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Application of Siemens Index of Green Cities for Selected Areas in Iraq

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Abstract
Irregular urban design and use of traditional resources to provide energy have a major impact on people's lives and climate in the future. The goal of this paper is to determine the best place to design a sustainable city, based on the Siemens Index for Green Cities and Comfort Factor. Four sites were selected in Iraq based on the geographical location and weather variables for each site, namely Um Qasr, Baghdad, Anah and Sulaymaniyah. Weights and percentages were distributed on the categories of the Siemens index, which are renewable energy, water and air quality, in addition to the comfort factor, and then analyzed and evaluated at each site. With regard to the renewable energy category represented by solar and wind energy, the best evaluation of the energy category was found at Um Qasr by 60.88%. As for the evaluation of the water resources category, it was found that the Anah site possesses the highest percentage of available water quantities in the study sites by 85%. As for the air quality category represented by the percentage of pollutants for each site, which are CO_2, SO_2, NO_2, and Particulate Matter in the air, it was found that Sulaymaniyah site has the lowest percentage of pollutants in the study sites by 24.86%. Finally, the comfort factor category represented by the Temperature Humidity Index and Wind Chill Factor shows Sulaymaniyah's location with the highest percentage of the comfort factor value at 94%. After distributing the weights and percentages and collecting them for each site, the results showed that it was the best site for designing a sustainable city in Iraq, by 72% due to the abundance of water and renewable energy sources, in addition to high air quality.

Keywords: Air quality, Anah, Renewable energy, Siemens index, Sustainability, Water Resources.

1. Introduction
Climate change is one of the most visible examples of global environmental problems. The Intergovernmental Panel on Climate Change explored the potential causes and impacts of climate change in reports that concluded that climate change is real and driven by human activities and therefore needs to be addressed (Gray, 2007), where the sustainable cities project was developed as one of the solutions to the problems of the environment and pollution (Keeble, 1988). The most prominent challenges that Iraq faces lie in the irregular urban design, scarcity of energy, loss of a healthy environment and non-exploitation of natural resources. Therefore, the sustainable city project is considered as a source of inspiration to meet and overcome those challenges. In 2004, Anna Chiesura presented research aimed at addressing the importance of the urban nature of the wellbeing of citizens and the sustainability of the city in which they live, and confirmed the results that the experience of nature in the urban environment is a source of positive feelings and services that meet human needs (Chiesura, 2004). In 2015, El-Bana presented a research aiming at a case study of the new sustainable urban settlement from the sustainable city of Dubai through a comparative analytical study of the project chosen for the city, and a comparative study between the current design and the design after applying the recommendations of the research (El-Bana, 2015). In 2015, Brodowicz wrote a book on green urban models and the challenges facing 21st century cities. These challenges include population growth, air pollution, congestion, energy efficiency and demand for high quality of life

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(Brodowicz, 2015). In 2017, Ibrahim Hegazy and others presented research aimed atanalyzing the sustainable urban management system for Egyptian cities to develop green mechanisms for urban settlements (Hegazy et al., 2017). The aim of this paper is to design a sustainable city in Iraq using the most effective technologies, based on the Siemens Green Cities Index and the comfort factor, through which one can obtain the well-being of the population and contribute to improving the environment and reducing pollution.

2. Locations of Study areas and Data Sources

The study and application of the Siemens Index for Green Cities depend on eight major categories that fall into several sub-categories. Most of the categories are achieved by setting specific standards and controls, and the otherscan be calculated scientifically by collecting site data and analyzing it including energy, water and gases. These categories depend on their calculations on the atmospheric variables represented by all types of solar radiation, temperature, humidity, and wind speed, in addition to the available safe water quantity, gas emissions rate and other physical properties of the site. Four locations were evaluated in Iraq: Baghdad, the capital of Iraq, located in the center; Sulaymaniyah, which has a moderate climate, located in the north; Um Qasr, overlooking the Shatt al-Arab, located in the south; and Anah, which has green areas, located in the west. The sites are illustrated in Figure 1.

Figure 1. Study locations are shown on the map of Iraq.

As for the study data, the data that includes many variables for all study sites were used to estimate Renewable Energy, Water Resources, Air Quality indicator represented by Gases Emissions. Also, Comfort Index indicators represented by the Temperature Humidity Index and the Wind Chill Factor, and thus relying on them to choose the best site to design a sustainable city.

Data was for 2007-2017 time period in calculations, which is in the form of hourly data and through which the results are calculated. Renewable energy resources are important in the site classification process GHI and DNI, and the Average Ambient Temperature, as these variables are important in analyzing the potential of solar energy on site. While the mean wind speed is chosen at an altitude of 90 m and Weibull Shape Factor k for each location is analyzed for wind energy potential. Table 1 summarizes the proposed grading system, which is the most important data necessary for the study, its details and its sources:

Table 1. Classification of important data, details and sources.

Parameter	Detailed	Description	Source
Renewable Energy Resources	Global Horizontal Irradiance (GHI) kWh/m²	For Photovoltaic system technology	Photovoltaic Geographical Information System (PVGIS)
	Average daily temperature °C	Photovoltaic system technology and its impact on photovoltaic modules	POWER Data for NASA
	Direct Normal Irradiance (DNI) kWh/m²	For technology of Concentrating Solar Power. This technique only depended on direct radiation.	
	mean wind speed at 90 m Height m/s	Wind Energy Potential	(SODa)
	Weibull distribution shape parameter *k*		
Water Resources	MCM/y of sustainable resource	Drinking water, household uses, and irrigation	Iraqi Ministry of Water Resources and NASA Earth Data (Giovanni)
Air Quality	CO_2, NO_2, SO_2 and Particular Matter		NASA Earth Data (Giovanni)
Comfort Factor	Temperature Humidity Index	know the feeling of human comfort or discomfort as a result of climate and weather changes	(SODa)
	Wind Chill Factor		

The sources mentioned in the table above have been relied upon as being one of the approved sources in many published researches and papers (Carn et al., 2004).

3. Energy resources in Iraq

Energy is known to have many forms, such as thermal, photovoltaic, mechanical, electrical, chemical, and nuclear energy. These forms can be classified into two categories (Firas, 2014):

- Non-renewable energy sources: are the sources that have limited supplies, whether in the form of solid, liquid and gaseous, meaning that they are resources that can end and cannot be renewed or remanufactured within a limited time period. Examples of these sources are oil, natural gas, uranium which can be called fossil fuels.
- Renewable energy sources: are defined as the energy that comes from natural and sustainable sources, such as the sun and wind, meaning that it is renewed in a short period of time and cannot be depleted. Examples of renewable energy are solar, wind, biomass, and hydropower.

Local consumption of energy from fossil fuels is predominant in Iraq. Electricity generation is based on liquid fuel, with heavy fuel oil, crude oil, and gas oil, which accounted for 57% of electricity generation in 2010, while NG accounted for 33% and the remainder is hydroelectric energy generated from dams. The annual gross output is expected to increase from about 50 terawatt hour in 2010 to more than 200 terawatt hour in 2020, to generate energy in Iraq (Kazem and Chaichan, 2012).

4. Water resources in Iraq

Water resources in nature form the basis for the wealth on which human well-being depends and affect the perpetuation of life, the state of the population, their distribution and their standard of living. Therefore, water resources are essential in the overall development process in most parts of the world, especially Iraq.

Water resources in Iraq are in three forms: rainfall, surface water (rivers, lakes, and streams) and groundwater.

4-1. Rainfall

The rainfall is a natural source of water. In Iraq, the rain follows the Mediterranean climate. Most of the rain falls in Iraq during the winter, spring and autumn and is not present in the summer. The average annual rainfall is 154 mm, ranging from less than 100 mm and more than 60% of the country in the south, and up to 1200 mm in the northeastern part of Iraq (Ministry of Planning of Iraq, 2010). In Figure 2, a map of the annual average precipitation in Iraq over the period 1995-2009 is shown.

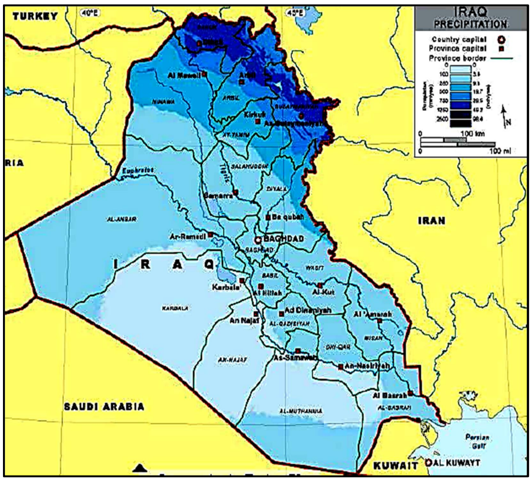

Figure 2. Precipitation in Iraq (Zakaria et al., 2013).

4-2. Surface Water

The main surface water resource in Iraq are the Tigris and Euphrates rivers. The main source of both rivers is Turkey.

4-2-1. The Tigris River

It is one of the most important water sources in Iraq that originates from the southeastern region of Turkey. This river occupies an area of approximately 103,473 km^2, most of which is in Iraq that is about 58% with a length of about 1,718 km. The river course runs through the area of Fish Khaborhi, the first region of the Iraqi lands to which the river enters, and it continues to flow south through the city of Mosul, whose emptying rate in this region is about 630 m^3/s and continues to run in the rest of the Iraqi regions until it meets a Euphrates river in Qurna District in the south Iraq (Al-Ansari and Knutsson, 2011).

4-2-2. The Euphrates River

One of the most important sources of water in Iraq, which comes from the southeastern region of Turkey, occupies an area estimated at 104,444 km^2. The Euphrates River passes through four countries, namely: Turkey, Iraq, Syria and Saudi Arabia. The total length of the river is about 2,940 km, and its length in Iraqi territory is about 1,160 km. The Hassiba region is the first region to enter the river inside the border, passing through the rest of the Iraqi regions. In the city Heet in west of Iraq, the average daily discharge of the river is about 909 m^3/s. The river also provides a number of small tributaries in the central and southern parts of Iraq and are used for irrigation. Some of its water is diverted to Habbaniyah Lake, located about 40 km south of Ramadi, during the flood period. While an alhindia dam reservoir receives drainage from the Euphrates, about 471.5 m^3/s is spread across small parallel tributaries. It meets the Tigris River when Qurna is spent, to form the Shatt al-Arab, which empties into the Persian Gulf (Al-Ansari and Knutsson, 2011). The surface runoff of the Tigris River and its tributaries is estimated at between 41.2 and 58.3 billion cubic meters per year, while the total surface runoff of the Euphrates water is estimated at between 27.0 and 35.1 billion cubic meters during one year (Kliot, 2005).

4-3. Groundwater

Groundwater is water stored in the ground, whether it is stagnant or running, and this water appears on the surface both naturally and without human intervention in the form of springs, or artificially in the form of wells. It is fed from rain water and leaks resulting from filtering and flowing of river and torrential water. Groundwater is the third source of water sources in Iraq, and its annual reserves are estimated at 6.2 billion m^3, 930 million m^3 in the Western Desert region. This water is characterized by high salinity in it in addition to the rain and snow water, which has declined and decreased significantly due to the climatic and environmental changes in the world and Iraq in particular (Shitzer and Tikuisis, 2012).

5. The Siemens Index for Green Cities

Urban areas are one of the main causes of environmental degradation, where emissions, gases, noise and congestion occur and pose a serious threat to human well-being. In recent years, concerns about environmental and urban issues have increased, and new concepts have been touched, such as a green city or a sustainable city. An important private sector initiative has emerged, the Siemens Green Cities Index (Brodowicz, 2015). The Siemens Green City Index measures nearly 30 sub-indicators, divided into 8 to 12 major categories, depending on the region. It covers energy, water, carbon dioxide emissions, air quality, buildings, transportation, land use, sanitation, waste management and environmental management. There are several types of Siemens indicators which are: US and Canada green city index, German green city index, European green city index, Asian green city index, Latin America green index, African green city index, Australia and New Zealand green city index (Siemens AG, 2012). Most of the indicators are quantitative data taken from official sources, such as per capita water consumption and carbon dioxide emissions, concentrations of air pollutants represented by fine particles and other gases, and rates of recycling of waste and water. There are also some indicators in the form of qualitative assessments of environmental policy in the region (Layla et al., 2019). For site selection in this paper, the European Green City Index was nominated for a sustainable city selection and design. This is because its standards are compatible with regional variants. This indicator contains eight main categories, each of which is divided into subcategories. The Siemens Green Cities Index can be illustrated in Figure 3.

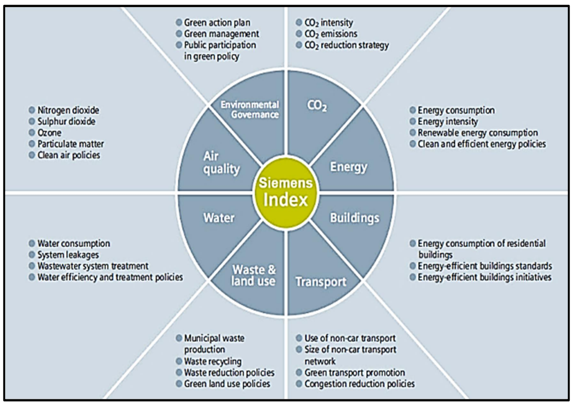

Figure 3. Siemens index for green city (Siemens AG, 2012).

6. Climate and Human Comfort

The effect of climate on human comfort is essential in choosing a sustainable city, as a person's feeling of climate change and its various elements represented by temperature, humidity, solar radiation and winds, which sometimes negatively affects human comfort. The high temperatures in the summer exacerbate the conditions of human comfort, on the other hand, very low temperatures lead to a feeling of discomfort. A number of indicators have been proposed by researchers to describe the climate as a result of changing some climatic variables and thus describe the human feeling of comfort (Stathopoulou et al., 2005). These experimental indicators depend on temperature, humidity, and wind speed (Tursilowati, 2007). This indicator can be included as an addition that enhances the Siemens Index for Green Cities in the optimal choice for a sustainable city. The most important factors and experimental indicators that are related to climate variables are:

6-1. Temperature Humidity Index (THI)

The temperature humidity index depends mainly on temperature and humidity and is used in urban areas to check the human comfort index in the region, it can be expressed by Equation (1) (Tursilowati, 2007):

$$THI = 0.8\, T_a + \frac{(RH \times T_a)}{500} \quad (1)$$

where T_a is air temperature in (^oC) and RH is Relative Humidity (%).

6-2. Wind Chill Factor (WCF)

The wind chill factor indicates the effect of wind speed on lowering the temperature of the human body, and it is known that the wind speed has an effect on the temperature change of the atmosphere. The degree of human feeling of cold varies with the speed of the wind. There is a relationship that determines the degree of cooling practiced by the wind on the human body, which depends on the temperature of the air and the speed of the wind (Shitzer and Tikuisis, 2012). The wind chill factor can be expressed by:

$$WCF = (33 - T_a)\left[\left(10\sqrt{v}\right) + (10.5 - v)\right] \quad (2)$$

7. Methodology and Assessment Site

Assessment and site location are carried out by proposing a system for distributing ratios on the Siemens Index categories and comfort factor by the authors. Emphasis has been placed on the categories of the Siemens Index, which include energy, water, CO2 and air quality, in addition to the comfort factor, which includes Temperature Humidity Index (THI) and Wind Chill Factor (WCF). The renewable energy category weighs 25%, the water resource category 25%, then both air quality and carbon dioxide 25%, while the comfort index is 25%. These percentages were determined to obtain a balance in the main important categories. After that, the sustainable city site is filtered through the highest percentage obtained by the site.

8. Selection Criteria and Grading System

The renewable energy resources of the study areas will be estimated by analyzing the data and converting the results into scores for comparison. After that, the score of the performance indicator for each site is calculated based on the ratio of the site performance indicator and thus determining the best value of the performance indicator. The way to calculate the performance degree for each site as follows:

The percentage difference between the maximum and minimum value is calculated as follows:

$$\text{Maximum value} - \text{Minimum value}/100 \quad (3)$$

As the maximum and minimum value is the highest and lowest value of the variable in Iraq, the performance indicator is calculated as follows:

$$\text{City value-Min. value/Perc. of difference} \quad (4)$$

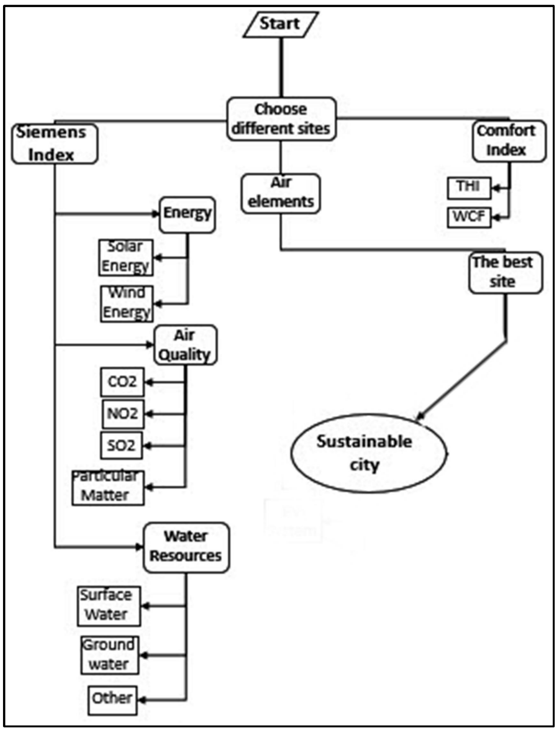

Figure 4. Sustainable City Site Assessment Methodology.

The final degree equals the sum of the product of the performance indicator value by the weight of the indicator (Alkhalidi et al., 2017). An example is assessing the energy performance of the Um Qasr site:

$$[(72*0.5)+(32.64*0.15)+(49*0.05)+(65.27*0.15)+(51.66*0.15)]=60.88 \quad (5)$$

9. Results and Discussion

9-1. Performance Indicators of Wind and Solar Energy

The renewable energy performance index obtained a percentage 25% of the overall site choice mark. This ratio is divided into Global Horizontal Irradiance and Direct Normal Irradiance. The most important solar energy potential index for any site is solar radiation. In addition to the average maximum ambient temperature due to its effects on the performance of the photovoltaic cells.

Whereas the average wind speed at an altitude of 90 m, the law of logarithmic equation was used to find the average wind speed at an altitude of 90 m by using the data available at altitudes of 10 m and 50 m. The Weibull form factor *k* was one of the most important indicators for assessing wind energy potential, in addition to relying on the wind rose to determine the direction of the prevailing wind. Table 2 shows the evaluation of renewable energy performance for the study areas for 2007-2017 data.

Table 2. Indicator of the evaluation of renewable energy performance for the study areas.

Performance Indicator		Um Qasr	Sulaymaniyah	Anah	Baghdad	Grading reference Min - Max, Avg.	Weight
Average Daily GHI	(kWh/m^{2}day)	5.6	5.07	5.4	5.32	4.88-5.89 , 5.38	50%
	(%)	72	19	52	44		
Annual Sum of DNI	(kWh/m^2)	1893	1869	1972	1798	1607-2483 , 2045	15%
	(%)	32.64	29.9	41.6	21.8		
Mean Maximum Ambient Temperature	(^{o}C)	26.15	18.21	21.15	24.04	39.4 - 13.9 , 26.7	5%
	(%)	49	17.24	29	40.56		
Average Wind Speed at 90 m Ht	(m/s)	7.2	4.92	6.7	5.52	2.5 - 9.7 , 6.1	15%
	(%)	65.27	33.61	58.3	41.94		
Weibull Shape Factor *k*	–	2.13	1.97	2.17	2.37	1.2 - 3 , 2.1	15%
	(%)	51.66	42.77	53.88	65		
Grade		60.88	26.3	50.51	43.33		100%

Um Qasr has the highest score on the Energy Index, with a total of 60.88%. It was found that the daily average of Global Horizontal Irradiance is 5.6 kWh/m^2 per day and the annual average of the total Direct Natural Irradiance is 1893 kWh/m^2, and the annual average for the ambient temperature is 26.15 ^{o}C. These values are considered high due to the geographical location of the area and the high concentration of sunlight in the area. As for the average wind speed, Um Qasr is one of the areas with the highest wind speed in Iraq, with a value of 7.1 m/s, as it is a coastal area on the Shatt al-Arab.

9-2. Water Resources Assessment

Water resources are one of the most important indicators on which to evaluate sites for choosing a sustainable city. The water index and its availability obtained 25% of the total score for site evaluation, represented by surface water, dams, safe groundwater and wastewater treatment. The most prominent results of water resources for the study areas during the period 2007-2017 are shown in Table 3.

Anah site is characterized by the highest percentage of water availability in the study areas by 85%, due to the abundance of surface water represented by the Euphrates River by 33.7% and its proximity to Haditha Dam, which provides large quantities of water. In addition to the availability of safe groundwater by 21%, which is estimated at 1019.8 mm annually, also the annual rate of precipitation reaches 697 mm, as well as the city's sewage treatment department.

9-3. Air Quality

The Air Quality Index scored 25% of the overall score for site evaluation. The annual rate of carbon dioxide, sulfur dioxide, nitrogen dioxide and particulate matter was calculated within 2007-2017, and weights were distributed among the pollutants at 25% per pollutant. The results can be illustrated in Table 4.

The highest percentage of pollutants at the Um Qasr site due to the oil wells and production processes in addition to the emissions resulting from the burning of fuel for the traditional electrical stations and the large transportation means that operate in the port of Um Qasr.

Table 3. Assessment of water resources for the study areas.

	Groundwater safe yield (%)	Dams (%)	Wastewater treatment (%)	Other (%)	Total (%)
Weight	25	25	10	40	100
Um Qasr	10	0	6.8	32	48.8
Baghdad	9.9	0	7.5	35	52.4
Sulaymaniah	11	0	4	10	25
Anah	21.2	25	5.1	33.7	85

Table 4. Air Quality Index for Study Areas.

Location	CO_2 (ppm)	NO_2 (ppm)	SO_2 (1/cm^2)	Particulate Matter (µg/m^3)	Grade (100%)
	weight				
	Grade (25%)				
Um Qasr	35	58.9	54.9	66.8	53.89
	8.75	14.72	13.72	16.7	
Baghdad	45	37.8	35.2	42.57	39.94
	11.25	9.25	8.8	10.64	
Anah	60	10.46	10.3	33.2	26.21
	15	2.61	0.3	8.3	
Sulaymaniah	45	18.6	17.6	18.3	24.86
	11.25	4.64	4.4	4.57	

9-4. Comfort Index for Climate

The comfort factor index has been added in the site evaluation to choose a sustainable city because its transactions are appropriate to the Iraqi atmosphere, where it has 25% of the total value of the site evaluation. To find the comfort factor value, the Temperature Humidity Index was calculated, which possesses an evaluation of 70% of the total rest factor, in addition to calculating the Wind Chill Factor by 30% of the total rest index value. These factors depend on the weather variables represented by temperature, relative humidity and wind speed. The distribution of weights and the final results of the comfort factor for data within the period 2007-2017 is illustrated in Table 5.

It is clear that the best value for the comfort factor in Sulaymaniyah region is that the index value is 94%, which indicates complete comfort because it is characterized by a moderate temperature for most part of the year and high relative humidity and a calm and steady wind speed.

9-5. The Sustainable City Location

The final score for the sites will be calculated to choose the best site for sustainable city design by distributing the final weights to the categories of the Siemens index and the comfort factor by 25% for each indicator, thus collecting the weights and obtaining a final score for each site. The highest score represents the best site for designing a sustainable city. The final value of the indicator results can be illustrated in Table 6. From Table 5, it is clear that the best site for designing a sustainable city is the Anah region, which has a grade of 72.31. Thus a sustainable city will be designed on this site, a photovoltaic system, a wind farm, and the distribution of residential buildings and green spaces in it.

10. Conclusions

The Siemens index for Green Cities with European standards can be applied in Iraq because most of its categories correspond to Iraqi climate conditions and changes. According to the renewable energy category, the best promising region in the study areas for the exploitation of renewable energy that is represented by solar and wind energy is Um Qasr. With regard to water resources, the highest rate of water availability in the study areas is in Anah, because it is adjacent to the Euphrates River and is also close to Haditha Dam, in addition to having a large amount of safe groundwater. With regard to the category of air quality and emission of gases, the highest pollutant emission rate at Um Qasr site is due to the well drilling operations, oil extraction and refining, in addition to emissions of electric power stations and factories that depend on their operation on fossil fuels in addition to the use of large transportation means at Um Qasr port that contribute to the emission of pollutants. The best value for the comfort factor in the study areas is located in Sulaymaniyah site, which is considered the best area for climatic comfort for people due to its moderate temperature and medium relative humidity in addition to the speed of calm winds. The final results demonstrate that the Anah site is the best site for designing a sustainable city within the criteria of the Siemens Index and the comfort factor of the study areas, as it got the highest percentage, which equals 72.31%.

Table 5. Comfort factor for the study areas.

Location	THI (%)	WCF (%)	Grade (100%)
	Weight (70%)	Weight (30%)	
Um Qasr	60	100	72
	42	30	
Baghdad	60	100	72
	42	30	
Anah	80	80	80
	56	24	
Sulaymaniah	100	80	94
	70	24	

Table 6. The degrees of choosing a sustainable city location.

Location	Renewable Energy	Water Resources	Air Quality	Comfort Factor	Total
Weight	25	25	25	25	100
Um Qasr	15.22	12.2	11.52	18	56.94
Baghdad	10.83	13.1	15.01	18	56.94
Anah	12.62	21.25	18.44	20	72.31
Sulaymaniah	6.57	6.25	18.7	23.5	55.02

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