ENERGY EFFICIENCY PRINCIPLES IN ERBIL VERNACULAR ARCHITECTURE: A CASE STUDY FROM ERBIL-NORTHERN IRAQ

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
SORAN SAAD AZIZ

In Partial Fulfilment of the Requirements for the Degree of Master of Science in Architecture

NICOSIA, 2019

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Approval of Director of Graduate School of Applied Sciences

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We certify this thesis is satisfactory for the award of the degree of Masters of Science in Architecture

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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To my parents …

DEDICATION

I dedicate my dissertation work to my family and many friends. A special feeling of gratitude to my loving parents, Shireen and Saad Aziz whose words of encouragement and push for tenacity ring in my ears. I also dedicate this to my supervisor Assoc. Prof. Dr. Nesil Baytin and all the lecturers, and to my Sister who have supported me throughout the process.

ABSTRACT

Building sector, in the whole world, drives a considerable role in the environmental crisis because of its remarkable energy consumption. Erbil city of Northern Iraq has witnessed a rapid development in the building sector since 2003. The design of majority of contemporary buildings built in Erbil is adapted from different climates and applied without paying attention to Erbil's hot and dry climate. Therefore, provision and maintenance of thermal comfort through active cooling and heating systems in these new buildings depends heavily on electricity. However, due to the lack of electric generating plant and infrastructure in the city, electrical energy is obtained through individual generators that utilize non-renewable resources-petroleum, which, in return, produce heavy environmental pollution. It is known that the mankind, through trial-and-error process of centuries, has developed vernacular architectures in perfect harmony with his natural environment- climatic characteristics, available natural materials, etc. Therefore, it is connatural that the elements of the vernacular and traditional buildings in Erbil, also, introduce solutions on the issue of providing thermal comfort through passive methods, based on the principles of energy efficiency. The aim of this thesis is to investigate the most effective passive design strategies in the vernacular architecture buildings which respond to the climate of the region. As to the methodology of this study, the scientific sources as books, journals, as well as credible internet sources have been investigated. On the other hand, the analysis of selected case studies in terms of form. through site observations and visual recordings have been made. Moreover, the qualitative method has been applied by developing semi-structured interviews with professionals. The results have exhibited the most effective passive strategies in vernacular and traditional buildings that can be utilized in contemporary building design in order to minimize energy consumption in Erbil's climate. Finally, suggestions about implementation of these strategies were made. This study can be a considerable guide to prevent excessive energy consumption in the contemporary buildings of Erbil.

Keywords: Erbil-northern Iraq; energy efficiency in buildings; hot and dry climate; vernacular and traditional architecture

ÖZET

Bütün dünyada yapı sektörü, büyük enerji tüketimi nedeniyle çevresel krizde önemli bir rol oynamaktadır. Kuzey Irak'ın Erbil kenti 2003 yılından beri çok hızlı bir gelişmeye şahit olmaktadır. Çağdaş yapıların büyük bir kısmının tasarımları farklı iklimlerden uyarlanıp, Erbil'in sıcak ve kuru iklimi dikkate alınmaksızın uygulanmaktadır. Dolayısıyla, bu binalarda, aktif ısıtma ve soğutma sistemleri kullanılarak ısıl komforun oluşturulması ağırlıkla elektriğe bağımlıdır. Ancak, kentteki elektrik üretim tesisinin ve altyapısının eksikliği nedeniyle, elektrik enerjisi,yenilenemez enerji kaynağı-petrol ile çalışan jeneratörler ile elde edilmekte, bu da ağır bir çevresel kirliliğe neden olmaktadır. İnsanlığın, dünyanın farklı yerlerinde, yüzyılların deneme-yanılma süreci içerisinde, kendi doğal çevresi ile mükemmel bir uyuma sahip ve sosyo-kültürel özellikleri ile de harmanladığı, yerel mimariler geliştirdiği bilinmektedir. Dolayısıyla, Erbil'deki yerel ve geleneksel yapı ögelerinin de, enerji-verimliliği ilkelerine dayanan pasif yöntemler yoluyla ısıl komfor sağlama konusunda çözümler sunması doğaldır. Bu çerçeve içerisinde, bu tezin amacı, yerel mimaride, bölgenin iklimsel özelliklerine yanıt veren ve gelecekteki binaların tasarımında, enerji tüketimini azaltmaya yönelik olarak yararlanılabilecek en etkin pasif tasarım ilkelerini incelemektir.Bu çalışmanın metodolojisi bütününde, Erbil'in sıcak ve kurak ikliminin yerel ve geleneksel binalarında en etkili pasif tasarım stratejilerini anlamak için kitaplar, tezler, indeksli dergiler ve güvenilir internet kaynakları gibi ikincil kaynaklar araştırılmıştır. Ayrıca, seçilen örnek-olay incelemelerinin, biçim, tipoloji, mimari elemanlar vb. açılardan, gözlem, görsel malzeme ve açıklamalarla analizi yapılmıştır. Ayrıca, nitel yöntem kullanılarak, konu hakkında profesyonellerle yarı yapılandırılmış görüşmeler uygulanmıştır. Sonuçlar, Erbil iklimindeki binalarda enerji tüketimini en aza indirmek için çağdaş bina tasarımında kullanılabilecek yerel ve geleneksel binalardaki en etkili pasif stratejilerin önerilmesiyle tamamlanmıştır. Bu çalışma Erbil'in çağdaş binalarındaki aşırı enerji tüketimini önlemek için önemli bir rehber olabilir.

Anahtar Kelimeler: Erbil-kuzey Irak; binalarda enerji verimliliği; sıcak ve kuru iklim; yöresel ve geleneksel mimari

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LIST OF ABBREVIATIONS

HAC:	Hot-Arid Climate
HVAC:	Heating, Ventilation and Air Conditioning
EEP:	Energy Efficient Principles
VA:	Vernacular Architecture

CHAPTER 1

INTRODUCTION

1.1 Background and the Significance of the Study

The tremendous increment of energy usage in the world gives a warning about depleting energy sources and severe effects on the environment (global warming and climate change, etc.). Buildings play a crucial role in climate changes because of the significant consumption of energy in this sector. Buildings are responsible on consuming 40% of total energy in the world and produces 30% of carbon dioxide emissions to the atmosphere (Ozdil, 2010). Nowadays, there is an argument amongst architects and engineers about the potential of taking lessons from vernacular architecture by applying the passive design strategies of vernacular buildings as the proper solution to controlling excessive energy consumption. Consequently, this will alleviate the environmental challenges such as increasing of pollution in atmosphere which leads to global warming (Burton, 2012). Hence, it might be workable to develop passive solar design strategies in contemporary buildings to promote energy efficiency. Proceeding from a principle that a building's design should ensure that constructions and actions of today would not compromise the right of future generations' opportunities to use the earth resources.

In vernacular architecture, people at the hot and dry climates employ suitable strategies of passive design into the buildings to adjust the inhabitants' atmosphere. Those techniques can be assessed and executed into recent buildings, and taking the vernacular architecture embodies valuable results of sagacity for reducing energy consumption in buildings. Gratis energy sources, could be provided, like the wind and sun to perform comfort inside the building.

Thus, designing and developing a specific system that can achieve energy efficiency in the almost entire building, through passive techniques, is a very real possibility. Where, there are many potentials in applying passive strategies, environmentally, economically, and aesthetically.

Erbil it is one of the ancient constantly dwelled cities and may date back to almost 6000 years (Khalid, 2014). Erbil has achieved a gigantic leap toward the development in building sectors. The majority of the building in the north part of Iraq, and Erbil as the capital of Northern part are applying electricity to maintain thermal comfort in the buildings. Therefore, the majority of the energy consumption in the buildings is employing to maintain thermal performance. This, consequently, increased the demand for energy in the region which already facing an energy shortage especially in providing the electricity power (Rozhbayani, 2018). See Figure 1.1.

Figure 1.1: Contemporary buildings in Erbil city nowadays (Ameen et al., 2016)

1.2 Problem Statement

The rapid growth of cities is making the demand on energy resources to satisfy people demands increase tremendously. Dependence on an active system inside the buildings is considered to be the major source of energy consumption.

Due to the economic and political openness of Iraq to other countries after 2003, Erbil has witnessed rapid development in building sector in the last decade. The economic blossom in entire Iraq has brought with it the construction boom-especially in Erbil of residential buildings of different types-from single-family dwellings to high rise apartments, mixed-use towers, medical and educational buildings etc. However, in Erbil, absence of electrical energy and relevant infrastructure is very significant since electrical energy for cooling and heating these new buildings through active systems, among other facilities, is obtained through generators that utilize non- renewable resources-petroleum, which, in return, produce heavy environmental pollution.

Disregarding this fact, the companies, architectural firms and their designers are using designs which focus only on so called aesthetics and appearance to attract clients. Moreover, they produce buildings which rely on active hvac systems for providing and maintaining comfortable indoor environments which consume electrical energy.

Although the vernacular architecture of Iraq in general and Erbil in specific is known to be very energy efficient through its design and construction characteristics (Rozhbayani, 2018), lack of awareness about the passive design strategies which have been utilized for centuries, leads to create high energy consumption buildings and, consequently, environmental contamination.

Therefore, the problem to be dealt with in this thesis is to bring out the energy-efficiency characteristics of vernacular architecture in Iraq and Erbil, with special reference to its formal peculiarities and to discuss how they can be applied to the future buildings.

1.3 Research Aim

The study aims to find the most repetitive and effective passive design strategies in the vernacular architecture the buildings in Erbil, in order to reduce the shortage of energy demands in this region of Iraq. In other word, to get a proper solution within the vernacular architecture from Erbil ancient city that can be utilized as a design process in the future buildings. Within this framework, the study aims to bring out the most effective passive design principles that have been utilized in the vernacular architecture of Erbil and discuss the ways they can be utilized in the design of the future buildings in the city that will help to reduce energy consumption in the building sector in Erbil.

1.4 Questions of the Study

- What are the most employed passive design strategies in the vernacular and traditional architecture in Erbil?
- How do passive design strategies in vernacular and traditional architecture of the same climatic conditions with erbil control energy efficiency?
- How and to what extent can the effective passive design strategies be reconsiled into contemporary building design so as to provide energy efficiency?

1.5 Objectives of the Study

Within the framework given above in section 1.4 the objective of the study is to analyze the characteristics of vernacular architecture in Erbil, with special reference to formal peculiarities of vernacular architecture of the city in order to find the most effective strategies. In order to achieve the main objective of this study, the following process will be applied:

- Analysis of the vernacular and traditional architecture characteristic in hot and arid climate of Erbil city.
- Investigation of the most repetitive passive solar design strategies which respond to the hot and arid climate of Erbil.
- Discussion of the acceptable and implementable passive design strategies in contemporary design in Erbil, in terms of reducing demand for use of mechanical active systems, and consequently for electrical energy in buildings.

1.6 Limitation of the Study

There are few limitations delineating the thesis given below:

- Field of the study will be limited to the climatic characteristics in several districts of Erbil city;
- The study will focus on residential buildings (houses) in vernacular architecture only, because they make up the basic category of buildings in Erbil;

- Since the major amount of energy in the houses is demanded and used for providing and maintaining indoor thermal comfort, the topic of energy consumption will focus on the energy serving this purpose in the study region.
- Only the most effective passive solar design strategies in form and material level of the buildings will be investigated according to its repetitive manner, depending on the literature review and site observation.
- Due to the renovation processes inside the citadel of Erbil, it was restricted to get more than three case studies, according to the authorities and government bodies in this place.

1.7 The Methodology

The methodology in this thesis can be divided into two main parts, first part is descriptive and the second is explanatory;

- The first part that will be discussed in Chapter two, and descriptive part in Chapter three, will be functional to employ because of the nature of this part of the thesis which focuses on the analysis of passive design strategies (in terms of architectural form) and their effects on energy consumption in a building's environment in hot and arid climate areas generally, and Erbil city particularly. The study is 'descriptive and exploratory' in nature, and seeks to understand the most effective passive design strategies in the vernacular houses and how could they be employed or developed to be used in contemporary houses in Erbil City in order to enhance their energy efficiency.
- The second part that will be discussed in Chapter three, is the methodology, which is involving the selection and analyzing case studies. This part will involve both quantitative and qualitative methods. Quantitative method is concerning with analyzing the case studies in terms of form, typology, architectural elements, etc., through site observations and description. Whereas, the qualitative method is including semi- structured interviews with the professional people like architects and engineers in order to get understanding about their opinions and attitudes towards involving passive strategies in contemporary or future design and their suggestions

based on applicability, functionality in architectural view and acceptability by the clients. Then, analysis will be carried out between;

a) The data and information about the most effective passive design strategies in Erbil vernacular houses reached in the literature survey, the theoretical framework, and gained through physical observations, and;
b) The attained results of the semi-structured interview undertaken with expert and professional people regarding the applicable, functional, and acceptable passive strategies that could be involved in the contemporary or future houses. Consequently, and based on this comparative analysis, the result will be discussed, and the guideline principles for future houses design will be suggested.

1.8 Thesis Structure

The present research is divided in five chapters.

- Chapter 1 introduces the thesis and it initiates with a summarized background on the design of the sustainable building, the heritage of vernacular architectural the relevance between both of them.
- Chapter 2, which is the evaluation of literature, focus on the capabilites of passive design strategies in vernacular architecture and buildings energy consumption and energy efficiency in buildings. Moreover, the chapter will highlight the vernacular architecture in hot and arid climate of Erbil.
- Chapter 3, which is the approach methods to achieve the study are described in detail. Chapter 4, that is 'discussion and findings', will be involved based on the obtained results from qualitative and quantitative methods.
- Chapter 5 delineate a conclusion of the study.

CHAPTER 2

THEORETICAL FRAMEWORK

2.1 Vernacular Architecture

The term vernacular is retrieved from word "*Vernaculus*" in Latin, and means domestic (Oliver ,1997). Vernacular building architecture is a hominid build that outcomes from the in relations between social, environmental, material, political and economic factors, (Asquith & Vellinga, 2006).

Vernacular architecture includes the residences and different buildings of the inhabitants, compromise with their environmental settings and accessible resources. All types of vernacular building architecture are constructed to address the need, offer the standards, financial prudence, and lifestyles of the culture that produce them (Oliver, 1997). Through history, several vernacular strategies formed by the domestic culture, climate, and the location have been utilized around the world. The identification of these methods or strategies for the building is generally reliant on the economic, climatic and social needs, in addition to the skill of builders, and availableness of the native materials. However, the climate is one of the most essential aspects which affect the development of the vernacular buildings in general and houses in specific. Through various time ranges, people have been building up their homes so as to accomplish climatic comfort in different climates, hence, utilization of the character of climate in building construction was deemed since the start of the history. (Oktay, 2001). Sun and wind orientation, moisture, pressure of air, temperature and precipitation characterize the climate which affects building form, material, and orientation of houses. (Yaldiz, 2009). Since northern Iraq and the city of Erbil lies in the hot-arid climatic zone, next part is devoted to its characteristics and effects on the vernacular-built environment.

2.2 Hot and Arid Climate Characteristics

Hot and arid climates include the areas that are described by dry climates. These are arid and semiarid regions that have three main characteristics: Very low precipitation, where the lowest rainfall occurs in arid regions in which the precipitation medians are fewer than 35 cm. Hot and dry climate is characterized also, by high evaporation ratio that commonly overrides precipitation and wide temperature swings both daily and seasonally. This leads to lacks in ground moisture because of the low average rainfall and quick evaporation. for instance, in the Middle East's arid regions the average of rainfall is less than 20 cm per year, while the annual evaporation ratio is reaching more than 200 cm. moreover, hot and arid climate characterized by a wide disparity in seasonal and daily temperatures. Hot and dry climates are located in everywhere on the globe, especially in Austra1ia area, southern zone of South America, and western North America, central zone and southern Africa, in addition to much of Asia. See Figure 2.1.

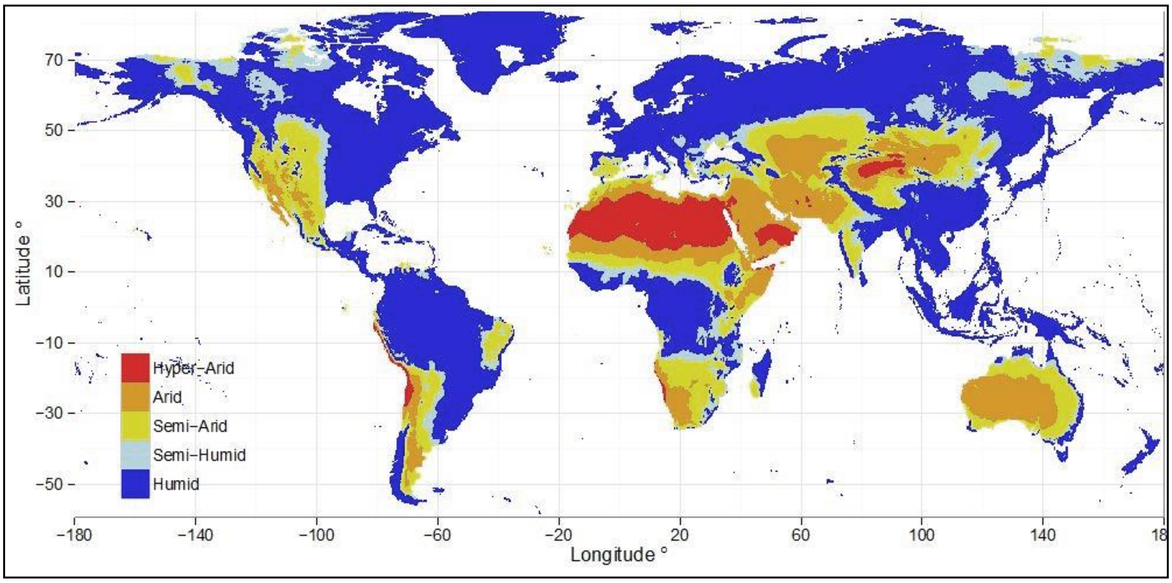


Figure 2.1: Map of climatic regions distribution (CGIAR-CSI, 2018)

2.3 Vernacular Architecture in Hot-Arid Climate

The researcher will explore the effect of a hot and dry climate in local architecture. The hot and arid climate directly affects design development in vernacular architecture. Compacted urban situations with narrow roads which are enveloped with arch and other shading components are the methods in hot-dry climate for designing vernacular architecture orderly to shun excessive sun radiations incidence. These sorts of methods in hot-dry climate give shading to inhabitants because it is a very important strategy to have in this kind of climates.

There are some vernacular methods that have been provided for hot and arid climates as cooling and daylight strategies. (Alp, 1991), addressed these methods as a courtyard, wind catchers (badger), evaporative towers, natural ventilation, stack ventilation, vegetation, as well as vent openings '*Mushrabiya/ Shanasheel*', which is especially covered balconies with woven timbers and small colored windows, as seen in Figure 2.2.

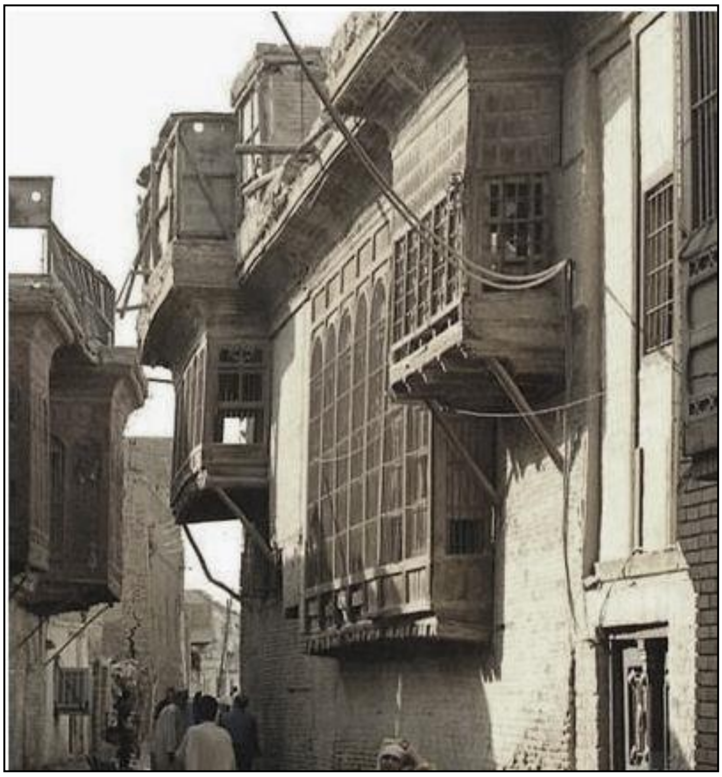


Figure 2.2: Mashrabyia/Shanasheel in Iraq (Ameen et al., 2016)

2.3.1 The form characteristic of vernacular architecture in hot- arid climate

As it is referenced, the forms of houses are impacted by the climatic characteristic. In the hot-arid climate zones, of which the characteristics were given above in the section 2.2, the main aim is to get minimum solar radiation in summer and to maximize it in winter. Therefore, the forms of houses are constructed around sunlight block insurance and sunlight allowance based on the needs in various seasons. The optimum shape for a house has the maximum solar radiation block in summer and the least heat losses in the winter. The compacted and cubic courtyard is the preferable compose in a hot and arid climate so as to limit the surface uncovered to the sun radiation incidence. Despite substantial spaces around it, but it has the smallest outside surface which is influenced by the sunlight radiation. Losses of energy because of extreme demand on cooling active systems happens when an uncovered surface to the sun results in heat gain. The whole uncovered surface to solar radiation can be controlled by the form of the building. Accordingly, that affect negatively therma1 performance of the entire building. It is essential to distinguish design factors, for example, those that are related to the heat exchange system (Bektas & Aksoy, 2011). Indeed, the internal form of the courtyard in the center gives air ventilation and shading to occupants by utilizing elevated walls rounding the building's border and planting trees for shading and fresh air in the middle of the courtyard, (Ghobadian, 2006). See Figure 2.3.

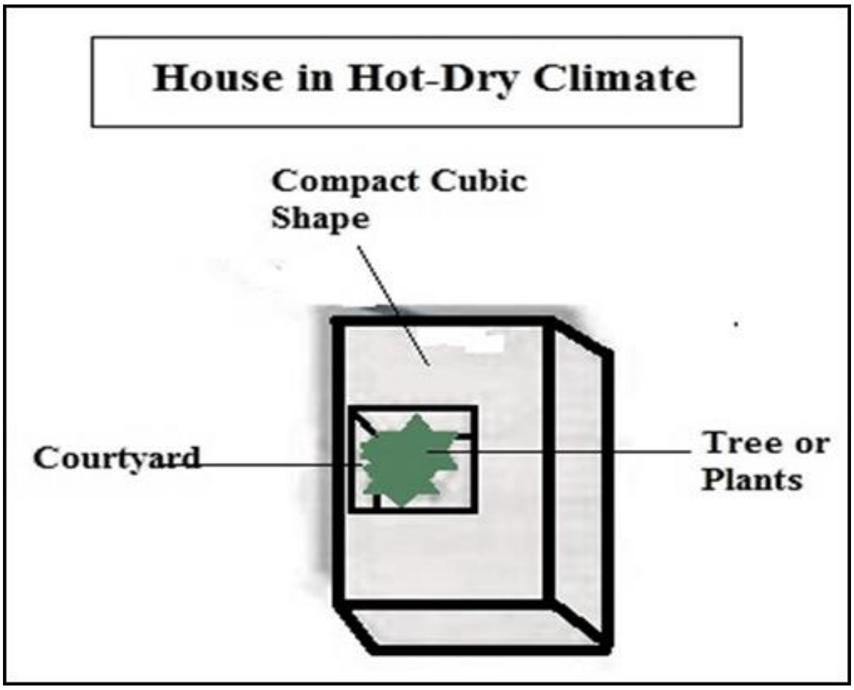


Figure 2.3: Climatic respond form of house in a hot and arid climate (Ghobadian, 2006)

2.3.2 The material of vernacular architecture in hot- arid climate

Material, for example, mud or stone with effective thermo-physical properties and good time lag may be a satisfactory material for the hot-arid region. Despite the materialistic endorsement, the hot air dependably shifts between the cool zones and oppositely. Actually, the external walls, incident by solar radiation could absorb and store heat for quite a while amid the day and after that can exchange that to the inside as a result of the lower temperature in inner spaces amid the evenings in a hot and dry climate. Accordingly, the internal walls will cool down amid the day and occupants feel comfort thermally, (Zandi, 2006). Climate has an impact on choosing the materials for building construction.

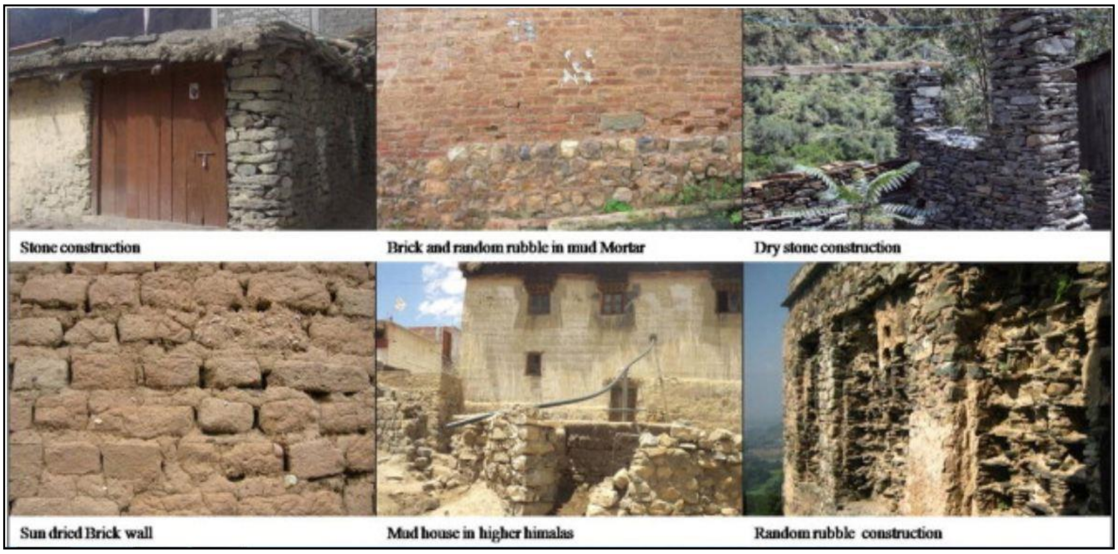


Figure 2.4: Building materials selection based on local sources and thermal potential in different climates (Kumar & Pushplata, 2014)

Thus, in various regions, the materials that can be adjusted to the climate needs must be considered. The fundamental features of the materials that ought to be considered are thermal resistance and thermal capacity. The properties of the materials must be determined based on the sensitive times in the region during the seasons' changes. For example, in hot and arid regions with cold winters, the warm days' events are exceeding than the events in chilly days. In this case, the hot days should be the critical season, so the materials in such sort of climates must be adjusted to the warmer days. Indeed, outside warmer air must be blocked to enter the buildings in a hot and dry climate, (Ghobadian, 2006). See Figure 2.5.

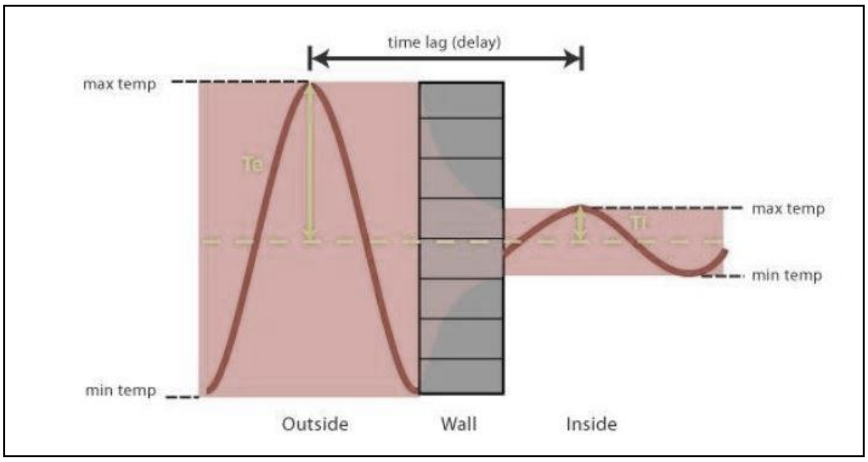


Figure 2.5: Thermal properties of building materials (Fesharaki, 2018)

2.3.3 The orientation of vernacular architecture in hot- arid climate

The orientation of the houses is relying upon its topography, sufficient private spaces, acoustic requirement, and sunlight and wind direction. One of the key obligations for an architect is to take in view the building's orientation toward the careful relationship between the building and sun path. According to the study and calculation of solar radiation in different seasons, 'Felix Marbutin' figured out some criteria to get benefit from sun path in buildings as follow:

- The building orientation ought to be southern to give indoor condition comfort by; heat in winter due to direct solar radiation penetration inside the building and cool in summer due to controlling or blocking solar radiation by overhangs and high path of the sun.
- However, the southwest and southeast orientation get similar solar radiation; hotter in the warm season and cool in cold season if compare it with the south orientation buildings.
- West and east exterior envelopes are cooler in chilled season and hotter in warmer season than the southern, southwest and southeast walls (Ghobadian, 2006). See Figure 2.6.

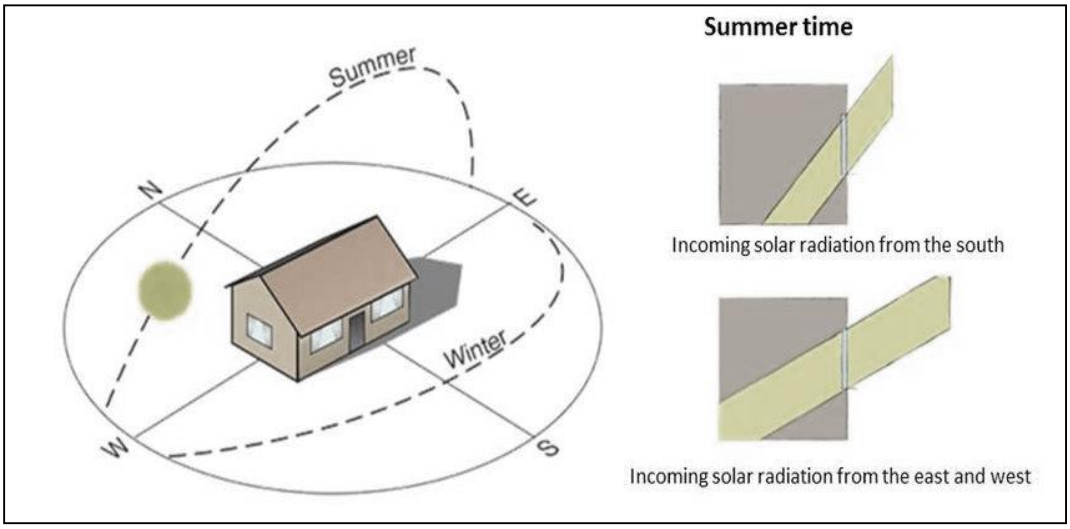


Figure 2.6: Orientation of the buildings responding to sun path in Northern hemisphere (Rovers et al., 2014)

Commonly, courtyard design that set basically on the north-south axis get the less exposure toward west and east to solar lighting in the warm season and the extreme quantity of south sun ray in cold season, (Zandi, 2006). Also, the hot-dry climate is directly affecting composition (form), direction, and used materials in the construction. Thus, design characteristics in hot and dry climates should fit the climate to obtain inner thermal comfort to the occupants through passive design strategies to reduce energy consumption (Koenigsberger et al., 2010).

2.4 Passive system in Vernacular buildings of Hot- Arid climate

Passive systems in a building are indicating to reduce energy consumption in the building by utilizing systems that depend on natural features through the source of nature. Passive design lessens the energy utilization in a building inner space along the lifetime relating to the microclimatic characteristic of the building location and the interaction design for the building elements, and, materials. There are several passive systems that have been used in the vernacular buildings of a hot and arid climates. In this part will explain some of the most effective ones.

2.4.1 Thermal mass

The idea of thermal mass as a method for enhancing diurnal temperature swings is a perfect and appropriate way for regions with a hot -arid characteristics, which are known by wide temperature during the day in summer, and a large number of sunny days during the winter. Therma1 mass is a necessary strategy for internal climate control in hot dry climates zone. In a hot-arid climate, the potential for heat gain absorb is a significant goal in controlling and improving the building indoor environment (Meir & Roaf, 2002). See Figure 2.7.

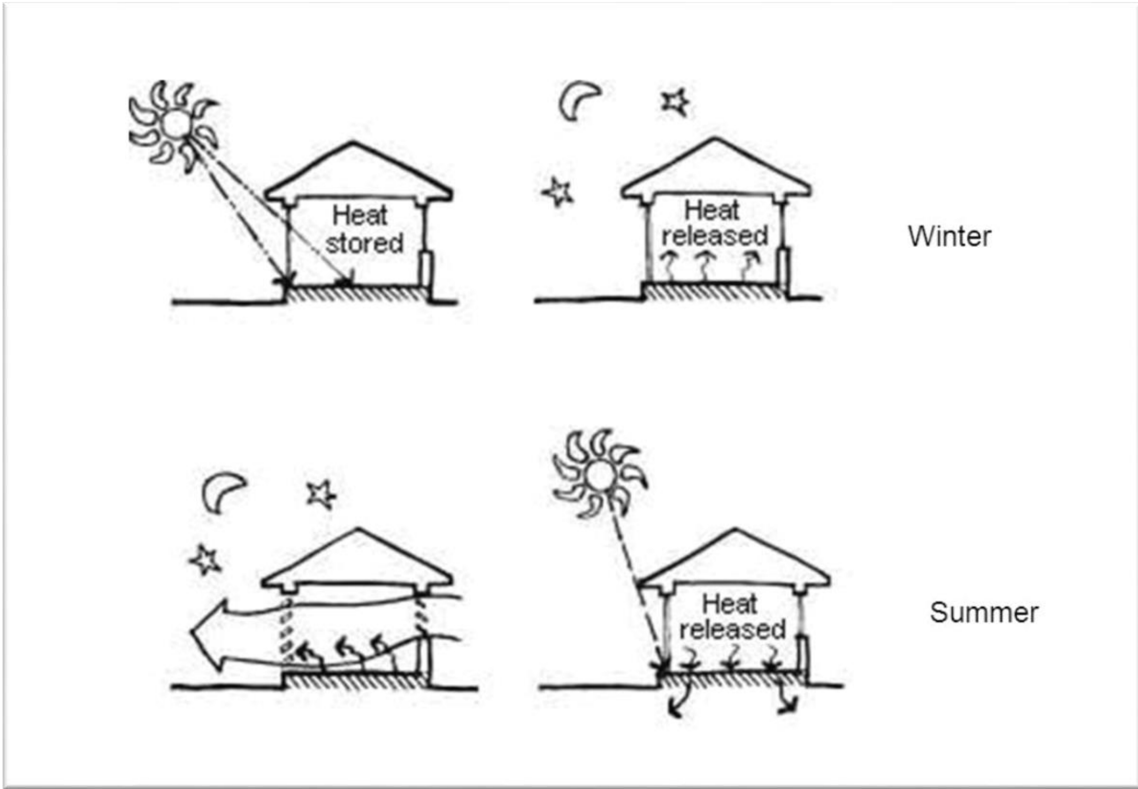


Figure 2.7: 'Thermal Mass' thermal behavior in the night and day as passive system in Hot-Arid climates (Mashhadi, 2012)

Thermal mass case as a passive system has been born a continuous review. It has been considered as a suitable passive system for housing in hot dry climates, and its advantages are being re-evaluated for free running buildings as well as conditioned ones, in wide building categories in different types of climates (Szockolay, 1996). Thermal mass potential in a shaded building capable to lower indoor temperature by 36-44% of the outdoor temperature when the dwelling is not ventilated (Givoni, 1994).

2.4.2 Natural ventilation

Ventilation can be defined as the replacing of warm air in the building with the cool air of outside (Szokolay, 1980). The main characteristic of hot-dry climates is long summer with a remarkable difference in temperature between day time and night, low precipitation, and low relative humidity. The indoor temperature will become higher than the outside temperature during the day time in hot- arid climates. Thus, day ventilation will raise indoor temperatures, while night ventilation (comfort ventilation) will lower them because the outside temperature will drop lower than inside temperature. There are several ventilation strategies in hot-dry climates. Ventilation as cooling passive strategies can be divided to; Stack ventilation, nocturnal ventilation, cross-ventilation (convective cooling), and evaporative cooling. The stack ventilation happens when warm air goes up due to its light weight and then will be changed by cold air beneath (heavy) so the heat will be shifted and is replaced by cool air by the stack ventilation from inner spaces of the building and cause a cool inner space for occupants, (Zandi, 2006). Nocturnal cooling occurs during the night when the building structure starts to radiate the absorbed heat during the day to the sky so, which leads to cool down the mass and surface of the building. The cross ventilation or (convective cooling) is produced in the day by increasing the humidification of the dry air through the evaporation of water molecules to reduce inner temperature and spread the cold air which known by (evaporative cooling). These ventilation strategies of cooling as architectural passive design will be explained in this part as follow;

2.4.2.1 Stack- ventilation

As mentioned previously, cool air introduces into the building through the openings at a lower level, whilst warm air is expelling out of the building through higher level. For instance, the proper position for the stack ventilation placement is highest part near the roof, where, warm and light air will rise to go outside from this placed. According to stack ventilation physical properties, and for more workability for stack ventilation a specified height is required to be designed between the inlet openings of cool air below, and the outlet openings of warm air above. To achieve effective stack ventilation, it is important to increase the height between floor and ceiling like creating atrium or a chimney or tilt the surface of the ceiling (Kleiven, 2003). See Figure 2.8.

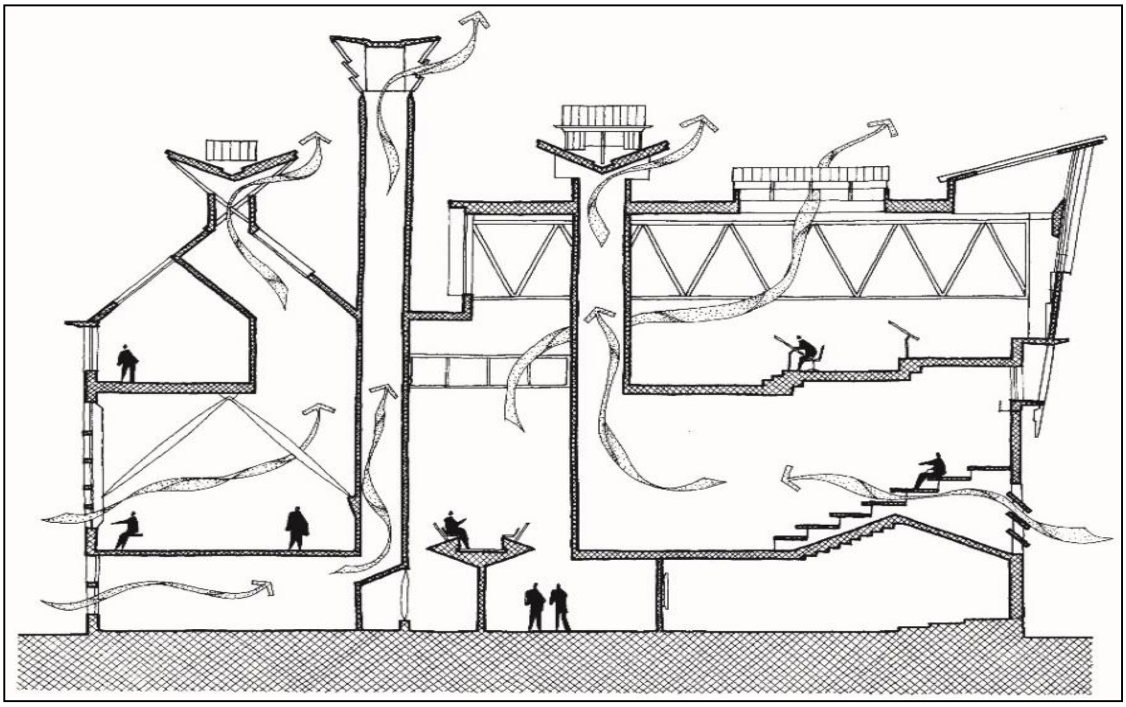


Figure 2.8: Stack Ventilation in Buildings (Section: The Qucen's Building, Dc Monfort University-Leicester Eng1and) (Mashhadi, 2012)

Commonly, the positioning and the size of the window drive a key role in cooling inner space if the movement of air is proper. The inner air velocity is depending on the exterior air velocity, and the direction angle of the wind incidence on the opening surface, in addition to the opining size. The following table shows the relationship between location and number of the openings, and the air velocity as a percentage of the exterior wind speed (Brown and Dekay, 2001). See Table 2.1.

Table 2.1 The effective criteria of location, number, and size for the openings on the air movement in/out the building (Brown & Dekay, 2001)

Opening width as a fraction of wall height	1/3	1/3	1/3
Opening width as a fraction of wall width	**1/3**	**2/3**	**3/3**
Single opening	12-14%	13-17%	16-23%
Two openings in same wall	-	22%	23%
Two openings in adjacent walls	37-45%	33.33%	40-51%
Two openings in opposite walls	35-42%	37-51%	47-65%

Range=wind 45oC perpendicular to opening

2.4.2.2 Convective cooling (cross ventilation)

As stated previously, convective cooling works in two ways during the evening in hot and arid climates. In the first way, at night time, cool air is created on the building's roof due to the long infrared radiation from the sky. Then, cool air (heavy) will move down into the courtyard and take out the hot air (light weighted). The parapet at the peripheral of the roof bans the cool air to escape to the outside of the building. Then, the down of the building and its structures will cool through the mass of cold air (Aksugür, 1988). See Figure 2.9.

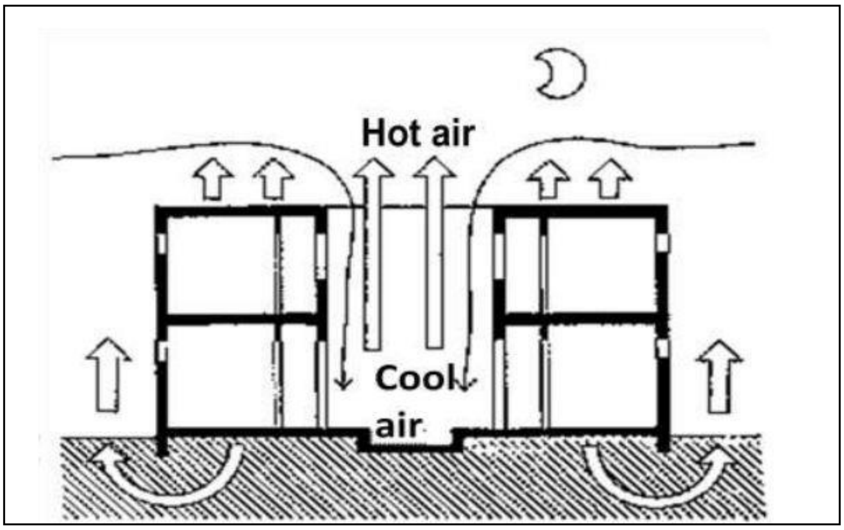


Figure 2.9: Convective cooling during night time as passive strategy in a hot and arid climates (Mashhadi, 2012)

In a second way, the outer cool air will be introduced to the inner space through openings in the outer walls (cross ventilation), or through the wind catchers, which get the prevailed wind in some hot-dry climates. The cool air will enter the inner spaces of the building and take out the warm air during the night (Raja, *et al.*, 2001), as seen in Figure 2.10. Consequently, during the day, the heat will be taken from the air by thermal mass strategy.

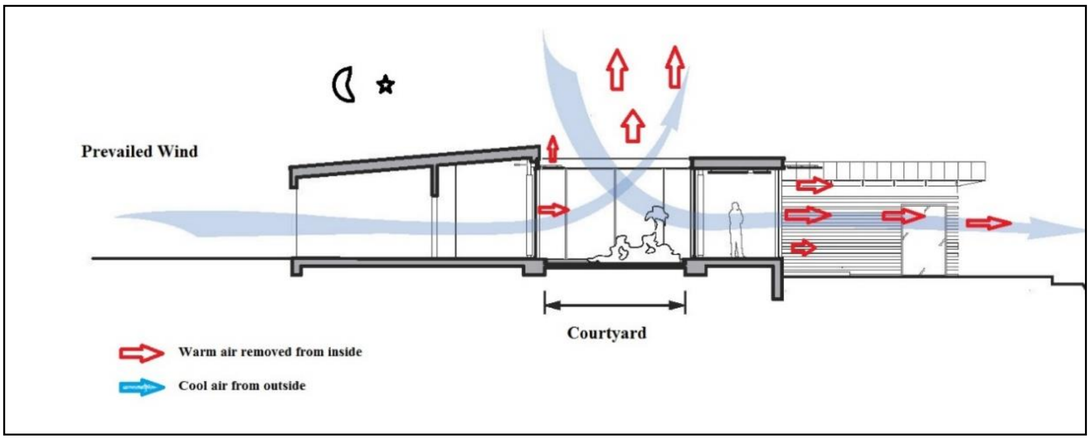


Figure 2.10: Cross- ventilation at night in a hot and arid climate (Mashhadi, 2012)

2.4.2.2.1 Wind catcher in hot –arid climate

Wind-catchers or 'Badger' is one of the more famous and traditional passive cooling strategies in vernacular architectures of hot-dry climates. Wind-catchers have been utilized as a natural ventilation tool in the buildings of the hot and arid region to remove the inside heat gain during long sunny days. the design of the wind-catcher is above the building, facing the dominated wind, to promote the cool air inside the building, because usually, the windows cannot supply ventilation during the day because of dusty winds that characterized in these regions which are becoming less dusty as much as get higher from ground (Kalantar, 2005). In architectural context, the wind catcher designs generally by making an empty square tower, made with the building fabric, has openings in the upper side and inside partition in the building space to aid the wind to enter from all the directions, causing an air stream in the tower's shaft to inter to the occupation space. The perfect effect of this strategy has made wind catcher an important architectural element in the vernacular buildings of the hot and arid climate (El-Shorbagy, 2010). See Figure 2.11.

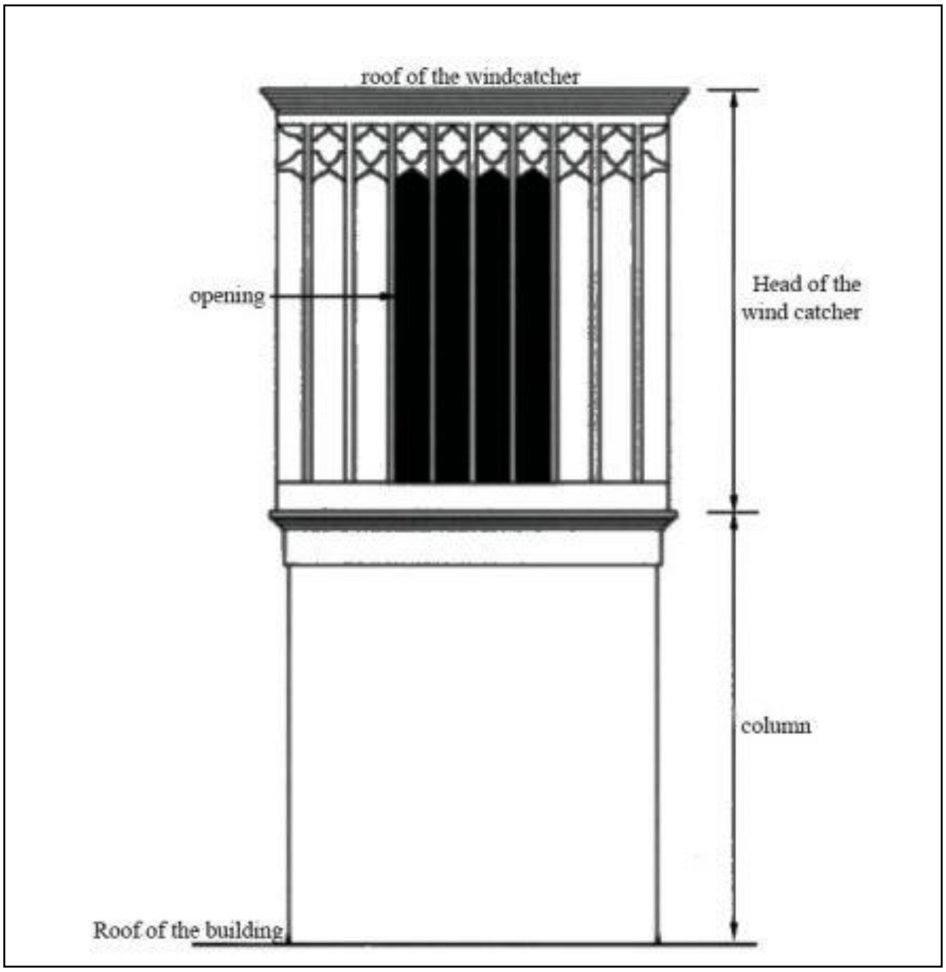


Figure 2.11: Wind catcher in a hot and arid climate (Bahadori & Dehghani 2008)

The height of wind catcher is between 2m and 22m and some time the design arrives up to thirty meters in some regions like (Yazd) in Iran. The local masonry will be commonly used in the building of wind catchers to be adjusted to the climate (Zandi, 2006). There are categories of wind towers according to their opening (Al-Shaali, 2002), as seen in Figure 2.12.

Sometime, and because of dry air in hot and arid climates the wind catcher's openings from outside covers by wet pads in order to evaporate the inlet air for better thermal comfort inside the buildings. This strategy known as evaporative cooling and this element known as evaporative towers.

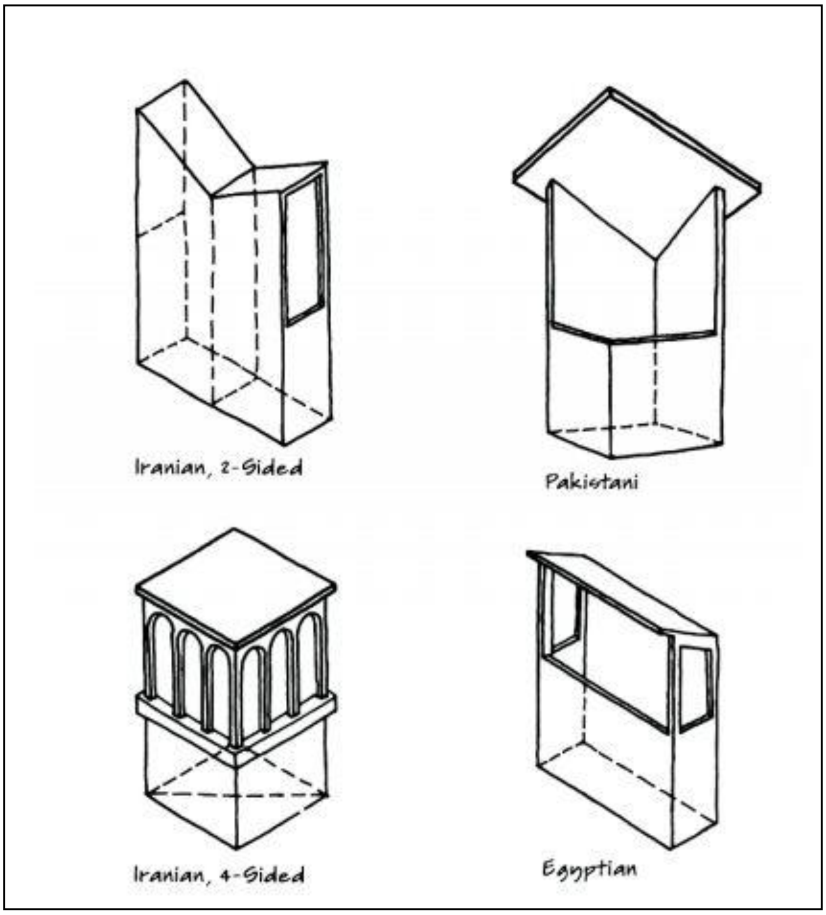


Figure 2.12: Types of Wind-catchers according their openings and shapes in hot and arid climates (Al-Shaali, 2002)

2.4.2.3 Evaporative cooling

As mentioned, the convective cooling is produces during the day by increasing the humidification in the air through evaporative towers or through placing fountains and vegetation in the courtyard area. Essentially, the evaporative cooling happens through wind-catchers. The made wind stream will be passed inside wet bodies like a wet pad or a wetted permeable clay. The evaporative cooling technique for occupants who are identified with the cooperation of their body and the environment. The evaporation from the skins of the occupants is quickened by moving the air development upon their body, making them thermally more comfort. (Zandi, 2006). The air stream speed is depending on the performance of the evaporative cooling design, for example, the height of the tower and cross section area, likewise the resistance to the air flow in the cooling tower (Thompson et al., 1994). See Figure 2.13.

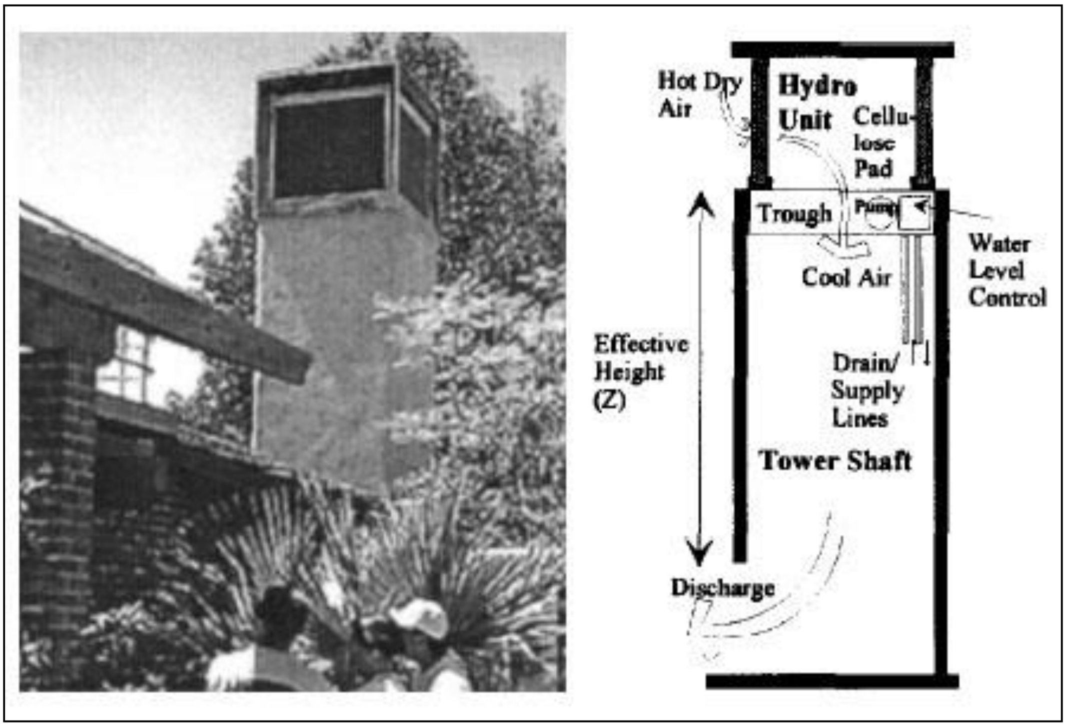


Figure 2.13: Evaporative towers as a passive strategy for evaporative cooling system in hot and arid regions (Soflaei et al., 2017)

The evaporative cooling system produces through moving the breeze above the water bodies or fountain inside the building. The heat of air will be reduced by moving the air over the water surface and gives fresh air to the around ambiance which is adequate hot and arid climates (Mashhadi, 2012).

Goulding (1992) addresses that as long as the pressure of water steam in the shape of droplets is higher than the fractional pressure of the water steam in the surrounding weather, the vaporization will happen. The changing condition of water from a fluid to steam coincides the taking out the warmth from its circumstance and other neighboring faces. The surface temperature will be decreased through the vaporization from the inner face of a closed can such as a pipe. Means, the vaporization cooling happens indirectly when nearby air out of the pipe is become cooler but without an increase in dampness (Goulding, 1992).

2.4.3 Shading

Shading is one of the passive strategies to reduce energy demands in buildings and improve thermal comfort especially in hot and arid climates (Farrar-Nagy et al., 2000). This is because of the high solar radiation incidence on the buildings in these climates, which characterized by the long and sunny days in summer. The shading of the buildings is related significantly with the opining size, and orientation of the buildings, and the shading can be achieved through many ways, like vegetation (trees), or shading devices like overhangs or other architectural elements. (Brawm, & Dekay, 2001).

Openings are indispensable for natural lighting in dwelling for ventilation in the hot and arid climate. And the openings, especially windows must be covered either by shading devices, roof extends or by '*Shanasheel*' to reduce the direct solar heat gain penetration into the building, as shown in figure '3' in this chapter. The size of the windows on the west and east flanks should be lessened in order to reduce heat gains into the house in the early dawn and late afternoon (Alp, 1991).

2.4.2 Courtyard house

A courtyard can be defined as; a surrounded outdoor or semi-outdoor space encompassed by buildings and uncovered by a roof. Courtyards were firstly used in vernacular buildings in many hot regions like; the Middle East, parts of Asia, Mediterranean area, and South America. (Khan et al., 2008). See Figure 2.14.

Figure 2.14: Top view for a residential area in hot and arid climate cities, (Baghdad) (Soflaei, et al., 2017)

Courtyard is commonly, a square or rectangular room in the center of the house, and has no roof. The courtyard may contain a paved part, fountain or pool, trees and vegetation to improve surrounding ambient and produce a self-sufficient microclimate (Soflaei et al., 2017). See Figure 2.15.

Figure 2.15: Courtyard house in Shiraz, Iran (Soflaei et al., 2017)

It could be considered as the most successful prototype of climatic responsive architectural passive design in the hot and arid climatic regions, which is responding to the climatic demands. Furthermore, the central courtyard itself is one of key elements in the houses at the hot regions, therefore, in a hot and arid climate, the courtyard houses are preferred. So as to reduce the affected surfaces by solar radiation incidence, compact forms are chosen, as mentioned previously. Shaded areas can be created by organizing the courtyards with compact forms and the sun path in the hot and arid climates. (Leylian et al., 2010). See Figure 2.16.

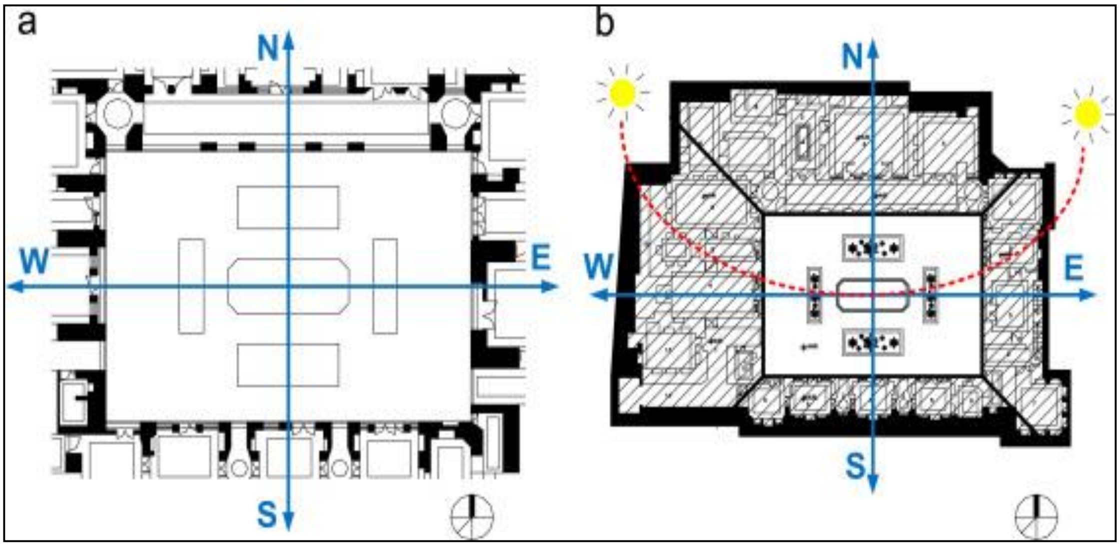


Figure 2.16: Typical Courtyard and its relationship with the sun path and orientations in a hot and arid climate (Soflaei, et al., 2017)

The courtyards main function was to enhance comfort performance in the buildings by adjusting the microclimate condition out of the rooms which surround the courtyard, and improve the ventilation.

In addition to the climatic benefit of courtyard, there are other benefits, like it can be considered as the better way to use of land. The archetype buildings in the majority of the hot and arid climate areas were opened all inward toward the courtyard, except the building main entrance door. The reason behind that was to protect the building from hot and sandy storms or prevailing winds (Al-Hemiddi & Al-Saud, 2001). Different shapes and types have been developed for courtyards design in different regions around the world based on the specific climatic characteristic in each region.

2.5 Passive Buildings as Energy Efficient Buildings

Energy efficient building is the building that requires low energy demand for performing comfort for its users, and their energy reach 50% from the regular building's energy demands. Passive houses are considered as energy efficient houses, which applying passive design strategies according to their specific climate. Passive buildings are known as buildings with acceptable thermal comfort for the occupants with low energy consumption. The passive building doesn't characterize by particular construction techniques only, but it recommends several performance standards. Moreover, the architect can choose their architectural design and building materials to the climatic characteristic of the region and the required energy target inside the building (Fesharaki, 2018).

The advantage of the passive building is its flexibility and adaptation in different climatic conditions. The strategies of each passive building will be different from others based on the climate that the building is located in. for example, in hot regions more focus will be on passive cooling strategies, including, ventilation design strategies, shading, and heat gain control, as explained in hot and dry climates passive strategies earlier in this chapter.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The research questions as assigned in chapter one, section 1.4 were:

- What are the most employed passive design strategies in the traditiona1 architecture in Erbil?
- How do passive design strategies in traditiona1 and vernacular architecture of the same climatic conditions with erbil control energy efficiency?
- How and to what extent can the passive design strategies be reconsiled into contemporary building design so as to provide energy efficiency?

The methodology applied in this study consists of both qualitative and quantitative research methods. Therefore, the following process will be approached as thesis methodology;

3.1.1 Quantitative method

It is based on inspecting the links between variables, where the numeric shape is applied in collecting data, and statistical tools are provided in the analyzing. Hence, this method will be applied in the theoretical analysis and physical observations, plus documentary analysis for the selected case studies as will be illustrated later in this chapter.

3.1.2 Qualitative method

The qualitative method is applied in the researches that targeting to implement profoundly more than wideness (Blaxter et al., 1996). It has provided to consider the subjective or personal experience of the individual within a natural framework (Saunders et al., 2012). Thus, the qualitative method takes into consideration that individual consciousness inspires social reality (Burns, 2000). Therefore, this way will be applied in the interview with professional people as will explained more in this chapter.

3.1.3 Case study method

Case study is both a tool and a method for study. In the ‘case study’ method, the investigator attempts to gather the parts in support of the assumption and increase the credibility. A case study proceeds only for a particular case. It needs a personal observation or objective method. In fact, the 'case study' method means a study in depth, which means to search features of the case (Devare, 2015). So as to approve and improve the credibility of the research, the real case studies for vernacular houses will be chosen from Erbil, and after that, the data gathering and investigation will be obtained.

3.2 Data collection

Both primary and secondary data sources were utilized in the implementation of this research as follow;

3.2.1 Secondary sources for data collection

Secondary sources have been approached to attain a sufficient comprehension about the principle thoughts and theories related to the topic. The survey of literature was conducted through various sources, for example, archives, government reports, books, indexed papers, published and unpublished theses, and credible internet sources records.

3.2.2 Primary sources for data collection

Two ways will be used in this part of the research to obtain data from primary sources; the first is through the analysis of the case studies according to personal site observation to assess the effective passive strategies. The second way is through semi-structured interviews with experts in order to reach comprehensive understanding about their attitude regarding the implication of passive strategies recalled from vernacular buildings into contemporary design.

3.2.2.1 Field observation

The observation is one of the regularly utilized methods in the researches, which the data is gathered by the analyst through direct examination. In this method individual bias could be neutralized, data gets by present conditions (Kothari, 2004). It had been utilized in this thesis to investigate passive strategies in vernacular houses for case studies in Erbil city to identify the most effective ones. The observation in this study will be focusing on investigating and analyzing the vernacular building passive strategies and the typology of these buildings and how could be understood in terms of energy reduction with the respect of climatic characteristics in that time without depending on active system which are available today and increasing energy loads in the buildings.

3.2.2.2 Semi- structured interviews

Three questions were designed so as to acquire the necessary data from thirty selected professional participants. Divided to ten academicians, ten architects, and ten engineers, from different public, and private sectors. The questions were covering one of the primary points in the research, which is the most effective passive strategies for the design of Erbil future houses:

- What is the most effective passive design strategies for houses in Erbil hot and arid climate in terms of reducing the demand on energy consumption in the houses, that can be re-call from vernacular or traditional buildings?
- What are the passive strategies that can be developed in the contemporary buildings depending on vernacular or traditional houses elements?
- How can develop effective passive strategies to be applied in contemporary design in terms of aesthetic value in the design project and the satisfaction of clients? See Figure 3.1.

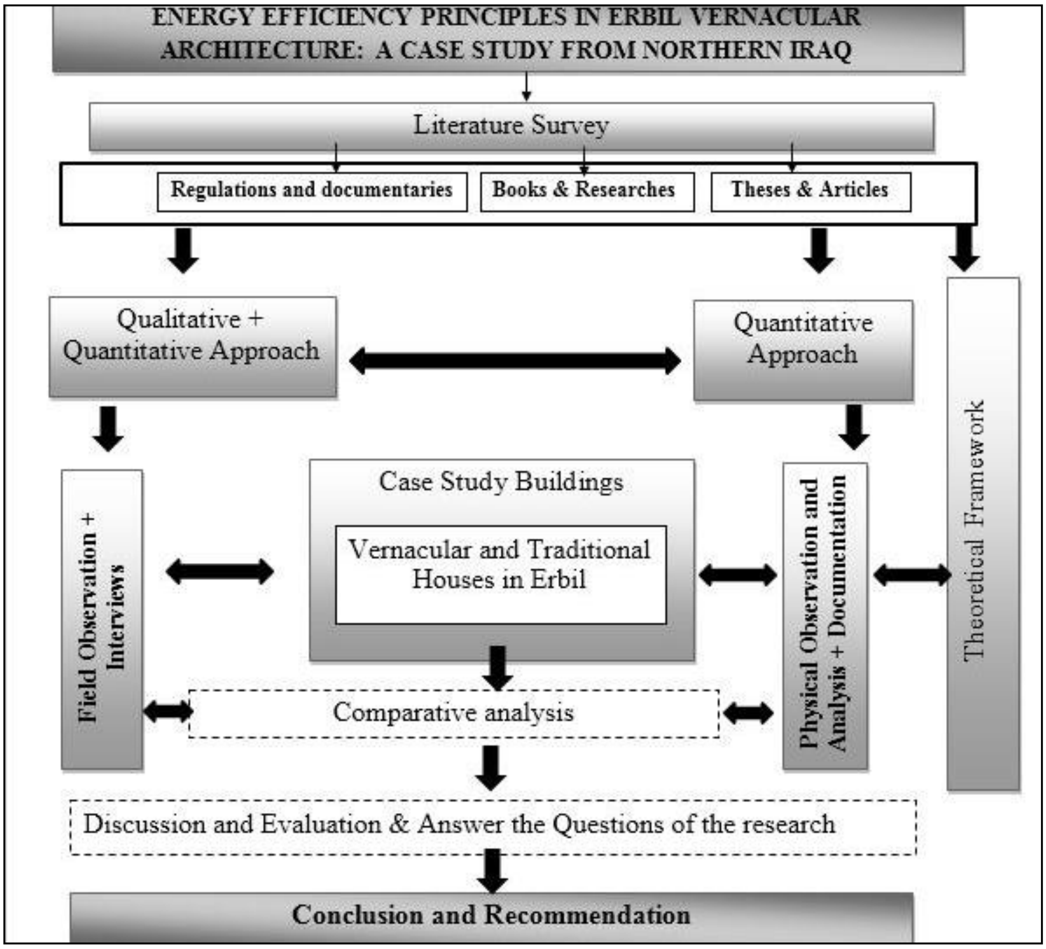


Figure 3.1: Methodology framework (Author, 2019)

3.3 Study Region Description

3.3.1 Erbil history and geography

Erbil is lying on wide fertile plains of almost 15,970 km^2 calls as ‘‘Dashtie Hawler” between the “Small Zab” and the “Great Zab” streams. It holds the identical name along history (HCECR, 2012). Erbil is historical city and the name of Erbil city had driven from Helios, the god of the sun. The historical texts about Erbil city return to Neo-Sumerian period when the greet kings of Ur assaulted Erbil between 2094 to 2046 BC and 2047 BC to 2039 BC but could not defeat the city. Erbil has considered one of the important trades and political center in the ancient era. The city was connecting all the trade ways among various places in the olden world. The city lost its prominence in the 13th century because of the Mongolian, Persian and Turkish occupations to the city.

The city of Erbil is locating geographically on (36°11′28″N longitude) and (44°0′33″E latitude) in the north-east of Republic of Federal Iraq. It is considered the capital of the Northern fragment of Iraq. The city of Erbil is lying in a relatively plain area and has an average elevation of 453 meters above sea level. Erbil is located about 88 kilometers east of Mosul (Saeed, 2003). The city's area is estimated by 130 km2, and the population in this city was estimated by 1,025,000, in 2008 (Fadhil, 2011). Today Erbil is the capita1 of the federal region of Iraqi Kurdistan. It is located in the north part of Iraq, around 350 km to the northeast of Baghdad capital of Iraq’s Federal Republic (Ameen, 2016). See Figure 3.2.

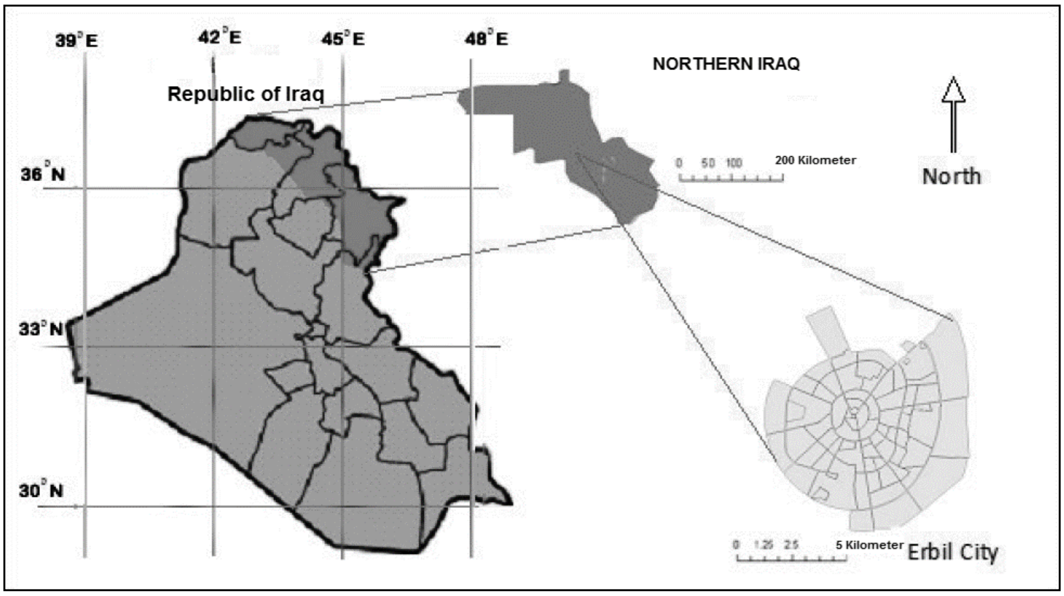


Figure 3.2: Erbil city location within Iraq (Rozhbayani, 2018)

3.3.2 Erbil Citadel (Qala’a)

Erbil Citadel (Qala’a) is one of the most important archaeological places in Iraq and Kurdistan region of Iraq; it more than 6000-year history of continuous settlement (Novacek, 2008). The texts demonstrate that refer to middle ages state that Erbil Citadel was strengthened and protected by a continuous wall which included gates and towers in addition to a trench that surrounded the citadel. In the 13th and 14th centuries, the citadel comprises dwelling places, an administrative center, monastic silos, and a Christian church. Thus, in this time the citadel wasn't only military or administrative place, but it was also an urban center. It has continued settlement units, markets, and public buildings (History of Erbil Citadel, 2015). The Citadel was exposed to a few changes after 1920: A gate was opened in the northern side somewhere in the range of 1920 and 1930, and the southern main gate was destroyed during the 1950s to open the street for passing vehicles. The street linked the two gates, dividing the urban texture of the citadel from the north toward the southern part, (Ameen, 2016). This Citadel was assembled on layers of archaeological debris which exemplifies consecutive historical settlements with a relatively ovoid in plan, the top gauging 430 x 340 m (Approximately 102,000 m2 as total area), which raises around 25–32m above the surrounding ground (Ibrahim et al., 2015), as seen in Figure 3.3.

Figure 3.3: Erbil Citadel (Qala'a) shows the street dividing the urban fabric (Amen, 2016)

The southern main entry was recreated somewhere in the range of 1970 and 1980 (HCER, 2014). In this period also, when there were numerous physical changes in the citadel, the society had been exposed to change too. The people started to leave life in the citadel and abandoned their homes. From 1986 until 2006, noteworthy social changes happened because of the dilapidating houses and bad physical condition of urban texture houses which affected negatively the health condition due to the bad water and sewerage system, (Ibrahim et al., 2015). See Figure 3.4.

Figure 3.4: A dilapidating house in Erbil Citadel (Ameen, 2016)

Thus, Kurdistan Regional Government in Iraq evacuated the citadel in 2006 and set up the High Commission for Erbil Citadel Revitalization, its goal is to conserve the legacy of the citadel (Mohammadi, 2014). See Figure 3.5.

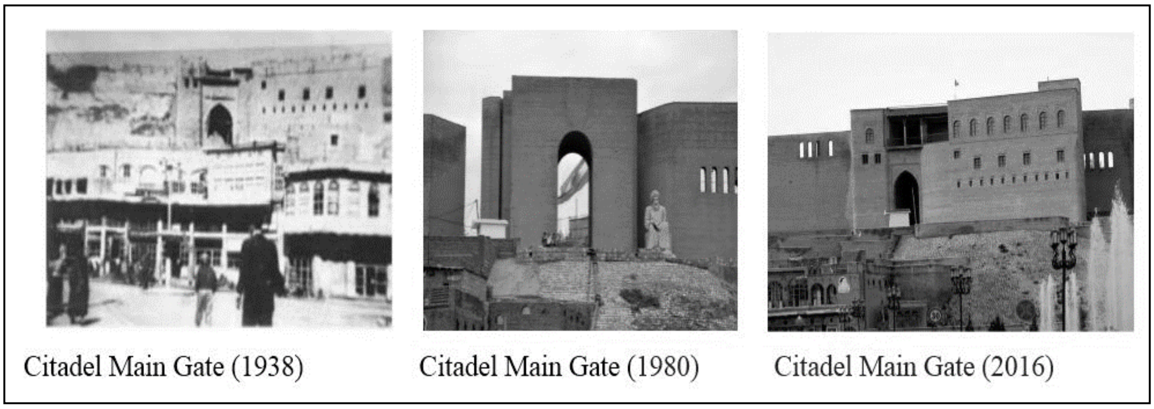


Figure 3.5: The changes in Erbil Citadel main Gate (Ameen, 2016)

3.4 The Effect of Erbil Climatic Characteristic on the Buildings

It is important to understand the climatic state of Erbil and Northern Iraq and comprehend the normal behavior of the buildings in various seasons. Thermal inconvenience occurs in buildings if an efficient - system isn't applied for lessening heat gain/loss from the buildings according to the season necessities. For instance, the reduction of heat gain in the buildings in summer time should be carried out, however, the heat losses from the buildings ought to minimize amid winter. Numerous factors can influence thermal comfort in people; such as open-air temperature, air movement, and relative humidity. Air movement could decrease heat pressure and improve thermal comfort performance in summer. Consequently, the strategies of ventilation could be applied for facilitating air movement inside the buildings in summer, in such a case that there is no air movement, the ratio of thermal comfort is around 44% when the temperatures underneath 29^{0}C, while during an air flow by 0.7m/s, the thermal comfort can enhance to 100 % (Ashen, 2009).

Commonly, the climate of Erbil can be named Semi-Arid Continental and is depicted by extreme conditions. The winter in Erbil is described to be so cold with precipitation and intermittent snowfall, though the summer is hot and dry. The greatest temperature amid the day may reach 50 °C in the warm summer, whereas the lower day time temperature may fall under zero in winter (Saeed, 2012).

Hence, and according to the previous explanations, Erbil and Northern Iraq areas are extremely rich by solar radiation. Solar irradiance is important for the providing warming framework in the winter, consequently, reduce the requirement on the active heating method. However, it has the contrary impact in summer because of expanding the active system requirements for cooling inside the buildings. Solar radiation frequency through the southern oriented windows in Erbil is 1205 kWh/year, while from the Northern bearing it increases 453 kWh/year (Husami, 2007).

3.5 Important Form and Material Strategies in Erbil Vernacular Architecture

This study will try to find out the passive strategies that have most effective role in responding to the climate of Erbil, as initial factors to reduce the harsh impact of the climate and consequently reduce the energy consumption. The study focused on the form of the vernacular or traditional architecture.

The literature review has been approached. The courtyards are the center of the plans of houses in Erbil Citadel region, with restrictions given by the shape of the land plot. If the frontage was broad, then the courtyard was retained in the mid orthogonal to the passageway with the long axis if it is rectangular. In such cases, the plan was often divided into two copied arcades with many rooms opened toward the courtyard. Courtyards were usually designed in geometrical shape, like to be square or rectangle. Commonly, a large and medium house were constructed in two floors to maximize floor area. Thickness masonry walls have been used to build the rooms and often use this thickness by mean of burnt or mud bricks to make shelves and niches from inside. Rozhbayani (2018), characterized the vernacular buildings in Erbil traditional and old districts by two main features; first is the thick walls with burnt or mud brick; second is courtyard shape. Raof (2018) emphasized that the most important character in Vernacular architecture in Northern Iraq and Erbil Citadel particularly is Courtyard prototype.

According to Morad and Ismail (2017), states that the Citadel of Erbil is occupied by vernacular and traditional courtyard-houses accessed through some narrow passageways to deliver covering above the path and neighboring dwelling that reduces the air temperature. The main characteristics of the vernacular houses are inward looking with courtyard, the courtyard is designed as a humble plan shape square and rectangular with cubic yard. Having one outdoor elevation and three other edges of the houses encircled by neighborhood dwelling, which protect the external brick walls and increase thermal resistance of these walls. Ayyash, (2015), demonstrated the characteristic of the vernacular and traditional houses in Erbil to be courtyard houses. Moreover, he addressed that the burnt brick in addition to mud brick masonry thick walls were always used in these types of buildings.

Based on previous studies regarding vernacular or traditional houses in Erbil hot and arid climate, the results demonstrate that the most prevailed passive strategies in these buildings are courtyard and thermal mass through thick masonry walls. See Table 3.1.

Table 3.1: The most effective and repetitive passive strategies in form and material's level in vernacular and traditional houses in Erbil Climate (Author, 2019)

Variable	Passive strategies	References
1	Courtyard form	Mandilawi, (2012); Rozhbayani, (2018); Raof, (2018); Morad and Ismail, (2017); Ayyash, (2015)
2	Thick-mass walls	Mandilawi, (2012); Rozhbayani, (2018); Ayyash, (2015)
3	Mud or Burnt Bricks	Mandilawi, (2012); Rozhbayani, (2018); Ayyash, (2015), Morad and Ismail, (2017)

Thus, the study will focus on these three strategies as initial factors extracted based on previous studies in Erbil- Northern Iraq in both form and material level. Hence, these factors will be applied to test the energy efficiency in the selected vernacular and traditional case studies.

3.6 Selection of Case Studies

In addition to literature review, the site observation to the old districts in Erbil city, such as Citadel, Taajeel and Arab areas, and Khankah, etc., in order to identify the common attributes in traditional architecture in Erbil. The researcher focused on the Citadel area as the oldest place in Erbil (Ibrahim et al., 2015). See Figure 3.6.

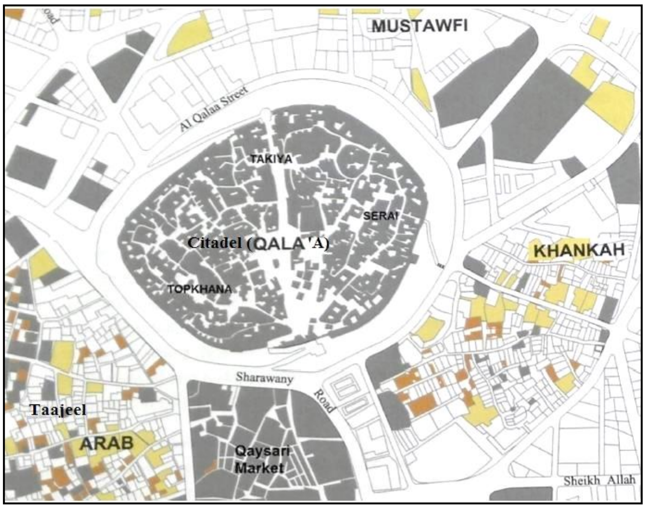


Figure 3.6: Old urban fabric with vernacular buildings in Erbil city shows main three (Mahalla) inside the citadel (Ibrahim et al., 2015)

3.6.1 Criteria for the samples' selection

The selected case studies had carried out based on criteria of selection which are;

- All the selected buildings are from the old district in Erbil which is Citadel district, because of ancient and old characteristic as one of the oldest place in the region.
- All the buildings are vernacular or traditional houses.
- The buildings are still keeping their original architectural elements (either physically or through documentations), which help the researchers in their investigations or studyings.
- Different area inside Erbil citadel with economic levels of living have been selected in order to insure the variety in the way of living to test the most common strategies in all these buildings

3.6.2 Selected case study houses

Three vernacular and traditional case studies have been selected in order to analyze the most effective passive strategies in them. The selected case studies where houses for different level of people in three parts (Mahalla) of citadel area, namely; the Seray that was rich families' area; the 'Takiya' area that was for mid-level families; and the 'Topkhana', area which was for common families like artists, musicians, and farmers, as mentioned previously.

3.6.2.1 Hashim chalabi house

This house is located in Seray area (*mahalla*), near the southern Gate of Citadel area, and it is belong one of the rich families in the citadel area at that time. See Figure 3.7.

Figure 3.7: Hashim Chalabi House location within Erbil Citadel area (Google Earth, 2019)

The house is two floors, and characterized by central Courtyard surrounded by several rooms, as seen in Figure 3.8, 3.9 & 3.10.

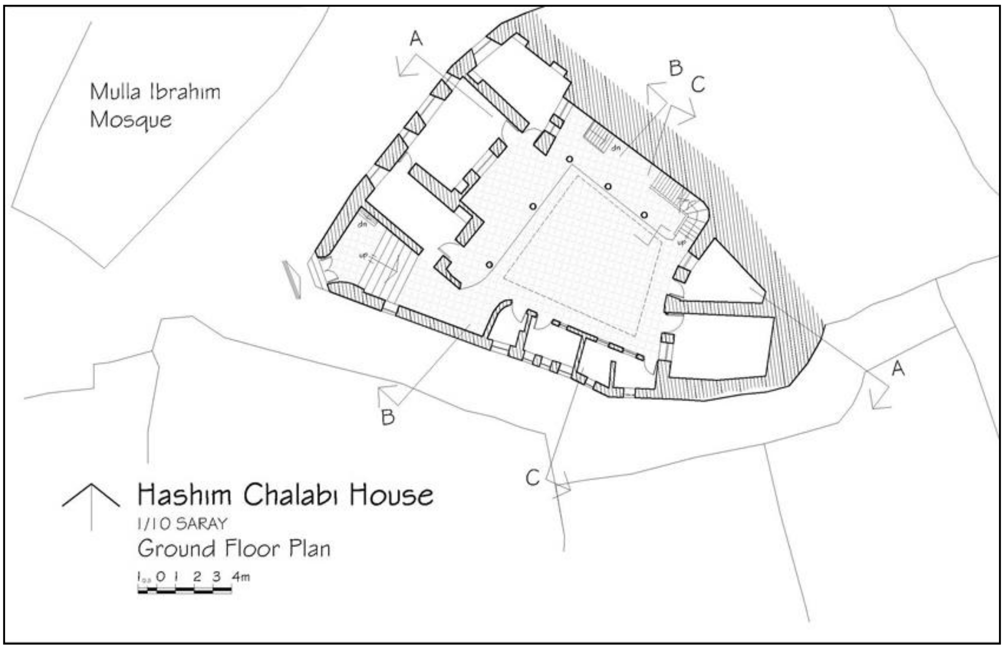


Figure 3.8: Plan of the ground floor in Hashim Chalabi house (HCECR, 2012)

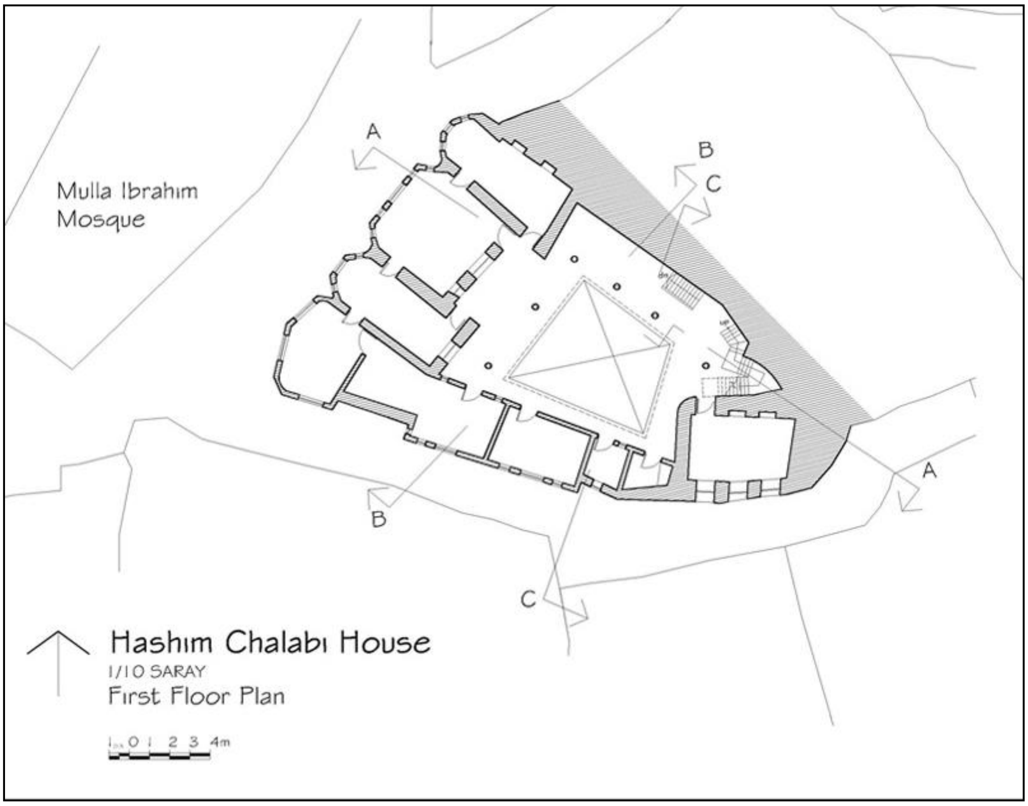


Figure 3.9: Plan of the first floor in Hashim Chalabi house (HCECR, 2012)

Figure 3.10: Central Courtyard in Hashim Chalabi house surrounded by rooms (Author, 2019)

The building walls are characterized by thick mass walls reach 75 cm built by brick, as seen in Figure 3.11, and the thickness of the walls are shown in the building sections (A-A & B-B). See Figure 3.12 and 3.13.

Figure 3.11: Brick thick wall for Hashim Chalabi house (Author, 2019)

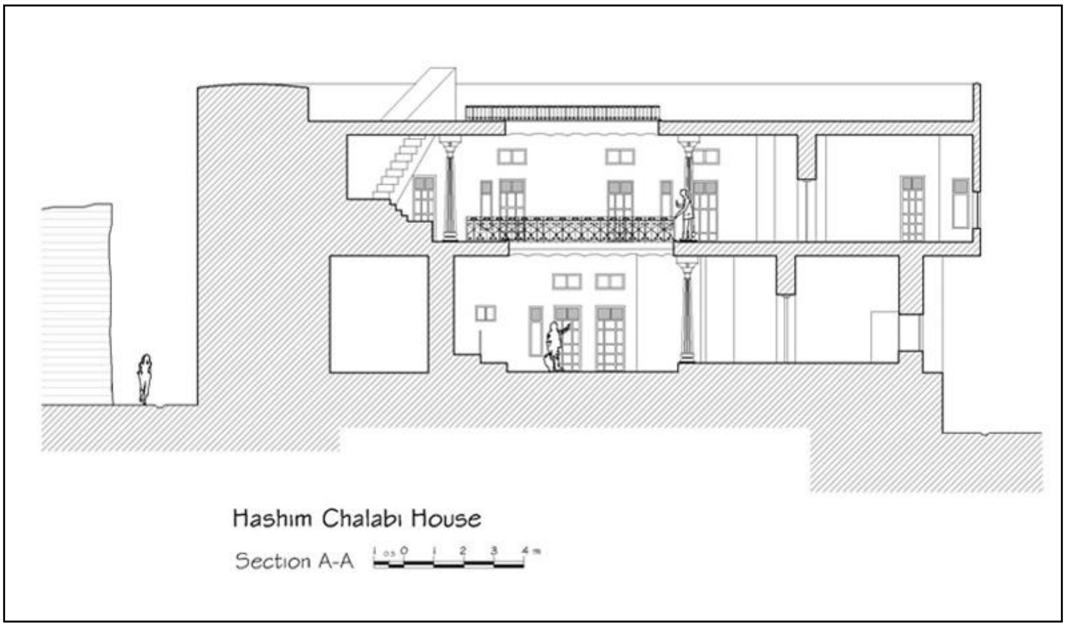


Figure 3.12: Section A-A in Hashim Chalabi house (HCECR, 2012)

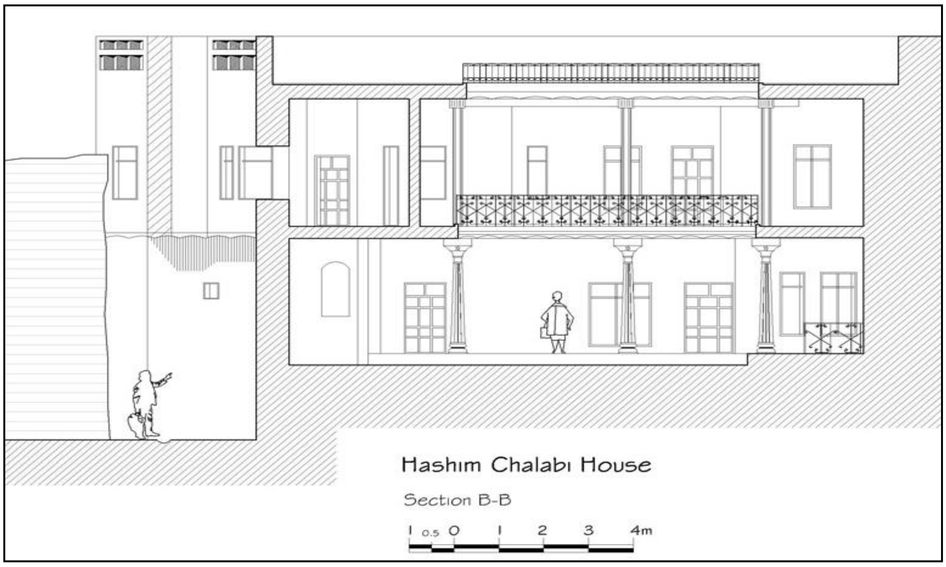


Figure 3.13: Section B-B in Hashim Chalabi house (HCECR, 2012)

3.6.2.2 Yasine Agha house;

This house is located in ‘Topkhana’ area, the western side of Erbil citadel southern gate, and it is considering one of the common families house in the citadel. See Figure 3.14.


Figure 3.14: The location of Yasine Agha House in Topkhana inside Erbil citadel (Google Earth, 2019)

The house has lateral courtyard and surrounded from four sides by rooms and services buildings, while, the northern part is bordered with the main exterior wall of the neighbor house. The house is two floor building, but today the second floor are demolished. See Figure 3.15.

Figure 3.15: Yasine Agha house in Citadel area recently, before the rehabilitation processing Courtyard (Above), and main entrance with stairs to first floor (down) (Author, 2019)

The house originally designed and constructed by two floors, as demonstrated in Figure 3.17. See Figures 3.16, 3.17.

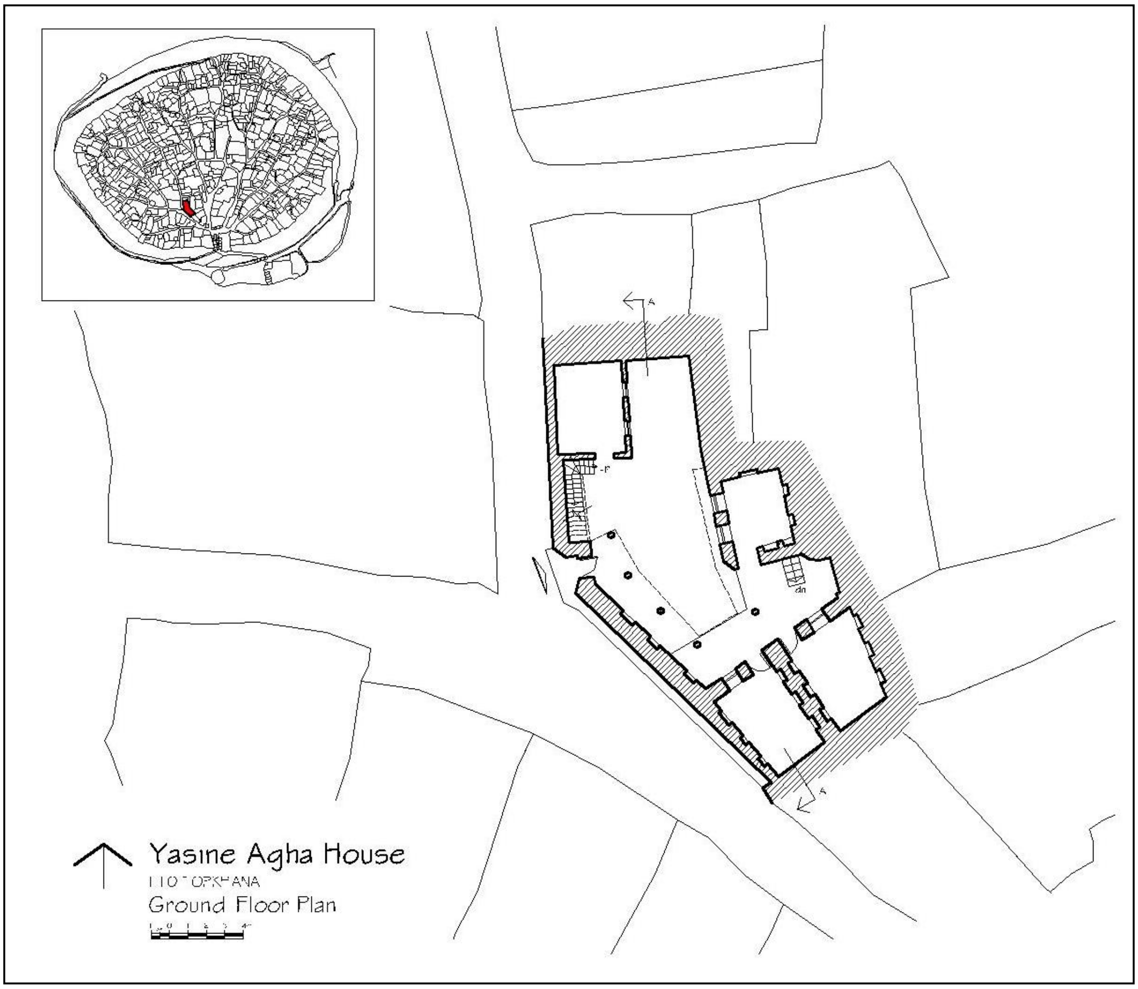


Figure 3.16: Plan of the ground floor in Yasine Agha house (HCECR, 2012)

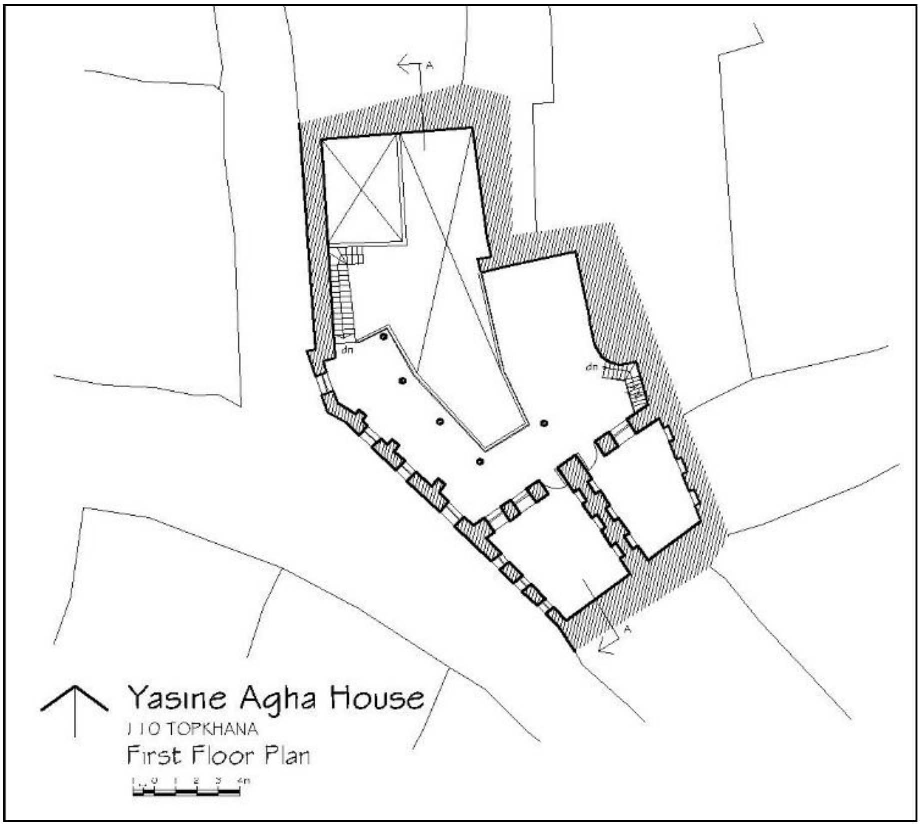


Figure 3.17: Plan of the first floor in Yasine Agha house (HCECR, 2012)

The building characterized by thick walls 75-100 cm thick, built by bricks ‘*Farshi*’, as seen in Figure 3.18.

Figure 3.18: The building masonry of Yasine Agha house in Citadel of Erbil. (Author, 2019)

The following figures demonstrates the section in the original house before demolishing the first floor. The section is demonstrating thick masonry walls of the building and the lateral courtyard. See Figure 3.19.

Figure 3.19: Section in Yasine Agha house at Citadel (HCECR, 2012)

3.6.2.3 Takiya house;

This house is located on the peripheral of the citadel crown from north side near the northern gate of Erbil citadel. The house is located in the part (*Mahallah*), that occupied by religious people as stated earlier in this chapter. See Figure 3.20.

Figure 3.20: The location of Takiya house in the citadel of Erbil (Google Earth, 2019)

The house is under rehabilitation now. It has built by thick wall masonry burnt brick, and it has central courtyard. See Figure 3.21.

Figure 3.21: Takiya House courtyard and rooms (Author, 2019)

The plan of the house demonstrates the central courtyard with the surrounding rooms opened toward the courtyard and also, shows the main iterance. See Figure 3.22.

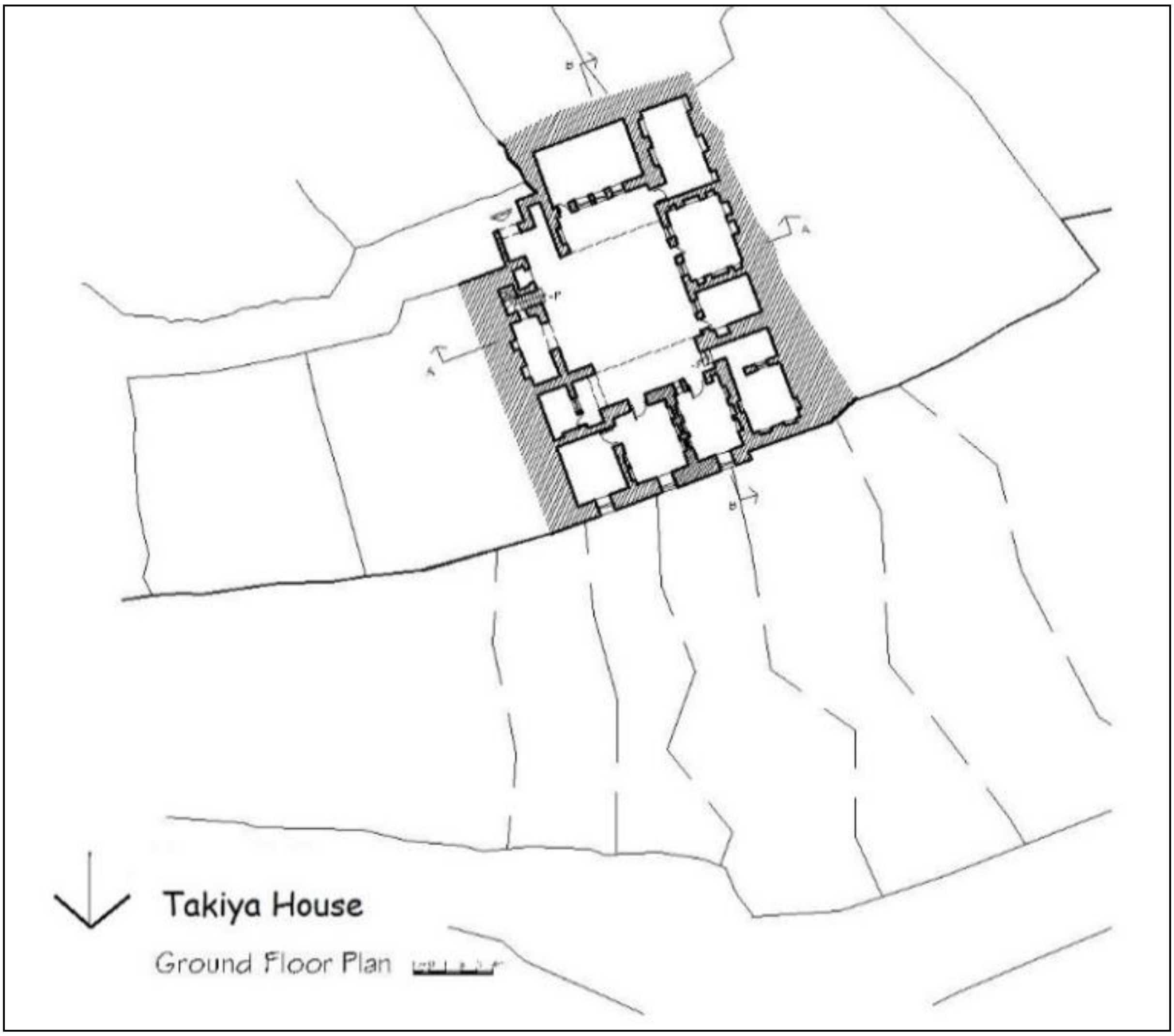


Figure 3.22: Plan of Takiya house (HCECR, 2012)

The House is one floor, as shown in the section 'A-A'. See Figure 3.23.

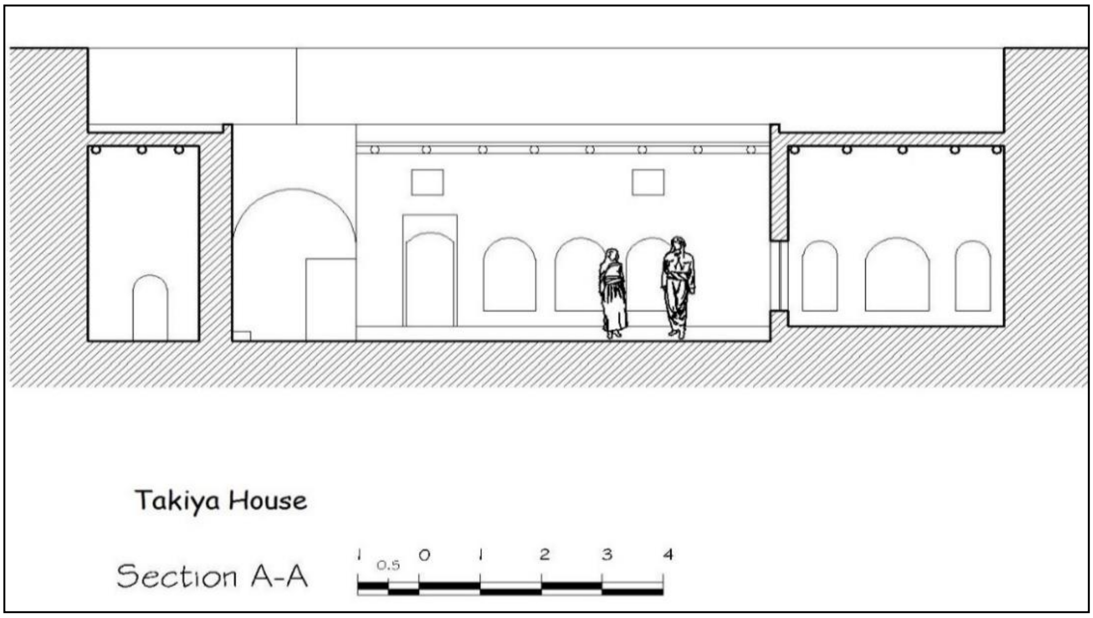


Figure 3.23: Section A-A of Takiya house, shows the location of courtyard and thick walls (HCECR, 2012)

The walls of the building are made by masonry bricks with thickness reach to 1 meter thickness, as shown in Figure 3.24.

Figure 3.24: Thickness of walls reach one meter in the Takiya house at Citadel of Erbil (Author, 2019)

3.7 Summary

The chapter illustrated the methodology of the thesis, and the ways that the thesis have approached through. Description of the study region has been mentioned in this chapter with details of the Erbil historical and geographical characteristics. The effect of Erbil Climatic characteristic on the buildings have been explained based on the literature review. The most important and repetitive strategies in Erbil vernacular architecture has been investigated based on previous studies and initial indicators had been attained based on that. Selection of case studies and the criteria to choose them have been explained and three case studies have been selected and described in this chapter and all of them from the oldest area in Erbil, which is the citadel area. In the next chapter, the case studies that had been selected will by examine in term of building materials and architectural elements that used in these cases and their impact on the indoor thermal comfort of the building. The semi-structured interview will also be discussed with experienced people in the field of architecture and construction, design to learn their opinions on most impact passive design strategies and how to use the vernacular architecture building element in the existing and future building.

CHAPTER 4

ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter will analyze the main characteristics of the case studies through field survey and documents analysis. Moreover, the results of the interviewed people will be demonstrated in this chapter based on the answers of the three questions that have been developed and shown in chapter three.

4.2 Results of the Field Observation and Documents Analysis

Based on the field observations and the documentary analysis the buildings have been analyzed. The first case study (Hashim Chalabi House), have been analyzed. The building is characterized as traditional and its construction return back to 1900-1930. The building is courtyard house and opened toward inside Site planning, internal spaces, and spatial analysis have been carried out. The total plot area has been found 325 m^2, and the built-up area was 612 m^2. The building has two floors and the total number of private or bed rooms are nine (2 in ground floor and 7 in the first floor). The public, semipublic, as well as private areas have identified. See Figure 4.1.

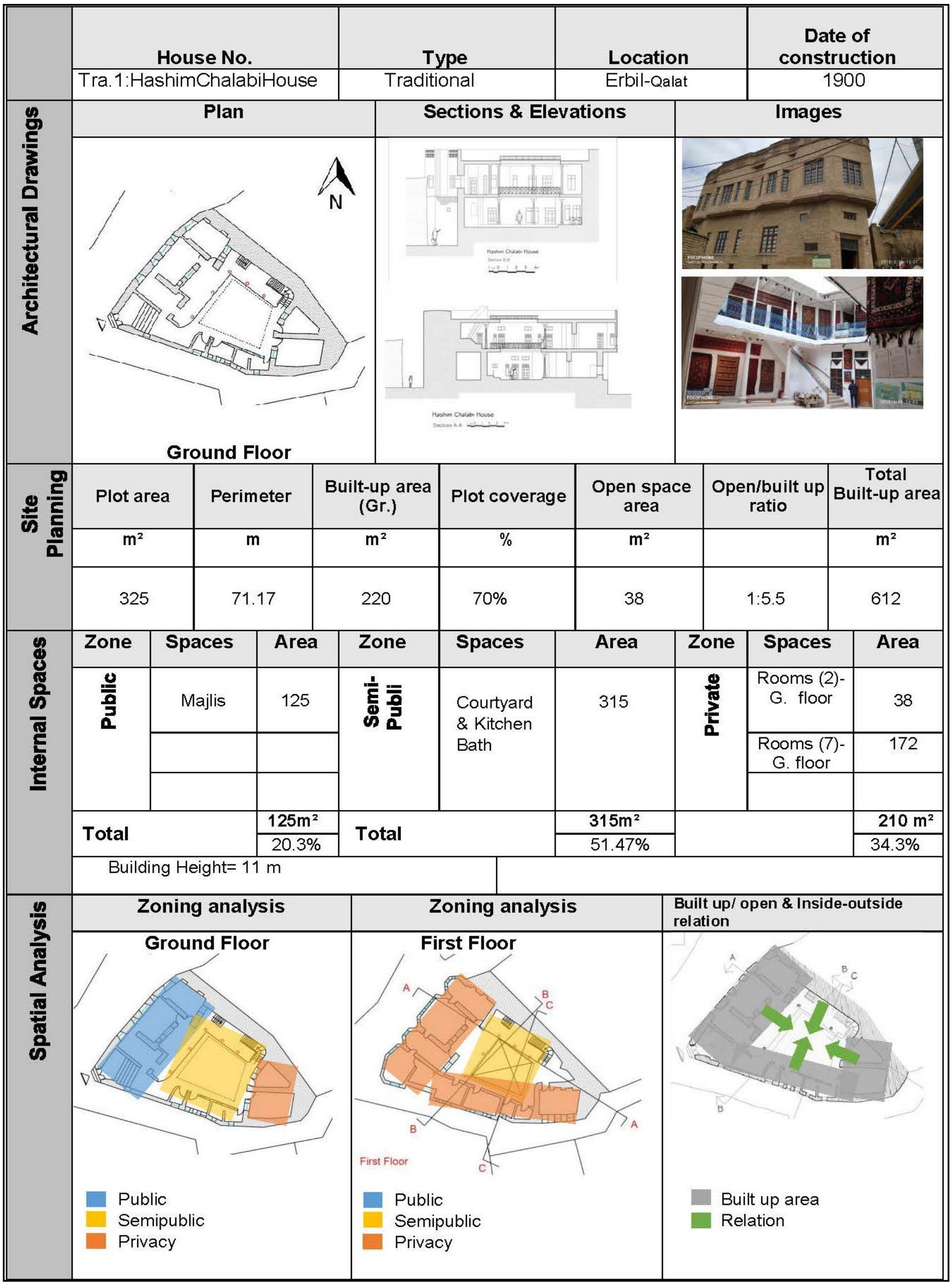
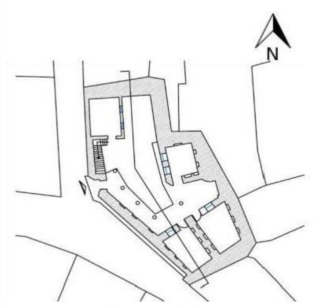
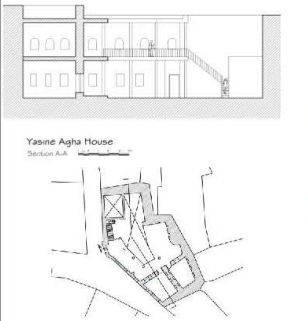


Figure 4.1: The analysis for the first case study (Hashim Chalaby House) (Author, 2019)

In the same context, another two case studies have been analyzed based on their public, semi-public, and private area too. The area of the plot for the second case study (Yasine Agha House) have been found 310 m^2, while built up area was 560 m^2, because the building also two floors. The building construction returns to before 1930 according to the Erbil citadel municipality. It is courtyard house and the opening of the building is to inside. Total numbers of private or bed rooms are five (3 in ground floor and 2 in the first floor) See Figure 4.2.

House No.	Type	Location	Date of construction
Tra.2:Yasine Agha	Traditional	Erbil-Qalat	1930

Architectural Drawings

Plan	Sections & Elevations	Images
 Ground Floor		

Site Planning

Plot area	Perimeter	Built-up area (Gr.)	Plot coverage	Open space area	Open/built up ratio	Total Built-up area
m²	m	m²	%	m²		m²
310	75.76	250	63.8%	64	1:8	560

Internal Spaces

Zone	Spaces	Area	Zone	Spaces	Area	Zone	Spaces	Area
Public	Majlis	130	Semi-publi	Courtyard& Kitchen Bath Store	160	Private	Rooms (3)-G.F floor	108
	Open area						Rooms (2)-F.F floor	162
Total		130m² 23.2%	Total		160m² 28.57%			270 m² 48.21%
Building Height= 9 m			Currant Total Built Area= 250 m					

Spatial Analysis

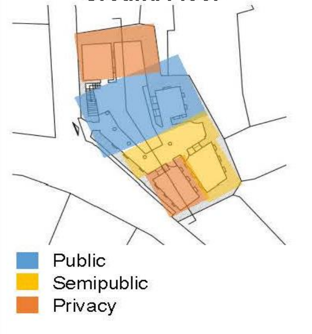
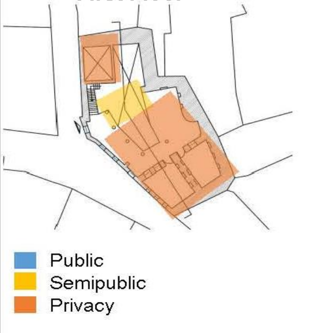
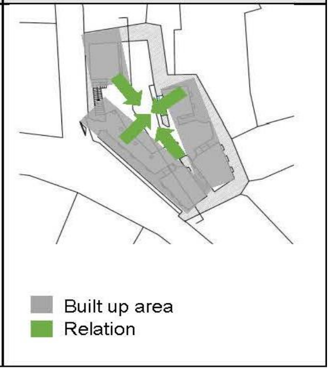
Zoning analysis	Zoning analysis	Built up/ open & Inside-outside relation
Ground Floor 	First Floor 	

Figure 4.2: The analysis for the first case study (Yasine Agha House) (Author,2019)

Whereas, the third case study (Takiya House), is one floor building. The total area of the plot is 438 m^2, and the building area is 371 m^2. The building is courtyard, contains four private or bed rooms and all the rooms are opened to inside, as seen in Figure 4.3.

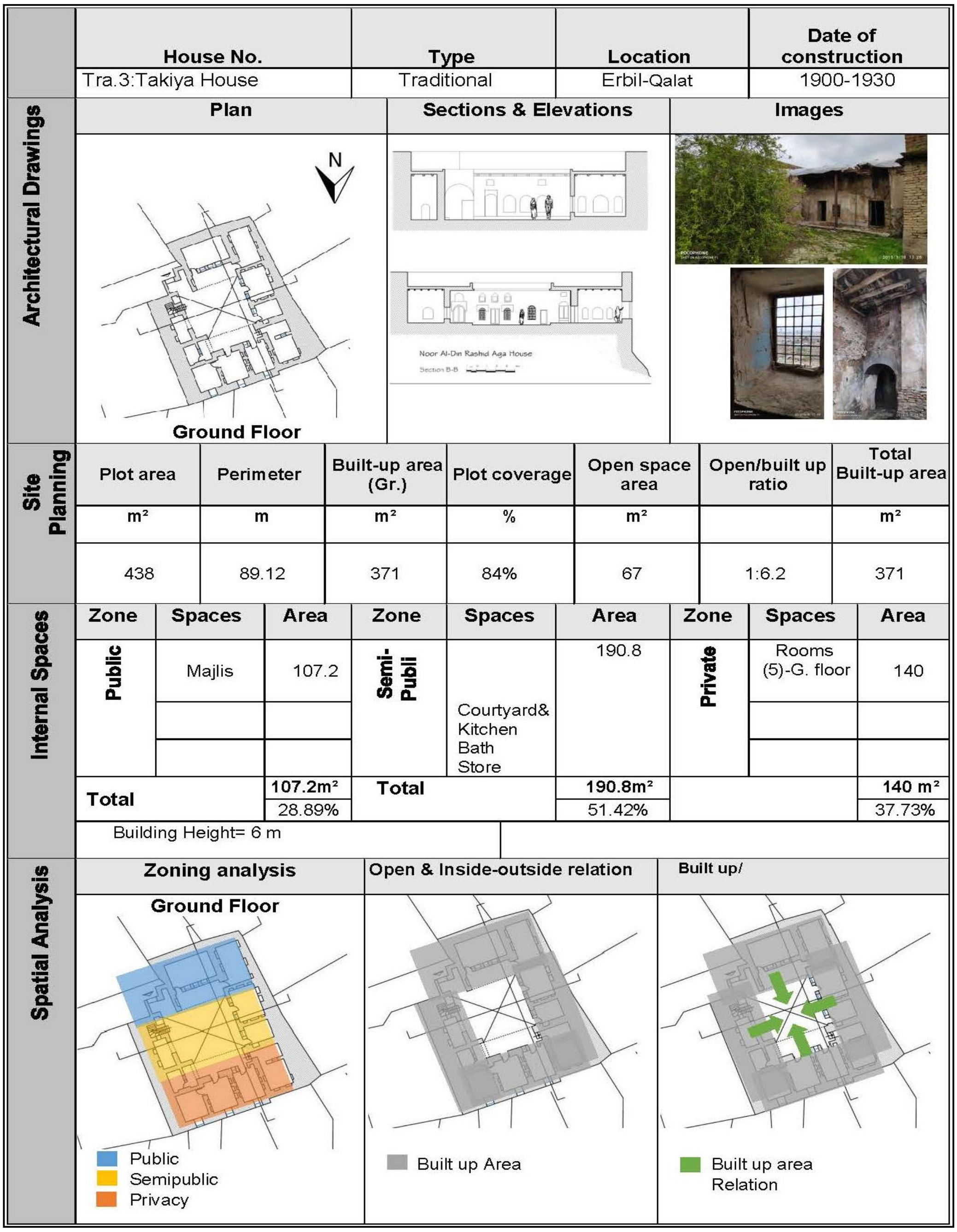


Figure 4.3: The analysis for the first case study (Takiya House) (Author,2019)

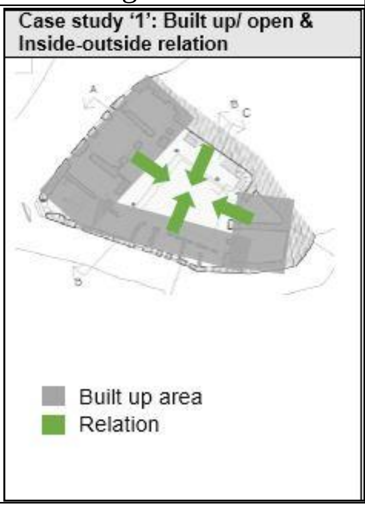
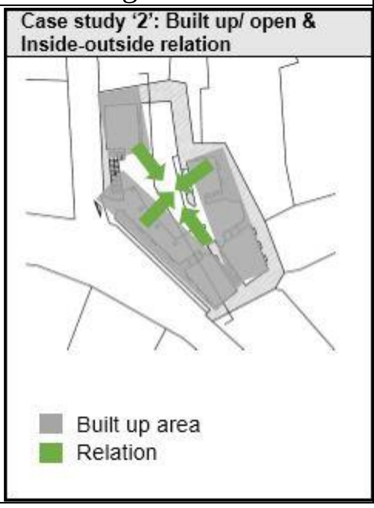
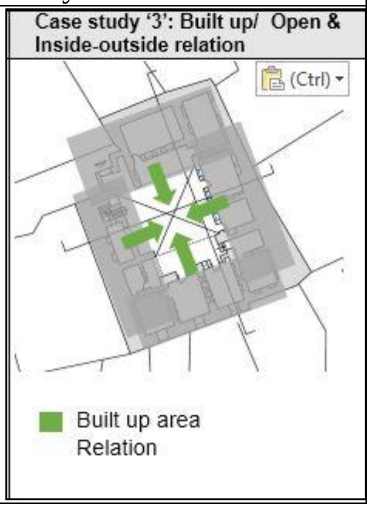
4.2.1 Similarity in the form of the buildings

In accordance with the most effective and repetitive passive strategies in form and material's level in vernacular and traditional houses in Erbil Climate which obtained in Chapter Three (See Table 3.1), this study will focus on the presence of these strategies; courtyard, thick mass walls, and masonry or building's material as effective factors to reduce energy consumption in buildings.

4.2.2 Courtyard

Because the courtyard in the building has a role in the solar incidence and wind circulation, as well as the heat gain/loss. Therefore, the design of the all case study houses in Erbil are a central courtyard and all rooms open and overlooking it. Where, the analysis of the documents as well as field observation demonstrated that all the case studies are courtyard houses and closed from outside with less opening to outside than inside. The study demonstrated that the courtyards are not with regular shapes always, because it is depending on the shape of the plot and the mason was deciding the shape of courtyard based on the plot shape

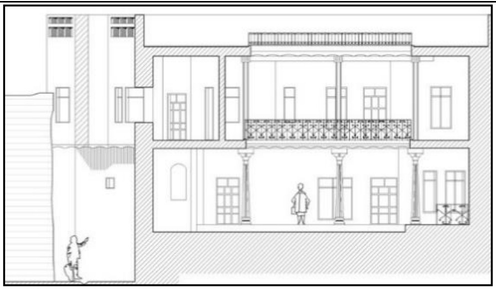
Table 4.1 The type of buildings and the inside outside relationship (Author, 2019)

	Yasine Agha House 1	Yasine Agha House 2	Takiya House 3
			

4.2.3 Thermal mass walls

Thick walls have a significant role in protecting the building against the solar heat gain in the day hours and stored it, then re-radiate it in the night and early morning to reduce the heat gain on the buildings. Furthermore, the combination of thick mass and courtyard provides a good strategy for acquiring less temperature through the day hours and heat loss in the night at summer, whilst acquiring good solar gain in winter. Hence, the first case study outer walls have 75cm thickness. While, the second case study has 75 to 1-meter thickness for the external walls. Third case study has 1-meter thickness for the walls too. See Table 4.2.

Table 4.2 The thick wall of the three case studies (Author,2019)

	Case study 1	Case study 2	Case study 3
			

4.2.4 Building masonry material

Buildings thermo-physical properties or the U-value for the mud or burnt brick is very effective to control heat gain and heat loss in the buildings in Erbil (see table '2.1'). Then using these types of material as masonry increase the ability of the buildings to conserve the energy. The analysis for the walls material for the three case studies, the results demonstrated that all the case studies are built up with burnt brick (*Tabouk or Farshi*), as demonstrated in Table 4.3.

Table 4.3 The buildings Masonry and material of the three case studies (Author,2019)

	Case study 1	Case study 2	Case study 3
			

4.3 Interviews Data Analysis

The semi-structured interview has been developed and carried out with thirty professionals in the field of architecture and civil engineering. The interviewee were ten architects, ten academicians (in the field of architecture and construction), and ten engineers (professionals in civil and buildings constructions). See Table 4.4.

Table 4.4 The interviewed of professionals and the percentage of each profession (Author,2019)

Participants	Number of participants	Percentage
Architects	10	33.33%
Academicians	10	33.33%
Engineers	10	33.33%
Total	**30**	**100%**

The following questions have been asked to them as mentioned in chapter three;

- What is the most effective passive design strategies for houses in Erbil hot and arid climate in terms of reducing the demand on energy consumption in the houses, that can be re-call from vernacular or traditional buildings?
- What are the passive strategies that can be developed in the contemporary buildings depending on vernacular or traditional houses elements?
- How can develop effective passive strategies to be applied in contemporary design in terms of aesthetic value in the design project and the satisfaction of clients?"

4.3.1 Obtained results from interview

1. The answer of the first question ***"1. What is the most effective passive design strategies for houses in Erbil hot and arid climate in terms of reducing the demand on energy consumption in the vernacular or traditional houses?"*** came out with the following results;

Architects:

The interview with architects who are working in private sector or inside government bodies, demonstrated that all of them believes that the most effective passive design strategies in the vernacular and traditional buildings in Erbil for reducing energy consumption are; courtyard, and thermal mass, as well as masonry materials. Whereas 70% of them believed in the shading system and 60% of them in ventilation system as the most effective passive strategies too. See Figure 4.4.

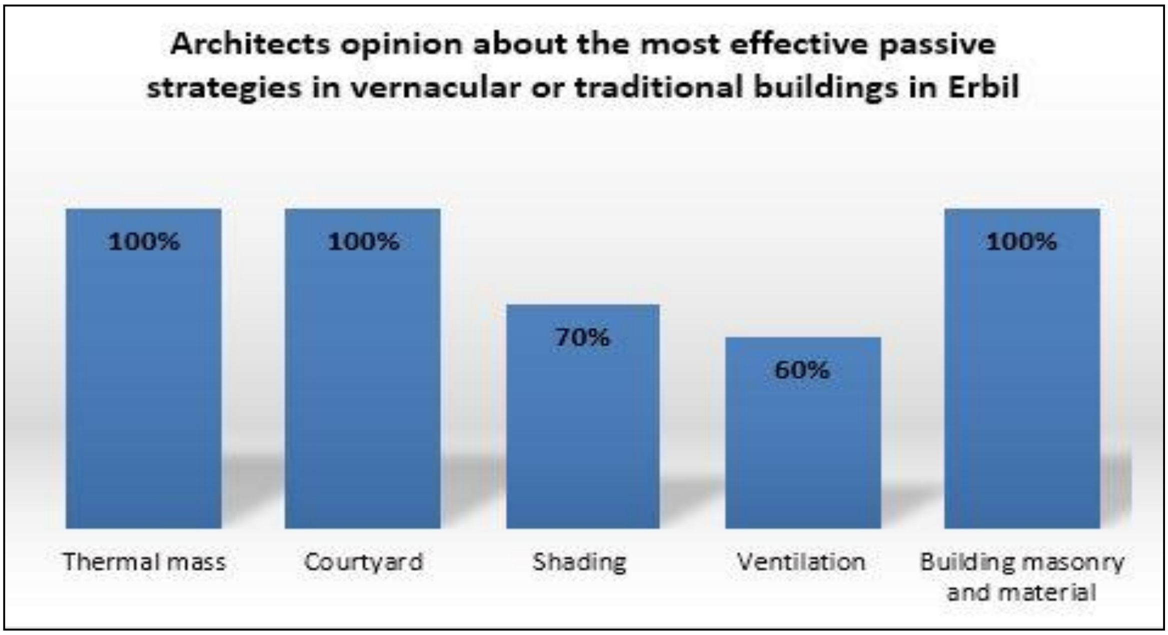


Figure 4.4: The most effective passive strategies to reduce energy consumption in buildings at Erbil, based on architects' opinion (Author,2019)

Academicians:

Academic people who are professional in architecture, sustainable architecture, construction, and construction technology from universities and research centers in Erbil and north part of Iraq have been interviewed. Their opinion was focusing on four most effective passive strategies in the vernacular and traditional buildings to reduce energy in these buildings in Erbil. These passive strategies are courtyard, thermal mass, shading, ventilation, and building materials and masonry. See Figure 4.5.

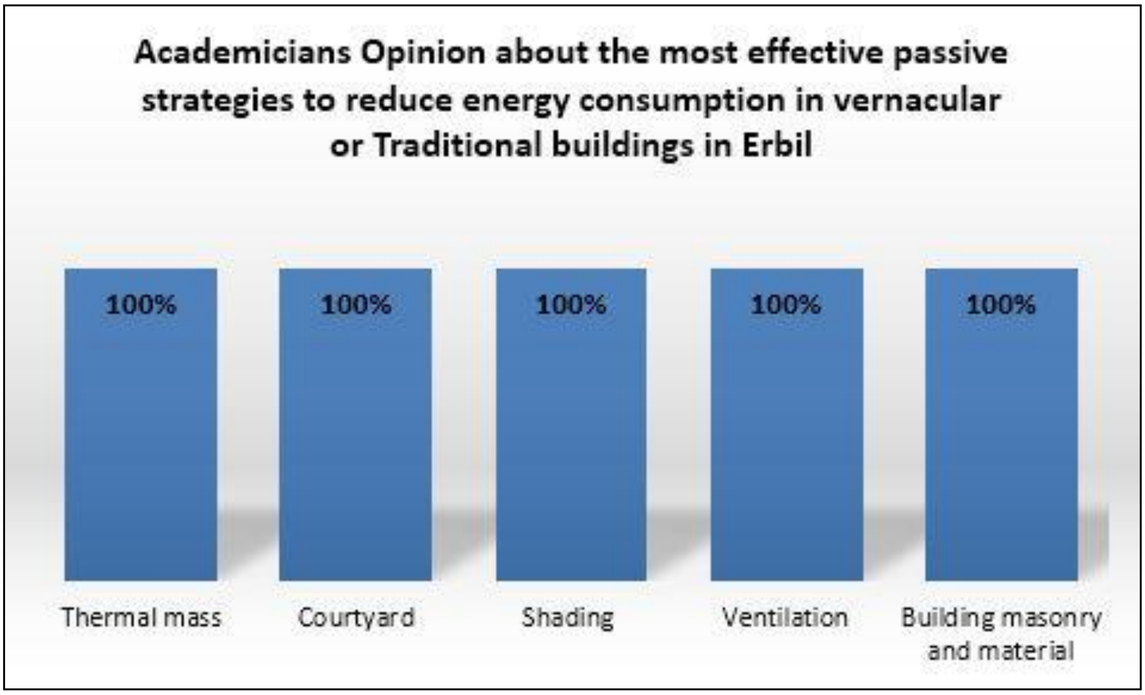


Figure 4.5: The most effective passive strategies to reduce energy consumption in buildings at Erbil, based on academicians' opinion. (Author, 2019)

Engineers:

Ten engineers in government and private sector have been interviewed and asked the same previous question. The engineers involved construction projects managers, construction designers, civil engineers and mechanical engineers. The results demonstrated that 100% of them believes in courtyard, thermal mass, and building materials as the most effective passive strategies to decrease energy in vernacular and traditional buildings. Whereas, 30% of them believes that shading and natural ventilation systems also considers as the most effective passive strategies in this matter. See Figure 4.6.

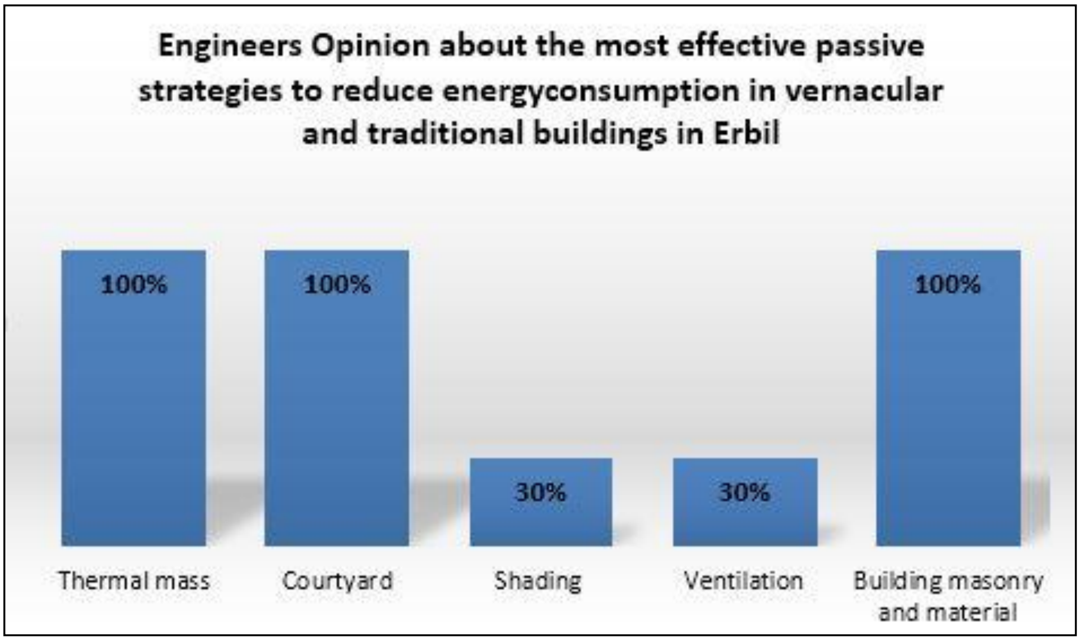


Figure 4.6: The most effective passive strategies to reduce energy consumption in buildings at Erbil, based on engineers' opinion (Author, 2019)

According to the previous results based on the first question to interviewee, the majority of the architects were answering that thermal mass and masonry materials, as well as courtyard house was the most effective passive design strategies in vernacular or traditional houses of Erbil. Moreover, shading devices and ventilation system through windows as another important strategy but with less effects. The academicians supported the opinion of the architects, but they emphasize on shading and ventilation as strategies that is not less than other ones, but in the same time shading and ventilation can be enhanced through courtyard design. The Engineers, commonly have focused on the materials and masonry of the buildings as important passive strategies in vernacular and traditional houses. Moreover, they considered courtyard house as very effective strategy too. Furthermore, they considered shading and ventilation with less importance than previous passive strategies. Figure 4.7, demonstrates the opinion of the participants with the percentage of their answers.

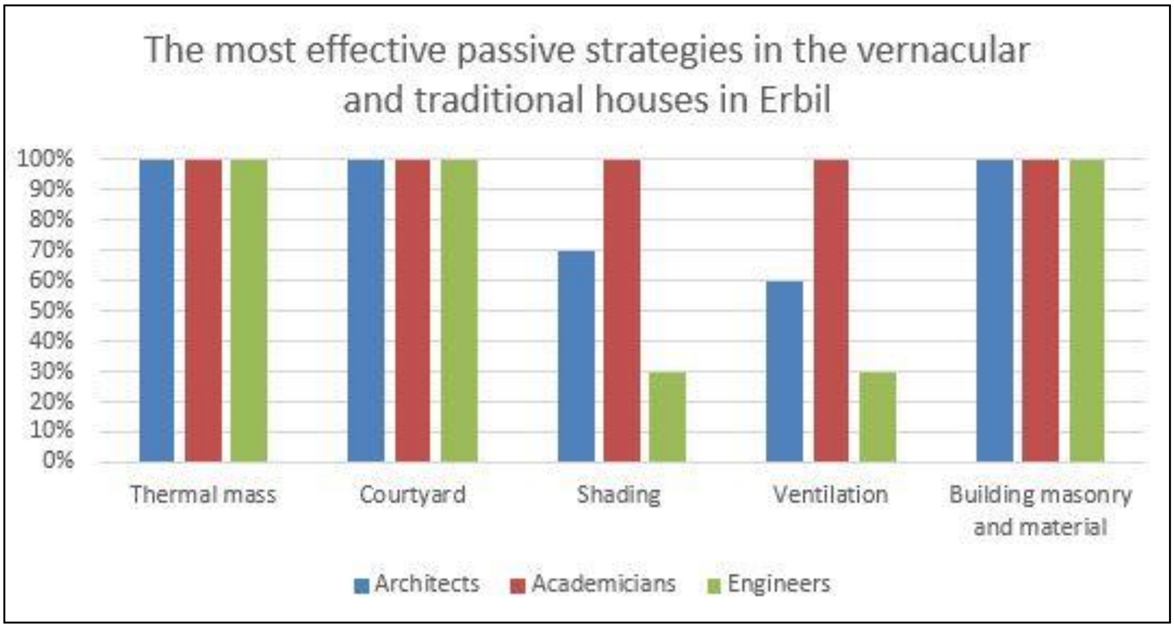


Figure 4.7: The opinions of the professionals about the most effective passive strategies in vernacular or traditional houses in Erbil (Author, 2019)

2. The answer of the second question ***"2. What are the passive strategies that can be developed in the contemporary buildings depending on vernacular or traditional houses elements?"*** has demonstrated following results;

Architects:

The result from the interview regarding the second question among the architects has shown the following; 100% of the architects believes in the development of thermal mass and building masonry materials in contemporary buildings as the main factors to control heat gain and heat loss in the buildings, and consequently, reduce energy consumption. Only 30% of the architects have believed that courtyard can be developed to be applied in contemporary buildings to reduce energy usage at new buildings in Erbil. See Figure 4.8.

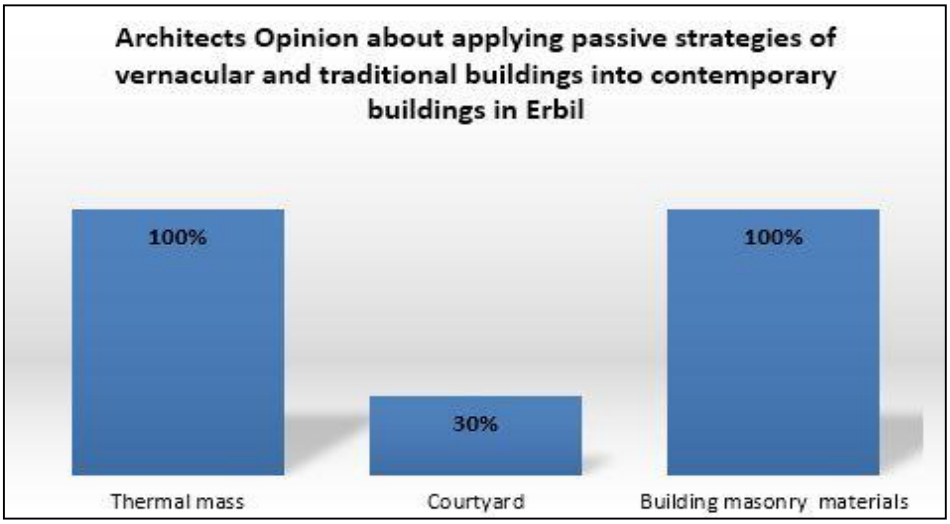


Figure 4.8: The opinion of architects about the strategies that can be developed in contemporary buildings in Erbil (Author, 2019)

Academicians:

The answers of the interviewed academician have demonstrated that 100% of them supporting to develop thermal mass, building masonry materials, and courtyard. Because, the courtyard can assure ventilation and manage the shading and solar incidence as per required. Thus these three strategies are important to reduce energy inside the buildings in Erbil. See Figure 4.9.

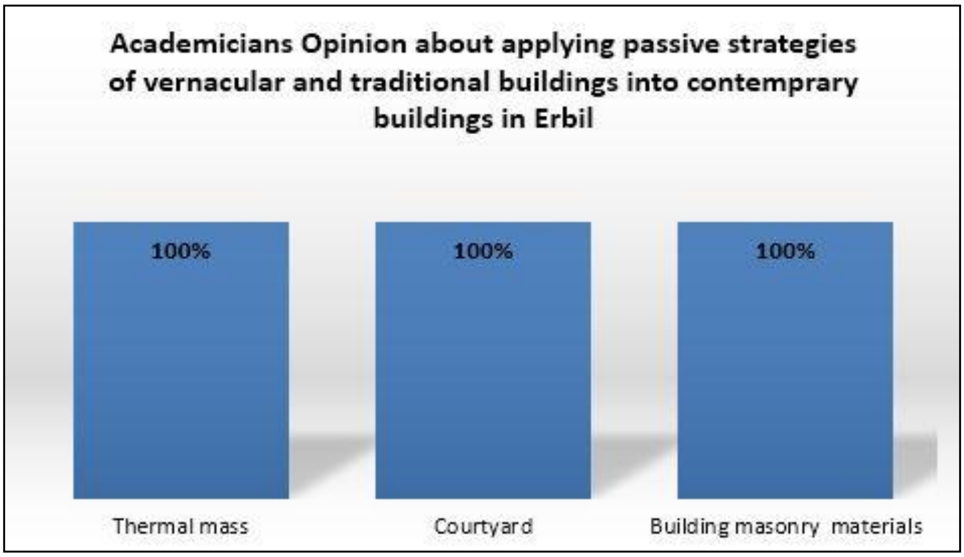


Figure 4.9: The opinion of academicians about the strategies that can be developed in contemporary buildings in Erbil (Author, 2019)

Engineers:

The answers of the engineers regarding the second question are showing that they are totally agreed to develop thermal mass, and building masonry material to be used in contemporary buildings to reduce energy consumption. Whereas, 10% of them have believed in developing courtyard in contemporary buildings. See Figure 4.10.

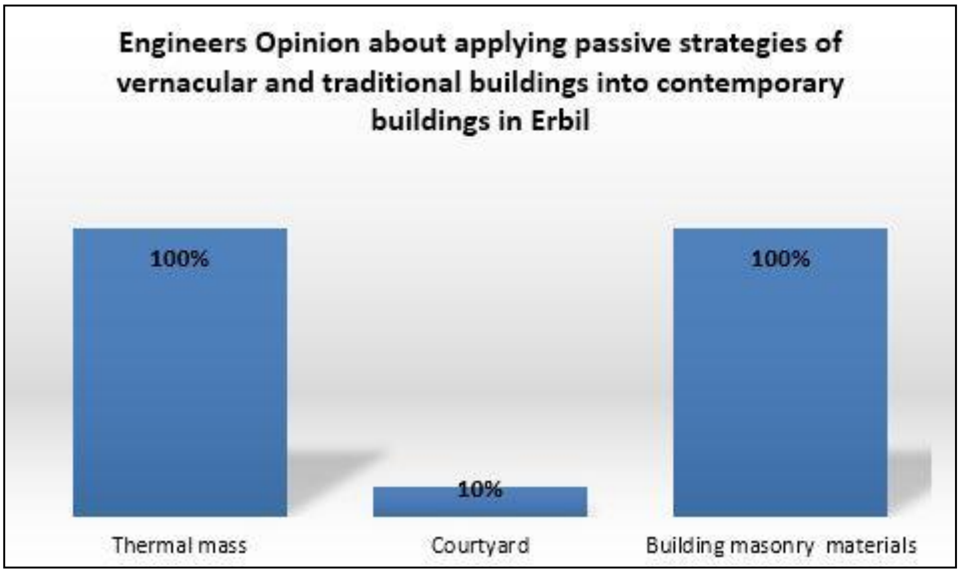


Figure 4.10: The opinion of academicians about the strategies that can be developed in Contemporary buildings in Erbil (Author, 2019)

The plurality of architects was preferring to control the solar heat gain/loss in the buildings to reduce the energy consumption in the buildings. This is through improving thermo-physical properties of the building envelope materials to resist heat gain and heat loss. Hence, thick mass is one of the crucial passive strategies, but with new materials and technologies can develop thermal mass to reach to the same thermo-physical properties of old but with less thickness. The academicians supported the opinion of the architects, but they added another point. Improving the shade and ventilation system to be harmonized with the previous strategy is important too. Hence, they have recommended a courtyard house too, as one of the very important strategies to control solar heat gain and promoting night ventilation which is required in Erbil hot and arid climate to reduce energy consumption in buildings. The courtyard could be designed with contemporary way, like to be designed in proper size and shape, as well as to have movable cover. Engineers, commonly they preferred the improvement of thermo-physical properties of the building material as the most effective strategy in Erbil climate to reduce energy consumption. This is through double glazing, new insulation materials. This is supporting the opinion of architects, but they do not show tendency to courtyard houses. Table 4.5, demonstrates the opinion of the participants.

Table 4.5 The passive strategies that can be developed from vernacular and traditional architecture in the contemporary architecture in Erbil to reduce energy consumption (Author, 2019)

Professional	Passive strategies from vernacular and traditional buildings to be developed in contemporary buildings	Percentage
Architects	Thick mass	100%
	Building masonry materials	100%
	Courtyard	30%
Academicians	Thick mass	100%
	Building masonry materials	100%
	Courtyard	100%
Engineers	Thick mass	100%
	Building masonry materials	100%
	Courtyard	100%

3. The answers of the third question "***"3. How can develop effective passive strategies to be applied in contemporary design in terms of aesthetic value in the design project and the satisfaction of clients?*** *"* showed the following results;

Architects:

The answer of the third question during the interview of the architects, they showed more tendency to develop passive strategies through the development of buildings' masonry materials or thermo-physical properties of these materials. Hence, 100% of them suggested to add cladding to the building exterior walls like stones or marbles. Also, suggested to select masonry materials with high heat resistance properties. However, 30% of the architects suggested a courtyard to the contemporary buildings in Erbil, with modern ways. See Figure 4.11.

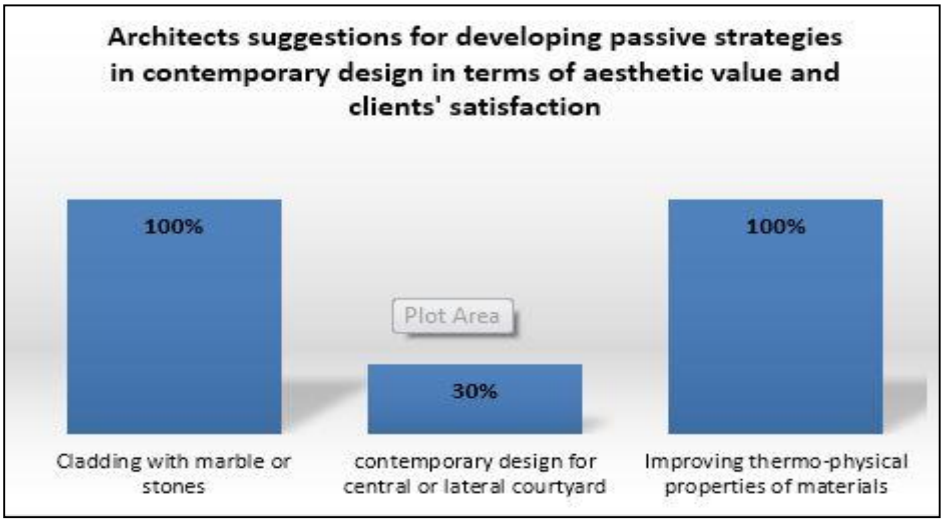


Figure 4.11: Architects' suggestions for developing passive strategies in contemporary design to reach client's satisfaction and aesthetic value (Author, 2019)

Academicians:

The academician suggestions to the third question was as follow; they suggested to develop courtyard, thermal mass, and building masonry materials, with modern architectural concepts to serve aesthetic value, and functionality with considering the economic level. Moreover, 80% of them was suggesting to increase the awareness of the clients about the importance of the energy efficiency in contemporary buildings in Erbil. See Figure 4.12.

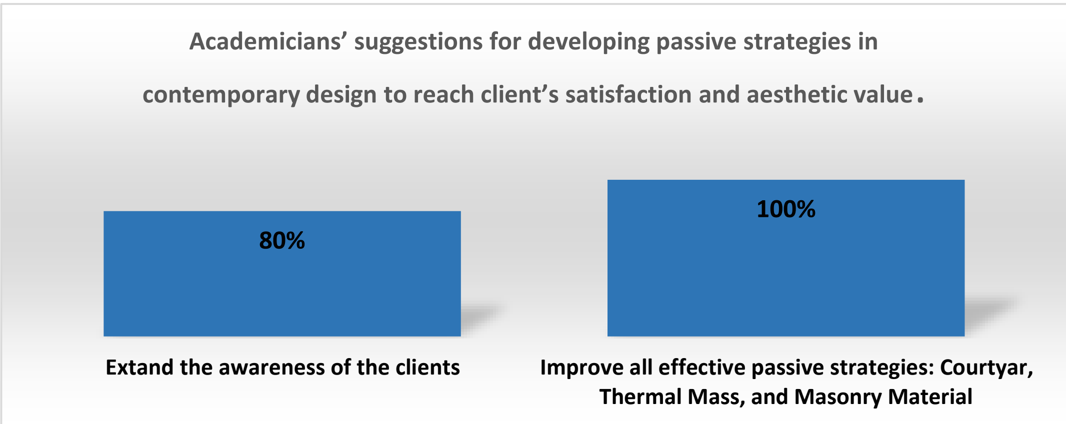


Figure 4.12: Academicians' suggestions for developing passive strategies in contemporary design to reach client's satisfaction and aesthetic value (Author, 2019)

Engineers:

The engineer's answers were suggesting functional ways, and suggested to improve buildings material thermally through increasing the thermal ability of building material through adding insulation material, but to take in consideration the total cost. See Figure 4.13.

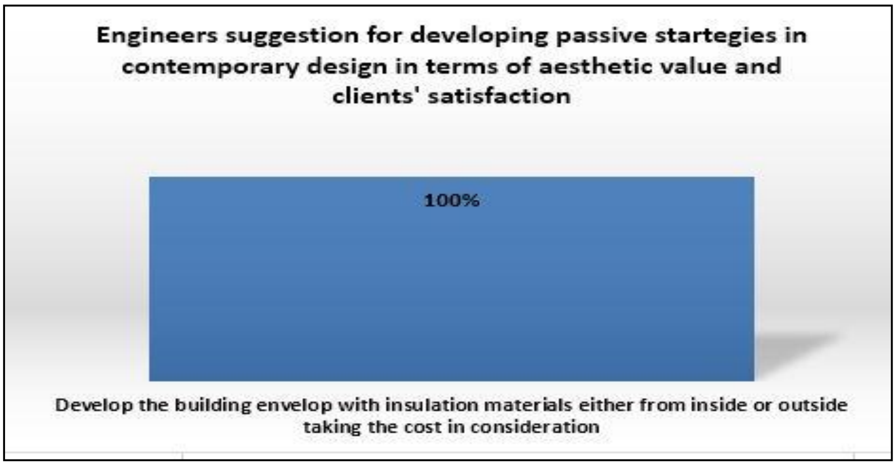


Figure 4.13: Academicians' suggestions for developing passive strategies in contemporary design to reach client's satisfaction and aesthetic value (Author, 2019)

The architects were more concern with aesthetic value, hence they were preferring to develop strategies to improve thermo-physical properties for building materials as they mentioned before. The development could be through adding cladding to the building's outer walls (Marble, stones) as decorative elements in the same time improve the building's resistance for solar heat gain/loss. Moreover, they preferred to use special types of glass in the windows, such as double glass or reflective glasses, with plastic or coated aluminum frames. The academicians were concerned with aesthetic value and functionality. They recommended to develop all the effective passive strategies that mentioned, namely; courtyard, thick mass, and building materials. Furthermore, they emphasized on the extending the view of clients and improve their knowledge about the necessity of energy saving in their buildings in terms of economic level and environmental level. Engineers have been interested to develop the buildings in term of functionality and they concentrated less on aesthetic value than economic and cost of the building. Thus, they preferred the development of building skin with insulation materials either from inside or outside with less costs to satisfy the clients. Table 4.6, demonstrate the way of the passive strategies development to reduce energy consumption in Erbil, as per the view of interviewee.

Table 4.6 The suggestions of the interviewee about the ways of developing passive strategies in contemporary buildings to reduce energy usage in Erbil climate (Author, 2019)

Participants Professional	Percentage
Architects	Cladding with marble or stones
	Improving thermo-physical properties of materials
	Through contemporary design for central or lateral courtyard
Academicians	Improving all effective passive strategies with new technology
	Extend the awareness of the clients about the importance of energy reduction in buildings.
Engineers	Develop the building envelop with insulation materials either from inside or outside taking the cost in consideration

4.4 Discussion

4.4.1 Summary of documents and field observation analyses

The analysis of the documentary for the three selected case study traditional and vernacular buildings in Citadel of Erbil and field observation demonstrated that the most effective strategies for energy conservation in the climate of Erbil are present in all the case studies, which are courtyard, thick mass walls, and mud or burnt brick masonry material. The results approve that these strategies are very important to attain acceptable thermal performance and consequently save energy in the buildings, because they are the most repetitive in almost all the buildings in Citadel historical area in Erbil.

4.4.2 Summary of interview data analyses

The answers for the first question have demonstrated the awareness of the professionals about the importance of courtyard, thick mass, and the masonry materials of the buildings in the process of energy reduction in the vernacular and traditional buildings. Furthermore, all of them have agreed that courtyard, thermal mass, and buildings’ masonry materials are the most effective passive strategies to reduce energy usage in vernacular and traditional buildings at Erbil city.

Regarding second questions, the majority of the architects and engineers were not an enthusiast for courtyard as passive strategy could be developed for the contemporary buildings in Erbil to reduce energy consumption in buildings. Whereas, the academicians where more emphasizing on the courtyard house as one of the most effective strategies to enhance ventilation and control solar heat gain introduction in winter and block it in summer. This is returns to the difficulties to change the form of the buildings to courtyard building in the contemporary buildings' design. While the development of the building masonry materials or thermal mass properties are possible without to affect the form of the building or the design concept.

Based on the answers of the professional people for third question, the attitude of the professional demonstrates that the academicians are looking for aesthetic and functional issues, as well as social issue, while the architects, focusing more on the aesthetic matter in their development. The engineers are more functional and nearly neglecting the aesthetic value, and focusing on the cost.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusions

The successful environmental design of the traditional and vernacular buildings in Erbil, comparison with the deficiency in the contemporary design environmentally led to think seriously to recall the strategies of the design from vernacular and traditional architecture in Erbil and combined them in contemporary design. The failure in the contemporary design in terms of maintaining thermal comfort with passive strategies led to complicate the condition of living inside the buildings. The contemporary buildings are facing several challenges in terms of comfort and energy performance, indoor air quality and inner environment.

The thesis identified many objectives such as the most effective passive strategies in the vernacular and traditional buildings to decrease energy consumption in the buildings in Erbil-Northern Iraq. The benefit behind that is to determine the possibility of using these passive strategies in contemporary buildings in the region of the study. The region which is in confrontation with an energy shortage especially in providing the electrical power. The majority of the energy and power in Erbil going to maintain thermal comfort inside the buildings. This issue made it important to focus on the passive strategies that can offer more thermal comfort in Erbil hot and arid climate. The study focused on homes as the most dominant class buildings in the construction sector of the study area. These buildings have been analyzed to find the most effective passive strategies to enhance thermal comfort inside the buildings responding to the climatic characteristic of Erbil. Consequently, reduce the energy consumption demanded to preserve thermal comfort in these buildings. Furthermore, thirty professionals and Specialists in the field of architecture and construction have been selected from the region of the study (Northern Iraq), to show their professional opinions about the most important passive strategies in the vernacular or traditional buildings, as well as their suggestions for the capability of combine these passive strategies in contemporary buildings in order to lessen the energy consumption.

Consequently, to answer the raised questions at the start of this study which are;

"1. What are the most employed passive design strategies in the vernacular architecture in Erbil?

2. How do passive design strategies in vernacular architecture of the same climatic conditions with Erbil control energy efficiency?

3. How and to what extent can the effective passive design strategies be reconciled into contemporary building design so as to provide energy efficiency?"

Regarding the answer of the first question the study demonstrated based on the observations and the document analysis for the selected case study buildings that the most effective strategies to reduce heating and cooling effects of climatic characteristic in Erbil, are; Thermal mass, Courtyard, and building masonry materials thermo-physical characteristics. The reason behind this decision primarily is their repetitive in each case study during the analysis, which is indicating their importance in responding to the climatic needs in Erbil. In another hand, the professional opinions during the interview were compatible with the findings through observation and documents analysis for the case study buildings. Where, they affirmed that the most effective strategies to reduce energy consumption in vernacular or traditional buildings are; thermal mass, Courtyard, and building masonry materials' thermal properties. The answer for the second question is complementary to the first question and support it as will be explained.

For answering the second question, indeed, it is not an easy task to have strategies to respond to all the climatic needs in the hot and arid climate of Erbil, unless to apply the courtyard. The courtyard is able to implement those needs throughout time through the following; it reduces the solar radiation incidence on the exterior walls and offers a shaded area within the building in summer and allows sufficient solar radiation penetration during the winter. It also meets other needs by enhancing ventilation (especially in the night), to reduce heat load inside the building, in addition, to protect the whole building from outer dusty winds.

Because of the specific characteristic of Erbil climate with long hours of sunny days and dropping the temperature during the night significantly, as one of the significant characteristics for a hot and arid climate. It is essential to provide exterior walls with high thermal resistance properties. Hence, thermal mass is one of the important strategies to meet the requirements of this climate for Erbil. A thick exterior wall will have the capability to make a time lag for penetration of heat into inside the building during the long sunny days with high solar radiation incidence on these walls. This is through storing the heat inside the thick wall and release it in the night to the outer sky by re-radiating it when the heat of outer ambiance drops. So, selecting materials with high thermal resistance will add extra potential to reduce heat gain during the day. Thus, mud brick, burnt brick for building masonry as thermal protective elements to be applied as another effective passive strategy to reduce heat gain and heat loss, and reduce energy usage as a result. Based on these facts it is obvious that these strategies are protecting buildings from excess heat gain by solar radiation, and enhance natural ventilation to reduce heat gain inside the building especially during the night. Consequently, more acceptable thermal comfort will be achieved based on these strategies, and less energy will be used to maintain thermal comfort inside the buildings, thus, they can improve energy efficiency in the buildings at Erbil climate.

The researcher supports what the architects had answered about the materials and at the same time supporting the engineers for the isolating materials, and suggesting that block concrete should be replaced by local material like stone, brick and preferred used new material and system that have thermal resistance to maintain the thermal comfort inside the building, using suitable thick of thermal insulating of walls and roof, and suggesting of semi-open and open spaces for example courtyards, balconies, terraces and verandas, and suggesting a courtyard to be shared for each group of houses, four houses share courtyard as an outer space. Design of landscape, in the courtyard especially, to providing utilizing suitable building element shading and cooling for spaces during the hot-summer times by the trees and vegetation. Shading device that provides climate solutions for instance sun devices, blinds, and overhangs.

5.2 Recommendations

It is obvious that thermal mass and building masonry materials as two of the most effective strategies in vernacular and traditional buildings in Erbil, it has been recommended and can be developed for the future design of buildings. This is through improving the thermo-physical properties of building materials by adding cladding or insulations to the building envelope, and this can be considered as one of the effective ways. This is because it can be applied to a new building and even could be added to the old stock of buildings which did not have the potential to conserve energy in the region of study (Erbil). The buildings which have been built before the thinking about the energy crisis in the region. This flexibility made it important to develop these strategies (improvement of thermo-physical properties of exterior walls, and selecting high thermal resistant masonry materials) to implement it in contemporary buildings for better energy conservation performance. This what also have supported and recommended by professional people; architects, academicians, and engineers. However, each group of them had their own view regarding the development, but all of them agreed that these two strategies are the ones that can be developed in the new design of buildings at Erbil to reduce energy consumption. Furthermore, the courtyard has been seen as limited to be developed in contemporary buildings.

The study concluded that courtyard is a very important strategy to be involved in the contemporary design but it is restricted with more complicated criteria. Therefore, the study recommends the courtyard as a passive strategy strongly, but with special development like lateral and central courtyards with modern and acceptable concept as proposed by the interviewees. Finally, the raised questions at the beginning of this study have been answered and the study can contribute significant proof for the upgrading of our comprehension regarding the solution of energy conservation in buildings of Erbil. This is based on the implementation of the passive strategies of the vernacular and traditional buildings in contemporary buildings in a practical way and sophisticated appearance.

5.3 Suggestions for Future Studies

The study only provides insights of the applicability of energy efficient principles in Erbil vernacular architecture using case studies. Future studies can be a departure point for further studies on the most effective passive design strategy and develop these strategies to be more effective by harnessing the new technology and test its efficiency experimentally. Furthermore, the notion of energy efficiency in the vernacular and traditional architecture of Erbil would open many possibilities to enhance and develop with other vernacular and traditional architectural element in the same climatic region. Therefore, further studies related to energy efficiency principle of vernacular architecture in a hot and arid climate can benefit from this study.

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