Climate-responsive design strategy for Erbil city

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Abstract

Purpose – The purpose of this paper is to investigate passive techniques used in traditional and indigenous architecture in order to decrease energy use in the buildings and to increase thermal and users’ comfort. The city of Erbil is explored where in the rapid transformation and import of Western architectural styles and materials have resulted in ignorance of climate-responsive tradition existing in the city since thousands of years.

Design/methodology/approach – In order to propose a design strategy for modern residential buildings in Erbil city, a descriptive and interpretative approach is used as a methodology of this study. A literature review is done to explore the traditional use of passive techniques, and Waziran district of the city is analyzed and used as a pilot site in this study.

Findings – Due to the shortage of electric power in the city, residential buildings have limited access to electric power. Therefore, thermal comfort and reduction of the energy use in residential buildings have become vital for Erbil. The use of passive techniques in architectural design will help to reduce energy dependency.

Research limitations/implications – This study is limited to residential function in Erbil. Waziran district is used for the design proposals where dwellings are in a row context. The proposals are made on a geometrical basis and plan organization; however, the selection of construction materials is not included.

Originality/value – There is a proposal to reduce the use of electricity, which currently has limited access in Erbil city.

Keywords Thermal comfort, Solar energy, Climate response, Erbil city, Passive techniques, Semi-arid climate

Paper type Research paper

1. Introduction

The consumption of energy is one of the crucial topics around the globe. It can be traced in a wide range of sectors such as industrial, transportation, residential, commercial, electric power and several other sectors. According to the Directive 2010/31/EU, buildings within the European Union account for 40 percent of total energy consumption (Directive, 2010/31/ EU, pp. 153/13). Similarly, data of US Energy Information Administration (EIA) show that the energy use of the buildings is 40 percent and buildings’ electricity use is 74 percent of the US total energy (EIA – Annual Energy Outlook, 2017).

As the building construction sector is growing parallel to the growing population, the energy need would be increasing as well. EIA’s Annual Energy outlook (2019) report shows that energy consumption and on-site generation in the residential buildings sector are expected to further grow by 2050. With technological advances in energy efficiency, this growth is partially offset (Annual Energy Outlook, 2017, p. 131). The projection of EIA’s Annual Energy outlook (2019) report is the increase of electricity consumption by 0.4–0.5 percent per year because of the increasing demand of electricity in residential buildings (appliances, devices and equipment that are used in daily life), particularly the need of cooling is significant (Annual Energy Outlook, 2017, p. 134, 136). Therefore, on the basis of
these data, it can be said that the use of renewable energy and passive techniques and reducing the energy needs of buildings have become more important than ever.

Energy consumption is not related only with the limited sources of the earth but it also has a relation with the increase of carbon dioxide emission, which has a direct effect on the climate change and global temperature rise. In this regard, in Directive 2010/31/EU, it is declared that “The energy performance of buildings should be calculated on the basis of a methodology, which may be differentiated at national and regional level.” The needs of “passive heating and cooling elements, shading, indoor air-quality, adequate natural light and design of the building” and “the methodology for calculating energy performance to include annual energy performance of a building” are also mentioned (Directive, 2010/31/EU, p. 153/14, item: 9). Thus, low-energy and climate-responsive strategies such as passive techniques are emerging design approaches in architecture.

Due to the influence of solar energy on the earth and water masses, human beings have had the intention to use sun radiation. Therefore, since ancient times, climate-responsive design and passive solar energy have been used in vernacular and indigenous architectural examples. The use of passive solar techniques as an adaptation to the climate dates back to the fifth BC (Maurerova, 2014, p. 420). The Ancient Greeks had used the forests for heating purposes and when the level had reached to the exploitation of the trees, they had experienced the energy crisis. This was the time of passive solar genesis. Ancient philosopher Socrates had introduced the use of solar energy for designing houses (Lechner, 2015, p. 35). He observed the sun radiation and sun path, and he struggled with economic crises by developing a house design in order to benefit from sun radiation. Historian Xenophon explained the approach of Socrates by pointing out the importance of house orientation. This house building, which is called Socrates’ House, was designed associated with the heights and azimuths in the course of a day and a year. South-oriented houses have sun penetration in their portico during the winter, whereas the sun radiation has an effect on the roof during the summer, which creates shading (Lechner, 2015, p. 35; Maurerova, 2014, p. 420). South façade must be built lower than the northern one in order to gain sunlight, otherwise winter sun will be cut off (Lechner, 2015, p. 35). Hence, more solar energy is gained during the winter time and overheating is minimized during the summer time.

During the course of time, later in 1933, George Fred and William Keck brothers from Chicago, US, had presented “house of tomorrow” and, a year later, “crystal house” where passive solar architecture approach was used for heating and cooling. Similarly in the ancient time, these attempts were driven by a crisis, which was the crash of the stock market in New York City. Then, the oil crisis of the 1970s (Lin, 2003, p. 15) brought to the scene a new term “low-energy house,” which was introduced by Danish designer Vagn Korsgaard in cooperation with the Technical University of Copenhagen in 1974. This house was energy self-sufficient one, which did not need any external energy import (Maurerova, 2014, p. 421).

The idea of the use of solar energy in housing, understanding the climate condition of each location and making the buildings adapt to its characteristics, can be dated back more than 100 years. According to the topography, altitude, prevailing wind, vegetation patterns, land–water mass interaction, etc., there are various climatic zones. In the 1900s, Wladimir Köppen had made a classification of climate zones, which is still used by many researchers across a range of the disciplines in order to assess the global climate models. In general, Köppen classified the climate regions as tropical, arid, temperate, cold and polar (Peel et al., 2007, p. 440, 462). Another classification is made by Gut and Ackernecht (1993) as hot–arid zone, warm–humid zone and temperate zones (Gut and Ackernecht, 1993, p. 15). These zones are considered vital to differentiate the climate conditions around the globe. Mainly, the classifications are made according to the factors that affect human comfort, such as extreme air temperature differences between day and night and winter and summer, humidity and
precipitation, solar radiation and winds. According to these zones, the main principles of climate-responsive design are presented.

Construction techniques of traditional and indigenous architecture mostly have respective climatic conditions, which is referred to as “climate-responsive architecture.” Therefore, there are lessons to be learned from traditional constructions that are adapted to the climate condition of their locations. Most of the strategies used in traditional “climate-responsive” buildings included passive cooling, sun orientation, thermal mass, insulation, passive solar heating, etc. The reduction of natural energy resources has brought passive strategies back to the scene in recent decades. Thus, the strategies of climate-responsive architecture have an important role in the present time because of their energy-saving attribute.

The aim of this study is to explore the case of Erbil city where the present condition has a lack of electric power in daily life. Consequently, the use of renewable energy and reduction of the energy needs in residential buildings have become very important for Erbil city. The oldest settlement of the city, which is called Citadel, includes traditional house buildings that were constructed with respect to the climate. The lack of energy for daily use in Erbil city has brought back the idea of design strategies that had been used in traditional buildings wherein passive solar and respective climate approaches were applied. Thus, the focus of this study is to investigate the passive use in traditional Erbil houses in order to develop strategies for designing new dwellings. The target is to increase thermal comfort and to reduce the energy use by taking lessons from the past. The existing energy shortage in Erbil city proves the importance of saving energy, the need for exploration of renewable energy resources and the use of passive solar techniques.

2. Climate-responsive architecture
Climate-responsive architecture refers to the effective incorporation of the elements of the local climate in order to achieve thermal and visual comfort with little or non-use of non-renewable energy resources. This achievement helps to sustain the ecosystem and to reduce the negative impact on the environment as well. Design approach and decisions regarding the building form, including plan geometry consideration, building orientation, wall opening-to-wall surface ratio, surface-to-volume ratio, natural ventilation, natural light, thermal mass, shading, etc., are essential considerations that need to be taken into account within the local climatic context in any climate-responsive design. Briefly, these concerns are called passive design techniques.

The principles of climate-responsive architecture are listed as “Energy Efficient Design, Preservation of Natural Ecosystems, Use of Renewable Energy, Water Resource Management, Use of Eco-friendly materials, Ecological Landscape Design, Solid Waste Management and Healthy Indoor Environment” by Panarelli et al. (2016, p. 11). Incorporation of these principles in the initial and conceptual design phases helps to achieve more efficient and less energy consuming buildings, thereby ensuring the users’ comfort.

Climate control includes active, passive and hybrid systems based on the understanding of the climate, site condition, function of the building and locally available energy resources. Within these systems, a passive approach basically uses natural ventilation, daylight, heating or cooling buildings in order to reduce or eliminate the need for active systems such as HVAC and fossil-based energy consumption. Passive techniques simply use the sun, light, air and wind, existing topography and environmental conditions. They take the advantages of solar heating such as direct heat, indirect heat and isolated heat gain and passive cooling such as natural cross-ventilation, thermal mass cooling with night ventilation and evaporative cooling. In addition to the natural energy resources, the landscape has an important role within the climate-responsive approach. The use of trees and vegetation is a very effective method of natural cooling and protecting the building from solar radiation. The process of photosynthesis,
performed by the leaves of the plants and trees, helps to absorb the solar radiation and to lose the heat by evaporation. Also, the fluids in the trees and plants store a part of the solar radiation (Panarelli et al., 2016, pp. 15-17).

This study addresses thermal comfort and passive techniques within the principal of energy efficient design as a criterion of climate-responsive architecture. The definition of comfort is consented in accordance with Heerwagen (2004) as “the state of pursuing an activity without experiencing environmental stress” (Heerwagen, 2004, p. 3). Besides the materials used in building construction, thermal comfort is affected mainly by the form of the building and its orientation to the sun. Thus, building envelope plays an important role of regulating the thermal exchange (Panarelli et al., 2016, p. 13; Li et al., 2018, p. 2) and the aesthetic of the façade as well. So, the design of the walls and the selection of their construction material are crucial for energy saving in the buildings in terms of applying passive solar techniques as a climate-responsive strategy.

3. The case study: Erbil city

3.1 Location

Erbil is located in an autonomous region of Kurdistan, in the northern part of Federal Republic of Iraq (Figure 1) in the Middle East. It is a large and mountainous plateau surrounded by four states – South East of Turkey, North East of Syria, North West of Iran, and North of Iraq. The plateau of Erbil is inhabited since 30m years (Akram et al., 2016, p. 96). It is the capital city, which has assumingly a population of 2m according to 2017 data (Gordon, 2008; Akram et al., 2016, p. 96). After Baghdad, Mosel and Basra, Erbil is the fourth largest city in Iraq, located about 350 km North East of Baghdad; it is the capital of Iraq and is about 80 km South East of Mosul (Shwany, 2018, p. 27; (Gordon, 2008). The city is stated as the oldest, continuously inhabited city in the world by the International Council on Monuments and Sites (ICOMOS), with its history around 6,000 years of age (Akram et al., 2016, p. 96).

Growth of the city. The city of Erbil, with its long history, had been ruled by many different empires (Morris, 1994). However, the growth of the city and its modernization are dated back to the establishment of Iraq in the 1920s–2000s. Sabr stated that 90 percent of the city has been built in this period of time (Sabr, 2014, p. 327). The growth of the city is dominated by the political changes of the state. After the establishment of the Republic system in 1958, rural and urban areas and housing settlements were rearranged by the new
legislations. Based on this change, low-cost housing projects were initiated. The increasing demand for housing ended up with new governmental decisions (1979) so as to reduce the differences between the neighborhoods. According to this decision, “the minimum allowed area of the plot subdivision was 120 m² in the center of provinces (cities) regardless the urban area category and 100 m² in towns and suburbs.” As a result of this decision, the urban fabric and house building typology in all cities of Iraq have changed, including Erbil city (Sabr, 2014, pp. 330-331).

Another impact on the housing of Iraq, in general (and for Erbil city), was the period of war between Iraq and Iran (1980–1988) in which new policies were established. The government offered lands for free to the families of soldiers and martyrs for housing purposes. These areas had created new neighborhoods including the plot area between 200 and 600 m². The continuity of the legislative changes of housing in Iraq has brought a significant effect on the urban fabric and panoramic view of the cities. Additionally, the economic crises after the war created new neighborhoods. Due to the politically unstable condition, urbanization and building process were not well controlled by the authority. As a result, illegal and slum quarters appeared. Later on, in the first master plan of Erbil city, which was prepared during 2006–2009, a noticeable change in the urban fabric emerged (Sabr, 2014, pp. 332-335).

To summarize the growth of the Erbil city, it is clearly observed that the city has witnessed significant and sensational changes in certain periods wherein housing has been affected more than the other functions. The differences in each period of change and the policies as well have influenced the formation and transformation of the urban and house planning. As a result, the traditional and indigenous architectural character of house buildings, which has a continuity since 6,000 years, and climate-responsive approach have been ignored, and Western architectural styles concerning only aesthetics and modern life have started to dominate the urban fabric.

Climate zone. Erbil city, located in the northern part of Iraq, has a semi-arid continental climate (Figure 2). The main characteristics of this climate zone are the big differences between summer and winter and between the day and the night temperatures. The summer season (June–September) is typically hot and dry and the winter season (November–February) is cold and wet. Between October and November, there is a limited rainfall (Erbil Governorate Profile, 2015; Diler and Serbest, 2017). In the hot summer time,
the maximum daily temperature can reach 50°C, whereas in the cold winter time, the minimum temperature can decrease to −5°C (Rozhgar, 2018, p. 22; Shwany, 2018, p. 26). The level of humidity is very high as 80 percent (average) in the winter time and low as 20 percent (average) in the summer time (Qusai and Lookman, 2012).

3.2 Erbil Citadel
The Erbil Citadel, listed in the World Heritage List of UNESCO since 2014 (https://whc.unesco.org/en/list/1437), is a man-made settlement that is inhabited continuously for thousands of years. Citadel is located in the central part of Erbil City; it is defined by its residents as “the crown of the Erbil” since it rises about 32 m above the city level (Shwany, 2018, p. 29). The footprint of the Citadel is approximately 430 m in width and 340 m in length, with a 45° slope (UNESCO Pilot project for the Erbil citadel, 2004). There are two main gates, located on the south side of the Citadel, that open to the spreading streets to the residential neighborhoods (Shwany, 2018, p. 29).

The Citadel is a large and mountainous plateau on a hill (Plate 1), which is created through the generations of its residents. The presence of its fortification wall (Plate 2) represents its remarkable dominance to the city (https://whc.unesco.org/en/list/1437). Archeological findings show that it has a history dated back to at least 6000 years, which makes it the longest inhabited place on the earth (Akram et al., 2016, p. 97). According to Pavelka et al. (2007), the Citadel includes layers of Assyrian, Akkadian, Babylonian, Persian, Greek and pre-Arabic settlements. Thus, traditional architecture has started to grow and is continuous since more than 6,000 years for this central part of Erbil City.

The typology of the houses located in the Citadel is mostly shaped by courtyard houses, reached through a maze of narrow alleyways. The houses were usually two storied with flat roofs, and most of the courtyard houses were formed in irregular geometric shapes (Shwany, 2018, p. 30). Traditional buildings were designed and constructed with respect to climate

Plate 1.
Erbil Citadel

Source: https://whc.unesco.org/en/list/1437
conditions (Diler and Serbest, 2017). The fact that the Citadel still exists and the houses have shown a good performance to the test of the time, climate-responsive design approach and construction techniques used have proved themselves to be successful.

3.3 Climate-responsive traditional architecture in Citadel

As it is explained in the above paragraphs, the history of Erbil Citadel dates back to thousands of years, and during its long history, it was settled by various societies. Thus, its traditional and indigenous architectural examples are very rich. Especially, the use of passive architectural techniques with regard to the climate is impressive and there are many lessons to be learned for new constructions of Erbil city.

The main characteristics of the Citadel houses as climate responses are as follows:

- urban fabric;
- form and orientation;
- the use of courtyard;
- plan arrangement;
- construction material;
- windows (ventilation);
The urban fabric of the Citadel has evolved in an organic shape during the course of the time. The width of the pedestrian alleyways ranges between 1.00 and 2.5 m in a pattern similar to branches of the trees, which provides many advantages against climate exposure. First, the narrow and organic pattern of the streets provides shading over them and neighboring buildings, reduces the air temperature and contributes to the protection from the sand storms, because the high density of the buildings helps to reduce the wind effect (Givoni and Orlick, 1985). This approach allows the occupants to have comfortable use of outside areas during the hot summer days. The form and orientation of the houses to the sun have been made in an ecological way so as to include south orientation in order to get solar radiation during the winter time and to exclude the summer heat (Givoni and Orlick, 1985).

One of the main concerns for the form and plan arrangement of the houses is the use of the courtyards. Courtyards are mostly located centrally and shaped in accordance with the geometry of the plot shapes. The main idea is to locate long axis perpendicular to the sun orientation and to have openings of the rooms toward the courtyard in order to provide natural ventilation (Fazia, and Helmut, 2006). The organization of the central courtyard (Plate 3), also known as introvert enclosure, has solid outer façade walls, which provide privacy to the occupants and help in the noise control. Figure 3 shows the typical formation of courtyard geometries.

The plan arrangement of the traditional houses is based on the idea of placing summer rooms with high ceilings (4.00–4.50 m) at the ground floor to keep them cool during the summer days (Shwany, 2018, p. 33). The arrangement of having summer rooms at the ground floor with a high ceiling and winter rooms at the upper level (where more solar radiation reaches during the winter time) provides comfort (in terms of thermal comfort) to the occupants.

Construction materials have an important role in climate-responsive design because of their potential to absorb and collect solar radiation during the day and to transfer the heat during the night. Mostly, the walls were made of masonry such as fired bricks or sun-dried mud bricks. The roof constructions were flat and made of mud, pieces of broken bricks and smaller stones (Abdulkareem, 2012).
Another feature used within the passive architectural techniques is natural ventilation, which has been quite successful for increasing thermal comfort. It has an important role in the manipulation of the hot and dry climate in order to increase the comfort level of the occupants. Natural ventilation is based on the convection principle, which is provided by the arrangement of the wall openings or the use of wind towers. Water masses and vegetation also help to increase the thermal comfort level.

3.4 Current state of residential architecture in Erbil city

The housing architecture of Erbil city has been affected by the Iraqi liberation in 2003, resulting in its transformation in accordance with the economic, cultural and political changes. This transformation has led to the misconception of the traditional architectural characteristics (Baper and Hassan, 2010). Most of the modern buildings in Erbil (built after 2000s), particularly residential ones, are influenced from Western architectural styles and contextually are far from the local characteristics and culture (Shwany, 2018, p. 26).

Especially, climate condition, social, cultural and environmental aspects are not considered well enough in the modern residential designs. Particularly, the use of imported materials and the lack of information about their thermal characteristics, fluctuation of the policies and ignorance of the local attributes have not resulted to attain a comfortable level of the occupants in terms of their physical and mental needs. The current state of the urban fabric, form and orientation, plan organization, natural ventilation and shading, the use of water mass and vegetation in Erbil city is far from the climate response concept of the semi-arid continental climate.

Plate 4 shows an example of a modern house building in Erbil city. In this building, facade windows are oriented toward the street and the front garden, whereas interior ones face the lighting shaft, which is locally called as “minwar” (Shwany, 2018, p. 39; Srivastav and Jones, 2009). As a result of this formation, there is no benefit, as the sun radiation cannot be gained during the winter time and the heat cannot be excluded during the summer time. It is obvious that the large windows in semi-arid continental climate overheat in the summer and lose the heat in the winter. Consequently, active systems such as HVAC are required to achieve thermal comfort for the occupants. So, the idea of traditional construction techniques to respond to the local climate condition and the needs of the occupants is far from the concept of modern buildings in Erbil city. Table I shows a comparison between the features of traditional and modern residential buildings’ aspects.

4. The climate-responsive design strategy for Erbil city

The thermal comfort level, achieved naturally by the construction (without the addition of any mechanical system), of the modern buildings in Erbil city is far from the users’ comfort requirements. Rapid transformation and import of Western architectural styles and materials have resulted in ignorance of climate-responsive tradition existing in the city since

![Figure 3. Courtyard geometries](Source: Architecture Faculty of the University of Texas at San Antonio 2009)
Plate 4.
House building in Erbil city

Source: Shwany (2018, p. 40; photo courtesy: Pavel Shwany)

<table>
<thead>
<tr>
<th>Building elements</th>
<th>Traditional architecture</th>
<th>Modern architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>Small houses: 50–100 m²</td>
<td>Small houses: 50–100 m²</td>
</tr>
<tr>
<td></td>
<td>Medium houses: 100–150 m²</td>
<td>Medium houses: 100–150 m²</td>
</tr>
<tr>
<td></td>
<td>Large houses: 300–400 m²</td>
<td>Large houses: 300–400 m²</td>
</tr>
<tr>
<td>Geometry/form</td>
<td>Regular and non-regular geometries</td>
<td>Regular and non-regular geometries</td>
</tr>
<tr>
<td>Courtyard</td>
<td>All the rooms look toward the courtyard. Benefit from the sun, overheating is avoided in the summer, and heat loss is achieved in the winter</td>
<td>Mostly is not included</td>
</tr>
<tr>
<td>Interaction with the ground</td>
<td>Ground level is equal/similar with the ground line</td>
<td>Raised ground floors are used</td>
</tr>
<tr>
<td>Number of the floors</td>
<td>Mostly, 2–3 floors</td>
<td>Mostly, 2–3 floors</td>
</tr>
<tr>
<td>Walls</td>
<td>Thick mud bricks, wall thickness: 50–70 cm; walls are used as thermal masses</td>
<td>Bricks, wall thickness: 15–25 cm without any thermal insulation</td>
</tr>
<tr>
<td>Windows</td>
<td>Rectangular windows with a square vent hole above the windows. Sun orientation is attained.</td>
<td>Large rectangular or circular windows. Sun orientation is not considered.</td>
</tr>
<tr>
<td>Shading elements</td>
<td>Dense urban fabric and narrow streets help to shade the external walls. Wooden screens, locally called “mashrabiya,” are often used</td>
<td>Most of the walls and windows are not shaded</td>
</tr>
<tr>
<td>Natural ventilation</td>
<td>Cross ventilation is ensured by the plan organization; vent holes above the windows are used</td>
<td>Passive techniques are not considered</td>
</tr>
<tr>
<td>Cooling</td>
<td>Existence of the courtyard is the main element to cool summer rooms. Additionally, evaporated cooling and wind towers are used</td>
<td>Passive techniques are not considered</td>
</tr>
</tbody>
</table>

Table I.
Comparison between traditional and modern residential buildings in Erbil city

Notes: Shwany (2018, pp. 43, 45) and Ayyash (2015)
thousands of years. As Erbil city is located in semi-arid continental climate zone, the exposure of the weather and climate is a very important feature to be considered in the design of residential buildings in order to attain thermal comfort for the occupants. Therefore, the main aim of this study is to explore the lessons learnt from the traditional passive techniques as climate-responsive approach to the design of residential buildings in order to propose solutions for improving thermal comfort in modern ones. By this way, the reduction of dependency on electric power can be reached.

The adaptation of the use of passive techniques in new buildings is considered as the backbone of this study. Due to many different reasons explained shortly in part three (growth of the city), the urban fabric has changed dramatically during the course of the time, and the use of passive techniques is proposed by their adaptation to the new urban fabric. The peculiarities of the urban transformation are considered, such as the use of buildings in a row instead of individual houses. So, the current urban fabric is taken into account.

Waziran district of Erbil city is chosen as the pilot location for the proposed method (Figure 4). This district is a quite new built neighborhood. The total area of residential buildings in Waziran district ranges across 300 and 600 m². The number of floors is mostly two or three.

For developing the proposal, two different sites (in respect to their total area) are considered. The first one is 600 m² (Proposal I) and the second one is 300 m² (Proposal II). These sites reflect the average of the existing plot scales. Both sites have one main elevation facing the street and the urban fabric is buildings in a row. Each proposal includes the identified passive design strategies based on traditional techniques. The proposals are made on a geometrical basis and plan organization; however, the selection of construction materials is not included in this study.

Both design alternatives are two-storey buildings. Proposal I (I-a, I-b, I-c) includes three alternatives, whereas Proposal II has four different alternative types (II-a, II-b, II-c, II-d). The use of a courtyard and a pool is considered as a passive technique for responding to the climate and increasing the thermal comfort quality.
4.1 Proposal I (600 m²)
Proposal I-a: it includes a central courtyard with a pool shaded by pergolas. Entrance, living room and the kitchen, facing the front garden, are located in the ground floor. The pool and vegetation within the courtyard have been used to help cooling (Figure 5).

Location: Waziran, Erbil and Iraq
Total Area: 600 m²
Number of Floors: 2 floors

The ground and first floor plan, top view and the cross section of the house are shown below. The ground floor consists of entrance, living, dining, office, library, gym, laundry, kitchen, bedroom, whereas there are bedrooms, living area, gaming room and terrace on the second floor.

Figure 5.
Proposal I-a

Source: Shwany (2018)
Proposal I-b: it includes a bigger courtyard than I-a, ending at the edge of the plot. The pool and vegetation within the courtyard have been used to help natural cooling (Figure 6).

Proposal I-c: it includes twin courtyards located at the side edges of the building. Increasing the number of courtyards can help to reach more portions of the living rooms.

Location: Waziran, Erbil and Iraq
Total Area: 600 m$^2$
Number of Floors: 2 floors

The site plan, ground and first floor plan, top view and the cross section of the house are shown below. There are the entrance, dining, living, library, office, gym, kitchen, laundry, bedroom on the ground floor, whereas living area, bedrooms, gaming room and terrace are on the second floor.

Source: Shwany (2018)
that have contact with the courtyard. The semi-open part is located on the south and is covered with the shading element (Figure 7).

4.2 Proposal II (300 m²)
Proposal II-a: it includes a central courtyard at the ground floor. All the other functions are placed accordingly to benefit from the natural lighting and the ventilation since there are

Location: Waziran, Erbil and Iraq
Total Area: 600 m²
Number of Floors: 2 floors

The site plan, ground and first floor plan, top view and the cross section of the house are shown. Entrance, living, dining, office, library, gym, laundry, kitchen, bedroom are on the ground level, and bedrooms, living area, gaming room and terrace are on the second floor.

Figure 7.
Proposal I-c
common walls between neighboring houses. There is only one elevation facing the street and there are possibilities to provide openings (Figure 8).

Proposal II-b: the courtyard is located in order to prevent dead ends and to provide a larger space for the users to benefit from the courtyard’s natural air and vegetation compared to Proposal II-a. In both design alternatives, the south elevation is the only elevation facing the street (Figure 9).

Location: Waziran, Erbil and Iraq
Total Area: 300 m²
Number of Floors: 2 floors

Here, the site plan, ground and first floor plan, top view and the cross section of the house are shown. Entrance, living, dining, office, library, gym, laundry, kitchen, bedroom are on the ground level, and bedrooms, living area, gaming room and terrace are on the second floor

Source: Shwany (2018)
Proposal II-c: it includes twin courtyards. The functional organization is similar to the others (Figure 10).

Proposal II-d: the living room and bedrooms on both floors face the single courtyard, which is located on the back side of the building. The kitchen and the other functions are oriented toward the south elevation. The south elevation is the only elevation, which is not common with the neighboring house. The shading elements are provided on the veranda and south side windows to prevent overheating (Figure 11).

Location: Waziran, Erbil and Iraq
Total Area: 300 m²
Number of Floors: 2 floors

The proposal consists of site plan, ground and first floor plan, top view, and the cross section of the house. Entrance, dining, living, office, library, laundry, gym, kitchen, bedroom are on the ground level, and bedrooms, living area, gaming room and terrace are on the second floor.

Source: Shwany (2018)
5. Conclusion and final remarks
Design requirements for any building are numerous and vary according to the existing environment, function, and context, such as the level of the thermal comfort, noise control, safety and security, aesthetic and so on. Fundamental concerns to achieve these requirements focus on how to control the building environment and how to satisfy the physical and mental health of the occupants.
This paper is focused on climate-responsive architecture as part of building environmental control systems in general and Erbil city, located in hot-arid climate zone, in particular. The question of this study is formulated to identify what are the design strategies that can be employed in contemporary residential buildings of Erbil city to provide shelter, to ensure comfort, to reduce energy use, to use passive solar and climate-responsive techniques as lessons learned from traditional and indigenous architecture.

Figure 11. Proposal II-d

Source: Shwany (2018)
The climate-responsive design approach and the use of passive techniques reduce the embodied energy directly and carbon footprint indirectly. Therefore, in places such as Erbil city where the energy shortage is a fact, the climate-responsive design approach for residential buildings has an important role to increase the comfort level of the occupants.

Erbil city, as listed in UNESCO World Heritage List and as being accepted as the oldest continuous inhabited city in the world, has very rich architectural characteristics. Particularly, the traditional architectural design approach in accordance with the semi-arid continental climate condition, which provides thermal comfort to the occupants and reduces the energy use, is significant. However, in the course of the time, the city of Erbil has experienced many changes both politically and architecturally. As a result of these changes, urban fabric and construction traditions of the city have been transformed dramatically. The peculiarities of past traditions and adaptation to the climate gave place to the Western architectural styles, which do not have any consideration of the local condition. Therefore, modern buildings do not meet the thermal comfort requirements of the occupants.

Another important fact for Erbil is the shortage of electric power in the city. Residential buildings have limited access (both the time period and the amount) to electric power for their daily routine. Therefore, thermal comfort and reduction of the energy use in residential buildings have become vital.

This study is focused on the application of passive techniques within the climate-responsive design phenomenon in order to increase thermal comfort and decrease dependency on electric energy. As a result of a detailed study about climate-responsive architecture in general and traditional passive techniques, particularly in Erbil city, seven design alternatives for two different plots are proposed. The study area is selected as Waziran district, which is a quite new neighborhood.

The main principles of the proposals are the use of the courtyard and organizing the rooms according to the sun orientation. This method is structured as a step-by-step approach, which is possible to be applied in any other location. It is successful due to the first step that starts with analyzing the site. Therefore, climate zone, site condition, urban fabric and so on will be investigated and proposals will be based on the local characteristics. The steps suggested in this design approach are given below.

5.1 Step 1
Investigation of the site condition. The local characteristics of topography, prevailing wind, sun orientation and the impact of the immediate environment need to be analyzed.

5.2 Step 2
Evaluation of the data obtained from the site. Decisions need to be taken on the optimal use of existing local conditions such as the use of topography, sun orientation, and mass orientation; the possibilities of natural ventilation, maximum heat gain, minimum heat loss, compatibility and accordance between functions and passive strategies and the like should be investigated.

5.3 Step 3
Synthesis of the data. The relationship between functional requirements and local conditions needs to be investigated. Targeted orientation aims to find optimal, cost-effective, easy maintained, long-lasting, comfortable solutions.

5.4 Step 4
Decisions need to be taken on the use of passive cooling, passive solar heating, building orientation, shading and thermal mass considering local climatic context, design concept and functional requirements.
5.5 Step 5

Design alternative proposals. The advantages and disadvantages of each proposal should be investigated and the final decision should be made as a project proposal.

In order to make this approach successful, consideration of thermal mass, maximization of cross ventilation and evaporative cooling, using vegetation and shading, are vital. Additionally, in order to develop a plan and a geometry for the building, studying the orientation of short side and long side and wall to openings ratio will have an important effect on the performance of the building.

Alongside the climatic condition and characteristics of the site, local and regional authorities are critical for the successful design and a good building performance including thermal comfort. National and regional legislative procedures need to support climate-responsive design approach and to include this aspect in urban planning both in the national and regional level. Furthermore, the government should enable and encourage architects and planners to involve climate-responsive strategies and to improve the energy efficiency of the buildings by reduction of energy use and by using renewable energy.

The results of this study show that incompatibility between local condition and design decisions and ignorance of the climate and local conditions increase the energy use and decrease thermal comfort of the buildings and the comfort level of the occupants as well.

References


Further reading

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