Local Climate Zones Definition in Relation to ENVI-met in the City of Dubai, UAE.

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Abstract. The city of Dubai has experienced a rapid urban growth in the last 60 years. Located in the north west of the United Arab Emirates, Dubai has a linear development expanding mainly towards the coast. However recently this expansion is going towards the desert. Mapping such development creates a history that is relevant to many research entities. WUDAPT is a network that facilitates city mapping. With open source tools it is possible to create Local Climate Zones (LCZ). This zones have similar properties. Therefore, in the end of the process it would be possible to see the most dense urban areas of the city where the UHI phenomena is higher.

The process of mapping involves, Google Earth Pro, high definition satellite images and the CFD software, ENVI-met. The first two tools detect the LCZ and create the general map of the city. Then this map is compared with the validated models of ENVI-met. This comparison shows the connection of the UHI between one approach and the other. The site data taken from an open-source are used as a boundary condition in the simulations. The climate of Dubai is hot arid, with high temperatures in the summer and cool winters. The spring and autumn are short periods of 2-4 weeks.

The aim of this study is to detect problematic areas in the city in terms of surface/air temperature, high levels of UHI. This detection helps understanding where should be intervened in order to have more walkable districts.

1. Introduction
The recent development of the cities around the world requires deeper analysis and evaluation. The expansion of the neighbourhoods, their characteristics need to be documented. The type of the materials applied, the green zones, the building distances and the general plan create the so called Local Climate Zones (LCZ). In several European Cities such as London, Milan, Rome, Amsterdam etch., the urban development is mapped and the information is available for the researches. This process help detecting the build-up area according to a template. It recognises the highest levels of the UHI phenomena. The link between landscape change and climate has been visualised in recent research on several urban cities, namely the World Urban Database and Portal Tool (WUDAPT). This is a global collaborative project dedicated to the acquisition, storage and dissemination of climate-relevant data on the physical geographies of cities worldwide. The city mapping has expanded in the Americas, India, China, etc. [1-3].

The second tool used in this study is ENVI-met. It’s a CFD tool that simulates the wind speed, air temperature, relative humidity and much more parameters. The software in the version 4.0 has several
limitations such as the anthropogenic heat calculation. The tool still doesn’t include it. The templates of the soil needs to be modified in order not to have overheated surfaces. However, ENVI-met is largely used in the urban planning area. It helps understanding and calculating the Outdoor Thermal Comfort as well. A relevant parameter especially for the middle eastern countries. In several other studies the focus is on the building itself. The latest version of the software permits detailed 3D models therefore more accurate results. The boundary conditions can be easily modified based on the available data of the specific study. In very detailed models (scale 250x250) the wind turbulences are visible in the plan and in the section, showing a clear image in different types of neighbourhoods. [4-6].

2. Methodology
The methodology shows the steps taken in this study. The city of Dubai was selected for this study considering the urban growth achieved in the last 50 years. The city has a hot arid climate with high levels of humidity, different from the cities inside the country such as Al Ain. [7-9]
The methodology focuses in the below points;
- City analysis, climate zones selection,
- Weather data,
- Modeling and simulations,
- Results,

2.1 City analysis, climate zones selection
The city of Dubai has had a rapid in the last 50 years. The main areas develop close to the sea. However, the city is expanding rapidly towards the desert. Mapping such development is quite relevant in defining the most heated areas. There are 3 main highways going in parallel to the coast. It’s a linear development with a number of centres on both sides of the highways.
The main LCZ that are also taken into the next step of the study are the urban districts. The rest include the industrial zones, the parks, the water areas, the shrub area and the desert zones. The list of characteristics of the urban zones is mentioned in table 1.
LCZ 1- Compact high-rise, the district analyzed is aligned with Shaikh Zayed Road.
LCZ 2- Compact mid-rise, this are refers to the historic center of Deira.
LCZ 3- Compact low-rise, is located to the area of Karama, close to the downtown area.
LCZ 4- Open high-rise, this zone refer to Jumeirah Lake Towers, where the towers are spread around the central artificial lake living more space between each building.
LCZ 5- Open mid-rise, this are refers to the latest developed zones in the Greens.
LCZ 6- Open low-rise, the zone refers to the typical villa compounds like the Irish Village.
LCZ 9- Sparsely Built, this are typically nationals villas with vast space and green between the units. This type of units are spread in different locations all over the city.

| LCZ 1 | LCZ 2 | LCZ 3 | LCZ 4 | LCZ 5 | LCZ 6 | LCZ 9 |
|-------|-------|-------|-------|-------|-------|-------|
| District dimensions (m) | 574x7960 | 314x195 | 293x237 | 931x612 | 885x558 | 362x304 | 498x517 |
| District area (m2) | 188951 | 61467 | 69821 | 570228 | 494864 | 107919 | 258427 |
| No. of buildings | 15 | 29 | 36 | 25 | 23 | 52 | 54 |
| Average height (m) | 240 | 24 | 10 | 240 | 24 | 10 | 10 |
| Tree % | 5 | 0 | 6 | 8 | 9 | 10 | 17 |
2.2 Weather data
The site measurements are used as boundary conditions for the CFD (Computational Fluid Dynamic) software called ENVI-met. A detailed description is placed in the simulation section. The site data for this study are taken from an open source located in Dubai.
In figure 1 are shown the values of the temperature, Wind speed and wind direction for the week of 20-27 December 2019.

![Temperature, Wind speed, Wind direction graph](image)

**Figure 1.** Air temperature, wind speed, wind direction graph, 20-27 December 2019, Dubai.

2.3 Modelling and simulations.
Two main softwares are used for the modelling: WUDAPT and ENVI-met. Each tool has a different function. However, the results of ENVI-met should be aligned with the WUDAPT map.

2.3.1 WUDAPT software. Referring to previous studies, the analysis in this analysis is used Level 0 of the LCZ scheme. The LCZ have a correlation with the air temperature. The districts have specific characteristics of the buildings patterns, distance, materials, green zones eth. In order to detect the LCZ first has to be created an initial group of training areas. Through a careful study of the heights of the buildings, the land use and land cover areas, the Dubai region can be classified into nine types of buildings and six land cover classes, i.e. a total of 12 LCZ classes, as shown in Table 2. The LCZ classification task is performed using SAGA software on Landsat images after the careful selection of a minimum of three samples of each class. Table 2 shows the outcome of the LCZ for the region of the Dubai City. We make use of Landsat satellite data for LCZ classification. This group is created by an expert that knows the city, such as an architect, urban planner etc., [3][4].

| LCZ 1- Compact high-rise | LCZ 2- Compact mid-rise | LCZ 3- Compact low-rise |
|--------------------------|-------------------------|-------------------------|
| ![LCZ 1- Compact high-rise](image) | ![LCZ 2- Compact mid-rise](image) | ![LCZ 3- Compact low-rise](image) |

| LCZ 4- Open high-rise | LCZ 5- Open mid-rise | LCZ 6- Open low-rise |
|-----------------------|----------------------|----------------------|
| ![LCZ 4- Open high-rise](image) | ![LCZ 5- Open mid-rise](image) | ![LCZ 6- Open low-rise](image) |

Table 2. Training LCZ of Dubai.
2.3.2  ENVI-met simulations. The 7 selected districts were built with version 4.0. The 3D shown in the table has a telescoping factor greater than 20 m. This makes the 3D images non-realistic. The walls and other surface materials were modified from the original ENVI-met template. This change was made in order to save time in the simulation. In this version of the software, the simulation runs for 24 h. The trees considered in the simulation are close to the local ones, with small leaves and low irrigation. Meanwhile, the soil underneath is irrigating soil so the CFD simulation can go through the evapotranspiration process. The pavement and asphalt have also been modified in order to have better heat fluxes. With all this modification the model is closer to the real conditions. [10-12].

3. Results
The results are shown in two sections: the WUDAPT results and the ENVI-met results.

3.1. WUDAPT results
Through a careful study of the heights of the buildings, the land use and land cover areas, the Dubai region can be classified into nine types of buildings and six land cover classes, i.e., a total of 12 LCZ classes, as shown in figure 1. The LCZ classification task is performed using SAGA software on Landsat images after the careful selection of a minimum of three samples of each class. Figure 2 shows the outcome of the LCZ for the region of the Dubai City. We make use of Landsat satellite data for LCZ classification.
3.2. **ENVI-met results**

The ENVI-met results show the different air temperatures at a height of 5 m. The results for a 24 h period were compared with the results from LST. Since a discrepancy is obvious between the simulation results and the measurements of the sensors, we use a fitting model. The model developed to fit the ENVI-met. The simulated Error RMSE $=2.73$, corrected Error RMSE $=1.32$

4. **Conclusion**

This study shows that the results of the LCZ are in alignment with the ENVI-met results. Due to this analysis the city of Dubai has a map of the LCZ therefore of the UHI phenomena. The simulations in the CFD tool are done only for one district due to the time limitation. The aim of the future work is to complete the simulation for the rest of the districts. Also this study refers to one specific season due to the limited site data. The aim is to expand the analysis in the four main seasons of the year. The tools used can be improved according to the latest versions released online.
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