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Evaluation of Applying Urban Features Design Guides Concerning their Environmental Impact Inside Residential Complexes

Binaee Yaseen Raof [1,2,*]
[1]Department of City Planning, Technical College of Engineering, Sulaimani Polytechnic University, Sulaimani – Iraq;
[2]Department of Architectural Engineering, Cihan University/Sulaimaniya, Sulaimani – Iraq;
*Corresponding author email: binaee.yaseen@spu.edu.iq, or benaee.yaseen@sulicihan.edu.krd

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Abstract –Urban population growth has affected the spread of residential buildings in many countries. The Kurdistan region of Iraq has been witnessing rapid progress in residential complex projects. The energy consumption in buildings, especially residential buildings, is immensely affected by the design of urban open spaces around these buildings. Accordingly, this has contributed to the massive increase in energy consumption. In this paper, through analyzing previous studies, the impacts of each of the urban features of open spaces (aspect ratio, orientation of street pattern, density, and spacing ratio) on both energy consumption and outdoor thermal comfort are introduced. Also, the study is to focus on the criteria of urban features of open spaces in three existing residential projects in Sulaimani city- Iraq, by considering that there is a remarkable unawareness of the influence of urban design on microclimate and energy use. Furthermore, a direct comparison between the ratios and the optimal settings of urban features of open spaces that reduce energy consumption in buildings and achieve outdoor thermal comfort for the hot-dry climate in the context of urban open spaces in residential complexes is made. The comparison shows that the aspect ratio for two selected residential projects is below the ideal urban features ratio, and at the same time, the density and spacing ratio for all the chosen residential cities is higher than the optimal urban features ratio of open spaces in hot arid climate zone and as a result, the total loads of energy increased.

Keywords: Energy Efficiency, Residential Complex, Outdoor Thermal Comfort, Spacing Ratio, Aspect Ratio, Street Orientation, Optimal Urban Features Ratio, Open Space.

Introduction

Urban design features, such as building distribution, spacing ratio, aspect ratio, street orientation, urban density, and many other factors affect the outdoor environment. and there is a strong relationship between these features with energy consumption in buildings and the thermal comfort of outdoor spaces (El Dallal & Visser, 2017).

In general terms, energy efficiency refers to using less energy to produce the same number of services or useful output (Patterson, 1996). Moreover, according to the Environmental and Energy Study Institute (EESI), energy efficiency offers a number of benefits, such as avoiding wasting energy, including reduced greenhouse gas emissions and demand for energy imports. Improving energy efficiency is often the most direct way to decrease fossil fuel consumption, and there is great potential for efficiency in all areas of the economy, including buildings, transportation, industry, and power generation.

In modern society, energy efficiency is one of the main concerns in achieving sustainability. Buildings make up the majority of the city and are responsible for most of its energy consumption and air emissions of (40%) (Peces & Ibadah, 2020). The energy of the building is not only influenced by the design of the building but also by the complex urban form that is used on a larger spatial scale. The relationship between the shape of the city and the energy efficiency of the building is attracting more and more attention these days, as the energy consumption of the building accounts for a significant proportion of the total consumption of overall energy (Quan *et al*., 2016).

Developing countries have been witnessing rapid growth in residential complexes, while the effect of urban design on microclimate and building energy efficiency is not given appropriate consideration (Sanaieian *et al*., 2014). The number of residential projects is increasing inside the chosen city without considering their effect on the environment in general and using less energy to produce thermal comfort for occupants. In the meantime, the problem is there is a lack of research to explain the effect of the urban features designs of open spaces on building energy efficiency and outdoor thermal comfort for residential projects in the city of Sulaimani. Meanwhile, no specific study explains whether the urban planning for new residential projects inside the city is in accordance with the acceptable ratio of the design of their urban features as required for energy efficiency.

The hypothesis is that there is a significant ignorance of the implementation of the optimal settings of urban features of open spaces that contribute to reducing energy consumption in buildings and achieving outdoor thermal comfort in the context of urban open spaces in residential projects.

The main aim of the present study was to investigate how and when knowledge about the climate is used in the urban planning process. This paper is attempting to overcome this gap and aims to comprehensively show if the urban features design guides concerning their environmental impact inside residential complexes in Sulaimani city-Iraq (as an example of hot climate zone) are considered during the design process of the chosen residential complexes.

Previous studies of urban microclimate have focused mainly on the impact of the physical environment on climatic parameters (air temperature, relative humidity, radiation, and wind speed) in different climates. The study of Yahia & Johansson (2013) explained the relationship between the urban planning regulations and microclimate in the hot city. Generally, most of the studies in hot-dry climates have provided new insights on how to improve the outdoor thermal environment.

Urban microclimate and outdoor thermal comfort are generally given little importance in the urban design and planning processes. Moreover, few studies have dealt with the relationship between urban planning regulations and the local microclimate. Several studies, however, indicate that the existing planning regulations in hot-dry climates are not adapted to the climate (Yahia & Johansson, 2013).

Urban areas are one of the major contributors to electricity consumption. Open spaces encompass shared active areas between the constructing envelope and urban canopy (Bahgat *et al*., 2020). The design of these areas affects the indoor and outside environment and has an essential role in determining the energy efficiency of buildings (Teller & Azar, 2001). Urban functions of open areas have huge effects on their neighborhood micro-climate, which has an influence on the energy demand of buildings and on human comfort and health in urban areas (Allegrinia *et al*., 2015).

The streets' height-to-width ratio (H/W) produces the most significant effect on the energy consumption of buildings, followed by street orientation and density of roadside vegetation (Huang & Li, 2017). Techniques for low-energy design do not include buildings only, but there are impacts of urban block form on the energy performance of buildings, and predicting thermal behavior, solar access, and ventilation on a neighborhood scale is important (Sanaieian *et al*., 2014). Moreover, there are different strategies along with the street pattern and building orientation to promote shading and natural ventilation, as well as parks between buildings to assist in passive cooling (Bahgat *et al*., 2020). However, both urban morphology and individual behavior have a significant role in reducing energy demands (Allegrinia, 2015) most of the urban design-features impact climate on the local scale; consisting of city morphology, urban structure, homes distribution, orientation, and concrete density (Bahgat *et al*., 2020). There are considerable relationships between these features and their impact on energy consumption in buildings (Sanaieian *et al*., 2014).

Urban Features of Open Spaces

Aspect Ratio

Aspect ratio and street orientation will directly influence the design choices in relation to street usage. In hot-dry weather, the increase in the height/width (H/W) ratio can moderately reduce air temperature. Furthermore, streets (H/W<1) are thermally uncomfortable for occupants and pedestrians. Building height has to be determined to provide a large aspect ratio (H/W), especially in the north-south street (Toudert & Mayer, 2006). The H/W ratio is shown in Figure 1.

The reduction of the height to width (H/W) ratio in the urban open spaces increases the quantity of solar radiation gained by the facades of surrounding buildings. High-rise buildings reduce urban heat during daylight because of their daytime shading properties. Additionally, a properly-designed city canyon, produced through an arrangement of mid-high-upward push homes, enables the reduction of the daylight hour temperature (Bahgat *et al.*, 2020).

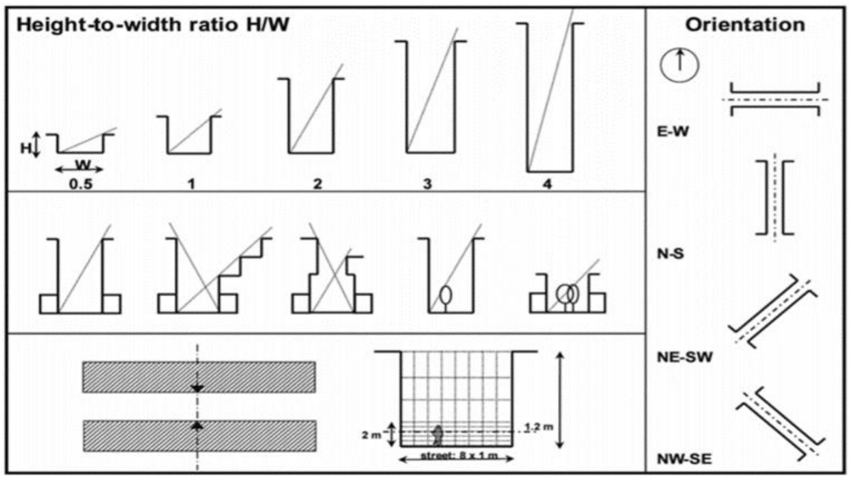

Figure 1. Scheme of the urban canyon geometries simulated by use of the ENVI-met model (Toudert & Mayer, 2006).

Deep canyons are quite comfortable and help to minimize the frontage area affected by solar radiation and cause less heat gain from outside, while shallow canyons with a H/W ratio of 0.24~0.6 are uncomfortable (Abdallah, 2015). Increasing the aspect ratio slightly reduces the cooling load and significantly increases the heating load on east-west streets). On the other hand, increasing the aspect ratio from 0.25 to 4 greatly reduces the cooling load and slightly increases the heating load on the north-south streets. Additionally, increasing the aspect ratio on north-south streets can improve the number of thermal comfort hours of the day (Muhaisen & Abed, 2014).

The orientation of street patterns

The vertical profile and orientation of the urban canyon have a decisive impact on the human thermal sensation at street level, as well as all other design details studied (Toudert & Mayer, 2006). Buildings in east/west street canyon configurations consume higher cooling energy than stand-alone buildings in the same street orientation in hot and dry climates. But, buildings in north/south road canyon configurations consume less cooling energy compared to stand-alone buildings inside the same street orientation. Generally, east/west street canyon orientation contributes to greater solar radiation received using building facades than north/south street canyon orientation (Huang & Li, 2017).

Density

The energy efficiency in residential buildings is highly dependent on their density. The high density of urban patterns (number of dwelling units (du) per floor area) increases the total loads of energy. A case of 9 du/1000 m^2 of density recorded less heat gain in summer and less heat loss in winter than 14 du/1000 m^2. It is found that compact horizontal housing configurations can perform better in terms of energy efficiency when compared to vertical ones (Asfour & Alshawaf, 2015).

Spacing Ratio

The spacing ratio (L1/L2) is measured as the ratio of the distance between adjoining buildings and the frontal length of the construction. The increase in the spacing ratio between buildings decreases the ability of shading on facades, which explains the increase in cooling demand (Bahgat *et al.*, 2019). Cases of housing with the same properties and different spacing ratios of 0.1 and 0.8 have been examined in terms of energy consumption for cooling of Mediterranean climate. It clarified that the case of 0.1 spacing ratio recorded less cooling energy than

0.8. The proportions of buildings must be determined with full knowledge of their relationship to urban morphology. It is also advisable to take advantage of the mutual vertical arrangement of the buildings to obtain shade on the roof and the facade of the building using different heights of the buildings (Muhaisen & Abed, 2014).

Materials and Methods

The climatic of Sulaimani city

The city of Sulaimani is located in Kurdistan Region in Iraq, at a latitude of 35°33'53" N and a longitude of 45°25'58" E, with an elevation above sea level of 847 m (Date and Time Info, 2020). The locality of the study area is shown in Figure 2.

Figure 2. Location map of Sulaimani city (Maphill, 2011).

The Köppen-Geiger, climate classification system classifies its climate as a hot-dry summer and cool, wet winters (Csa) zone. The city has a long hot summer with high solar radiation, low humidity with average temperatures ranging from 0 to 39°C, cold and rainy winter, and mild in spring and autumn. Figure 3 demonstrates the year-round temperatures for Sulaimani city. It shows that the maximum temperature in January is 13℃, and the maximum temperature in July is 42℃. Data was collected on the basis of the EPW (energy plus weather) file of the Sulaimani weather (Milne & Liggett, 2019).

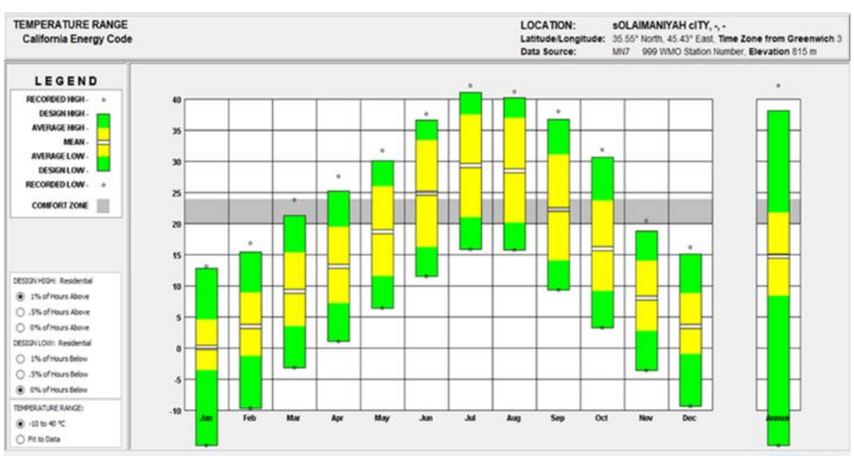

Figure 3. Sulaimani air temperature data, based on the Sulaimani weather data file reproduced by Climate consultant 6.0 software (Milne & Liggett, 2019).

Materials and Methods

The process was carried out to achieve the objective of the study, using the following methodology:

A. Chosen case studies: Case studies involve three randomly selected projects of residential complexes inside the city of Sulaimani, which are the Garden city project, Miran city project, and Darwaza city project. After collecting all the information about each project by the researcher, the data used in this study are the distance between adjoining buildings, frontal length of the construction, the height of buildings, the width of open space, and the street between buildings shown in Table 1.

B. Values of urban features of open spaces in residential complexes considered in the evaluation are aspect ratio, the orientation of street pattern, density, spacing ratio, and orientation of the street pattern. All these data are calculated through the following equations and by using the data from Table 1.

1- Aspect Ratio = Height/Width(H/W).
2- Density = number of dwellings/Floor area.
3- Spacing ratio =(L1/L2).

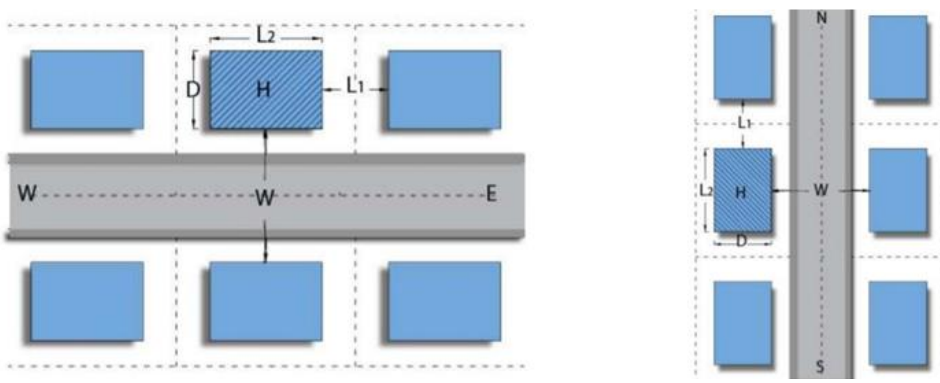

Figure 4. The form of urban block shows (L1, L2) (H and W) (Muhaisen & Abed, 2014).

Table 1. Residential projects' data that are used for calculating the features of open spaces

Projects	L1: Distance between adjoining buildings	L2: Frontal length of the construction	Heigh of buildings	Width of open space/street between buildings
Garden City	37m	28m	42m	31m
Miran	27m	22m	64m	32m
Darwaza	34m	38m	39m	93m

C. The calculated values will be compared and evaluated analytically to the optimal settings of urban features of open spaces, as shown in Table 2. The basis of the principles for each of the urban features concerning their impacts on both energy consumption and outdoor thermal comfort are analyzed.

Table 2. Optimal settings of urban features of open spaces reduce energy consumption in buildings and achieve outdoor thermal comfort (Bahgat *et al.*, 2019).

Climate zone	Aspect Ratio	Orientation of street pattern	Density (du/1000m²)	Spacing Ratio
Hot Arid	2/1	N/S	3-4	0.1

Results

Garden city Project

A residential project in Sulaimani city near Shar Hospital, with a total area (of 138,667 m²), consists of 18 blocks of multifamily housing buildings differentiated by three types of apartments. The total number of accommodations is 864 units. The land use of the Garden city is shown in Figure 5.

Figure 5. Land use map of Garden city project.

The analysis shows that the aspect ratio in Garden city is 2/1.5, but the optimal aspect ratio for the hot-dry climate is 2/1. This means that the width of a street between the buildings is higher than the ideal range. Moreover, most of the street pattern orientation inside the project is N/S, as shown in Figure 5. This phenomenon is explained in the study by Huang & Li (2017) that the buildings in this orientation consume less cooling energy and receive less solar radiation than in E/W orientation. In addition, density is 4.5 and higher than the optimal setting's ratio as defined in the literature review section that by adding the dwelling number in residential areas, the total loads of energy increased. The spacing ratio between buildings inside Garden city is nearly 1.32, as shown in Table 4. This is because of increasing the distance between adjoining buildings.

Table 3. land uses in the Garden city project with the related ratios.

Land uses	Area	Ratio
Residential	41,685m2	10%
Open Area	75,034 m2	18%
Services	158,406 m2	38%
Green Area	141,731 m2	34%
Total	416,858 m2	100%

Table 4. Analyzing urban features of open spaces inside Garden city project.

Garden city	Optimal setting	Actual	Evaluation
Aspect Ratio H/W	02-Jan	2/1.5	Under
Orientation	N/S	< 90% of street pattern is N/S	Acceptable
Density	3-4/1000m²	4.5/1000m²	Above
Spacing Ratio	0.1	1.32	Above

Miran city Project

A residential project situated in the western part of Sulaimani city at Qularaisy consists of 35 residential multifamily buildings with two different types of apartments. Each residential building has 20 floors, as shown in Figure 6. The project's total area is 416,857m², as shown in Table 5, and it is under construction.

Table 5. Land use in Miran city project with the related ratio

Land uses	Area	Ratio
Residential	66,697 m²	16%
Open Area	58,360 m²	14%
Services	154,237 m²	37%
Green Area	137,563 m²	33%
Total	416,857 m²	100%

Table 6 shows that the aspect ratio, which is the H/W ratio, inside the Miran city project is = 2/1, depending on Table 2, which is the optimal setting ratio for hot-dry climates. In addition, it is mentioned in the study of Muhaisen & Abed (2014) that aspect ratio, especially in the north-south street, influences solar radiation and affects the pedestrian thermal comfort hours. Moreover, nearly 60% of street patterns in Miran city are orientated to N/S, as shown in Figure 6.

The density in the project is (5.7/1000m²) higher than the optimal level, which means the total amount of energy consumption is increased. Furthermore, inside Miran city, the spacing ratio is 1.23, as shown in Table 6. Increasing space ratio has a negative impact on the solar potential on the building's surfaces and the mutual shading in hot-dry climates (Muhaisen & Abed, 2014).

Figure 6. Land use map of the Miran city project.

Table 6. Analyzing urban features of open spaces inside Miran city project

Miran city	Optimal setting	Actual	Evaluation
Aspect Ratio	02-Jan	02-Jan	Acceptable
Orientation	N/S	60% of the street pattern is N/S	Acceptable
Density	3-4/1000m²	5.7/1000m²	Above
Spacing Ratio	0.1	1.23	above

Darwaza City Project

This residential project is located in the southern part of Sulaimani city near the Sulaimani Governorate Building, with a total area of 132,365m². It consists of 23 residential apartments, as shown in Figure 7. The total number of accommodations is 1,050, with an area of 22,800 m² (see Table 7).

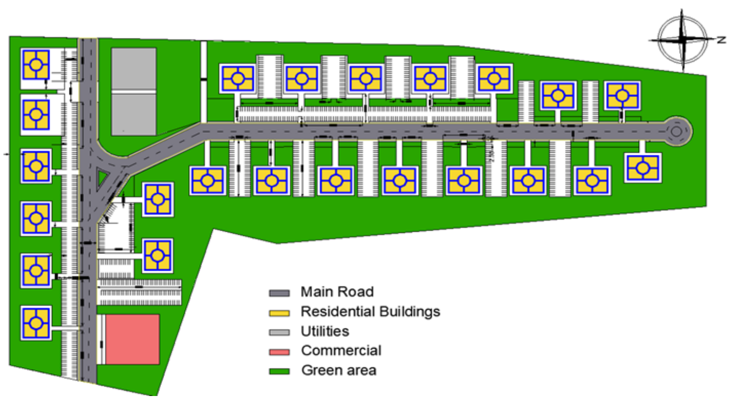

Figure 7. Land use map of the Darwaza city project.

Table 7. Land use in Darwaza city project with the related ratio

Land uses	Area	Ratio
Residential	22800 m²	17.27%
Open Area	61683 m²	46.73%
Services	20162 m²	15%
Green Area	27720 m²	21%
Total	132365 m²	100%

The aspect ratio in Darwaza city is less than the ideal rate for a hot-dry climate (Table 8), and nearly more than 70% of the buildings are orientated to N/S inside the city (Figure 7). Furthermore, the density is more than the standard level, and as a result, the total loads of energy consumption are increased. The spacing ratio between buildings in Darwaza city is nearly 0.89, as shown in Table 8. This means that the shaded area between buildings is less than the optimal setting rate (Muhaisen & Abed, 2014).

Table 8. Analyzing urban features of open spaces inside Darwaza city project

Darwaza city	Optimal setting	Actual	Evaluation
Aspect Ratio	02-Jan	2/4.7	Under
Orientation	N/S	N/S <70% of the street pattern	Acceptable
Density	3-4/1,000m²	5.6/1,000m²	Above
Spacing Ratio	0.1	0.89	Above

Discussion

The spacing between buildings and the street orientation directly relates to the solar potential on the building's surfaces and the mutual shading from the adjacent buildings in hot climate regions that significantly impact the energy efficiency of buildings.

Regarding results, the ratio of the distance between adjoining buildings and the frontal length of construction is not considered inside the chosen residential projects, and the increasing spacing ratio between buildings decreases the amount of shading on facades in hot climate zone. This affects energy consumption and outdoor thermal comfort (Bahgat *et al.*, 2019).

The relationship between aspect ratio, the orientation of street pattern, density, spacing ratio, and energy is multifaceted. Having a high level of density means that the total loads of energy consumption are increased. This is because of the shortage in the design without considering the design for energy efficiency of urban features. Moreover, the optimum orientation of the street in hot climates is north /south, and increasing the aspect ratio in those streets can reduce solar radiation and have a positive effect on outdoor thermal comfort (Toudert & Mayer, 2006).

Conclusions

The following findings were determined by investigating the urban features of open spaces of the above residential projects in Sulaimani city-Iraq; as follows, the results obtained from the calculation of urban features ratio for the mentioned projects explain that in most of the projects, the values of urban features of open spaces in residential complexes regarding energy and outdoor thermal comfort are not studied. The density of all chosen projects is higher than the optimal level of urban features. The spacing ratio for all projects is more than the optimal setting. This means that the ratio of the distance between adjoining buildings and the frontal length of construction is not considered. The aspect ratio in the Miran city project is in a satisfactory range that depends on the building height and the width of the street between buildings. Moreover, Garden city is the only project where most of the streets' orientation is directed to N/S. The values for each of the urban features of open spaces described that there is no such consideration for urban microclimate in the urban design and planning processes for choosing residential projects.

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