V4). It is a computer program used to simulate microclimatic conditions in urban environments assess and analyze environmental aspects, and predict climate change within urban environment. The total study area for each model was 86,400 m2, 320 m length * 270 m width as in Figure 2. Both models were designed in the environmental simulation program, in a grid of dimensions 135 * 160 * 15, and accuracy of 2 m * 2 m * 2 m. The model T rotates from the north of the grid at 47.6 degrees. The asphalt material was used for the two model streets and buildings materials were chosen as typical materials in Baghdad buildings, as shown in Figure 3. The environmental simulation for the two study areas was carried out in the summer of 2019. The meteorological data were as follows: a maximum temperature of 45 degrees Celsius, a minimum of 26 degrees Celsius with a northwest wind direction 315 degrees north and a wind speed of 2.5 m/s. The simulation was carried out several times during the day, morning, noon and night**.**

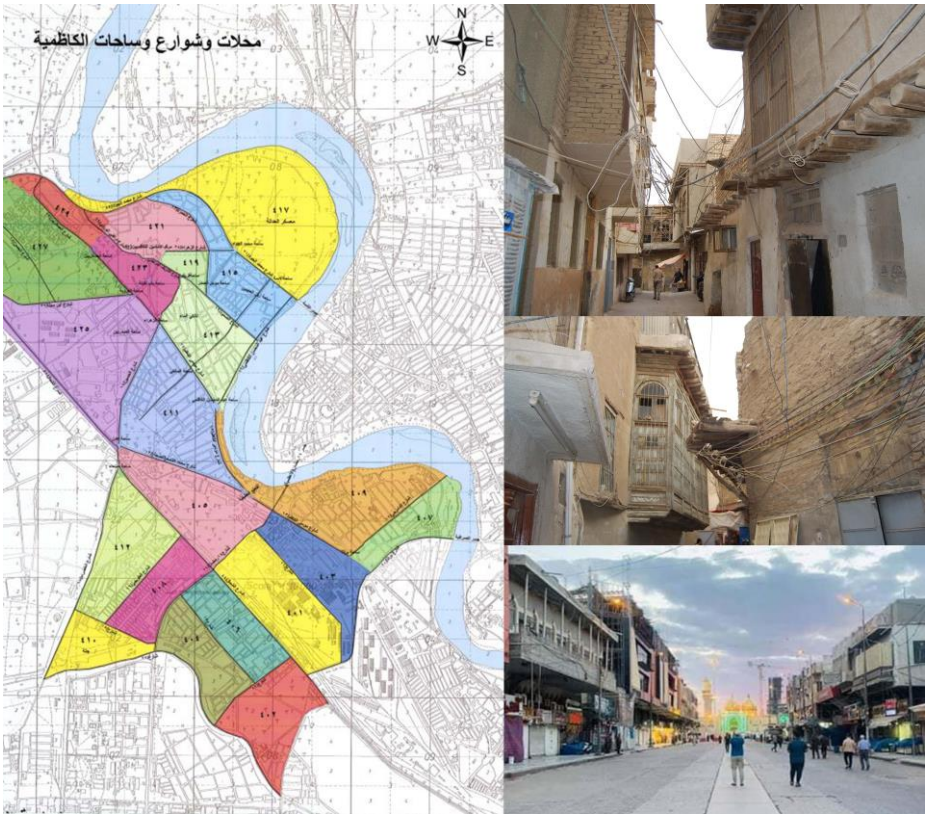

Figure 1 The selected case: Al-Kadhimiya, Baghdad

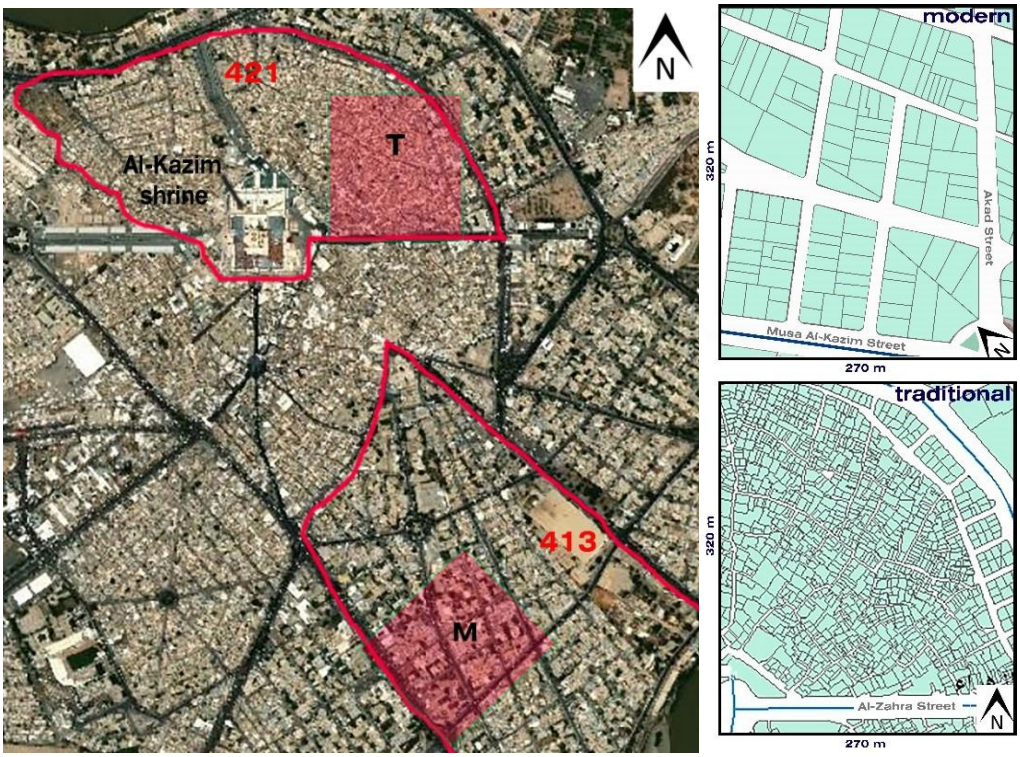

Figure 2 The traditional urban fabric (T) , and modern urban fabric (M)

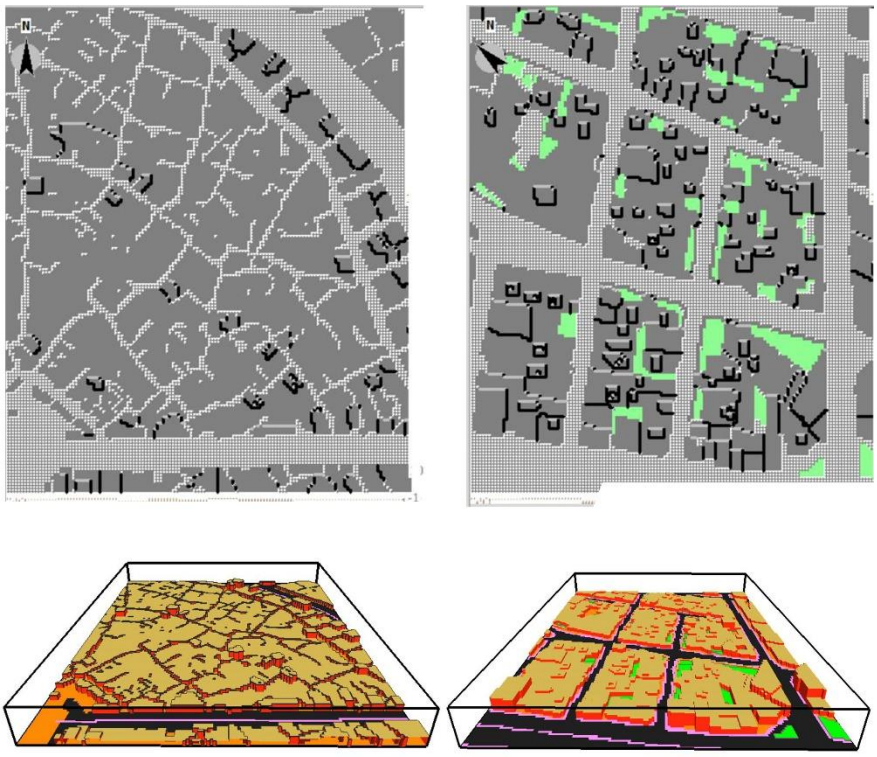

Figure 3 The models selected in the simulation program (Envi-met V4)

3. Results

The results showed that the effect of urban forms types on microclimate for each tested case.

3.1 The effect of urban forms types on air temperatures

According to the simulation findings in Appendix A, the average air temperature in model T for the day at 8 a.m. was 29.71min to 32.51max °C, whereas in model M it was 28.97 min to 31.37 max °C. At midday, 1 o'clock, the temperature ranged from 37.36 min to 40.00 max °C, whereas the current model ranged from 37.38 min to 40.30 max °C. It rises at 2 p.m., ranging from 38.94 min to 41.96 max °C. Temperatures in the contemporary ranged from 39.07 min to 42.46 max °C. At night (9 p.m.), the average temperature in the research area's model T was 33.27min – 38.13 max °C, while it was 32.41min – 38.10 max °C in model M.

3.2 The effect of urban forms types on Mean radiant temperature (Tmrt)

The simulation findings in Appendix B for the typical urban fabric T revealed that the average Tmrt at 8 a.m. was 31.22 min and 64.59 max °C, whereas model M in the same time and conditions was 35.21 min to 65.61 max °C. The mean radiant temperature of the Model T runs from 44.96 min to 64.88 max °C at 1 o'clock in the afternoon, and 50.17 min – 69.13 max °C in the model M. At 2 o'clock, the temperature ranges from 45.96 min to 70.23 max °C for model T, and from 53.21 min to 74.73 max °C for model M. The Tmrt for the model T for the specified hour at night was 16.56 min -24.14 max °C and varies from 16.55 min to 24.25 max °C for the model M.

3.3 The effect of urban forms types on air speed

The simulation results in Appendix C showed that the average wind speed of the traditional urban fabric (T) in the study area at the chosen hour in the morning was 2.07 m/s. while the modern urban fabric (model M) was 2.12 m/s. The average wind speed increased in the afternoon hours to 2.52 m/s for model T and 2.62 m/s for model (M). During the night at (9) o'clock, the average wind speed of the model T was 2.40 m/s, and 2.48 m/s for the model M.

4. Conclusion

According to the results of environmental simulations in comparison between the traditional urban form and the modern urban form, the average air temperature in the modern model was less than (0.94) ° C than the old model at 8 am, While the air temperature rises around midday for both models, particularly the modern model, the difference in the average air temperature at 2 p.m. was 0.50 ° C. However, at night the air temperatures are generally close in

the measured models, and gradually decrease in the early morning hours in the modern model. Whereas the mean radiant temperatures increased in the modern fabric, at all times measured during the day, the difference was in the morning 2.5° C, and reached during the afternoon hours between 4.70 and 5.85 ° C. But at night, the difference was very little. Relative humidity rates increased significantly in modern urban fabric compared to traditional ones, as during the morning hours (8 am) a big difference was reached (28.62%), While the relative humidity rates decreased during the afternoon hours measured in the modern model by about 1.42% to 1.12%. Then, it increased slightly during the night hours, so the difference in the rate of relative humidity was 2 %. While, about the mean wind speed in the measured areas, the modern urban fabric recorded a slight increase during all measured times, especially the noon times.

The distinction in urban fabric development between the traditional model, defined by small winding alleyways and high density of buildings, and the contemporary fabric, characterized by large and straight streets, low density of buildings, and a lack of shading with some open and green areas. This has led to a change in the parameters of the urban microclimate where air temperatures, and the average mean radiant temperature in general increases in modern urban fabric during daytime periods, especially in hot afternoon times. The relative humidity also increases greatly, which may negatively affect the urban microclimate and the thermal comfort of pedestrians in the spaces of modern urban fabric at these times.

5 . References

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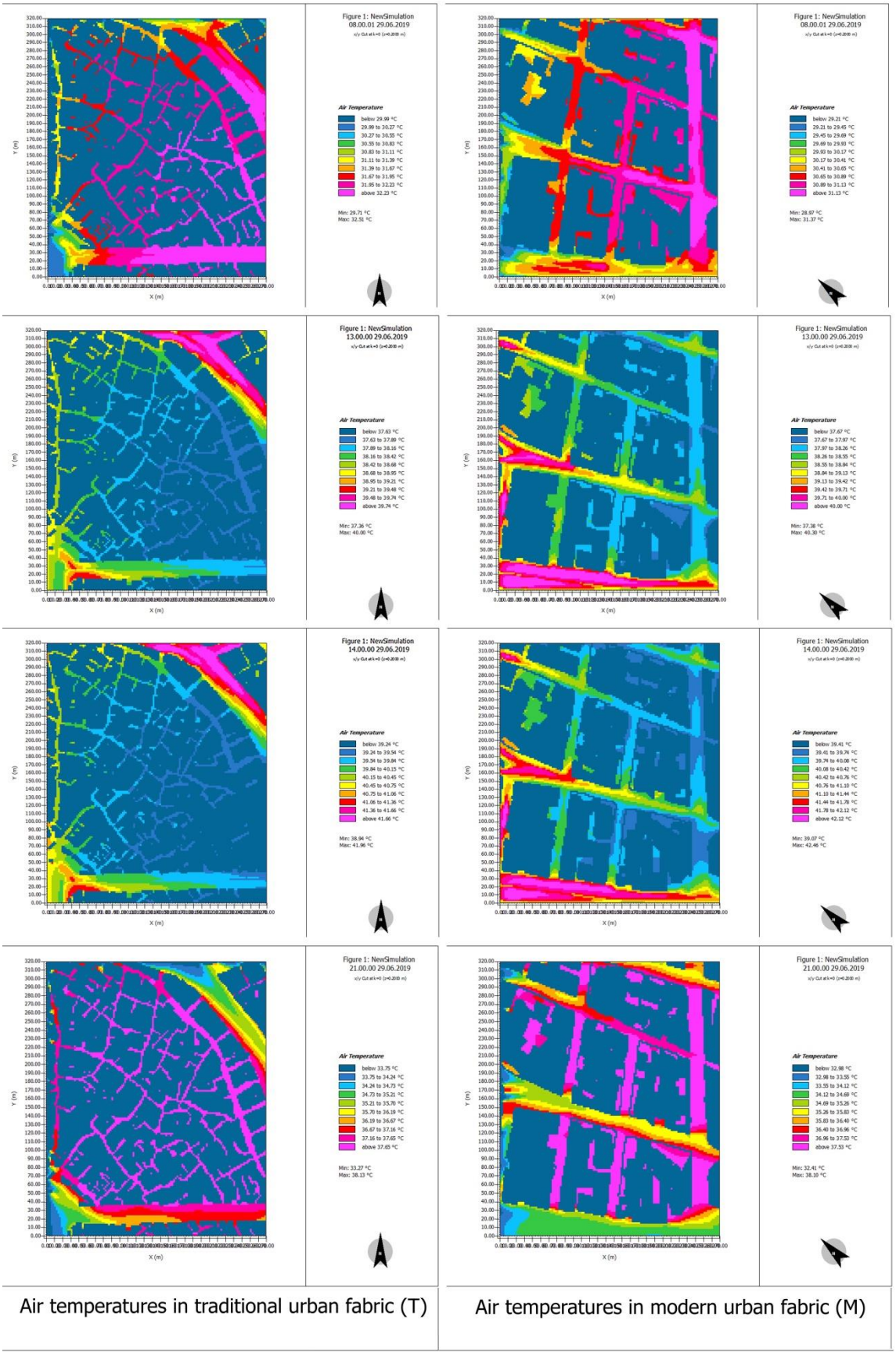
تأثير الأشكال الحضرية المختلفة على المناخ المصغر في المناخات الحارة الجافة

***الخلاصة**: تتميز المدن التقليدية بأنماط مختلفة من الأشكال الحضرية، جاءت التحولات والتغيرات في الشكل الحضري لتحقيق احتياجات الإنسان والتطورات التكنولوجية. استكشف هذا البحث العلاقة بين الأشكال الحضرية والمناخ المحلي في مدينة ذات مناخ حار جاف .من خلال تحليل مقارن لنمطين من الأشكال الحضرية المختارة في مدينة بغداد كمثال للمدن القديمة في المناخ الحار الجاف. يكتشف البحث آثار الشكل الحضري على المناخ المحلي. اعتمد البحث على برنامج المحاكاة البيئي ENVIMET 4.4.2 لتحديد الفروق المناخية. أظهرت النتائج أن الشكل الحضري في المناطق التقليدية حقق نتائج أفضل في المناخ المصغر (درجات حرارة الهواء، متوسط درجة الحرارة المشعة، وسرعة الرياح) مقارنة بالشكل الحضري الحديث خلال فترات النهار، خاصة في أوقات الظهيرة الحارة، والتي قد تؤثر بشكل سلبي على المناخ المصغر الحضري والراحة الحرارية للمشاة في المساحات ذات الشكل الحضري الحديث.*

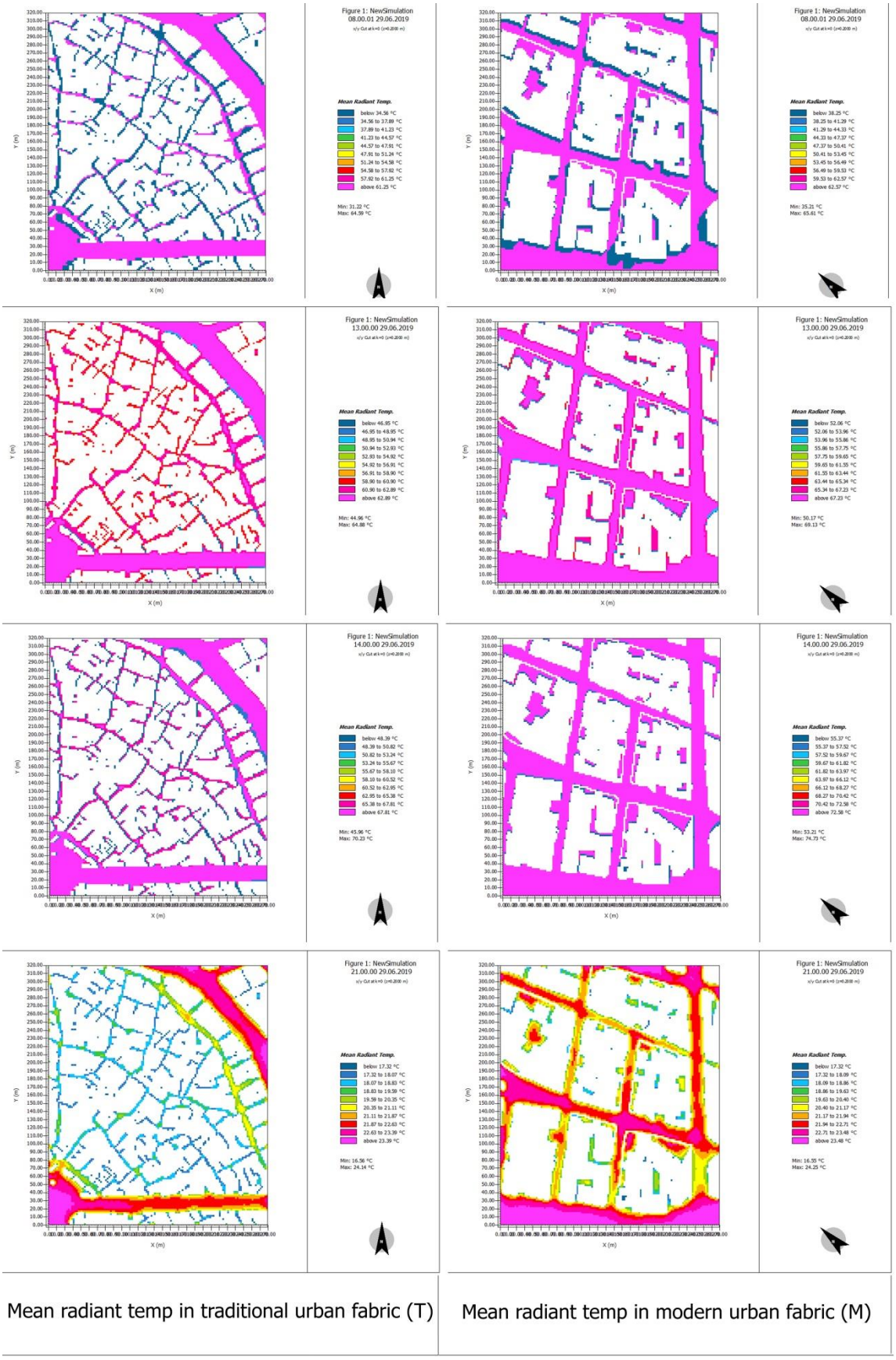
Appendix A



Air temperatures in traditional urban fabric (T)

Air temperatures in modern urban fabric (M)

Appendix B



Mean radiant temp in traditional urban fabric (T)

Mean radiant temp in modern urban fabric (M)

Appendix C

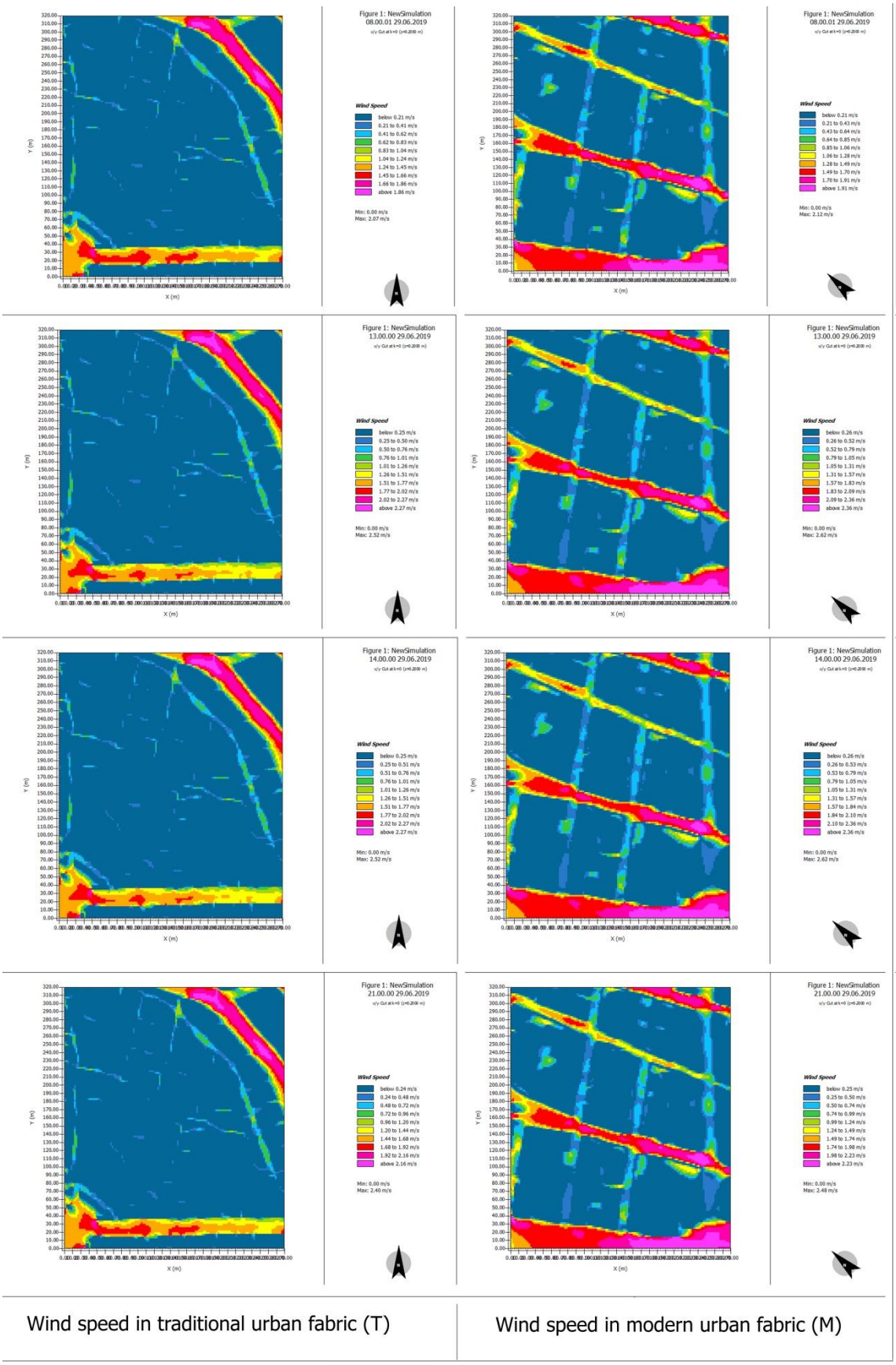


Figure 1: NewSimulation
08.00.01 29.06.2019
Wind Speed
below 0.21 m/s
0.21 to 0.41 m/s
0.41 to 0.62 m/s
0.62 to 0.83 m/s
0.83 to 1.04 m/s
1.04 to 1.24 m/s
1.24 to 1.45 m/s
1.45 to 1.66 m/s
1.66 to 1.86 m/s
above 1.86 m/s
Min: 0.00 m/s
Max: 2.07 m/s
Figure 1: NewSimulation
08.00.01 29.06.2019
Wind Speed
below 0.21 m/s
0.21 to 0.43 m/s
0.43 to 0.64 m/s
0.64 to 0.85 m/s
0.85 to 1.06 m/s
1.06 to 1.28 m/s
1.28 to 1.49 m/s
1.49 to 1.70 m/s
1.70 to 1.91 m/s
above 1.91 m/s
Min: 0.00 m/s
Max: 2.12 m/s
Figure 1: NewSimulation
13.00.00 29.06.2019
Wind Speed
below 0.25 m/s
0.25 to 0.50 m/s
0.50 to 0.76 m/s
0.76 to 1.01 m/s
1.01 to 1.26 m/s
1.26 to 1.51 m/s
1.51 to 1.77 m/s
1.77 to 2.02 m/s
2.02 to 2.27 m/s
above 2.27 m/s
Min: 0.00 m/s
Max: 2.52 m/s
Figure 1: NewSimulation
13.00.00 29.06.2019
Wind Speed
below 0.26 m/s
0.26 to 0.52 m/s
0.52 to 0.79 m/s
0.79 to 1.05 m/s
1.05 to 1.31 m/s
1.31 to 1.57 m/s
1.57 to 1.83 m/s
1.83 to 2.09 m/s
2.09 to 2.36 m/s
above 2.36 m/s
Min: 0.00 m/s
Max: 2.62 m/s
Figure 1: NewSimulation
14.00.00 29.06.2019
Wind Speed
below 0.25 m/s
0.25 to 0.51 m/s
0.51 to 0.76 m/s
0.76 to 1.01 m/s
1.01 to 1.26 m/s
1.26 to 1.51 m/s
1.51 to 1.77 m/s
1.77 to 2.02 m/s
2.02 to 2.27 m/s
above 2.27 m/s
Min: 0.00 m/s
Max: 2.52 m/s
Figure 1: NewSimulation
14.00.00 29.06.2019
Wind Speed
below 0.26 m/s
0.26 to 0.53 m/s
0.53 to 0.79 m/s
0.79 to 1.05 m/s
1.05 to 1.31 m/s
1.31 to 1.57 m/s
1.57 to 1.84 m/s
1.84 to 2.10 m/s
2.10 to 2.36 m/s
above 2.36 m/s
Min: 0.00 m/s
Max: 2.62 m/s
Figure 1: NewSimulation
21.00.00 29.06.2019
Wind Speed
below 0.24 m/s
0.24 to 0.48 m/s
0.48 to 0.72 m/s
0.72 to 0.96 m/s
0.96 to 1.20 m/s
1.20 to 1.44 m/s
1.44 to 1.68 m/s
1.68 to 1.92 m/s
1.92 to 2.16 m/s
above 2.16 m/s
Min: 0.00 m/s
Max: 2.40 m/s
Figure 1: NewSimulation
21.00.00 29.06.2019
Wind Speed
below 0.25 m/s
0.25 to 0.50 m/s
0.50 to 0.74 m/s
0.74 to 0.99 m/s
0.99 to 1.24 m/s
1.24 to 1.49 m/s
1.49 to 1.74 m/s
1.74 to 1.98 m/s
1.98 to 2.23 m/s
above 2.23 m/s
Min: 0.00 m/s
Max: 2.48 m/s
Wind speed in traditional urban fabric (T)
Wind speed in modern urban fabric (M)