Civil Engineering and Architecture 10(5): 2041-2053, 2022 http://www.hrpub.org
DOI: 10.13189/cea.2022.100525

Integrated Built Environment that Meets Human Needs for Thermal Comfort

Tala Mari[1], Kabila Faris Hmood[1,*], Jawdat Goussous[2]

[1]Department of Architecture, Al-Zaytoonah University of Jordan, Amman, 11733, Jordan
[2]Department of Architecture Engineering, University of Jordan, Amman, 11942, Jordan

Received April 30, 2022; Revised June 10, 2022; Accepted July 11, 2022

Cite This Paper in the Following Citation Styles

(a): *[1] Tala Mari, Kabila Faris Hmood, Jawdat Goussous , "Integrated Built Environment that Meets Human Needs for Thermal Comfort," Civil Engineering and Architecture, Vol. 10, No. 5, pp. 2041-2053, 2022. DOI: 10.13189/cea.2022.100525.*

(b): *Tala Mari, Kabila Faris Hmood, Jawdat Goussous (2022). Integrated Built Environment that Meets Human Needs for Thermal Comfort. Civil Engineering and Architecture, 10(5), 2041-2053. DOI: 10.13189/cea.2022.100525.*

Abstract This research aims to find principles that achieve an integrated architectural environment in the desert environment that meets human needs and preserves the rights of future generations. Studying and analyzing the successful solutions and treatments provided by the traditional architectural environment in a desert environment and in a hot, dry climate help achieve this aim. Nowadays, we find a growing research interest in sustainability. This research paper concentrated on the relationship of the desert environment with the built environment to achieve an integrated environment to meet human needs, ration energy consumption and preserve the identity of the architecture. This research studies traditional architecture in a desert environment to identify appropriate solutions to the climatic environment and its ability to harmonize and respond to its climatic environment, with its high capacity to respond to human needs in these communities. The research adopted the analytical descriptive approach in its study of the relationship of the desert climatic environment with the built architectural environment. The Climate Consultant software is used for this research to recommend various design strategies suitable for each climate. The three central climates analyzed in this study are coastal desert areas, moderate desert areas, and hot, dry desert environments. In conclusion, this research found that in the past, the traditional environment has provided and continues to provide effective climatic solutions.

Keywords Traditional Architecture, Thermal Comfort, Built Environment, Sustainability, Psychometric Chart

1. Introduction

Sustainability concept: Sustainability is a balancing act. The United Nation’s 1987 report of the World Commission on Environment and Development, “Our Common Future,” noted that sustainable development meets the needs of the present without compromising the well-being of future generations. Therefore, the efficient use of natural and renewable resources without harming nature or affecting the environment imposes the importance of changing how we live and build to respect the environment. In the past, when the building envelope was the main element, man used it to protect himself from a harsh climate; it depended on passive energy and natural resources, such as the sun, wind, and earth. Passive energy involves using natural energy sources for environmental, health, and economic reasons in our buildings. Traditional architecture in the Arab world forms a living witness for the suitability of this architecture within the local environment, which incorporates the essence of sustainable architecture [1]. Traditional architecture is a characteristic and identity of an area, so it must be preserved and become a lesson for contemporary building design [2]. Traditional cultures embody ideas and principles on which sustainable living is based. They claim that sustainable living satisfies our needs today without diminishing the prospect of future generations doing the same. Today, increasingly, more architects and residents are applying these methods in the

Arab world and different areas around the world where a similar climate exists. The rarity of energy resources nowadays forces researchers and architects to return to their roots, understand what the future should look like, and benefit from hundreds of years of experience [3].

2. Climatic and Built Environment

The relationship between humans and their environment is continuous. Environment means everything that surrounds humans, such as nature, human societies, social systems, and personal relationships; these relationships are believed to be behind human life and its activity. Every urban and architectural act affects and is affected by the environment because architecture is a human-made construct that interacts with the natural environment. Architects and designers in all design and planning decisions must consider this.

There are five climatic regions in the Arab world: the desert climate region, semi-desert climate region (semi-dry), tropical climate region, seasonal climate region, and the Mediterranean climate region (Figure 1). What are the characteristics of a desert climate? First, there are high temperatures in summer and a significant degree of heat (more than 50°C in summer), while in winter, it drops below 0°C in some desert areas.

The dry desert region has little rain with cyclonic rains, where it sometimes rains from an hour to several hours with torrents, while—and especially in the major desert—it can go through a whole year without one millimeter of rain. Therefore, it is probable that some areas of the major deserts go without rain for several years [4].

Deserts are areas with severe solar radiation, sandstorms, water scarcity, and low relative humidity during daylight hours, but the air temperature sharply decreases at night. Such effects and others make the climate a critical natural component in the built environment, along with all the natural environmental and cultural elements. Therefore, the housing of Al-Tuareg in Africa does not have stable building materials due to climatic conditions and the nature of their tribal life, so the portable tent made with local materials which provide shade was their non-permanent urban style [5]. Based on climatic considerations, it is found that the wide windows and the broad streets are the main features of cities in cold regions. In hot tropical regions, the primary climatic consideration is to reduce the direct sunlight that reaches into homes and buildings.

Elements of the natural environment directly impact architecture and planning, so they are a suitable basis for the designer and architect. At the same time, they try to extend the bonds of communication between the past and the future. It shows that the traditional architecture reflects the ideal human response towards the environment, particularly the climatic environment.

In hot, dry climate areas, we use buildings, which are surrounded by high walls, with a large thermal capacity, which prevents the day heat from entering and use protective construction of the bright light, besides a large amount of heat and light reflected by the ground surface in these areas.

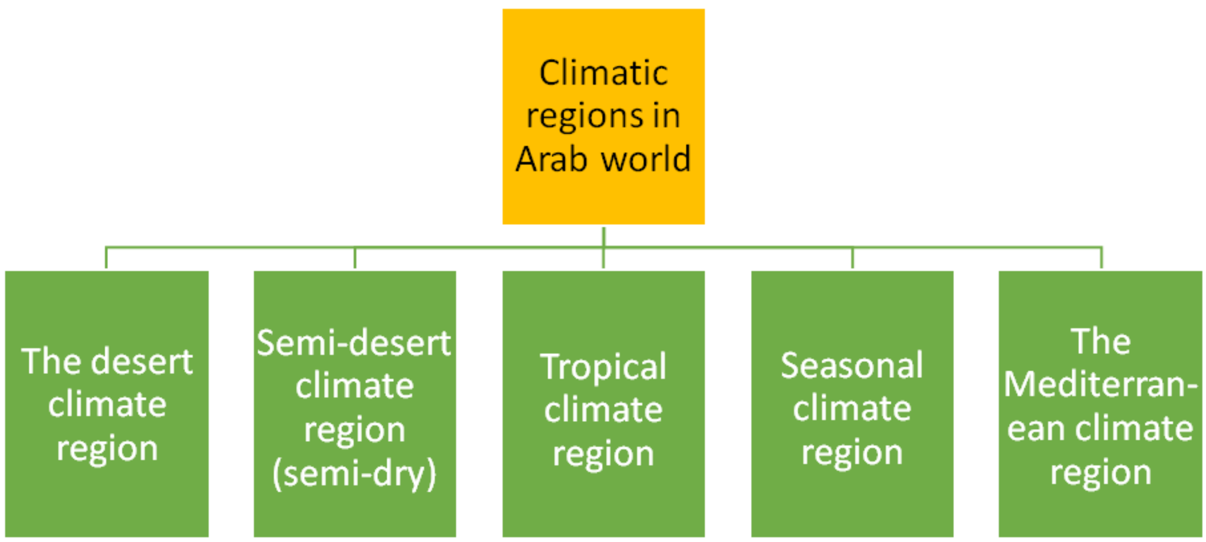

Figure 1. Climatic regions in the Arab world (authors)

3. Human Adaptation to Nature in Traditional Architecture: Passive Solutions

All references agree that we should aim for human adaptation to nature, and this adaptation is evident in traditional houses, primarily through the following aspects:

3.1. Buildings Materials

Architectural forms are often produced by local natural materials (mud, brick, stone, etc.) because of their ability to keep out the night cold and avoid the day heat, so the walls, surfaces, and the rest of the structural elements achieve efficient thermal resisting [6]. In Abu Dhabi, for example, the old housing was designed and built with local materials suitable for the hot climate. Some of those houses were made with palm fronds and others of coral with a weak thermal conductivity. In addition, the traditional mud houses in the hot and dry environment of Hadramout valley (Wadi Hadhramaut) were one mass with their courtyard. They were detached through the use of urban fabric and punctuated by narrow shady roads, as in Shibam in Yemen. This leads to minimizing exposure of external surfaces to the sun. Also, they are finished with a highly reflective material (norah) compared to other materials.

In addition to the self-thermal efficiency of the house mass and form, the mud house experiences a wide variation between day and night through the heavy mass of the walls, thermally insulated ceilings (thermal insulation), and thermal storage (thermal storage). While it absorbs direct solar energy with direct rays, it does not allow heat to pass inside the home by storing heat surplus during the day and releasing it to the skies at night [7].

The mud house exists in other Arab cities and not only in Yemen. For example, in Najd, in Saudi Arabia, houses are built of clay mixed with straw and water dried in the sun, with walls thicknesses of 60 cm to provide sufficient thermal insulation for external heat.

Using mud in construction is an excellent example of adaptation to the environment due to the advantage of its low heat conductivity. Another example is the use of limestone, widely available in the region, in the foundations of some houses to protect them from rainwater effects, with ornaments on the roof corners [8]. The use of a traditional mud house with wooden slats in the wall for structural purposes, in a way, conforms to the Islamic principle of encouraging the use of indigenous (local) materials for sustainable living. In 1945, the Egyptian Authority of Antiquities hired local architect Hassan Fathy to build New Gourna Village near Luxor in Upper Egypt. Fathy built houses with central courtyards and rooms oriented according to the sun's position in different seasons to be cool in summer and warm in winter. He also used wind catchers to enhance the courtyard's thermal and ventilation roles. Moreover, Fathy covered the spaces with vaulted roofs with small openings to direct and cool the prevailing winds. Most importantly, bricks made of sun-dried mud mixed with straw were used to construct the buildings of the entire village [3] (Figure 2).

In traditional architecture, the building material plays a distinct role in avoiding the undesirable local climate characteristics without the need to adopt technical means, which require high-energy consumption and high costs, as well as alienation in the architectural character of the buildings and the contemporary city.

(Libya)(2008) (Yemen)(2000) (Libya)(2008)

Figure 2. Organic traditional urban fabric and mud house (authors)

3.2. Openings in the Walls

A reaction to the impact of the dry desert climate can be represented in the form of thick walls made from local materials with thermal insulation, reducing openings and narrowing their area. The interior is visually protected, in addition to providing protection from the sun, usually by using wooden “mashrabiya,” “shanasheel,” or “alrawachine,” (projected wooden screened elements (Figure 3) which prevent heat entry [6]. In addition, they helped create airflow, which is necessary to modify the hot, dry climate inside the house, provide shade and help hot air rise to create air movement. They maintained the privacy of the interior spaces from being visually intruded upon by opposite dwellings [3]. The openings are narrow and high and are located on the ground floor or nonexistent on the first floor, as seen in the traditional house in Baghdad (Baghdadi).

3.3. The Malqaf and the Basement

The “malqaf” (Albadkir or Baragil), which receives air from its source, is located in the northwest. It channels it to the inside of the building to avoid any lack in the building’s orientation. The air circulation inside any building is one of the most critical factors in achieving thermal comfort. Thermal comfort plays a very strategic role in building design because most or about 80% of the time, people's activities are indoors [9]. Ventilation considerations are prioritized in the building’s design and urban planning in the hot, dry climate. The malqaf—either one-way or multi-directional—is used with the yard to complete the air circulation. Domes and vaults also contribute to the ventilation process by openings at the top to replace hot air with cold air. Domes in areas with dust and sand are used to pull air from the yard instead of using the malqaf [10]. In the traditional house of Baghdad (Al-Baghdadi), a basement with thick walls and a low floor level is a comfortable space to spend hours and long summer days. Ventilation of the basement is done with small side openings at the floor level of the courtyard and with “Albadkir” (the malqaf) (Figure 4), which is toward the northwest. Air over water in a clay pot facing the wind enters the malqaf and directs air toward the house’s spaces. This contributes to moisturizing the basement’s dry air, which comes from the roof through the malqaf.

Aleppo, 2005 Baghdad, 2002 Baghdad, 1997

Figure 3. Al-Mashrabiya, in traditional houses – Aleppo and Baghdad (authors)

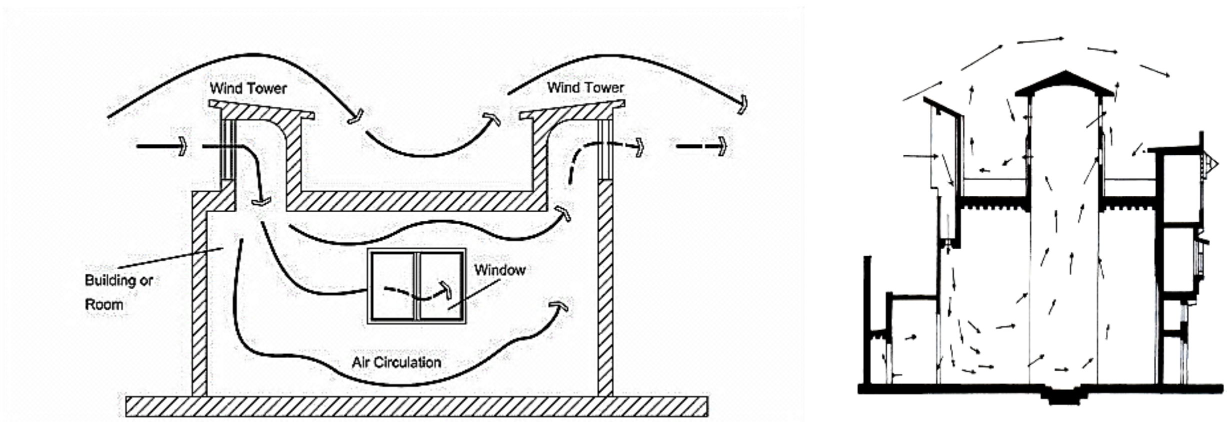

Figure 4. Part A and Part B. The malqaf is a crucial element in the traditional house. [12] [13]

The design strategy of the traditional house in Ibrid is to optimize natural ventilation and lighting systems to reduce energy consumption and use a central courtyard in the building to circulate fresh air throughout the house [11].

The adaptation of the traditional Arabic house to the dry, hot desert climate used local materials to build the thick walls of the house spaces, which are inward-looking. The lack of openings, which are small-sized and protected by "mashrabiya" that stand out from the first floor, contribute to the creation of houses in which individuals feel comfortable with the suitable thermal comfort needed. There are efficient processors for specific materials to stop heat reflectivity and rough textures and light colors for the external walls help achieve attenuation of sunlight and high temperatures. Therefore, design principles, construction techniques, and sustainability values of traditional architecture can be used as guidelines for future design and construction.

4. Materials and Methods; Discussion and Results

The research adopted the analytical descriptive approach in its study of the relationship of the desert climatic environment with the urban environment and its relation to the built architectural environment. The Climate Consultant software was used for this research to recommend various design strategies suitable for each climate. The central climates analyzed in this study are coastal desert areas, moderate desert areas, and hot, dry desert environments.

4.1. Methodology

The Psychrometric Chart in the Climate Consultant software was used to present the best-fit passive strategies for each climate discussed above to achieve the objectives. This was determined using a psychrometric diagram to illustrate the strategies for bioclimatic design based on actual and simulated climatic data with reference to the ASHRAE 55 standard [14]. Thermal comfort is based on dry bulb temperature, clothing level (clo), metabolic activity (met), air velocity, humidity, and mean radiant temperature and can significantly be improved with the application of passive design solutions [15]. Indoors, it is assumed that the mean radiant temperature is close to dry bulb temperature. The zone in which most people are comfortable is calculated using the PMV (Predicted Mean Vote) model. In residential settings, people adapt their clothing to match the season, feel comfortable in higher air velocities, and have a wider comfort range than in buildings with centralized HVAC systems [16].

First, Climate Consultant has identified design strategies for the three different climate regions. These regions are hot, dry desert (Cairo), moderate desert (Tehran), and coastal desert (Alexandria). The software outlines the values for subvariables based on a climatic analysis of the three climate regions. Then, the most adequate design strategies are identified through a certain percentage zone on a psychrometric chart for the three climatic regions. These charts are established according to indoor occupant comfort levels, thus providing us with the best practice design strategies for each zone for all months of the year.

Climate parameters that affect indoor occupant comfort levels are dry bulb temperature, Dew point temperature, and relative humidity. The graphs below demonstrate the difference in those parameters in each of the three chosen climate regions (Cairo, Tehran, and Alexandria). Figures 5-6-7 & Tables 1-2-3 compare all three climatic regions based on climate parameters.

This section discusses apartment building design, its components, its spaces, and the relationships between them, which were responsive and harmonious with the climatic environment. We will also discuss the traditional house, which expressed the cultural and natural environment and was responsive to the needs of the individual, society, and the natural and human conditions.

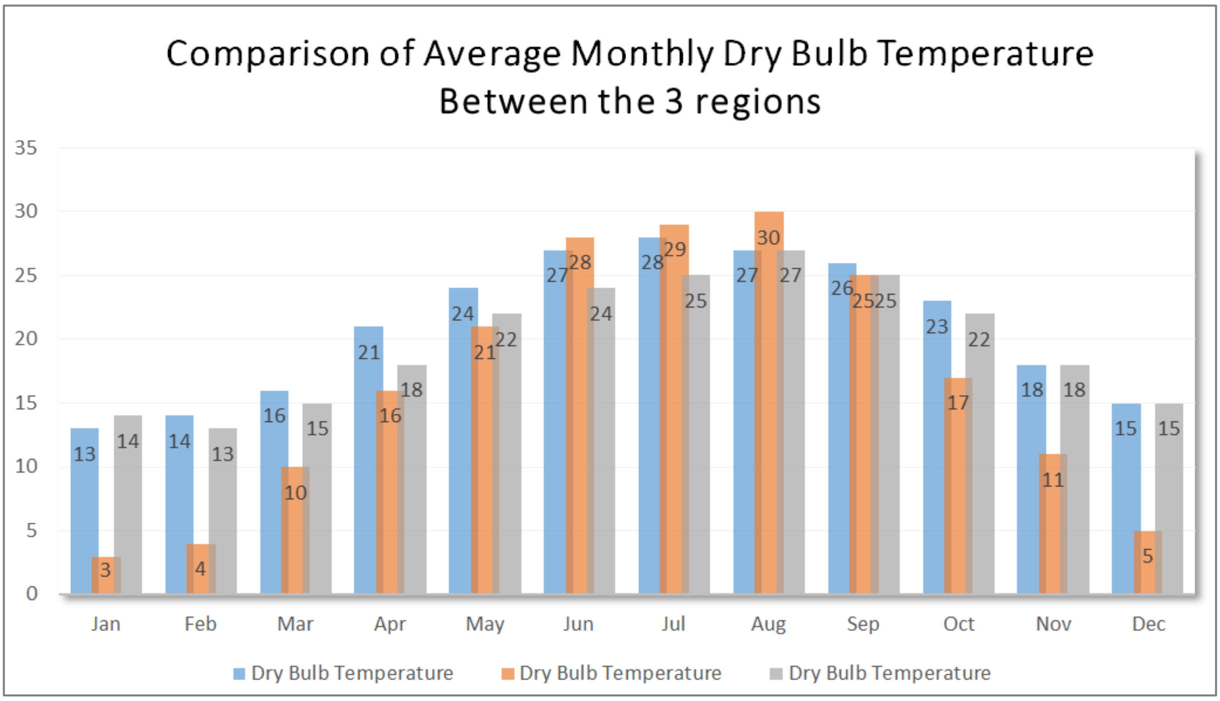

Figure 5. Comparison of average monthly dry bulb temperature between the 3 regions

Table 1. Comparison of average monthly dry bulb temperature between the 3 regions

Months	Cairo (hot, dry desert)	Tehran (moderate desert)	Alexandria (coastal desert)
January	13	3	14
February	14	4	13
Mars	16	10	15
April	21	16	18
May	24	21	22
June	27	28	24
July	28	29	25
August	27	30	27
September	26	25	25
October	23	17	22
November	18	11	18
December	15	5	15

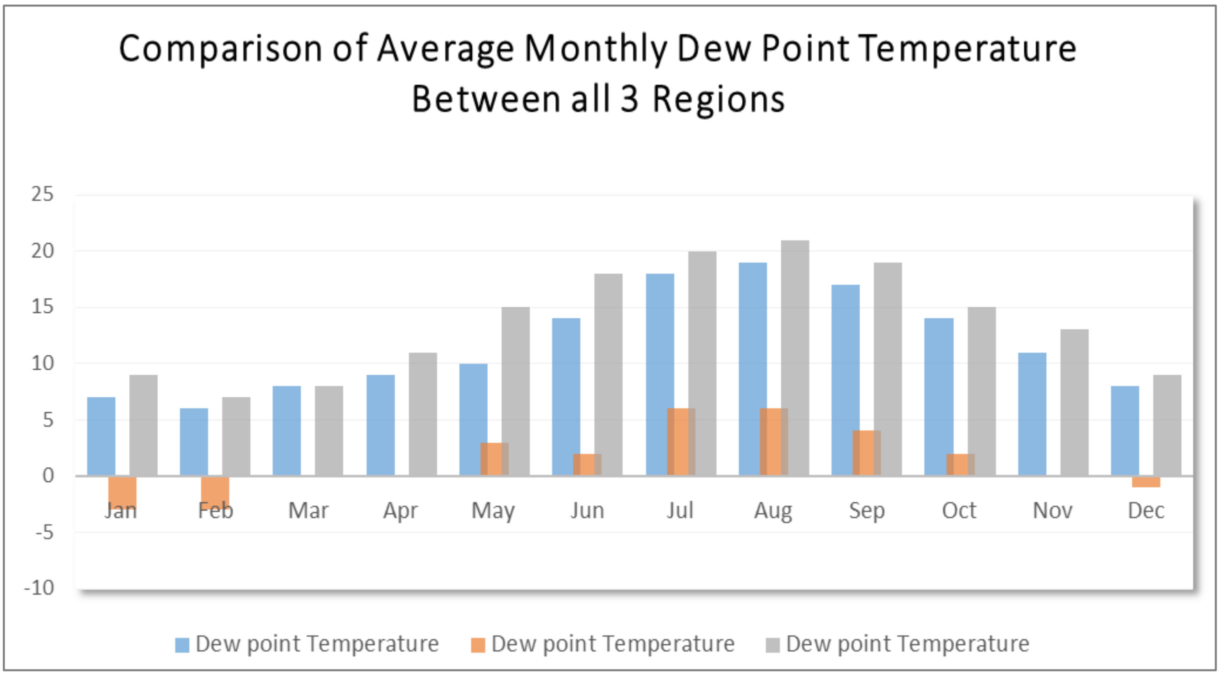

Figure 6. Comparison of the average monthly dew point temperature between the 3 regions

Table 2. Comparison of the average monthly dew point temperature between the 3 regions

Months	Cairo (hot, dry desert)	Tehran (moderate desert)	Alexandria (coastal desert)
January	7	-3	9
February	6	-3	7
Mars	8	0	8
April	9	0	11
May	10	3	15
June	14	2	18
July	18	6	20
August	19	6	21
September	17	4	19
October	14	2	15
November	11	0	13
December	8	-1	9

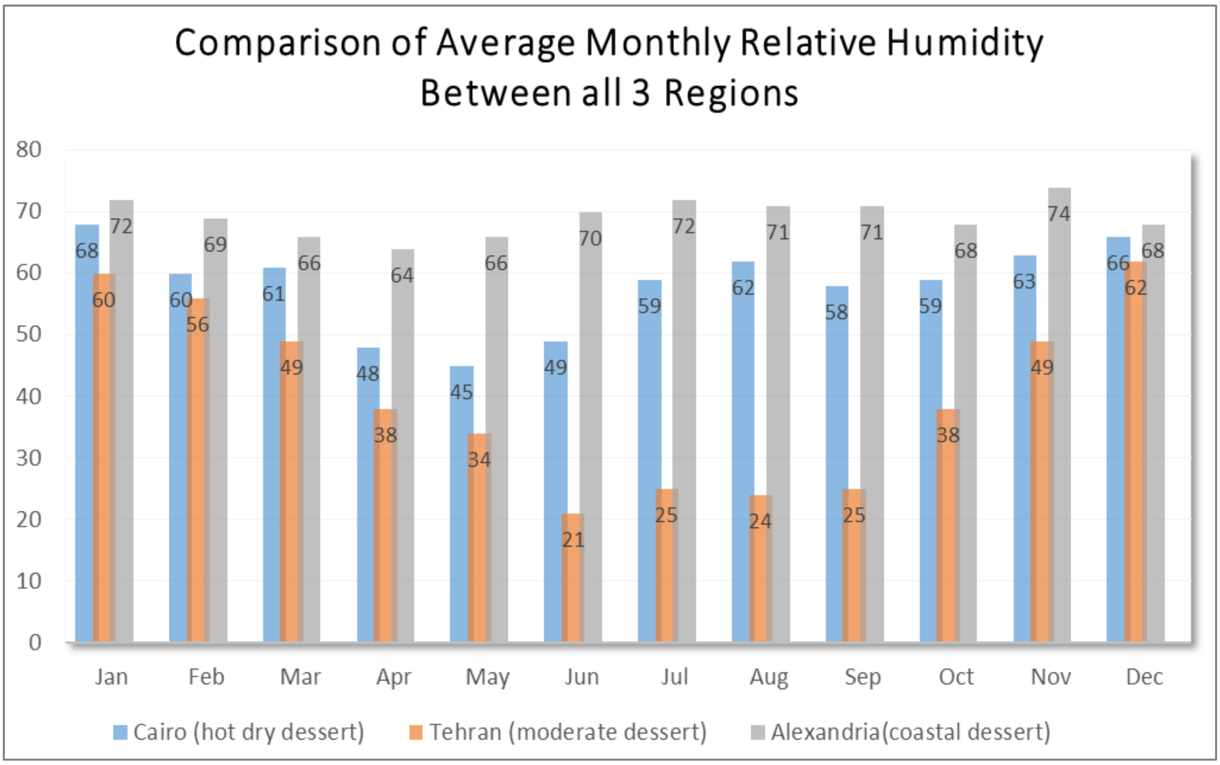

Figure 7. Comparison of the average humidity between the 3 regions

Table 3. Comparison of the average monthly humidity between the 3 regions

Months	Cairo (hot, dry desert)	Tehran (moderate desert)	Alexandria (coastal desert)
January	68	60	72
February	60	56	69
Mars	61	49	66
April	48	38	64
May	45	34	66
June	49	21	70
July	59	25	72
August	62	24	71
September	58	25	71
October	59	38	68
November	63	49	74
December	66	62	68

Housing in general, although it represents a variable manifestation, is linked to the nature of the regions and the cultural heritage of the population. Also, climate affects the morphology of residential buildings in several aspects, summarized as the design and orientation of the building, the spacing between the buildings, the openings, the walls, the floors, and the roofs. For example, in the coastal desert areas (Figure 8), buildings must be oriented on an east-west axis so that their long elevations face the north and south. However, it is possible to change the orientation of the buildings slightly to face the prevailing calm air (breeze) or to allow limited solar heating in the cold season.

Buildings must be spaced, so they can be punctuated by a breeze, but with protection from the cold wind or hot dust. Moreover, rooms, windows, and openings must be oriented in two directions (the north and the south) to ensure the continuous movement of air and ventilation. The openings must be 40-80% of the overall area of the northern and southern walls. The use of glass in these openings is not necessary but must be placed to achieve movement of air through the space of the room at the level of the human body. In addition, it is best to avoid direct sunlight throughout the year. The structures of the walls and floors are lightweight, the external walls have light-colored surfaces, and the roof is lightly and thermally insulated [17].

Figure 8 for Alexandria's coastal desert climate shows that sun shading, high thermal mass with night flush, natural ventilation, passive direct heat gain from high thermal mass, and dehumidification are the most effective strategies. In moderate desert areas, which are affected by Mediterranean winds (Figure 9), for example, it is recommended that buildings are designed with small courtyards close to each other, with small openings that are approximately 10-20% of the wall area. In addition, the structure of the walls and floors must be heavy and light-colored for large-mass external roofs.

The buildings in hot, dry desert areas are best designed with a 5-10% window-to-wall ratio to avoid direct sunlight all year round. In addition, their internal and external walls should be light-colored, and heavy structures for the floors and large masses for the ceilings are needed.

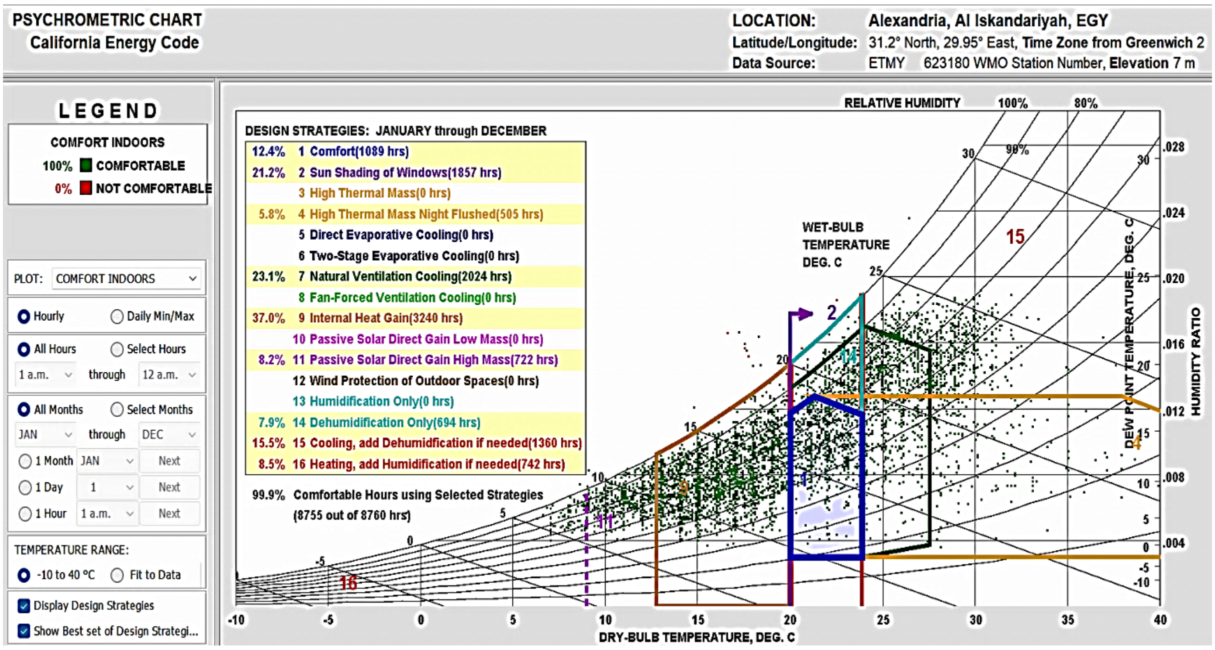

Figure 8. Psychometric chart for Alexandria obtained using Climate Consultant

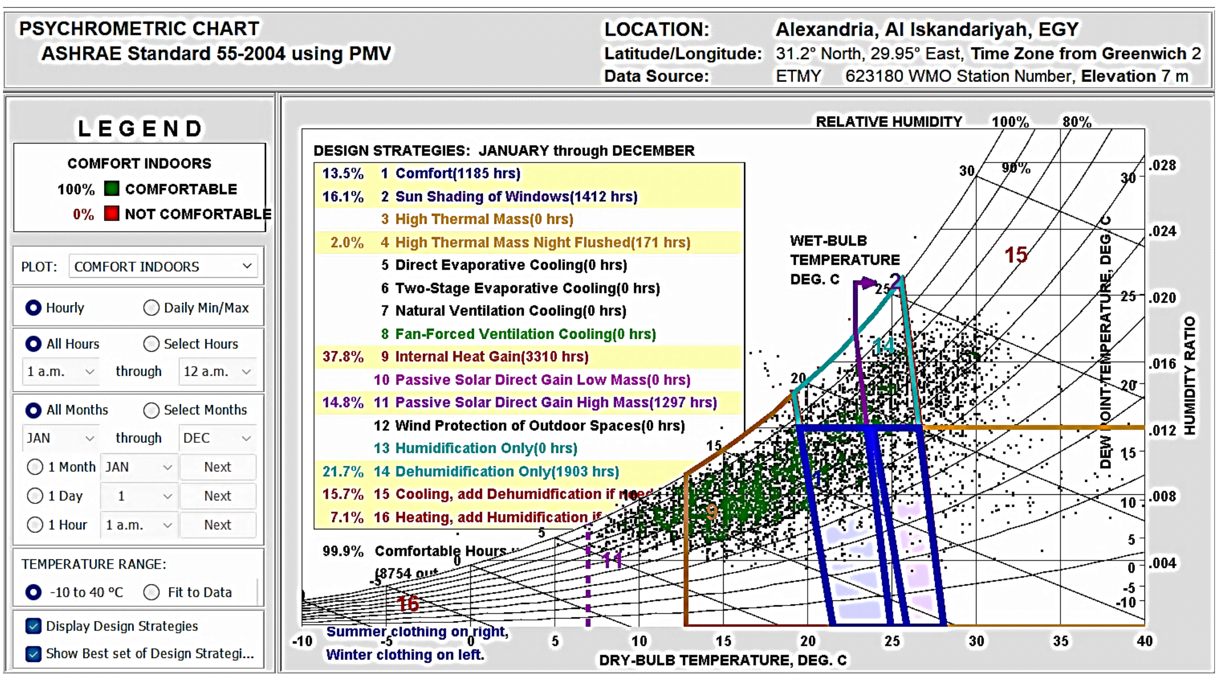

Figure 9. Psychrometric chart for Tehran obtained using Climate Consultant

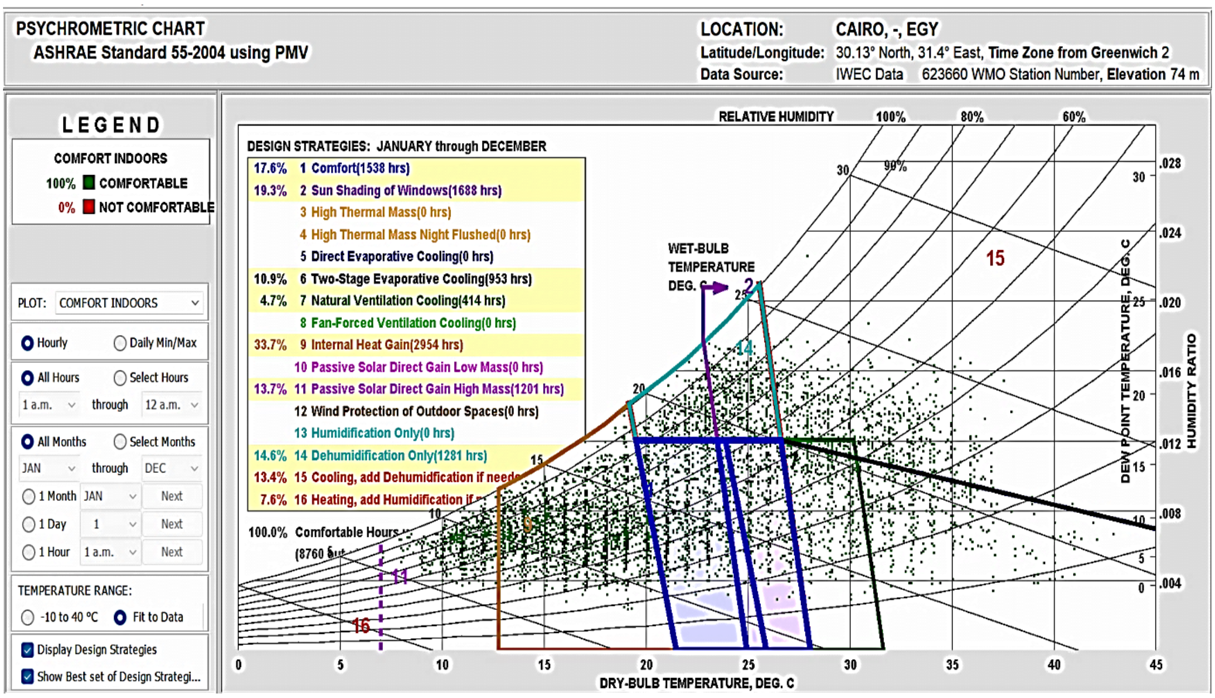

Figure 10. Psychrometric chart for Cairo obtained using Climate Consultant

The chart in Figure 9 shows the moderate climate of Tehran, with sun shading, evaporative cooling, passive solar direct heat gain from high thermal mass, and some wind protection as the most effective.

As for Cairo's hot, dry desert environment, the buildings' window-to-wall ratio is between 5-10%. Direct sunlight should be excluded year-round, and internal and external walls (light color), a heavy structure for the floors, and a large mass for the roof will be most effective (Figure 10).

Therefore, it was found that a hot, dry desert environment formed urban and architectural responsive patterns, which differ somehow in these coastal environments or with moderate temperatures. However, it generally develops distinct and adapted patterns. (Table 4)

4.2. Discussion and Analysis of the Method: The Results

This section presents a discussion and analysis based on the comparative analysis of percentages assigned to the strategies in the psychrometric charts for the three identified climatic regions based on the following climate data: dry bulb temperature, dew point temperature, and relative humidity [18]. The psychrometric chart from the Climate Consultant software is the graphic tool used to analyze the best appropriate design strategies for achieving thermal comfort for each climate zone. The dots on the chart signify the temperature and humidity of the 8,760 hours per year according to the ASHRAE 55 Standard [14]. Different design strategies are represented by specific zones on this chart during this study. The best set of design strategies was selected on the psychrometric chart to show which methods have the most significant impact in achieving a high level of thermal comfort. Although there are sixteen design strategies, not all strategies must be applied, and some tend to overlap. Therefore, one strategy can be used rather than another. Selection of the least number of design strategies that will still provide good thermal comfort is recommended to make climate-responsive buildings economical. The charts below display a suitable set of building design strategies for each climate region—Cairo, Tehran, and Alexandria—over a year. The blue area represents the thermal comfort zone of the occupant.

According to the ASHRAE Standard 55 comfort model from Climate Consultant software with Energy Plus climate data, the psychrometric chart analyzed different climate attributes for Cairo, Tehran, and Alexandria. It proposes the best design strategies for achieving 100% (8,760) comfortable hours for each region. For Cairo's hot, dry desert climate, sun shading, evaporative cooling, natural ventilation, passive solar direct heat gain from high thermal mass, and dehumidification are the most effective strategies. The effectiveness percentage of each method is summarized in Table 5.

Table 4. Buildings in coastal desert areas, moderate desert areas, and hot, dry desert environments (by author)

	Coastal Desert	Moderate Desert	Hot, Dry Desert
Building Orientation	Buildings must be oriented on an east-west axis, so their long elevations face north and south. However, it is possible to change the orientation of the buildings slightly to face the prevailing calm air (breeze) or allow limited solar heating in the cold season.	Buildings are to be designed with a small courtyard close to each other.	Buildings are to be designed with a small courtyard close to each other.
Windows and Openings	Openings are to be oriented north and south to ensure the continuous movement of air and ventilation. Window-to-wall ratio is suggested to range between 40%-80%. Using glass for all these openings is not necessary but must be placed to achieve air movement through the room at the level of the human body. Direct sunlight should be avoided throughout the year.	Openings should be 10%-20% of the wall area.	Openings should be 5%-10% of the wall area. Direct sunlight should be avoided all year round.
Walls, Roof, and Floors	High thermal mass and light-colored surfaces should be used for exterior walls. Roofs should be thermally insulated with special care.	High thermal mass and light-colored surfaces should also be used for exterior walls with high thermal mass for the floors and roof.	High thermal mass and light-colored surfaces should be used for interior and exterior walls. High thermal mass should be used for the floors and roof as well.

Table 5. Effective percentages of the strategies

Strategy	Percentage Effectiveness		
	Hot, Dry (Cairo)	**Moderate Desert (Tehran)**	**Coastal Desert (Alexandria)**
Sun shading	19.3%	15.1%	21.2%
Natural ventilation	4.7%	/	23.1%
Evaporative cooling	10.9%	21.6%	/
Passive solar direct gain using high thermal mass	13.7%	14.1%	8.2%
Dehumidification	7.9%	/	14.6%
High thermal mass with night flush	/	/	5.8%
Wind protection for outdoor space	/	0.5%	/

5. Conclusions

Traditional architecture devised creative solutions in cities, public buildings, and private houses; it has been able to find unique solutions to deal with the desert environment, especially in hot, dry regions. As a result, our contemporary architectural styles are affected by our fundamental traditional concepts to achieve comprehensive architectural works that respond to the cultural and natural environment, especially climatic ones. Returning to the available local materials that have achieved and continued to achieve remarkable climatic solutions help today to ration energy consumption and reduce the use of technical means that have swept our contemporary life and polluted cities aesthetically, visually, and environmentally. In addition, many treatments have achieved a comfortable architectural environment. They are suitable for the desert using scientific rules in calculating suitable openings for the environment, their distribution in the facades, and methods of protection against the effects of climate (Mashrabiya), which also helps achieve the aesthetic for buildings.

Table 6. Conclusion morphology of the buildings affected by the climatic environment

Type	The design and orientation of the building (Natural ventilation/ passive heating)	The openings (Natural ventilation)	The walls and the floors (Passive solar direct gain using high thermal mass/ High thermal mass with night flush)	The roofs (Passive solar direct gain using high thermal mass/High thermal mass with night flush)
Coastal desert areas	Orientation: east-west axis.	Openings: oriented in two directions (north and south) 40-80% of the overall area	Wall structure: lightweight, and the external walls have light-colored surfaces	Roof: thermally insulated.
Moderate desert areas	Courtyards: small	Openings: should be very small; their size should be approximately 10-20% of the wall area	Wall structure: heavy and light-colored. Floors must be heavy and light-colored.	Roof: high thermal mass.
Hot, dry desert environment	Courtyards: small rectangle (geometric proportions are more affected than orientation)	Openings: 5-10% of the wall area. Direct sunlight: excluded year-round	Wall structure: internal and external walls (light color), Floor: structure for the floors	Roof: high thermal mass.

As shown in Table 6, to create modern forms according to the ideas derived from the past—yet contemporary in their traits—we can achieve the inward-looking concept in a contemporary style when we succeed in achieving its distinctive role in mitigating the climate. We can also reduce the heat entering the building by dealing well with the spaces' form, the thickness of the walls, the area of the openings and their orientation, etc. In that and more, we find that climate as an environmental hardly changed element. On the other hand, it is the common denominator that helps us achieve contemporary architecture continuous with its past in historical continuity and integrated with other affecting factors in urbanism and architecture formation. This research and analytic study found a suitable set of building design strategies appropriate for a coastal desert climate, moderate desert climate, and hot, dry desert climate. Moreover, traditional architecture contains sustainability values that are beneficial to contemporary buildings today and in the future.

REFERENCES

[1] Al-Zubaid Maha, Sabah Salman, "The sustainability potential of traditional architecture in the Arab world - with reference to domestic buildings in the UAE." Doctoral thesis, University of Huddersfield, 2007, p.1.

[2] Mustamin Rahim, Maulana Ibrahim, Firdawati Marasabessy, "Construction System and Environment Adaptation of Traditional Architecture in Moluccas Island," Civil Engineering and Architecture, Vol. 9, No. 5, pp. 1530 - 1545, 2021. DOI: 10.13189/cea.2021.090524.

[3] Mortada, Hisham, "Traditional Islamic Principles of Built Environment," London & New York: Routledge Curzon, 2003, p.157.

[4] Al-Hiti, Sabri Faris, and Abu Sammor Hassan, "Geography of the Arab world," Amman: Dar Al-Saffaa for Publishing and Distribution, 1999, pp. 67-70.

[5] Abdul Jalil, Mohamed Medhat Gaber, "Traditional Urbanism in the United Arab Emirates," Al-Ain: Zayed Centre for Heritage and History, 2000, p.18.

[6] Khan, Fazlur R, "Toward an architecture in the spirit of Islam;" proceedings of Seminar One in the series "Architectural Transformations in the Islamic World," 1990, p. 35.

[7] Shaaban, Awni Kamel, "The mutual influence of the mud architecture with the climate environment in Wadi Hadhramaut" The first scientific conference; mud architecture at the gate of the twenty-first century; Hadramout University of Science and Technology, Centre for mud Architecture, 2000, pp. 149-152.

[8] Bahammam, Ali bin Salim bin Omar, "Urban and architectural characteristics of the traditional houses in the Kingdom of Saudi Arabi," the first scientific conference, mud architecture at the gate of the twenty-first century; Hadramout University of Science and Technology, Center for mud Architecture, 2000, pp. 176-180.

[9] Samsuddin, Ramli Rahim, Baharuddin Hamzah, Rosady Mulyadi, "Proposed Model of Neutral Temperature Equation for Adaptive Thermal Comfort in Student Flats Units in the Tropics," Civil Engineering and Architecture, Vol. 9, No. 2, pp. 477-492, 2021. DOI: 10.13189/cea.2021.090220.

[10] Al-Wan, Huda, "Almlagaf, one of the architectural elements in the homes of Islamic city;" Architectural Scientific Journal. Faculty of Architecture, Beirut Arab University; number (4), 1998, p. 140.

[11] Yaman, S. "Aspects of Sustainability in the Design Elements of Traditional Jordanian Houses," Civil Engineering and Architecture, vol. 8, no. 6, pp. 1194-1201,

2020. https://doi.org/10.13189/cea.2020.080604.

[12] Hassan, Abbas & Lee, Hyowon & Yoo, Uoosangc, “From medieval Cairo to modern Masdar City: Lessons learned through a comparative study,” Architectural Science Review. 59. 1-14. 10.1080/00038628.2015.1015947,2015

[13] Online Available: from http://www.quora.com/How-do-people-survive-the-summer-during-the-60s-where-there-wasnt-air-conditioning-or-fans-most-especially-those-in-the-Arab-world

[14] Bhattacharya, Yasmin & Milne, Murray, Psychrometric Chart Tutorial: A Tool for Understanding Human Thermal Comfort Conditions, 2009.

[15] Hamdan, M., Abd Elhamid, F. and Dabbour, L., Impact of Passive Techniques on Thermal Behavior of Emergency Shelters. *Ecological Engineering & Environmental Technology*, 22(3), pp.112-119, 2021.

[16] Standard ASHRAE. Standard 55-2004. Thermal environmental conditions for human occupancy. 2004:9–11.

[17] Husni, Samir Hassan Bayoumi, “Climate and Architecture,” Cairo: Dar el-Maaref, 1998, p. 23.

[18] Hausladen, G., Liedl, P. and de Saldanha, M., Building to suit the climate: a handbook. 1st ed. Birkhauser Basel, pp.38, 39,111, 2012.