BIO-CLIMATIC ARCHITECTURE IN LIBYA: CASE STUDIES FROM THREE CLIMATIC REGIONS

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NAHLA ADEL ELWEFATI

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CASE STUDIES FROM THREE CLIMATIC REGIONS

Submitted by **NAHLA ADEL ELWEFATI** in partial fulfilment of the requirements for the degree of **Master of Science in Building Science, Architecture Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen
Dean, Graduate School of **Natural and Applied Sciences** _______________

Assoc. Prof. Dr. Güven Arif Sargın
Head of Department, **Architecture Dept., METU** _______________

Assoc. Prof. Dr. Soofia Tahira Elias Özkan
Supervisor, **Architecture Dept., METU** _______________

Examining Committee Members

Prof. Dr. Ömür Bakırer
Architecture Dept., METU _______________

Assoc. Prof. Dr. Soofia Tahira Elias Özkan
Architecture Dept., METU _______________

Assoc. Prof. Dr. Arda Düzgüneş
Architecture Dept., METU _______________

Instr. Dr. Sema Onurlu
Architecture Dept., METU _______________

Instr. Dr. A. Berrin Çakmaklı
Interior Architecture Dept., Başkent University _______________

Date: **25.07.2007**

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.

Name, Last Name: Nahla Adel Elwefati

Signature :

ABSTRACT

BIO-CLIMATIC ARCHITECTURE IN LIBYA:
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Elwefati, Nahla Adel

M.S., in Building Science, Department of Architecture

Supervisor: Assoc. Prof. Dr. Soofia Tahira Elias Özkan

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The aim of this study was to investigate the bio-climatic characteristics of traditional and contemporary residential architecture in three different climatic/geographical regions of Libya, which are represented by Tripoli in the "coastal region"; Gharyan in the "mountainous region"; and Ghadames in the "desert region". It was undertaken to understand and evaluate the effects of building layout and orientation, wall thicknesses, ceiling height, construction materials, thermal mass and size of windows, on the resultant thermal comfort conditions of the buildings/dwellings in question.

An architectural survey of the dwellings was carried out and indoor and outdoor photos of houses were taken. Temperature and humidity data in pre-determined rooms of the dwellings, in addition to data relevant to exterior weather conditions were recorded by thermo-hygrometers. Residents who had experience of living in both traditional and contemporary dwellings were interviewed informally before preparing a comprehensive questionnaire, which was distributed to them to gather the required data.

It was found that traditional dwellings in Tripoli and Ghadames, in their present condition, did not provide the desired level of thermal comfort. This was attributed to a number of reasons. One was the abandonment of these dwellings by their occupants, in favor of those of modern style. The resulting collapse of some parts of adjacent house blocks, which used to provide a degree of protection against climatic conditions when working as a whole block of several attached houses. Another was the introduction of new construction materials that were incompatible with the original ones. However, traditional dwellings in both cities appeared to provide relatively better thermal comfort conditions in comparison with the use contemporary dwellings of recent years, except for those with air conditioning.

This situation was different in Gharyan, where the troglodyte dwellings were concerned. These dwellings were thermally more comfortable than the modern ones in the city. This was attributed to the fact that most of the existing troglodyte dwellings still preserved their original features to a large extent.

At length, this study recommends that modern types of dwellings should adapt those features of the traditional ones that are more compatible and suitable for the local climatic conditions, in a way which guarantees optimum exploitation of local resources in terms of energy consumption and cost.

Keywords: bio-climatic architecture, traditional dwellings, contemporary dwellings, thermal comfort, troglodyte, Libya.

ÖZ

LİBYA'DA BİYO-İKLİMSEL MİMARLIK
ÜÇ İKLİMSEL BÖLGEDEN VAKA ÇALIŞMALARI

Elwefati, Nahla Adel

Yüksek Lisans, Yapı Bilimleri Ana Bilim Dalı, Mimarlık Bölümü

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Bu çalışmada Libya'daki biyo-iklimsel mimarlığa odaklanılmıştır. Geleneksel ve çağdaş konut mimarisinin temel özelliklerinin araştırılması için üç farklı iklimsel/coğrafi bölgede çalışılmıştır. ”Kıyı bölgesi”ni temsilen Tripoli, “Dağlık bölge”yi temsilen Gharyan, “Çöl bölgesi”ni temsilen Ghadames incelenmiştir. Bu çalışma, tasarıma dayalı elemanlar olan, bina planı ve konumlandırılması, duvar kalınlıkları, tavan yüksekliği, yapı malzemeleri, pencerelerin termik kütle ve ölçüleri vs.'nin binaların termik konfor koşullarına olan etkisini anlamak ve değerlendirmek için yapılmıştır.

Konutlar mimari açıdan incelenmiş olup içeriden ve dışarıdan fotoğraflandırılmıştır. Aynı zamanda konutların önceden belirlenmiş odalarında sıcaklık ve nem verileri, ilişkili olan dış mekan verileriyle beraber termik-hyrometrelere kaydedilmiştir. Kapsamlı bir anket hazırlamak için geleneksel ve çağdaş konut sakinleriyle görüşülmüştür.

Çalışmanın sonunda Tripoli ve Ghademes'deki geleneksel konutlarda, şimdiki koşullarla istenen termal konfor seviyesinin sağlanamadığı görülmüştür. İstenen konfor seviyesinin olmaması bu bölgelerde çeşitli sonuçlar doğurmuştur. Bunlardan bazıları konutların terk edilmesi, konutların modern stillere adapte edilmesi, eskiden iklimsel koşullara karşı daha iyi koruma sağlayan blok olarak çalışan konut bloklarının bazı bölümlerinin yıkılması ve orijinal malzemeye uymayan yeni yapı malzemelerinin kullanılmasıdır. Diğer yandan her iki yerleşim bölgesindeki konutlar aynı bölgelerdeki yeni yapılmış betonarme konutlara göre(yapay havalandırma kullanılanlar dışında) daha iyi iklimsel konfor koşulları sağlamaktadır.

Gharyan'da durum farklılaşmaktadır. Eski yer altı konutları şehirdeki modern konutlara göre iklimsel olarak daha konforludur. Bunu sebebi yer altı konutlarının büyük ölçüde orijinal özelliklerini hala koruyor olmasıdır.

Bu çalışma, modern konut tiplerinin, yerel kaynakların optimum kullanımını garanti edip , enerji ve para tüketimini engeleyecek şekilde ülkenin iklimsel koşullarına uyacak biçimde eski geleneksel konutların karakteristik avantajlarından faydalanarak geliştirilmesini önermektedir.

Anahtar Kelimeler: biyo-iklimsel mimarlık, geleneksel konutlar, çağdaş konutlar, isıl konfor, troglodyte, Libya

TO

MY FAMILY

AND TO

THE MEMORY OF MY LATE TEACHER AND ARTIST

ALI GANA

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CHAPTER 1

INTRODUCTION

In this chapter the argument for the study, its objectives, the procedure followed in its conduct and the disposition of the various chapters within the thesis, are presented.

The term “Bio-climatic architecture”, refers to buildings that designed as that they readily respond to the effects of the local environment in order to provide comfort conditions for their occupants. Being environment-friendly leads to the construction of comfortable buildings with minimum depletion of natural resources and minimum waste. Much energy is wasted by way of requiring additional heating-cooling where there is inconsistency with the environment, and/or when inappropriate materials or design features are used. Selection of building forms and materials should, therefore, be always responsive to the local environment and climate.

1.1 Argument

In oil rich countries, many housing projects encourage the use of expensive imported materials, such as steel and cement and grown upon the use of local ones. For this reason such countries have become dependent on the import of building materials and infrastructure components. Additionally, such buildings are not suitable to the climatic conditions of the region.

Libya, like most developing countries, experienced rapid growth in the construction sector during the last thirty years. Unfortunately, this growth was only in favor of “modern” construction, which gave rise to large numbers of uniform-type reinforced concrete structures being built all over the country, with practically no regard for the conditions prevailing in their vicinity, climatic and otherwise. This resulted in not only uncomfortable and energy-consuming buildings but, according to the author's firm conviction also in severance of ties with the historical past and culture of the local people.

This study was undertaken to investigate some of the significant factors underlying the apparent success of the construction patterns that were dominate in the country until the 1970's. The main advantage of the traditional styles was that they were friendly to their environment by way of using local building materials and by their design, which not only respected, but also took advantage of the governing climatic conditions in the area.

This led to buildings that offered good thermal comfort to their occupants. In very simple words, they were to a high extent, warm in winter and cool in summer. In addition, there was a special building style for every environment or region in Libya. A style that was dependant mainly on whether the region was coastal, mountainous or desert. In contrast, it was clear that their replacements, the modern concrete buildings fell quite short on this count, as well as in terms of other environmental concerns.

1.2 Objectives

The main objectives of this research were to:

a) Study and understand the architectural and bio-climatic characteristics of both traditional and modern housing in Libya.
b) Compare the comfort levels in the two types of housing
c) Understand user preferences with regard to residential architecture in Libya.
d) Gather temperature and humidity data in representative buildings with the aim of comparing empirical data.

1.3 Procedure

Literature survey was first conducted to define the bio-climatic features of both the traditional and the modern houses in North Africa, especially Libya. An architectural survey of two dwellings each in the three bio-climatic regions was conducted, which included surveying the houses to produce architectural drawings and taking photographs.

At the same time, temperature and humidity data were recorded by thermo-hygrometers in predetermined rooms of the dwellings, and data relevant to exterior weather conditions were compiled. Those residents who had experienced living in both traditional and contemporary dwellings were interviewed informally before preparing a comprehensive questionnaire, which was then distributed to them to gather the required data. These were evaluated and presented graphically. Finally, some recommendations were made to improve comfort in the buildings for the research area.

1.4 Disposition

The study is presented in five chapters. This first chapter is composed of the argument, objectives and an overview of general procedure. It concludes with the disposition of subject matter that follows in the remaining chapters.

Chapter 2 is composed of a literature review, to include general aspects of thermal comfort, climatic and design-dependent elements affecting thermal performance of buildings and recent thermal comfort studies on buildings. Material regarding traditional housing in North Africa has also been provided in this review.

Chapter 3 presents the material and methodology used to conduct the research. Information gathered during the survey of contemporary and traditional houses has also been included here as study material.

Chapter 4 comprises analyses and discussions in the light of questionnaire data and the temperature and humidity charts.

Chapter 5 concludes the study by summarizing its findings and offers pertinent recommendations.

CHAPTER 2

LITERATURE REVIEW

This literature review is based on information taken from 25 published sources and 13 internet websites, Arabic sources were translated by the author. It covers topics related to bio-climatic architecture, bio-climatic factors and zones, including design factors that influence the thermal comfort level in houses and bio-climatic architecture in Libya.

2.1 Bio-climatic architecture

According to Ezz Aldin (1989), it is necessary to encourage a wider use of local building materials and construction techniques. This will also provide employment and training in basic skills, which will support small-scale entrepreneurs in the field of building construction. On the other hand, relevant codes, standards and regulations are needed to encourage wider use of local and affordable materials.

Bio-climatic architecture aims at obtaining conditions of internal comfort through design, and thereby substantially increasing the standard of living. According to one source (www.adoss.com), this can be achieved by making the most of our surroundings, using climate, microclimate, orientation, air movements, humidity, underground streams, electromagnetic fields and appropriate materials to give us a personalized solution for a house integrated into its environment, cheaper, more pleasant and above all ‘healthier'.

Olgyay (1969) refers to Le Corbusier’s words where he points out that the adaptation of a building to environment has been a problem for centuries; Le Corbusier underlines this situation with the following words:

> The symphony of climate…has not been understood…The sun differs along the curvature of the meridian, its intensity varies on the crust of the earth according to its incidence…In this play many conditions are created which await adequate solutions. It is at this point that an authentic regionalism has its rightful place.

Olgyay (1969) also states that the desirable procedure in terms of achieving better living conditions can be achieved by using the force of Nature, thus achieving a "climate balanced" building. It is hard to reach perfect balance in normal environmental circumstances. On the other hand, it is possible for a house to achieve great comfort at lowered cost with minimization of mechanical conditioning. The same author examines the process of building a climate-balanced house in four stages:

a) *Climatic data* of a specific region should be investigated considering annual characteristics of their sub elements, such as temperature, relative humidity, radiation, and wind effects, and Lippsmeier (1980) added cloudiness and precipitation to the list of elements that affect the climate requirements.
b) *Biological evaluation* should be based on human sensations. Within collaboration of climate data and bio-climatic chart, a diagnosis showing relative importance of the various climatic elements in the region is deduced. The results can be tabulated on a yearly timetable including necessary measures for revision of comfort conditions.
c) *Technological solutions* comprise some calculative methods, such as site selection, orientation, shading calculations, housing forms, air movements, and indoor temperature balance.
d) *Architectural application* of the results from the first three steps should be improved and adjusted in compliance with the importance of the different elements.

According to Lippsmeier (1980), it is essential that the local climatic conditions are taken into consideration when designing a building to ensure appropriate planning and construction. The author lists the consequences of ignoring these conditions as follows:

a) Human comfort, mental and physical capacities of the occupants can be impaired in case there are extreme conditions of solar radiation, glare, temperature and temperature change, precipitation, humidity, air movement or air pollution
b) The safety of buildings can be endangered due to earthquakes, windstorms, flooding, tidal waves or biological agents.
c) Building can be damaged due to premature fatigue of building materials by intense solar radiation, high humidity and condensation, dust and sand storms or salt content of the air.

2.2 Bio-climatic factors

> Using only architecture and without any additional complex systems we can obtain a level of comfort which in many places would be sufficient without having to resort to using conventional, or in the best cases, alternative energy supplies. Without necessarily increasing the initial investment in the construction, a bio-climatic house can save a high percentage of energy costs both in heating and in cooling by using passive and purely architectonic devices to collect the energy Nature offers us. (www.adoss.com).

It is commonly known that the work of the Egyptian architect Hasan Fathy epitomized what today is referred to as bio-climatic architecture. He studied and revived ancient and indigenous techniques of construction to achieve this goal. However, as Irfan (2004) points out, although Fathy revived adobe architecture he also emphasized the importance of applying scientific knowledge to buildings in such a way that, "…the quality and values inherent to the traditional and human response to the environment might be preserved without a loss of the advances of science." The author also points out that in order to employ energy-conservation techniques, six fundamental principles were adopted in Hassan Fathy's work, which were:

a) Use of appropriate technology.
b) Belief in the primacy of human values in architecture.
c) Importance of a universal rather than a limited approach.
d) Need for socially oriented, cooperative construction techniques.

e) The essential role of tradition.
f) The re-establishment of national cultural pride through the act of building.

The main climatic factors affecting human comfort are temperature, humidity and air movements. According to Lippsmeier (1980) the following factors affect the comfort zone:

i) Temperature: During the course of the day, maximum temperature is reached about 2 hours after mid day, when the effects of direct solar radiation and high air temperature already prevailing are combined. The greatest heat gain is thus found on southwest or northwest (depending on season and latitude) and west façades. As a rule of thumb, it can be assumed that the highest temperature occurs 1-2 hours after the sun passes the meridian and the lowest, about 1-2 hours before sunrise.

ii) Humidity: The moisture content of the air can, in contrast to the other constituents, fluctuate greatly and depends primarily on changes in air temperature. The higher the temperature the more moisture the air can absorb. To judge the compatibility of climate, it is of utmost importance to have information about the moisture content of the air. Climate becomes less tolerable with increased moisture content. This is worsened by a combination of high temperature with humidity, that is, by a high wet-bulb temperature. People feel uncomfortable under conditions with a vapour pressure of over about 2kPa. The cooling effect of evaporation from the skin is impeded above this level and the air itself cannot absorb enough moisture. Figure 2.1 shows a bio-climatic chart illustrates the comfort zone in the hot areas.

iii) Air movement: Movements of air result from the varied warming of air layers. On the Beaufort scale, this extends from perfect calm to hurricane force; that is, from wind force 0 to 12. Lippsmeier (1980) further argues that the aim of all planning should be to create the greatest possible comfort for occupants. Also, that unfortunately, it is not possible to measure comfort objectively; only after experiments with many people under different environmental conditions can conclusions be drawn and guiding principles be laid down. Hence, it remains for the designer to plan and design as pleasant and comfortable an environment as possible. Some experimental results of studies on the comfort zone, expressed in effective temperatures, are illustrated in Table 2.1.

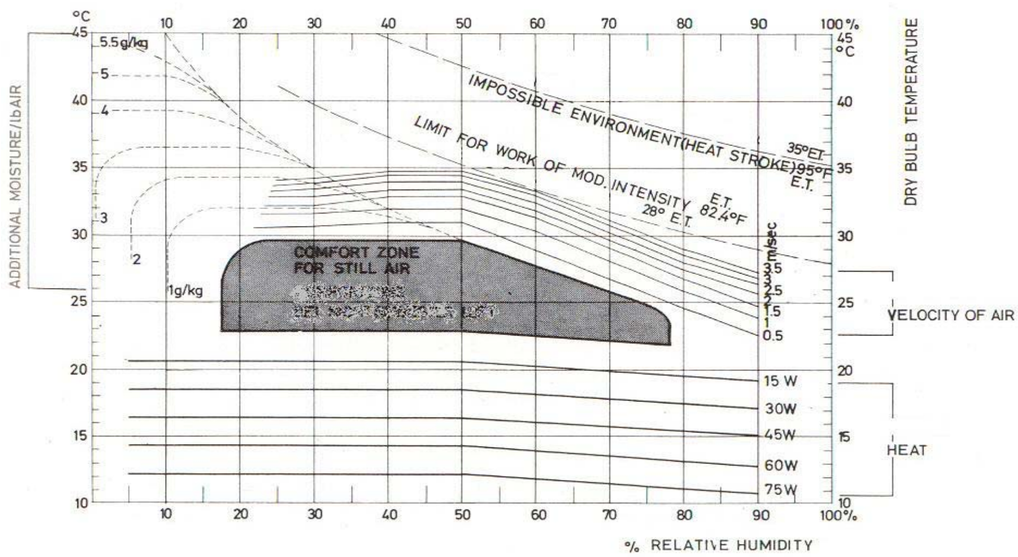


Figure 2.1 Bio-climatic chart.
(Source: Lippsmeier, 1980.)

Table 2.1 Comfort zones in the Tropics

Investigator	Locality	Group of people	Comfort zone
A.S.H.R.A.E.	Southern USA (30º north)	Local people	20.5-24.5º C
Rao	Calcutta (22º north)	Local people	20-24.5º C
Webb	Singapore (equatorial)	Local people	25-27 º C
Mom	Batavia (6º south)	Local people	20-26 º C
Ellis	Singapore (equatorial)	European	22-26 º C

(Source: Lippsmeier, 1980.)

2.3 Bio-climatic zones in the tropics

The hot-arid regions are marked by an absolute humidity (vapour pressure) of under 2.5 kPa and high daily temperatures in the summer months, to more than 50ºC, coupled with intense solar radiation. Summer and winter differ greatly and temperatures in winter can drop to 0ºC. Temperature differences between day and night can be as much as 20ºC in winter. Countries within this zone have strong direct radiation and high reflection of solar radiation by the earth's surface; slight precipitation and humidity; and the possibility of dust and sand storms and high temperature differences between day and night (Lippsmeier, 1980); Figure 2.2 shows the climatic zones in the tropics and moderate areas.

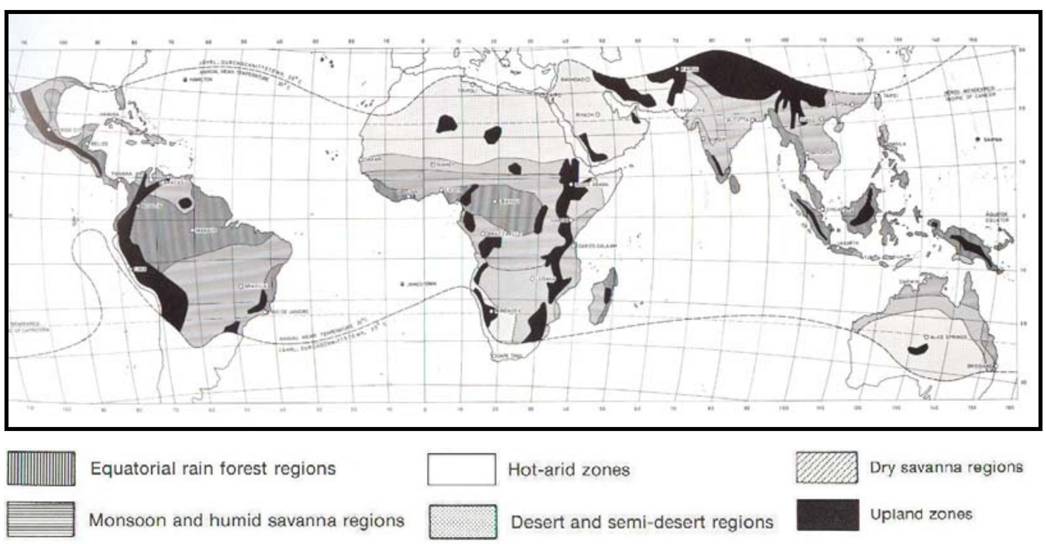


Figure 2.2 Climatic zones. *(Source: Lippsmeier, 1980.)*

2.4 Design factors affecting the level of thermal comfort

The improvement of housing quality is an issue of high priority in several countries. It has been found that many factors affect the level of this comfort; major effects, such as urban design, architectural design of the house and materials used in its construction, coupled with minor ones, such as economy, quality, *etc.*

2.4.1 Urban design

Alezzawi (1996) stated that the urban design of a settlement is one of the major factors which have an important effect on the thermal performance of the buildings within it. In general, most buildings in hot climates have evolved as a cluster more or less connected to each other in order to prevent the penetration of solar radiation and to provide shade. Moreover, the building designs and shapes are also appropriate to the local climate, as seen in the general view of a traditional city in Morocco illustrated in Figure 2.3. The city plans of other ancient cities, such as Tripoli and Ghadames in Libya reflect similar attitudes.

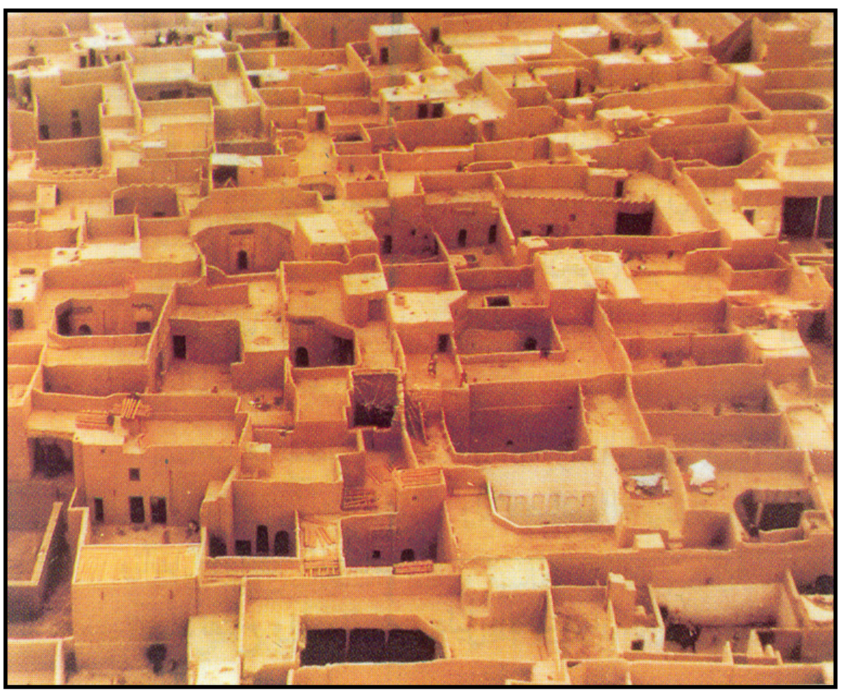


Figure 2.3 General view of a traditional city in Morocco.
(Source: Silkeeni, 1994.)

Elmahmudi (1997) commented that the old city of Tripoli, which has been selected by UNESCO to be included in the conservation program of the world's human heritage, is similar to other traditional cities in hot climates from an urban planning point of view. The streets are characterized by arched, flying buttresses built over narrow streets to support the building walls, to provide shade and to create spaces for social interaction. Figure 2.4 shows a general view of the old city of Tripoli. Figure 2.5 illustrates the treatment of the wind movement through the narrow streets and alleyways. Figures 2.6 and 2.7 give different views from the city showing the arches and flying buttresses.

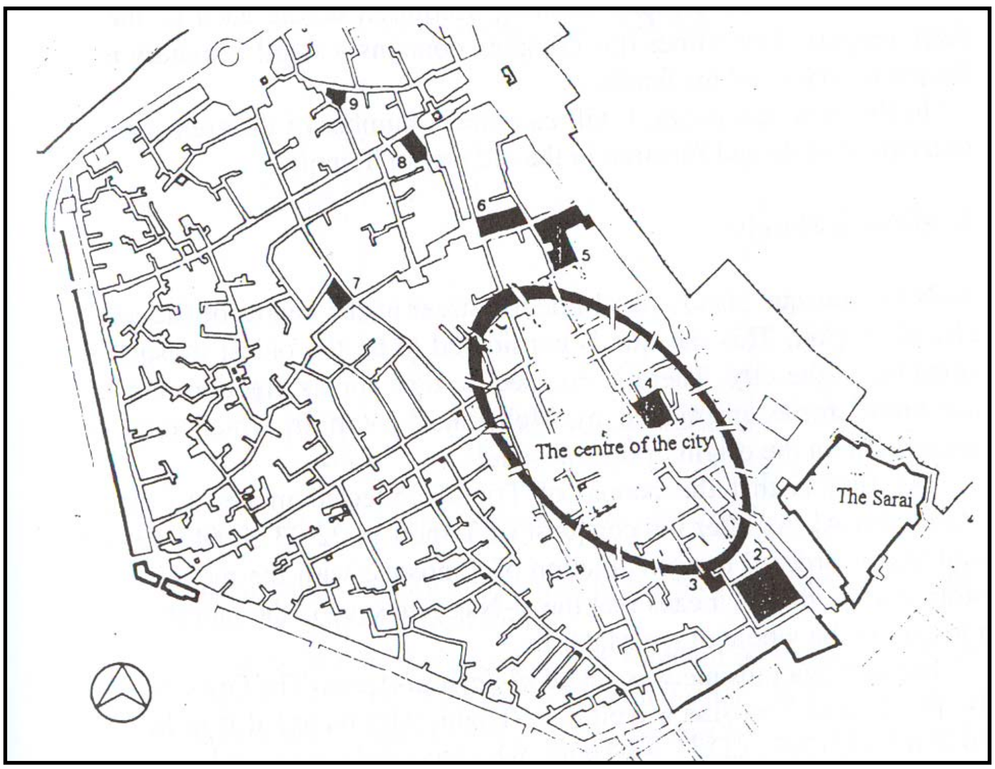


Figure 2.4 General plan of the old city of Tripoli. *(Scale not known)*
(Source: Elmahmudi, 1997.)

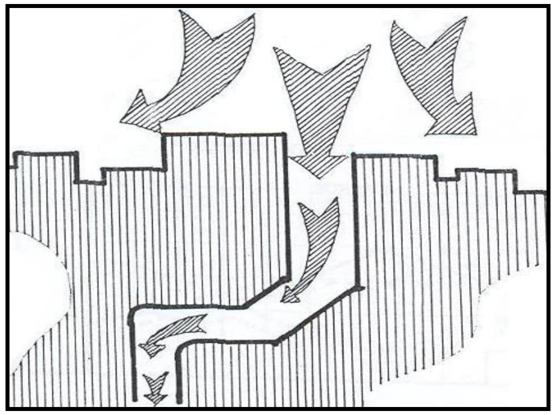


Figure 2.5 Sketch illustrating the treatment of streets in the old cities.
(Source: Ahmed, 1985.)

Figure 2.6 A view from the old city of Tripoli, showing streets shaded by cross-arches.
(Source: http://archnet.org)

**Figure 2.7 A view from the old city of Tripoli,
showing the flying buttresses**
(Photo by Hiba Shalabi)

According to Ahmed (1985)**,** the old city of Ghadames is one of the most important and largest examples of desert architecture in the Libyan Desert. The city shows generally the same characteristics as those in the old city of Tripoli. The roofs of the houses are interconnected, and most streets are covered, allowing for shade, privacy, and security, which make Ghadames a covered connected city, (Figure 2.8) (http://libyanheritage.com). The greenery surrounding the city such as farms of palm trees, and the sand hills on the northern and western sides provide pleasant weather conditions to the houses, by treating and filtering the wind movement from the desert, as shown in Figures 2.9a and 2.9b.

Figure 2.8 General plan of the old city of Ghadames. *(Scale not known)*
(Source: http://libyanheritage.com/)

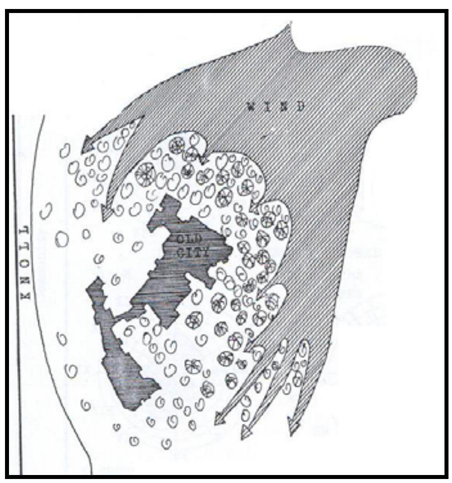


Figure 2.9a Sketch showing the treatment of the wind movement in the old city of Ghadames . *(Scale not known)*
(Source: Ahmed, 1985.)

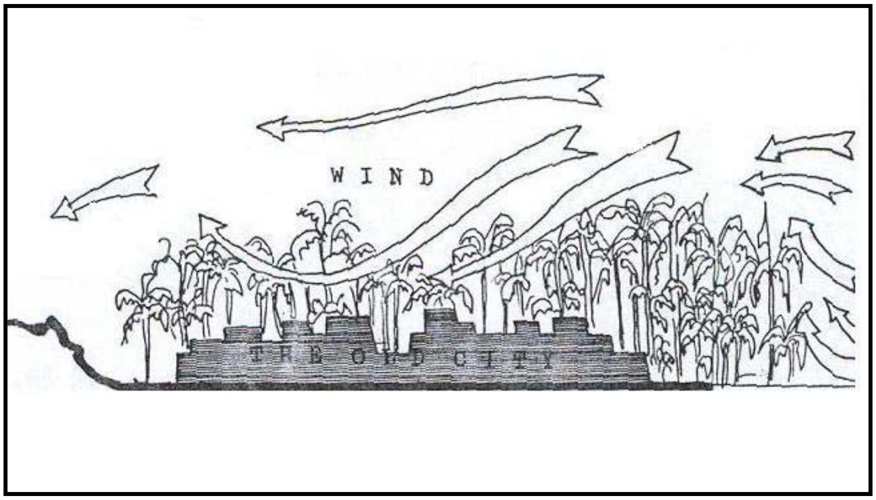


Figure 2.9b Sketch showing the same natural in the old city of Ghadames treatment of the wind. *(scale not known)*
(Source: Ahmed, 1985.)

2.4.2 Architectural design

The architectural design of the house is one of the factors that affect the thermal comfort within. The architectural elements play a great part in influencing the thermal comfort of the house; one of these elements is the courtyard. Many studies have been carried out on courtyards in houses, which emphasize the importance of this enclosed space as being multi-functional, able to provide a convenient natural environment to the interior, which makes it an appropriate architecture solution for semi arid hot areas.

The courtyard is a regulator of air movement within the house. Fathy (1998), illustrated the air movement by convection heat transfer where the density of the warm air is less than the moderate cold air, hence, it rises high were an air switching situation happened between the light density (warm air), and the heavy density (moderate cold air), where it makes an air circulation. This theory explains the function of the courtyard. Wazeeri (2002) refers to some studies, which have determined that the high efficiency and performance of the courtyard design is affected by certain specifications and factors; such as the orientation of the court, the court's dimensions, the latitude and the season.

Most traditional houses of the hot arid zones have the same architectural features, as the example from Egypt, as Wazeeri (2002) illustrated in his study. Another example from the old city of Tripoli – Libya. The residential clusters' design of the old city of Tripoli and the other old-style houses around the city are characterized by the courtyard, which is a common element in most traditional houses in the Mediterranean region. Sometimes, the courtyard is fitted with a fountain that serves as a focal point for family activities. The courtyard also provides cool, fresh air for the interior rooms. A covered balcony on the second floor encircles the courtyard and offers access to interconnect more private rooms, which are not otherwise interconnected.

Figure 2.10 illustrates a typical traditional building from the old city of Tripoli with its courtyard, (http://archnet.org). The rooms are rectangular in general with the long side overlooking the courtyard. They are not too deep so they have a good light distribution. The structural system of the houses depends on thick bearing walls. The houses are attached to each other with thick party walls, and that provide more strength and stability to the building. The thicknesses of the walls are 40 to 80 cm, approximately. The local sand lime stone *(called Bluk)* is the main construction material for walls beside other materials. Most houses are occupied by more than two related families, since extended families were part of traditional social system. This explains the relatively big size of such houses.

Many studies were done on the courtyard, as Wazeeri (2002) commented, to improve its thermal performance to be more efficient and implemented in practice; the studies recommended of:

a) Using upper shading methods.
b) A presence of external parapet walls as a divider between the houses to prevent the hot air on the neighbor roof to move to house.

c) Providing slope to the roof in the direction of the courtyard. This helps cold night air to flow into the court, as illustrated in Figure 2.11.

d) The large windows overlooking the courtyard should be closed during day to keep out the sun, and opened at night, to allow the cold air to enter the rooms.

e) Usage of wooden perforated pergola/ screens, vegetation on the pergola and the courtyard's walls and water elements such as fountains, provide more shade to the court, as illustrated in Figures 2.12a, 2.12b and 2.12c.

Figure 2.10 Courtyard of a traditional house in Tripoli.
(Source: http://archnet.org)

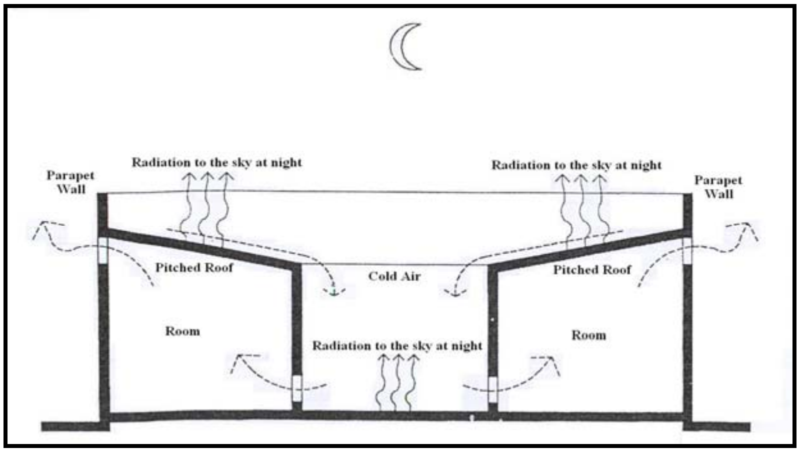


Figure 2.11 Making sloped roofs directed to the courtyard.
(Source: Wazeeri, 2002.)

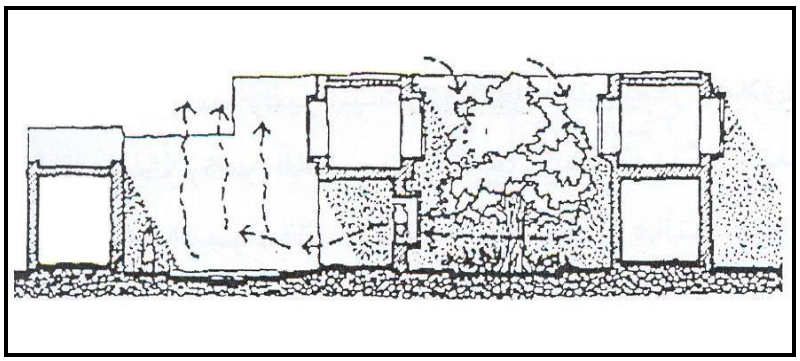


Figure 2.12a Presence of vegetation in the court provides a pleasant air to the house. *(Source: Wazeeri, 2002.)*

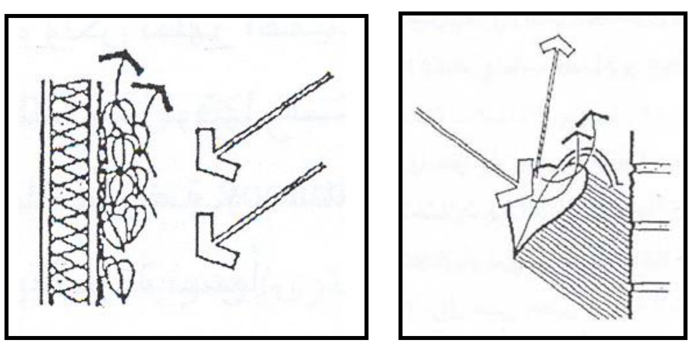


Figure 2.12b The green surface reflects, absorbs sunrays and reduces the sun heat. *(Source: Wazeeri, 2002.)*

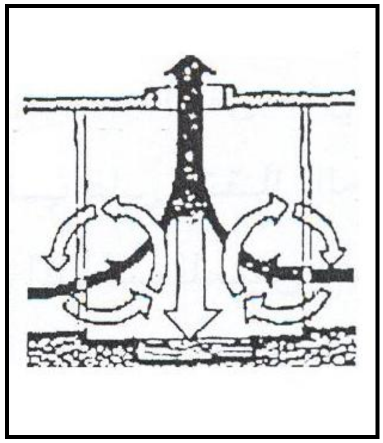


Figure 2.12c Presence of water surfaces helps providing pleasant air to the house. *(Source: Wazeeri, 2002.)*

Other types of dwellings which have a courtyard are the underground dwellings. One of the dwellings surveyed within the scope of this study is a troglodyte in the old city of Gharyan in Libya. The city of Gharyan reflects the unique style of buildings which was typical to the local people "Berbers", called "Troglodyte" or "Underground Dwellings". This type of buildings can be found in some areas in North Africa, (mainly Libya and Tunisia) having different styles. They are also found as a group of desert villages in many forms and types (http://lexicorient.com), as shown in Figures 2.13.

Troglodytes are made as caves or cubic holes dug vertically into the relatively soft ground, these holes/caves used to be dug manually by specialized workers. Because of the hot climate through summer and the freezing winter nights in the mountains of Gharyan, where normal ventilation and isolation does not manage to keep the heat out in summer, or within during winters in contemporary houses; the Troglodytes possess the capability of providing good heat isolation during the hot summers and cold winters. In other words, Troglodytes provide a comfortable climate for their occupants throughout the year (http://www.rediscover.co.uk).

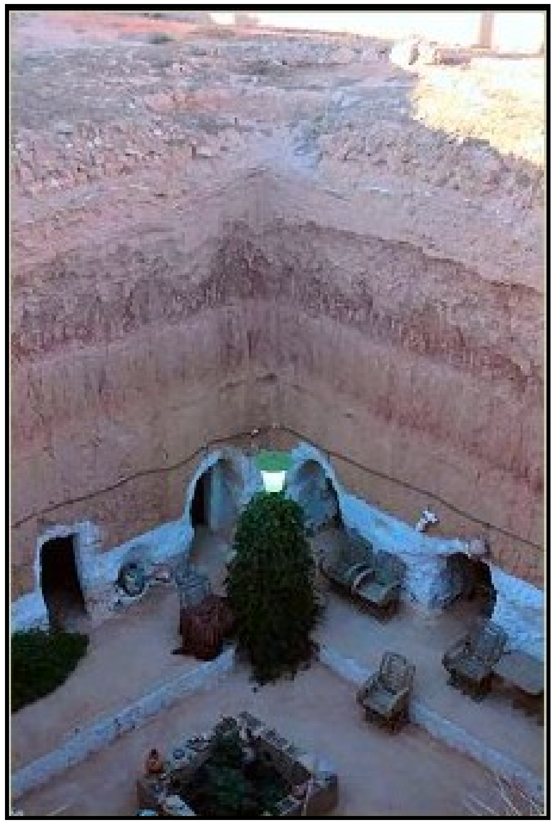


Figure 2.13 Troglodytes in North Africa, Libya.
(Source: http://lexicorient.com)

Bash-Imam and Bukra (2004) declared that in Gharyan, the Troglodytes are distinguished for their privacy and great simplicity. Due to the difficult topography of the area and the limited availability of the construction materials; local people adapted this housing system because it requires the minimum use of building materials. Most of the Troglodytes follow the system of the open court, which sometimes is regular in shape and level. Figures 2.14a and 2.14b illustrate general layouts and view of the Troglodyte or "Underground dwellings".

Krarti (1997) studied the thermal performance of the underground dwellings "*Troglodytes*", shown in Figure 2.15. These dwellings were built by the first inhabitants of North Africa, as early as in 500 BC and as late as in 1900 AD, and were later developed by the Berbers. The troglodytes are located in Matmata plateau, north of the Sahara desert, at the altitude 500 m. The advantages of building these houses were:

a) Easy to excavate the soil (free of stones)
b) Shelter against invaders attack
c) Protection from hot and arid climate

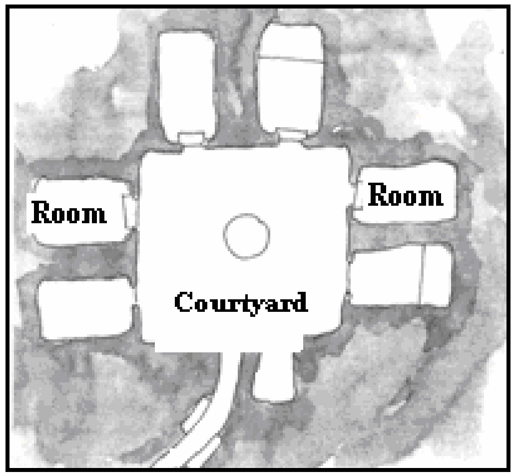


Figure 2.14a Plan of a troglodyte in Gharyan. *(Scale not known)*
(Source: Bash-Imam and Bukra, 2004.)

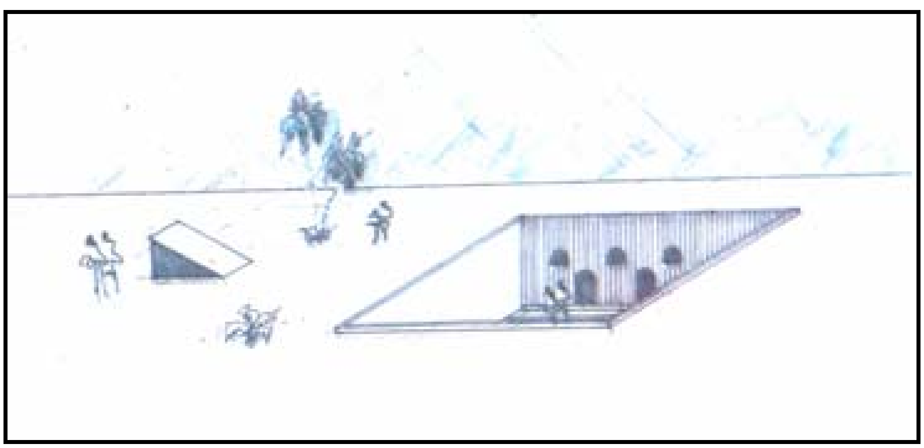


Figure 2.14b View of the troglodyte in Gharyan. *(Scale not known)*
(Source: Bash-Imam and Bukra, 2004.)

Figure 2.15 A troglodyte in Matmata, Tunisia.
(Source: http://lexicorient.com/e.o/troglod.htm)

The parameters measured in this study were air temperature and relative humidity, both outdoors and indoors. Figure 2.16 presents hourly dry-bulb temperatures measured during summer (July 24-25, 1997). Table 1 illustrates a comparison of indoor environment for typical winter and summer days in a subterranean dwelling and a conventional above-ground house in Matmata.

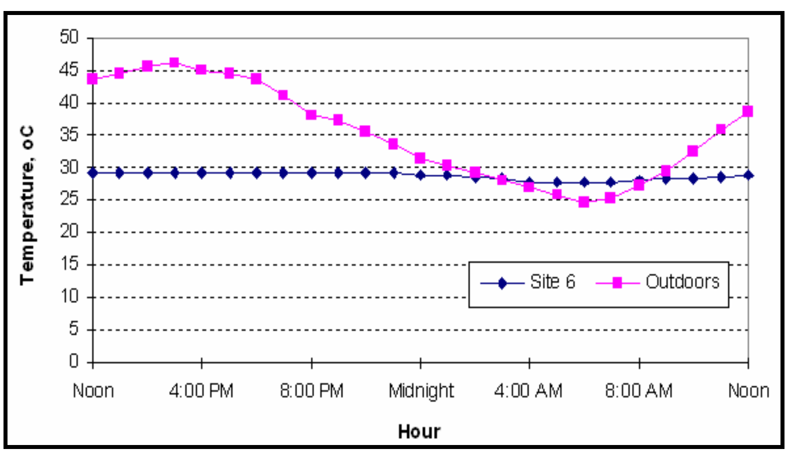


Figure 2.16 Dry bulbs in temperature in Matmata dwellings in summer.
(Source: Krarti, 1997.)

Table 2.2 Comparison between indoor and outdoor environment for winter and summer season.

Dwelling Type	Troglodyte		Above-Ground House	
Season	Winter	Summer	Winter	Summer
Outdoor C°. & RH%	6.6 C° 70%	41.1 C° 11%	6.6 C° 70%	41.1 C° 11%
Indoor C°. & RH%	15 C° 48%	25.5 C° 38%	10.5 C° 60%	36.5 C° 20%

(Source: Krarti, 1997.)

Krarti (1997) summarized and conclude his study with the following statements:

a) Field measurements indicated that the troglodyte dwellings provide more comfortable environment than above-grade houses in the Matmata region throughout the year.
b) The optimum depth for the dwellings is 10 m, as discovered by the first inhabitants of Matmata.
c) Design of Matmata dwellings needs to be improved to correct for lack of ventilation and natural lighting.

Another study of the bio-climatic architecture illustrates the simple architectural techniques, which are examples of desert architecture, from *Ghadames* in Libya and from *Amazerwa* in Algeria. Ahmed (1985) stated that the traditional houses of Ghadames used a small opening, about 1m×1m, located at the ceiling in the middle of the house, as shown in Figure 2.17. This small opening allowed an air circulation, and prevented the external heat from entering the house.

According to a study by Wazeeri (2002), in the same desert in Algeria, in Amazerwa, the houses were built around two internal courts. That provides a good air circulation; when the sun falls on one of the courts, the air becomes warmer and rises up outside to the sky. As for the cooler air, it is been pulled by the other court to replace the warmer air. By this movement, the cold air passes the rooms between the two courts, which provide a pleasant climate inside the house, (Figure 2.18).

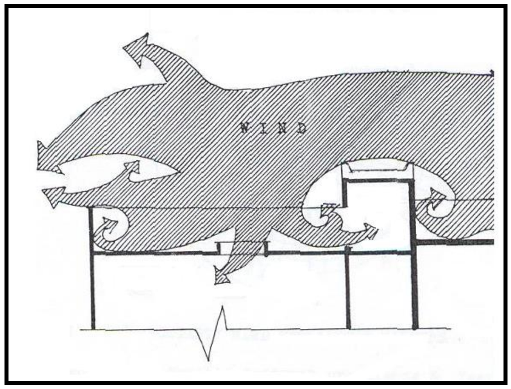


Figure 2.17 Sketch shows the wind movement on the roofs in a traditional house of Ghadames. *(Source: Ahmed, 1985.)*

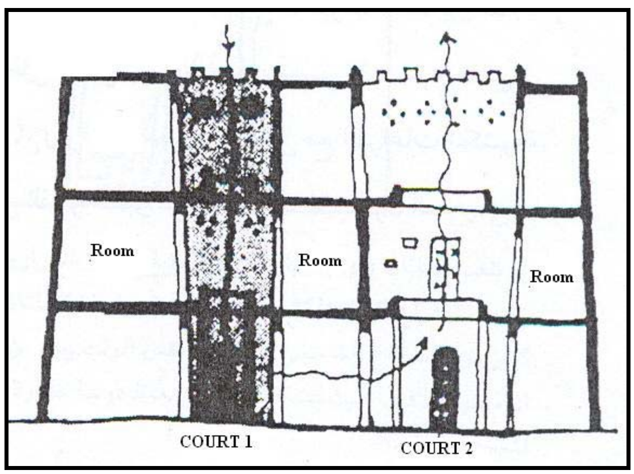


Figure 2.18 Sketch illustrates the theory of the two courts in the traditional house of Amazerwa. *(Source: Wazeeri, 2002.)*

Wazeeri (2002) commented that the courtyard is the common architectural element in designing the traditional houses in hot arid regions, such as: North Africa and the Middle East, where the big range in temperature between day and night is the important climatic phenomenon. The courtyard depends on this diurnal variation of temperature to perform its function, as storage of the cold air at night, where the courtyard floor and walls return their stored up sun's energy back to the open sky once again.

Other studies on the architectural design were implemented in practice for the arid desert zones. In 1967, Fathy used the *"Malkaf"* system in one of his famous projects, the "*New Baris Village*", in Egypt. This system worked as winds catchers; where the air gets through these catchers, which are connected to widespread channels around the whole building, as shown in Figure 2.19. This system also was used on some individual sectors, in other places in the same zone.

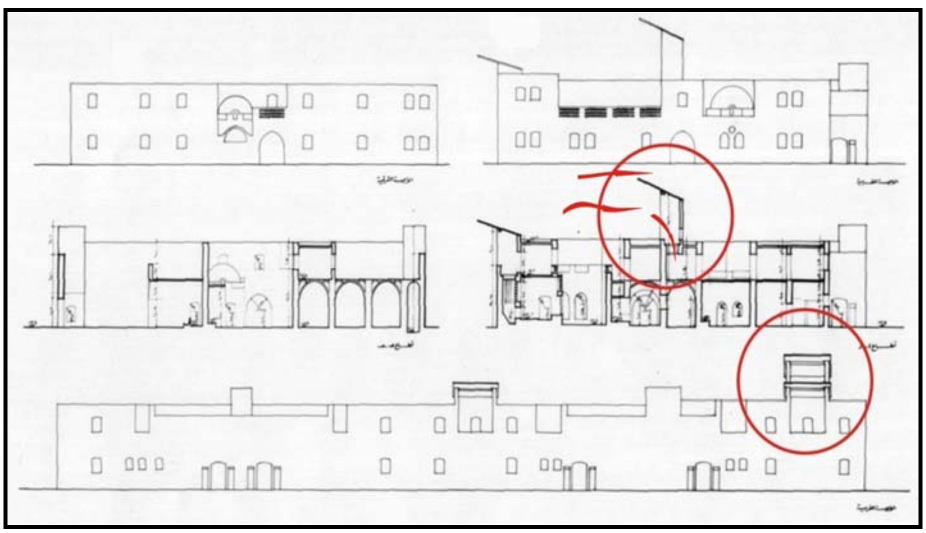


Figure 2.19 The Malkaf in New Baris Village in Egypt.
(Scale not known) (Source: Aga Khan Trust for Culture.)

2.4.3 Construction materials

Many studies focused on the benefits of using local construction materials as a solution to many problems such as; pollution, economy, complicated construction *etc*. Mills-Tettery (1989) declared that:

> ...since man started to evolve shelter forms for his habitation, climate, vegetation, soil conditions and the overall environment have played important roles. Through necessity rather than choice, he learnt the use of indigenous materials in the shaping of his house forms with due cognizance of local climate. The houses that emerged had more of users' value than market values, but were at least comfortable to live in and satisfied all his needs.

Fathy (1973) stated that the climate of Upper Egypt is characteristic of hot, arid zones, with a very wide difference between day and night temperatures. Due to the almost complete absence of cloud screening, the ground by day receives a great amount of solar radiation, while by night it radiates a great amount of heat out to the atmosphere again. Therefore, the comfort of people inside buildings in such zones depends largely upon the thermal properties of the walls and roof. The best materials are those that do not conduct heat.

Fathy (1973) commented that sun-dried earth brick is, fortunately, one of the poorest conductors of heat. Partly because of its very low natural conductivity (0.22 calories/minute/cm^2/unit thickness for bricks with 20 percent fine sand, 0.32 calories/minute/cm^2/unit thickness for bricks with 80 percent coarse sand, as against 0.48 for baked bricks and 0.8 for hollow concrete blocks), and partly because mud is weak and necessitates thick walls, the mud brick houses of Upper Egypt remain remarkably cool for the major part of the day. At *Kom Ombo*, the concrete houses built by the sugar company for its employees proved too hot to live in during summer and too cold in winter, and the employees preferred to live in the mud houses of the peasants.

Another example of constructing buildings with materials, which are compatible to the extreme climate in the tropics, and have a marked impact on human comfort; is the high rise clay buildings of the traditional town in Hadhramaut in Yemen (Figure 2.20). These buildings were built upto10 to 12 stories high, with air-dried clay bricks and without any steel reinforcement (Lippsmeier, 1980).

Figure 2.20 High-rise clay buildings of Hadhramut in Yemen.
(Source: Lippsmeier, 1980.)

Other studies introduce more types of local construction materials used in tropic zone. Bash-Imam (b) (1999) declared that the main traditional construction materials in the old city of Tripoli are:

a) *Lime:* which is the essential material in making lime mortar and used in painting and plastering.

b) *Clayey sand:* this material was used to construct the adobe walls after mixing it with gravel.

c) *Lime stone:* is the main construction material for walls in the old city of Tripoli. It is easy to cut and shaped, with great workability, high heat resistance up to 900ºC, good thermal insulation, high compressive strength, and good resistance to the environmental conditions (Figure 2.21).

d) *Sand stone:* is less used than lime stone, and it have to be plastered with mortar lime as a protective layer against weather conditions.

e) *Clay brick:* and commonly known as "*Red brick*" also used in constructing walls and arches (Figure 2.22).

f) *Timber:* wood of palm and olive trees is used for ceilings, roofs, fenestrations and in some decoration works as shown in Figure 2.23.

Figure 2.21 A wall constructed from limestone.
(Source: Bash-Imam and Bukra, 2004.)

Figure 2.22 Use of brick in arch construction.
(Source: Bash-Imam and Bukra, 2004.)

Figure 2.23 A wooden door of a house in the old city of Tripoli.
(Source: Bash-Imam and Bukra, 2004.)

2.5 Bio-climatic architecture in Libya

Libya is located in the desert and semi-desert regions. Figure 2.24 shows the map of Libya and its location in North Africa and in the Mediterranean Sea; Figure 2.25 shows the different climatic regions of the country. Houses in three cities in three different climatic/ geographical regions of Libya were studied.

Figure 2.24 Map of the location of Libya.
(Source: libyanheritage.com)

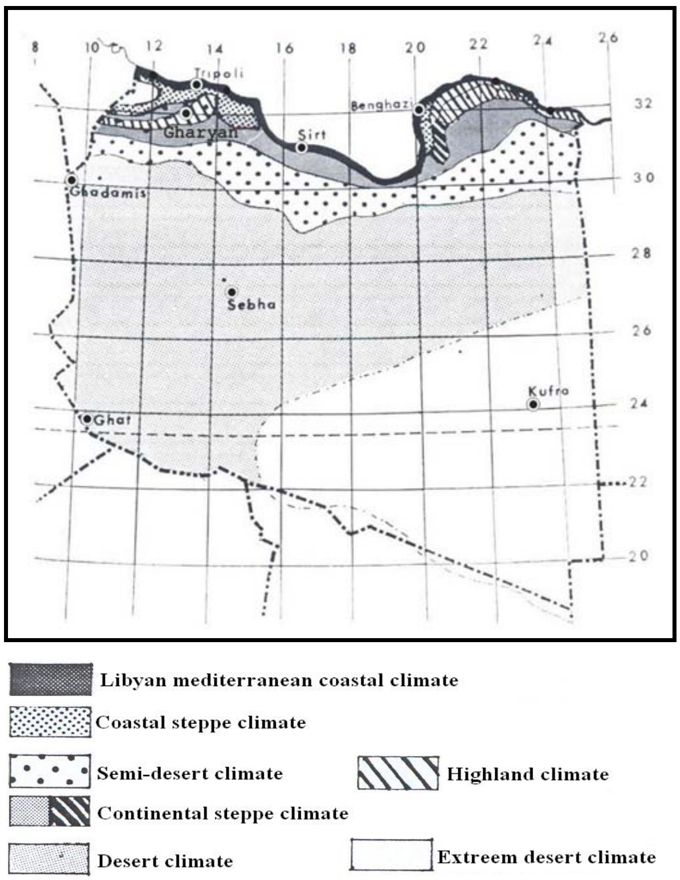


Figure 2.25 Map of climatic regions in Libya.
(Scale not known) (Source: Bukamur, 1985.)

2.5.1 Coastal area: Tripoli

Tripoli, the capital of Libya, is located on the north- west of Libya on the Mediterranean coast at 32º 52` N, 13º 10` E; its altitude is 9m above the sea level. Tripoli represents the coastal area of this study, as shown in Figure 2.25.

The climate of Tripoli is relatively pleasant even in summer time, but some days the temperatures can reach the level of 40°C with quite high humidity, especially in July and August. Winter in this region often brings rain and cold nights, with an average temperature of 15°C. During spring, the *ghibli* -which took place at the end of spring and the beginning of summer-, can offer an unpleasant experience of rapid increase in the temperatures, because of the sandy hot winds coming from the desert.

The old style in building houses is not restricted to the old city, but it can be found also in other parts of the modern city. However, the largest cluster of traditional houses is located in the "Old city".

2.5.2 Mountainous area: Gharyan

Gharyan is the biggest city of Jebel Nafusa (Western Mountain). It is located at the north-west of Libya, about 90km to the south of Tripoli, at 32º 11` N, 13º 00` E (Figure 2.25); and its altitude are about 1000 m above the sea level.

The climate of Gharyan is cold and rainy in winter, with an average temperature of 10°C, and hot and dry in summer with an average temperature of 35°C. The city of Gharyan is now a mixed of traditional and modern housing areas, because most modern houses were built near or over the buried old houses, as shown in Figure 2.26.

Figure 2.26 A view of a modern building in Gharyan taken from a troglodyte entrance.

2.5.3 Desert areas: Ghadames

The oasis city of Ghadames is known as “The Jewel of the Sahara”, because it is located in the Sahara desert and has been declared a World Heritage site by UNESCO since 1987 (http://www.rediscover.co.uk). The architecture of Ghadames is typical north-African desert architecture. This city lies 650 km south-west of Tripoli, and it is close to the meeting point of the Algerian, Libyan and Tunisian borders; at 30º 08` N, 9º 30` E; with an altitude of 300 m above sea level, as shown in Figure 2.25. This height of the city spares in the dangers from the valleys. It is also surrounded with sand hills from the Northern and western sides. This causes warmth in winter season from the fast heat coming out of the sand (Yusha, 2001).

Ghadames has a harsh climate, especially in the long summer season, with temperatures exceeding 40°C on some days. The winter weather is moderate during the day, but very cold at night. Therefore, the architecture and settlement pattern of the old city are designed to respond to the summer's heat and winter's cold (http://archnet.org).

In Ghadames today, there are two cities, each city with its own boundaries; the old city which preserves the history and heritage of the area; and the new modern city which was built in the late 1960's and 1970's. The planning of the new city adapted the design of the old city in many aspects, but without using traditional building materials (Catalogue of the Investment in Ghadames), (Figures 2.27a and 2.27b).

Figure 2.27a A view from Ghadames showing one of the city portals.
(Source: http://archnet.org)

Figure 2.27b A general view from the new city of Ghadames, showing the adapted features of the old city "the connected roofs".

CHAPTER 3

RESEARCH METHODOLOGY

This chapter includes details about the research methodology used in this study. The study was based on four items: the field survey of the six houses, traditional and contemporary types, and temperature and humidity data recorded by thermo-hygrometers, informal interviews with the authorities and occupants; a questionnaire survey and data evaluation procedures.

The methodology of this study focused on a comparison made in each of the three Libyan cities between certain criteria in the traditional and contemporary houses; especially their thermal comfort levels. Six houses were selected for a detailed survey; two houses (one contemporary and the other traditional) were studied in each of the three climatic regions in Libya. The study included visits to each house in the three regions; the starting point was Tripoli – the author's home town. The visits to Gharyan, a city 90 km southwest of Tripoli, were made in three different days during July 2006; and the visit to Ghadames took four full days during July 2006 also.

There were some difficulties in selecting the appropriate traditional house, due to a lack of documentation for most of them, especially in Gharyan. The lack of safety in some abandoned houses, which were nearly demolished and infested with insects and reptiles, and the lack of cooperation on the part of some local authorities were other difficulties. The researcher also faced some difficulty in finding a responsible person to take temperature and humidity readings in the three cities at the same times.

3.1 Field Survey

Architectural drawings of the contemporary houses were obtained from the owners and those for the traditional ones were obtained from the rehabilitation authorities of the old city of Tripoli and Ghadames. However as there was no documentation available for the troglodytes in Gharyan, it was surveyed and the drawings were prepared by the author. All photographs were taken either by the author or with help of relatives and friends. Details of these houses are given in Chapter 4.

3.2 Temperature and Humidity Data

The measurements of indoor and outdoor temperature and humidity were collected with the help of six thermo-hygrometers, in traditional and contemporary houses which were being monitored in the three cities. Data were recorded during one week in summer (July 2006) and during another week in winter (January 2007).

The recorded days for Tripoli were from 13th to 21st July 2006, and from 12th to 21st January 2007; for Gharyan from 20th to 28th July 2006 and from 6th to 11th January 2007; and for Ghadames were from 5th to 12th July 2006 and from 28th December 2006 to 5th January 2007. Recording of the data was done manually at 1:00 pm during day time and 1:00 am during night time, because this was the most convenient time for the occupants helping with the data recording.

All six devices were checked for consistency by comparing their readings with each other and with other measuring devices. Results showed that the thermo-hygrometers used in the field study were adequately reliable and efficient for purposes of the study. Readings of data had to be taken in the absence of mechanical cooling or heating and under unoccupied conditions to ensure reliability of results. Data were then put into tabular format as given in Appendix A.

A comparative analysis was conducted on the temperature and humidity data collected inside the contemporary and traditional houses and outside during the two seasons. The data was tabulated in MS Excel program and charts were prepared separately for humidity and temperature during summer and winter time. The comparative charts presented the curves for external as well as internal conditions in traditional and contemporary houses so that the differences between their performance and comfort levels can be seen concurrently.

3.3 Informal interviews

Informal interviews were carried out individually by the author with owners of traditional houses, with people who had earlier experienced living in both types of houses, with construction workers and visitors in the old city and some experts of local architecture in Libya. Many questions were asked, about the particular features of the houses, especially about the comfort level and the solutions which they adapted to provide more pleasant accommodation in the house during the whole year and to understand user preferences with regard to residential architecture in the country.

3.4 Questionnaire

A questionnaire was prepared in order to collect data regarding traditional and modern houses. This was distributed to a representative sample of people who had experienced living in both types of buildings. While the questionnaire proper was exactly the same for both Tripoli and Ghadames, a few non-relevant questions were omitted from the one covering the city of Gharyan; *e.g.* it did not ask for room designations, number of stories and average thicknesses of the external walls. Questionnaires were given out to people selected randomly, through mutual contacts into the owners of the houses being studied. Since the author did not have any bias in the selection of the respondees, the sample was being considered randomly selected and representative of the population.

The total number of questionnaires distributed was 36 for Tripoli, 40 for Gharyan and 25 for Ghadames. The total number of questionnaires collected was 69 but 3 of these were discarded since questions related to both types of houses had not been answered. With 24 from Tripoli, 26 from Gharyan and 16 questionnaires from Ghadames, a total of 66 questionnaires were evaluated. An English version of the questionnaire is given in Appendix B.

3.5 Data Evaluation

The data was evaluated according to analysis of the field survey. The first phase of evaluation was related to the collected temperature and humidity data, which were presented in linear charts that showed the situation in the traditional houses compared to the contemporary ones.

The second phase of evaluation was related to the questionnaire data, which was presented in tabular forms and charts. This data gives a clear picture of the lack of utilities in traditional houses which were the cause for people abandoning them in favor of the contemporary ones. It is also clear from this study that the estimated cost of energy consumption in traditional houses was less than that in the contemporary ones.

CHAPTER 4

RESEARCH MATERIALS

This chapter includes details about the material used in this study. It consists of the case study of the traditional and contemporary houses. The information collected about these houses; and the thermo-hygrometers used to collect temperature and humidity data. Additionally, information on the informal interviews and a comprehensive questionnaire is also presented here.

A field survey was conducted on both traditional and contemporary houses, in three cities during the same season. The chosen cities represent three different regions in Libya; coastal, mountainous and desert; which show distinct differences not only in terms of climate but also in those of topography and building style. The cities themselves are relatively close to each other compared to the vast area of Libya and are all located in the north-western part of the country.

The study comprised the following materials:

i) Architectural drawings of the buildings along with the photographs and details regarding the six case study buildings were buildings are described in detail in the following sections.

ii) Temperature and humidity data collected inside and outside the buildings with the help of digital thermo-hygrometers model 303C, (produced by *Rinch Industrial Co. Ltd, China*), as shown in Figure 4.1. There were two sensors in the sensor in the hygrometer; the one in the thermo-hygrometer itself recording the temperature and humility indoors while the one at the end of a 2m-long cable could be extended out of a window or a door to record the outdoor readings at the same time.

iii) Informal interviews with residents of both traditional and modern houses.

iv) Questionnaire distributed to a representative sample of people who experienced living in both types of house. The questionnaire itself focused on comparing comfort levels in both types and the reasons occupants gave for abandoning their old traditional houses for moving into their new contemporary ones.

The questionnaire also covered a range of issues related to residential architecture in the study areas, such as: number of families and/or occupants in the house; number of stories and rooms, including their sizes and designations; the average thickness of walls, average ceiling height, information regarding windows, construction materials, auxiliary spaces and whether or not any kind of modification was made in the house by the occupants.

Another aim was to collect information on the environmental comfort level, energy consumption and the facilities/utilities, such as electricity, water supply, and drainages, *etc*. in both types of houses. Lastly, it attempted to elicit the occupant's opinions and the level of their satisfaction with their houses.

Figure 4.1 The thermo-hygrometer device.

4.1 Contemporary housing construction

Contemporary houses throughout the country use the same type of construction materials, such as reinforced concrete skeleton structure, concrete masonry units or limestone blocks for infill walls and mostly clay pot ribbed slabs for roof and floors, decks, through other materials, such as reinforced or pre-cast concrete are also used for this latter.

Most residential buildings have been built by the government in certain areas, such as multiple storey buildings which range from 4 to 10 floors in general, as shown in Figure 4.2; while in other areas the houses are built by the owners themselves using their savings or bank loans. Those houses vary in size and design according to the financial capabilities of the owners, from small villas starting with one storey level, to big multiple storied houses. Figure 4.3 shows different housing styles built by various owners. With regard to indoor comfort, all over the country mechanical air-conditioning systems are necessary to achieve indoor comfort. This system is inappropriate for most areas for reasons such as the huge depletion of energy and also the high cost of purchase of these equipments.

Figure 4.2 Government housing in Libya.

(b) A private house in Tripoli. *(photo by E. Khairy)*

(b) A private house in Ghadames.

Figure 4.3 Examples of contemporary houses built by home-owners in Libya.

4.2 Composite housing construction

The composite housing style is a mixed style combining elements from both contemporary and traditional ones. A good example of this style can be seen in the village of Tuneen. It is about 3 km to the west of Ghadames. The houses in the village have been built at distance of 10-15m from each other, as shown in Figure

4.4. Some owners in Tuneen built their houses with a style distinguishing them from that of their neighbours' houses. In other words, the owners used:

a) Simple design for the house usually made without engineering consultants, Figure 4.4.
b) Reinforced concrete skeleton, Figure 4.5.
c) The foundations were from volcanic stone *"Sawwan"*, about 70cm high, Figure 4.6.
d) Wooden ceiling (in a modern shape), Figure 4.7.
e) Palm trunks *"Sannur"* for the lintels of doors and windows, Figure 4.8.
f) The windows were larger than the ones in the houses of the old city, about 1m×1m.
g) The local mud materials such as mud bricks were made manually at site, Figure 4.9.
h) The walls were constructed of mud bricks, as shown on Figure 4.10, with thickness 40cm, and were plastering with cement mortar.
i) The kitchen and the toilet were covered by concrete masonry units from the inside surface, to prevent the direct contact of the water pipes with the mud bricks.

Figure 4.4 A general view of houses under-construction in Tuneen.

Figure 4.5 Reinforced concrete skeletons of the houses in Tuneen.

Figure 4.6 Volcanic stone foundations of a house in Tuneen.

Figure 4.7 Wooden ceiling of a house in Tuneen.

Figure 4.8 Wooden lintels over a window opening for a house in Tuneen.

Figure 4.9 Mud bricks made manually on site in Tuneen.

Figure 4.10 Plastering with mortar of the houses in Tuneen.

4.3 Case studies in the three regions

This study focused on a comparison of traditional and contemporary houses in three cities in Libya which are located in three different climatic/geographical regions namely; coastal, mountainous and desert regions, represented by Tripoli, Gharyan and Ghadames respectively. The houses in these three cities were studied from the point of view of their architectural and structural design, the construction materials used, utilities and natural light and ventilation in the houses. These aspects were considered to highlight the effects of design-dependent parameters, such as thermal mass, window sizes and orientation and shading, on indoor thermal comfort. The following sections provide information, as obtained from the field survey described in Section 3.1, on the houses under study.

4.3.1 Coastal region: Tripoli

The survey included a visit to most of the local traditional houses located in the historical areas of Tripoli as well as in other areas around the city. During the field survey, the houses were surveyed and data regarding the dimensions of the rooms, including ceiling height, the types of window and the construction materials were noted. The traditional house under study was selected from the historical area in the old city of Tripoli; and the contemporary house is 7 km from the city center in a new developed area. These houses are described in detail in the following sections.

A) Traditional house of Tripoli

The house studied was built at least a century ago and can be classified as a medium in size; total floor area is about $250m^2$, double storied, and having all modern utilities. Gas services are not available in the old city. City gas is available only in limited areas around the old city of Tripoli. Other than that, the occupants provide their needs of gas by buying liquid gas bottles.

The house is located at the outer boundaries of the old city, near the sea. It has 6 rooms distributed around the courtyard, which usually presents the center of the house. The nearly rectangular shape of the rooms is a common feature in most traditional houses in Tripoli (Figure 4.11). According to the owner's statement, the courtyard provides air circulation to interior. The modest depth of rooms with their tall widows and high ceilings, allows natural sunlight to penetrate into all the rooms.

The structural system of the house depends on connected load bearing walls for the whole cluster; it provides more strength and support to all houses that were built next each other. In some traditional houses in the old city, iron-rods between the walls are used to increase the rigidity of the structure.

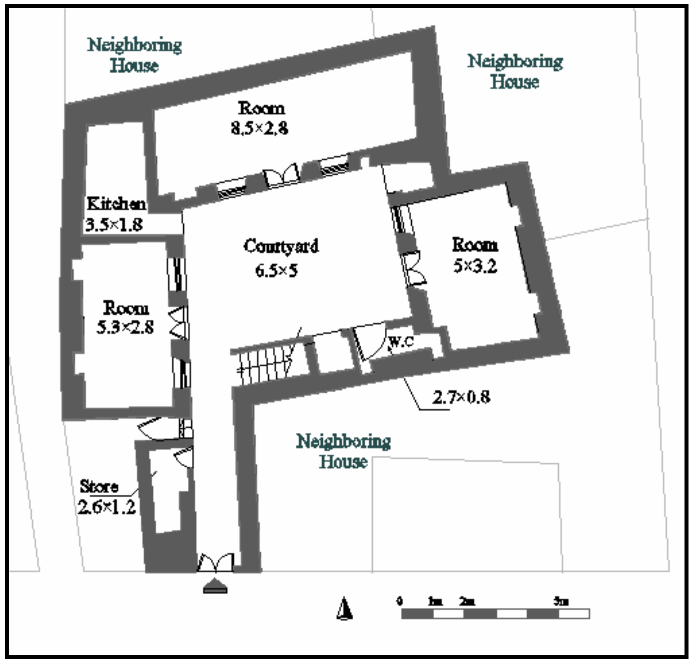
During the past two decades, repair and renovation works were done, as well as adding new rooms on the top floor. The extensive deterioration seen throughout the old city was also observed in the vicinity of the case study house, where most buildings were in a dilapidated condition while some had nearly collapsed. The owner of this particular house had done extensive repair work. Contemporary building materials and structural elements were used also to repair the house, such as concrete blocks, cement plaster and pre-cast concrete tie beams to keep the walls together and to prevent the house from collapsing, as shown in Figure 4.15. The various features of the house are tabulated in Table 4.1.

Table 4.1 Various features of the traditional house in Tripoli

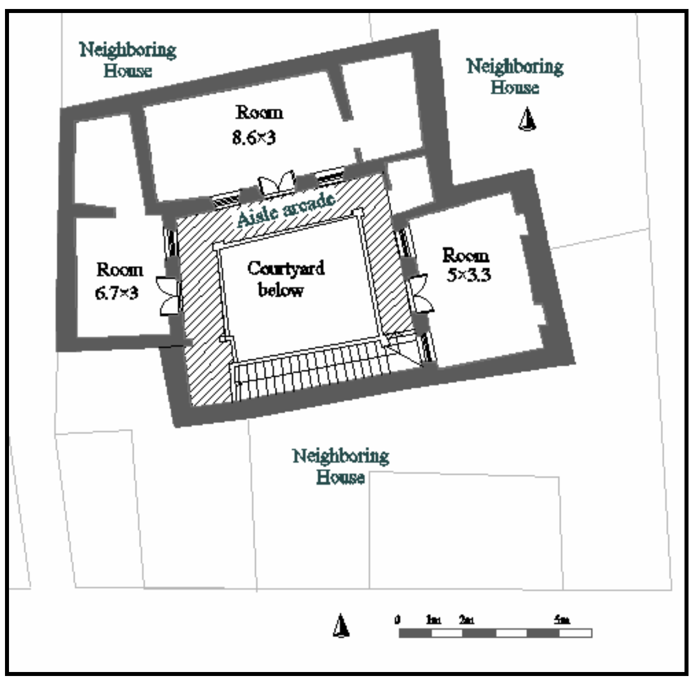
Item numb	Features	Description
01	**Layout**	
a)	Courtyard	Semi-square in shape dimensions about 6.5m×5m. Most windows overlook the courtyard, and all rooms are accessible from it. Covered with plastic sheets during the rainy season. (Figure 4.12)

Table 4.1 cont'd

b)	Rooms	Roughly rectangular in shape, not governed by a strict geometric grid. Longer side overlooking courtyard, Dimensions range from 2.5m to 4m wide and 3m to 9m long.
c)	Fenestration	Windows are classified as medium size, being about 0.8m to 1m wide and about 1.6m high. Door dimensions of approximately 1m by 2.2m. (Figure 4.13)
02	**Structure**	
a)	Walls	Internal walls thicknesses from 25cm to 35cm. External ones about 50cm to 60cm.
b)	Roof decks	Ceilings are quite high at about 4 m. (Figure 4.13)
03	**Construction Materials**	
a)	Limestone	Blocks of sizes 80cm × 40cm × 45cm, used for foundations and walls.
b)	Sandstone	For construction of roofs and also foundations and walls. Same dimensions as for limestone.
c)	Timber	Wood from palm and olive trees were used for ceiling joists, beams and joinery work. (Figure 4.14)
04	**Utilities and Services**	
a)	Electricity	Installed in the last four decades
b)	Gas	Provided by buying gas bottles recently
c)	Plumbing	Upgraded later in the eighty's of the last century. (Figures 4.16 and 4.17)
d)	Sewage System	Upgraded later in the eighty's and connected to the nearest city sewage system network.
e)	Light	Natural through courtyard
f)	Ventilation	Natural through courtyard



(a) Ground floor plan.



(b) First floor plan.

Figure 4.11 Layout of the traditional house in Tripoli.

Figure 4.12 Temporary plastic sheets covering the courtyard.

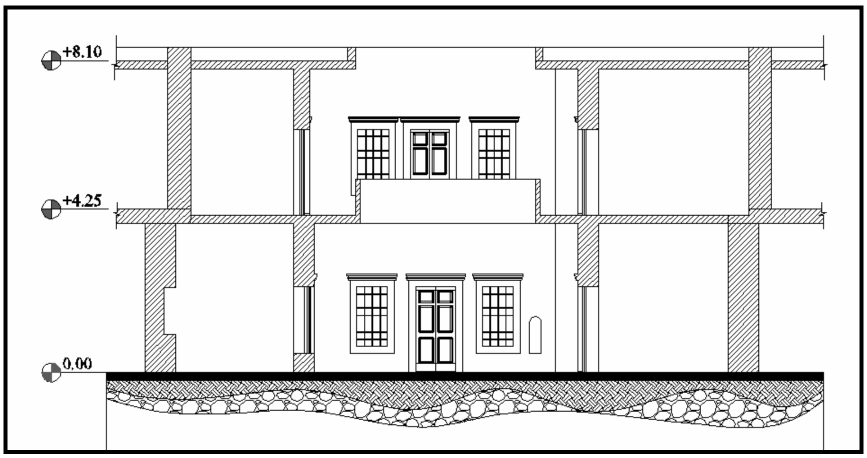


Figure 4.13 Section of the traditional house in Tripoli.

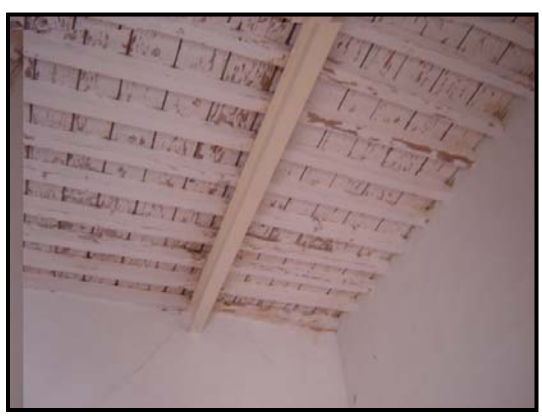


Figure 4.14 Timber ceiling in the traditional house in Tripoli.

Figure 4.15 Concrete block and cement plaster used for repair work in the traditional house in Tripoli.

Figure 4.16 Modern flushing toilet added later to the traditional house in Tripoli.

Figure 4.17 Water supply pipes added later to the traditional house in Tripoli.

B) Contemporary house of Tripoli

The house under study is classified as relatively large in size; its total floor area is about 400 m^2, double storey; and furnished with completes utilities since it was built in the mid 1970's by the owner. It is consists of 5 rooms, 2 toilets and 1 kitchen in every floor and some auxiliary spaces as basement with kitchen and toilet and a garage. It is also surrounded by a garden on three sides. See Figures (4.18 and 4.19). It can be seen from the layout, that the design follows certain orthogonal gridlines. Generally, contemporary houses are built as detached independent buildings in most cases, which provide more privacy for the house. The houses have open spaces all around with a boundary wall for protection, depending on the design of the house and the built area they may have small gardens both in front and the back.

The structural system of the contemporary house consists of a reinforced concrete skeleton structure. The house was provided with mechanical air conditioning units for cooling and heating, (Figure 4.21). The heating is usually required in the top floors during winter. On the other hand, these floors are hotter than the lower floors during summer. The various features of the house are tabulated in Table 4.2.

Table 4.2 Various features of the contemporary house in Tripoli

Item numb	Features	Description
01	**Layout**	
a)	Rooms	Mostly rectangular shaped. Average room sizes are 6m ×5m. (Figure 4.18) All rooms are accessible from the hall of the house.
b)	Fenestration	All windows are located on the peripheral walls only. Classified as medium size with wooden shutters. Dimensions are about 1.8m wide and about 1.2m height. (Figure 4.19) Doors dimensions 1m×2.2m approximately.
02	**Structure**	
a)	Walls	Non-load-bearing; thicknesses of both internal and external walls are between 25cm to 30cm.
b)	Roof Slabs	Height of ceilings are 3.30m
03	**Construction Materials**	
a)	Reinforced concrete	For the structural elements, such as beams, columns and staircases.
b)	Hollow clay pots and pre-cast tie beams	For constructing floors and slabs supported by pre-cast tie beams.
c)	Expanded polystyrene	Used for thermal insulation of roofs
d)	Tar	Used for water/moisture proofing.
04	**Utilities and Services**	
a)	Electricity	Installed during construction
b)	Gas	Provided by buying gas bottles
c)	Plumbing	Installed during construction. (Figures 4.20)
d)	Sewage System	Installed during construction, and connected to the public city network.
e)	Light	Natural lighting and sunshine through room's windows.
f)	Ventilation	Natural lighting and sunshine through rooms' windows.

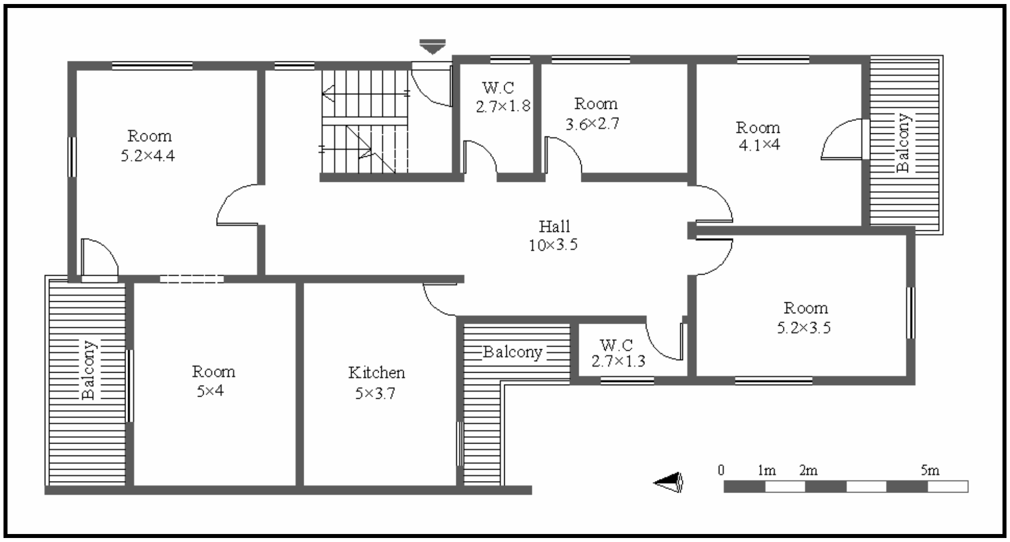


Figure 4.18 Typical floor layout of the contemporary house in Tripoli.

Figure 4.19 General view of the contemporary house in Tripoli.

Figure 4.20 Bath room of the contemporary house in Tripoli.

Figure 4.21 Air-conditioning system of the contemporary house in Tripoli.

4.3.2 Mountainous region: Gharyan

All the required information of the study was collected on field. The required measurements were taken, included the depth of the house which is dug into the ground, the number of rooms, and their dimensions, and the height of the ceiling; all information about the house design, and measurements of the temperature inside the house, at under ground level, and outside at ground level. The selected house under study can be classified as a relatively big house in size, and it is similar in size to most houses in the region.

A) Traditional house of Gharyan

The underground dwellings or the troglodytes in Gharyan are very simple in design and most of them were built around a century ago. They are formed by digging a huge cube in the clayey ground, which forms the troglodyte courtyard of the house, (Figure 4.22). Each troglodyte presents a house for number of related families; ranging from 3 to 10. In other words, each house consists of 3 to 10 large rooms were each room is a family's house for one family. The house investigated did not include many rooms for several functions such as bed rooms, living room and guest room. The room is used for most of daily activities as it is a self-contained unit for each family. The big area of the courtyard allows enough air circulation and sunlight to the rooms; besides using simple lighting means at night if necessary.

In general, traditional houses of Gharyan are distinguished by a minimum use of construction materials, where the only ones used were at the entrance area. Troglodytes are the only houses that do not depend on any built structural elements. Hence, in reality there are no walls built in the rooms, although, in some troglodytes a wall is sculptured while the room is dug, to divide the room into two parts, as shown in Figure 4.23.

Most troglodytes have storage areas for grains located above the rooms, these areas are normally accessible using ladders made of olive branches. The grain is poured into the storage spaces from the top through a vertical hole/shaft in the rooms. The various features of the house are tabulated in Table 4.3.

Table 4.3 Various features of the traditional house in Gharyan

Item numb	**Features**	**Description**
01	**Layout**	
a)	Courtyard	Dimensions are from 8m to10m deep and 9m by 10m width. All the rooms open into the courtyard. (Figure 4.22)
b)	Rooms	Dug deep with nearly a trapezoidal shape. The shortest dimension is at the entrance area, about 1.5m to 2m wide. It then gets wider towards the inside, where it reaches a width of about 5.0m to 7.0m. (Figure 4.22) Curtains or fabric stretched between walls used to divide rooms into two areas, the sleeping area, at the end of the room, and the living area. (Figure 4.24)
c)	Fenestration	No windows exist in front the interior of the troglodytes. Doors dimensions of approximately 75cm×175cm. (Figure 4.25) Door of main entrance is wide enough to provide access to the cattle of the residents when necessary.
02	**Structure**	
a)	Walls	Entrance is constructed of bearing walls, about 50cm to 70cm thick and 2.5m to 3.5m high. (Figure 4.26)
b)	Roof decks	The ceiling height is about 2.0m to 2.5m at its highest point, and it is shaped as a barrel vault. (Figure 4.27)
c)	Staircase	Located at the entrance, with landing about 1.5m to 2.0m deep, and leads to the courtyard inside the house. (Figures 4.28 and 4.29) The area of the hallway depends on presence of cattle.
03	**Construction Materials**	
a)	Hard limestone	Used to construct the bearing walls and foundations of the entrance. (Figure 4.26)
b)	Rubble stone	For walls of the entrance also. (Figure 4.26)

Table 4.3 cont'd

c)	Wood	Olive branches were used to construct the ceiling of the entrance and staircase. (Figure 4.30)
d)	Small stones	To construct the roof placed over the branches.
e)	Clayey soil and lime	Used as mortar and plastering of the walls and roof, and also used in decoration work in the rooms.
04	**Utilities and Services**	
a)	Electricity	Installed recently
b)	Gas	Not exist
c)	Plumbing	Simple toilets partly exist outside the house, at the surface level; and inside as a small cave about $1.5m^2$ to $2.5m^2$ accessible from the courtyard. No water supply in the house and water is carried from a well outside at some distance from the house.
d)	Sewage System	Not exist
e)	Light	Natural through courtyard by the doors
f)	Ventilation	Natural through courtyard by the doors
05	**Auxiliary spaces**	Small caves "*niche*" about $2m^2$ exist inside some rooms and used as sleeping area for children or storages. (Figure 4.31) Other auxiliary spaces of about $2m^2$ are placed between the rooms, without shutters at the entrances; these spaces are used as kitchens, toilets and/or storage. (Figure 4.32) Small storage areas placed above the rooms about 2m over ground level of the courtyard to store grain, as shown in Figure 4.33.

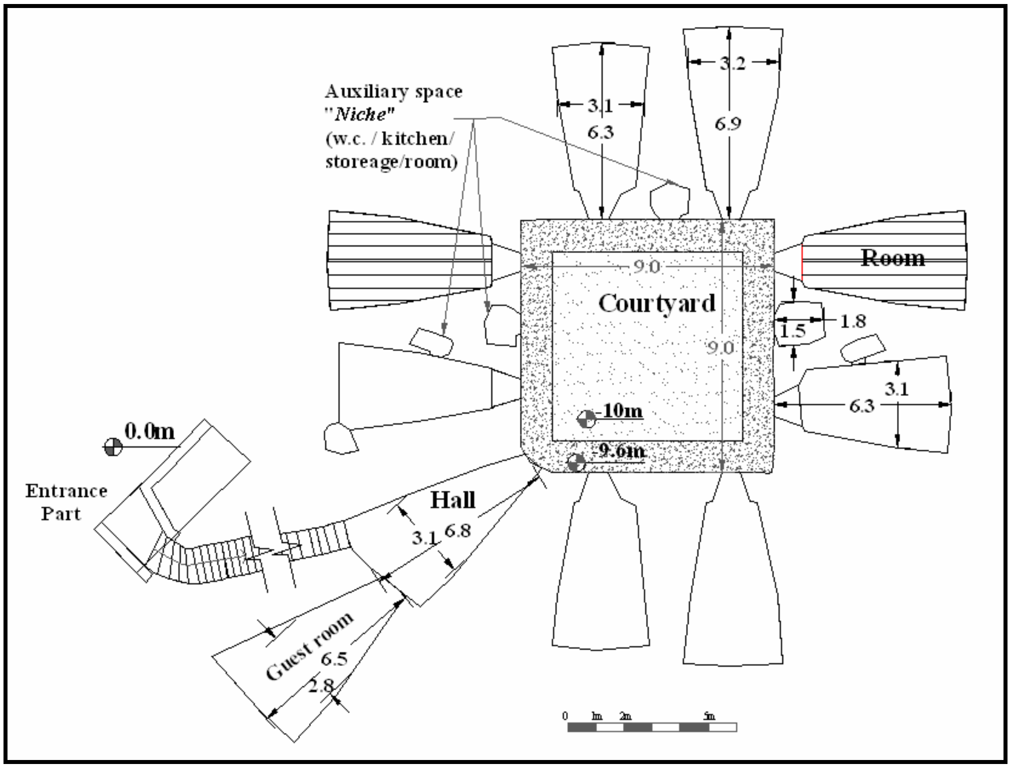


Figure 4.22 General layout of the troglodyte in Gharyan.

Figure 4.23 Interior sculptured partition walls in some troglodytes.

Figure 4.24 Dividing the room by curtains in troglodyte.

Figure 4.25: The entrance of the room viewed from inside and from the courtyard.

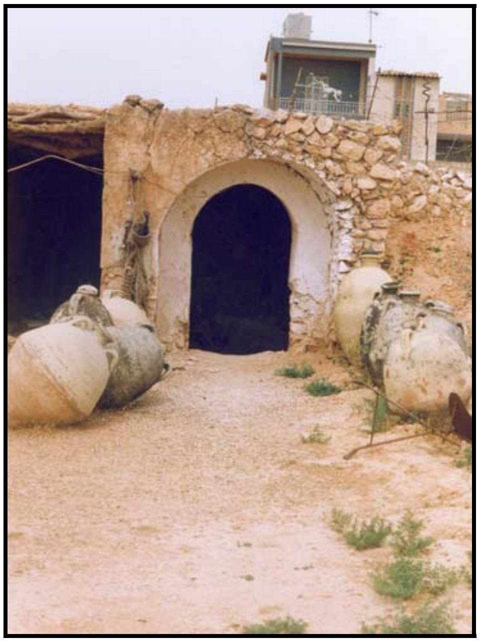


Figure 4.26 The front and side views of the main entrance to the troglodyte.

Figure 4.27 Barrel vaulted ceiling of troglodyte.

Figure 4.28 The staircase of the troglodyte.

Figure 4.29 View of the staircase from the courtyard.

Figure 4.30 Ceiling of the main entrance of troglodyte.

Figure 4.31 Small entrance of the children sleeping area inside a room of the troglodyte.

Figure 4.32 Location of the kitchen in the troglodyte.

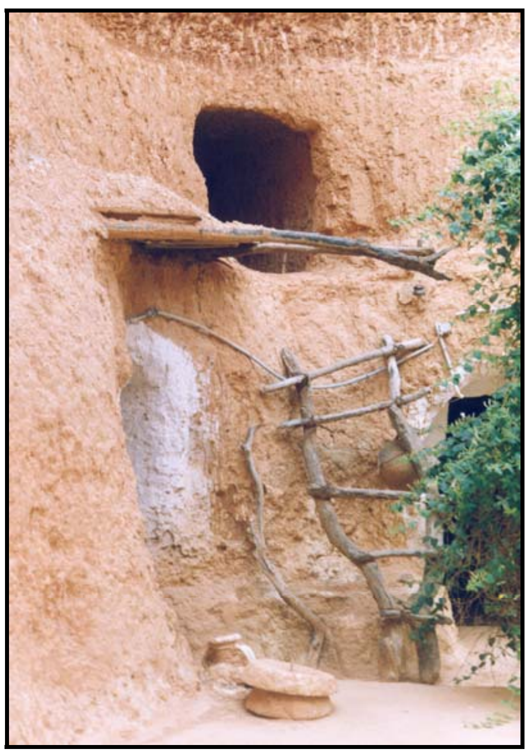


Figure 4.33 The grains storage place of the troglodyte with a ladder of olive branches.

B) Contemporary house of Gharyan

The house under study is classified as relatively large in size; its total floor area is about 385m^2, triple typical storey; (Figure 4.34), with full contemporary utilities since it was built in the 1970's by the owner. It consists of 3 rooms, 1 hall as a living room, 1 toilet and 1 kitchen in every floor, (Figure 4.35). The house has many features which are the same as in the contemporary house in Tripoli; the same auxiliary spaces and same structural system. It is also surrounded with a garden on three sides and built above ground level. The house was provided with mechanical air conditioning units for cooling and heating, (Figure 4.36). The various features of the house are presented in Table 4.4 below.

Table 4.4 Various features of the contemporary house in Gharyan

Item numb	Features	Description
01	**Layout**	
a)	Rooms	Mostly rectangular shaped. Average room sizes are 3.5m ×4m. (Figure 4.35) All rooms are accessible from the hall of the house.
b)	Fenestration	All windows are located on the peripheral walls only. Classified as medium size with wooden shutters. Dimensions are about 1.8m wide and about 1.2m height. Doors dimensions 1m×2.2m approximately.
02	**Structure**	
a)	Walls	Non-load-bearing; thicknesses of both internal and external walls are between 25cm to 30cm.
b)	Roof Slabs	Height of ceilings are 3m
03	**Construction Materials**	
a)	Reinforced concrete	For the structural elements, such as beams, columns and staircases.
b)	Hollow clay pots and pre-cast tie beams	For constructing floors and slabs supported by pre-cast tie beams.

Table 4.4 cont'd

c)	Expanded polystyrene	Used for thermal insulation of roofs
d)	Tar	Used for water/moisture proofing.
04	**Utilities and Services**	
a)	Electricity	Installed during construction
b)	Gas	Provided by buying gas bottles
c)	Plumbing	Installed during construction. (Figures 4.37)
d)	Sewage System	Installed during construction, and connected to the public city network.
e)	Light	Natural lighting and sunshine through rooms' windows.
f)	Ventilation	Natural lighting and sunshine through room's windows.

Figure 4.34 General view of the contemporary house in Gharyan.

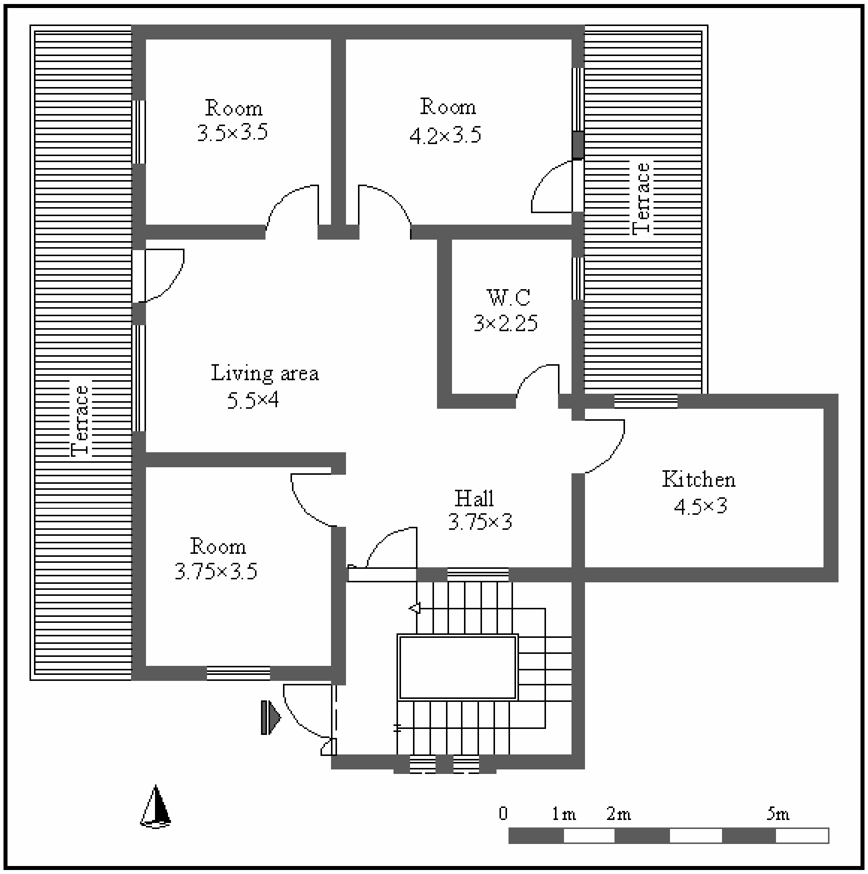


Figure 4.35 Typical layout of the contemporary house in Gharyan.

Figure 4.36 Cooling and heating system of contemporary house in Gharyan.

Figure 4.37 Bathroom in the contemporary house in Gharyan.

4.3.3 Desert region: Ghadames

Ghadames is locating about 650 km south west of Tripoli. During the visit, several houses from both styles have been studied, old traditional and contemporary residential buildings. Most measurements had been taken including dimensions of rooms, the ceiling's height, and measurements of the temperatures indoors and outdoors.

A) Traditional house of Ghadames

The house under study was built at least two centuries ago and it is classified as medium in size with its total floor area is about 100m^2 and four stories. Same as most traditional houses in Ghadames, the house consisted of 8 rooms with a variety of floor areas, some were small and some very big. The large living area which is positioned centrally in the house, resembles in its location and function to the courtyard in the traditional house in Tripoli. There are no standards or specifications of the room areas from one house to another; the areas depend on the needs of the house owner. On the other hand about 16% of the floor area was used for storages spaces. (Figure 4.38)

The structural system is the same as in the traditional houses in Tripoli depending on connected load bearing walls for the whole cluster. All houses are separated from each other by thick party walls. This system makes the houses attached to each other for increased support, and also provides isolation from the outdoor climate. In some houses the stone bearing walls could extend to the first floor only; depending on the financial capabilities of the owner, and proximity of the house to the quarry.

Windows are rare in number or do not exist in most houses, there are no windows over looking the street in most houses. The central opening in ceiling is closed with a plastic sheet in case of cold, or a rare rainfall, or when the house is empty for relatively long time for some reason.

All houses are provided with septic tanks which are called *"black wells"*. These wells are unsuitable in modern time because of health and environment reasons. On the other hand, a new modern flush toilet would also be incompatible with the house under study. However, the rare use of the house itself nowadays does not caused serious problems in this respect. Additionally, no shower was added because of the humidity problem that can result from hot water. In other words, the problem was that the new plumbing is incompatible with the sewage system of the house and the nature of the clayey building materials used which are not resistant to water. It can be noticed also from Figure 4.48 that the toilet walls are covered with ceramic tiles while the ceiling was left as it is.

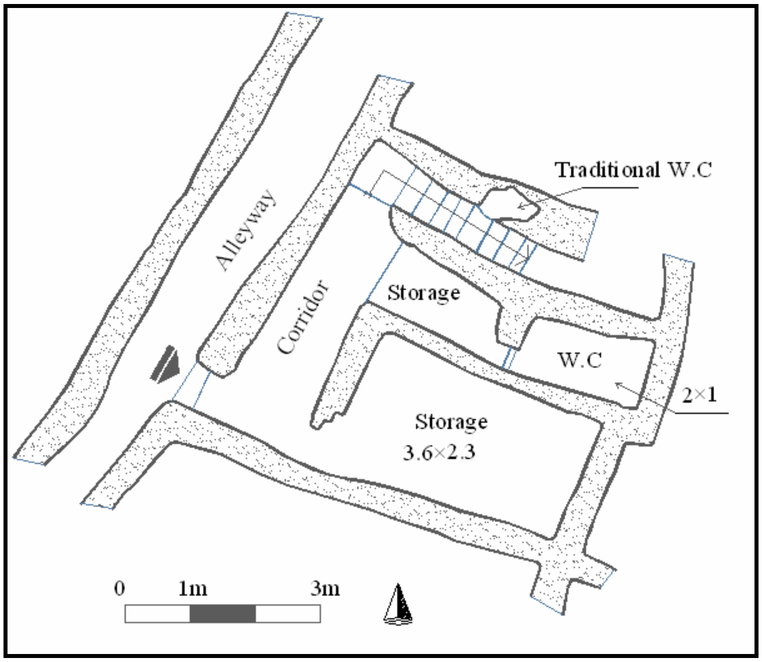
The houses are distinguished with a variety in color paint; these are very important in the social life of Ghadames and are extracted from natural resources. At the entrance hall of the Ghadames house, a big variety of painted walls found in many colors (Figure 4.46). The various features of the house are presented in Table 4.5 below.

Table 4.5 Various features of the traditional house in Ghadames

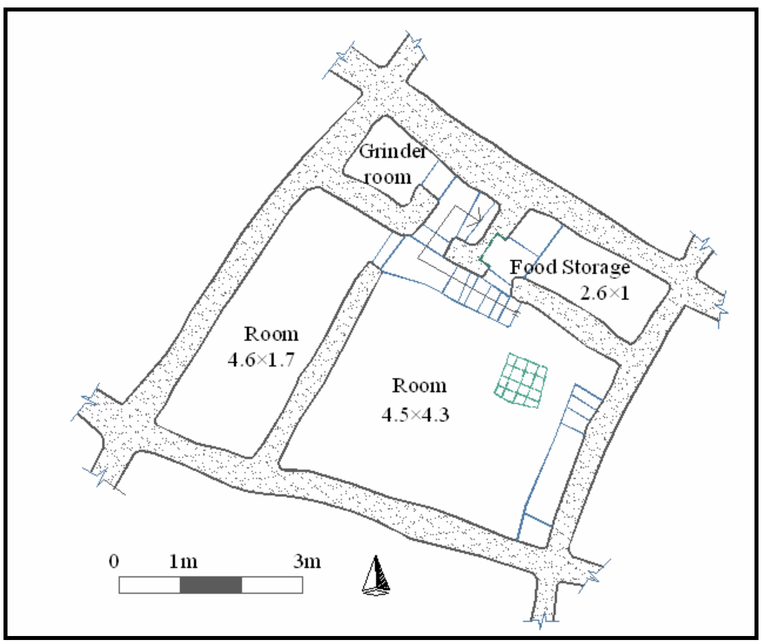
Item numb	Features	Description
01	**Layout**	
a)	Rooms	Sizes range between (1.4m by 2.6m to 1.8m by 6.2m). (Figures 4.38) The largest room which is the central hall is two stories high; measuring 4.7m×4.0m. (Figure 4.39)
b)	Fenestration	Doors of the house are quite small in size about 0.8m by 1.7m. Windows are few and exist in many shapes, such as a rectangular opening with 15cm×25cm, and a triangle shape with 20cm×20cm×75cm, there is no glass or shutters for the small openings. (Figure 4.40) Windows are generally located at the upper floors but in this house they were located on the third floor at level + 4.75m. The important opening of the house is the largest one, positioned on the ceiling of the living area; it is about 1m by 1m and it is the only source of light. (Figure 4.41) Small openings overlooking the living area about 25cm×25cm exist in the rooms.
02	**Structural**	
a)	Walls	These walls are built on top of strip foundations; the minimum height of foundation is about 60 to 80cm above the ground level. The thickness of the external and internal walls is nearly the same in many houses; about 40m to 60cm. (Figure 4.38)
b)	Roof decks	Ceiling height differ from one room to another; the living area can be two stories high up to 5m, (Figure 4.39), while the bedrooms, are 1.8m high and storage rooms can be as low as 1.6m.
03	**Construction Materials**	
a)	Hard volcanic stone	(*Sawwan, as called locally*) for foundations. (Figure 4.6)
b)	Mud brick	For constructing wall, about 40cm×30cm×10cm in dimensions, the sizes are almost standard. (Figure 4.42)
c)	Timber	Palm wood (*Sunnour*) for ceilings, beams and for the fenestration system. (Figures 4.41b, 4.43 and 4.44)
d)	Filler materials	Used as fillers for ceilings such as small stones, mud, and lime. (Figure 4.45)

Table 4.5 cont'd

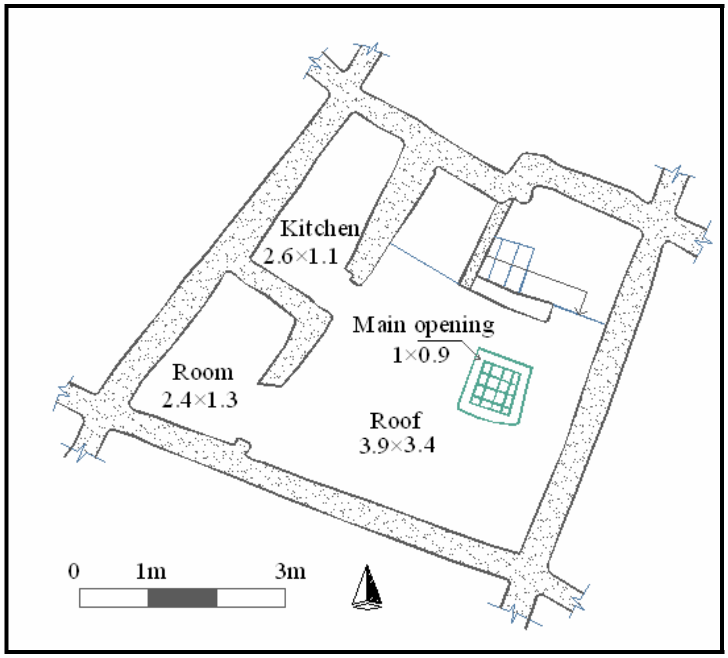
04	**Utilities and Services**	
a)	Electricity	Installed in the last three decades
b)	Gas	Not exist
c)	Plumbing	A simple toilet room is available, without any water supply, located at half way up from the ground floor accessible from the landing; the room's dimensions were about (0.7m by 1.9m) wide and 2m high. (Figure 4.47) A modern plumbing system was added recently within the last five or seven years, located at the ground floor, with limited facilities. (Figure 4.48)
d)	Sewage System	The commode is just a hole in the ground connected by a channel to a sump pit, which is like a small closet opened from the street, of dimensions about 0.7m wide 1.5m high that is filled with sand to absorbs the organic waste. Septic tanks are used here.
e)	Light	Natural through the top opening by reflecting light through the mirrors or bouncing off the copper antiques distributed on the walls and around the central hall. (Figure 4.49)
f)	Ventilation	Natural through the top opening to all rooms.



(a) Ground floor plan.



(b) Typical floor plan.



(c) Roof plan.

Figure 4.38 Layout of the traditional house in Ghadames.

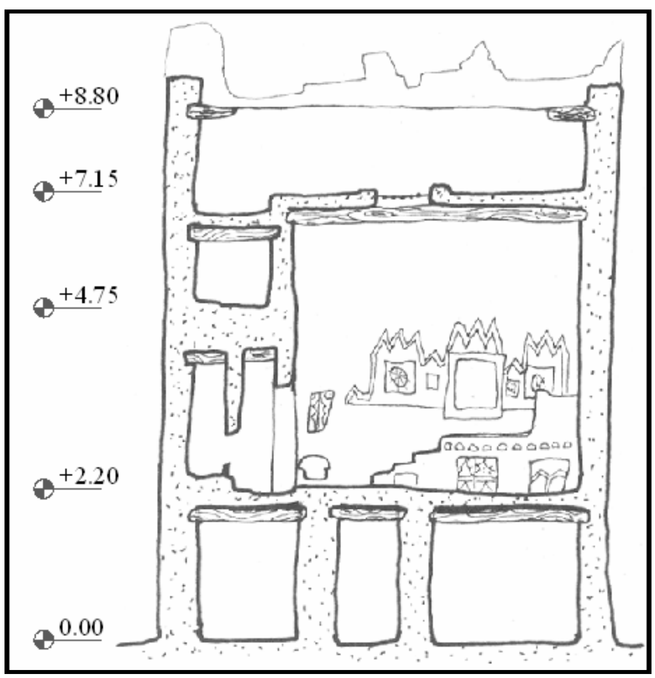


Figure 4.39 Section of the traditional house in Ghadames.

Figure 4.40 Small windows in the traditional house of Ghadames.

(a) Opening at the roof (top view)

(b) Opening in the ceiling (bottom view)

Figure 4.41 Main opening in traditional house of Ghadames.

Figure 4.42 Local mud brick of Ghadames.

Figure 4.43 Palm wood beams used for supporting the ceiling of the traditional house in Ghadames.

Figure 4.44 Wooden door of the traditional house in Ghadames.

Figure 4.45 Mud mortar and timber ceiling of the traditional house in Ghadames.

Figure 4.46 Decorative wall paintings in the traditional house, in Ghadames.

Figure 4.47 Toilet room of the traditional house in Ghadames.

Figure 4.48 Contemporary W.C. and the ceramic walls in the traditional house of Ghadames.

Figure 4.49 The mirrors and copper antiques in the traditional house of Ghadames, reflecting light into the rooms. *(Photo by E. Khairy)*

B) Contemporary house of Ghadames

The house under-study is classified as medium in size; its total floor area is about 300m^2, double storey; with full contemporary utilities since it was built. It is a typical unit in a housing project built by the governmental authorities in the late 1970's (Figure 4.50). As mentioned in Chapter 2, the houses here adapted some traditional features such as party walls.

The house consists of 8 rooms, 2 toilets and 1 kitchen and a small back yard. Also this house has some features similar to the contemporary houses in Tripoli and Gharyan, such as the reinforced skeleton structural system and also it is was provided with mechanical air conditioning units for cooling and heating. (Figure 4.51)

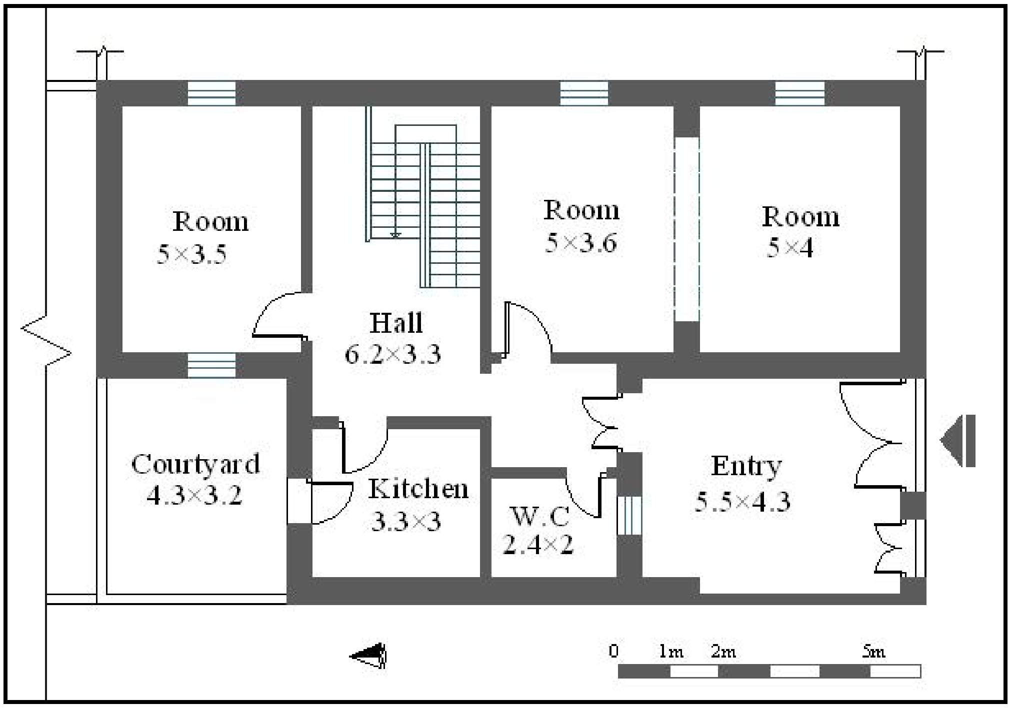
Usually, in Ghadames the skies are clear most of the time; therefore, there is enough sunshine to provide natural light through the windows in the buildings, which are relatively small in size, as illustrated in Figures 4.50, 4.52 and 4.53. A reduction in windows sizes, without sacrificing light and ventilation in the spaces, is desirable to reduce solar heating during the long summer seasons. The various features of the house are presented in Table 4.6 below.

Figure 4.50 The contemporary housing units project in Ghadames.

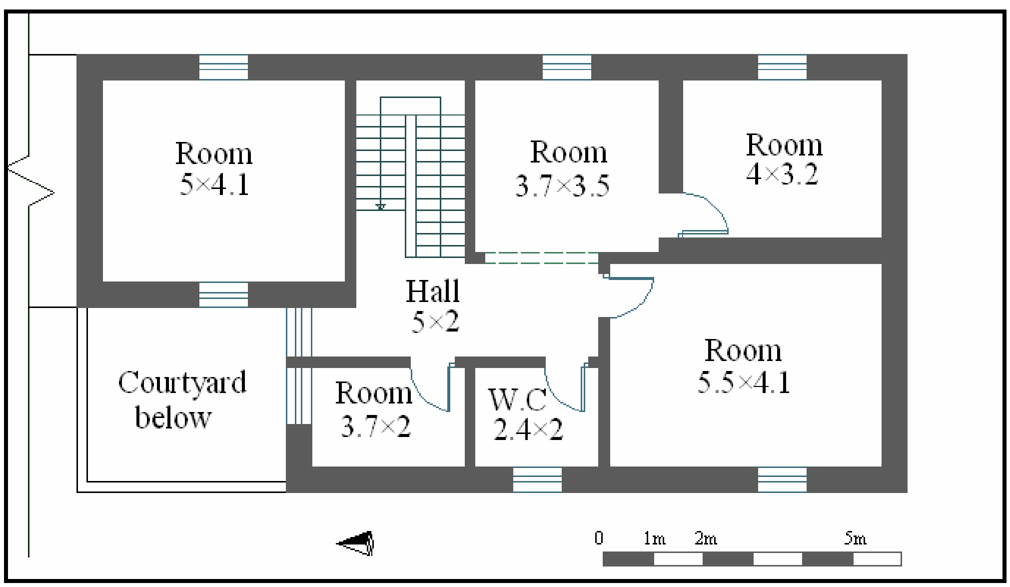
Figure 4.51 Cooling and heating system of the contemporary houses in Ghadames.

Table 4.6 Various features of the contemporary house in Ghadames

Item numb	Features	Description
01	**Layout**	
a)	Rooms	Mostly rectangular shaped. Average room sizes are between 3.5m ×4m to 4.5m ×5.5m. (Figure 4.35) All rooms are accessible from the hall of the house.
b)	Fenestration	All windows are located on the peripheral walls only. Classified as medium size with wooden shutters. Dimensions are 1m×1m, with wooden shutters. (Figure 4.52) Doors dimensions 1m×2.2m approximately.
02	**Structure**	
a)	Walls	Non-load-bearing; double wall system was used in an effort to protect the interiors from high external temperatures. The thicknesses of the walls are about 45cm. (Figure 4.54).
b)	Roof Slabs	Height of ceilings is 2.7m
03	**Construction Materials**	
a)	Reinforced concrete	For the structural elements, such as beams, columns and staircases.
b)	Hollow clay pots and pre-cast tie beams	For constructing floors and slabs supported by pre-cast tie beams.
c)	Expanded polystyrene	Used for thermal insulation of roofs
d)	Tar	Used for water/moisture proofing.
04	**Utilities and Services**	
a)	Electricity	Installed during construction
b)	Gas	Provided by buying gas bottles
c)	Plumbing	Installed during construction.
d)	Sewage System	Installed during construction, and connected to the public city network.
e)	Light	Natural lighting and sunshine through rooms' windows.
f)	Ventilation	Natural lighting and sunshine through rooms' windows.



(a) Ground floor plan.



(b) First floor plan.

Figure 4.52 Layout of the contemporary house in Ghadames.

Figure 4.53 Windows of the contemporary house in Ghadames.

Figure 4.54 Thick walls of the contemporary house in Ghadames.

CHAPTER 5

RESULTS AND DISCUSSION

In this chapter, information gathered through the informal interview is presented, as well as the questionnaire and data collected during the field survey *i.e.,* temperature and humidity data from the three regions.

5.1 Temperature and Humidity Data

Temperature and humidity was measured at certain assigned spots inside and outside the buildings, at several times during some days in summer and winter season by using a thermo-hygrometer. The data thus collected is presented below.

5.1.1 Temperature and humidity data for Tripoli

Results drawn from the tabular data were as follow.

a) Data during summer:

Figures 5.1 and 5.2 represent the ranges of internal and external temperature and humidity at 1:00am and 1:00pm during one week in July for both types of houses in Tripoli.

Figure 5.1 shows that the majority of indoor temperature readings for both types were quite close at some points while they centralized around (29Cº-34Cº). This temperature range of the traditional house is higher than that of the contemporary house and both types were beyond the range for human comfort, according to the bio-climatic chart, (Figure 2.1). Figure 5.2 shows the big differential between the readings of the traditional dwellings and external humidity, as opposed to the contemporary ones comparing to external humidity; which indicates many probabilities such as: the readings were taken incorrectly or not under the requirement conditions.

That illustrates the uncomfortable states of the traditional house, which was caused by many reasons; first was the deteriorating condition of the whole area of Tripoli old city, most houses around this house were in very dilapidated condition while some were nearly demolished. That makes the house more subjected to the outdoor weather, instead of having the protection as it supposed to be. The owner of the house did a lot of repair works, *i.e.* using new construction materials, which are incompatible with the original ones, such as: adding pre-cast tie beams to support the walls together and to prevent the house from collapsing. That makes the house more exposed to the outdoors weather.

On the other hand, the same observation is noticed in the contemporary houses. Figure 5.1 shows the uncomfortable states of the house, which was caused by many reasons; the adapting of the new design styles which are incompatible with the country's environment, besides depending completely on the new construction materials, which many studies proved that they are inappropriate for hot arid zones.

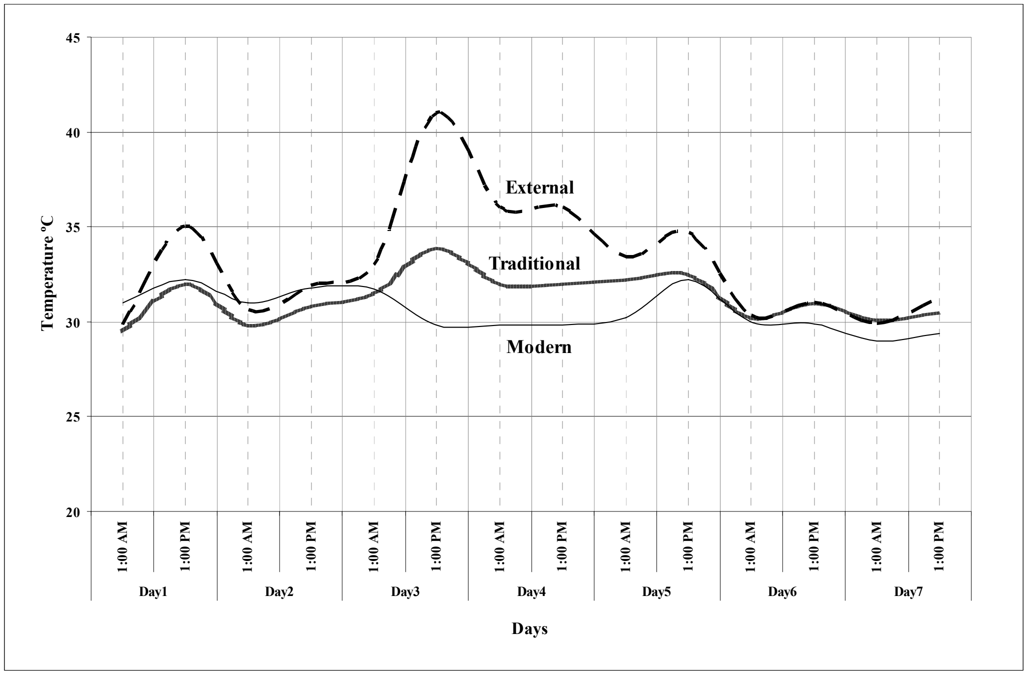


Figure 5.1 Temperature data for Tripoli during one week in July.

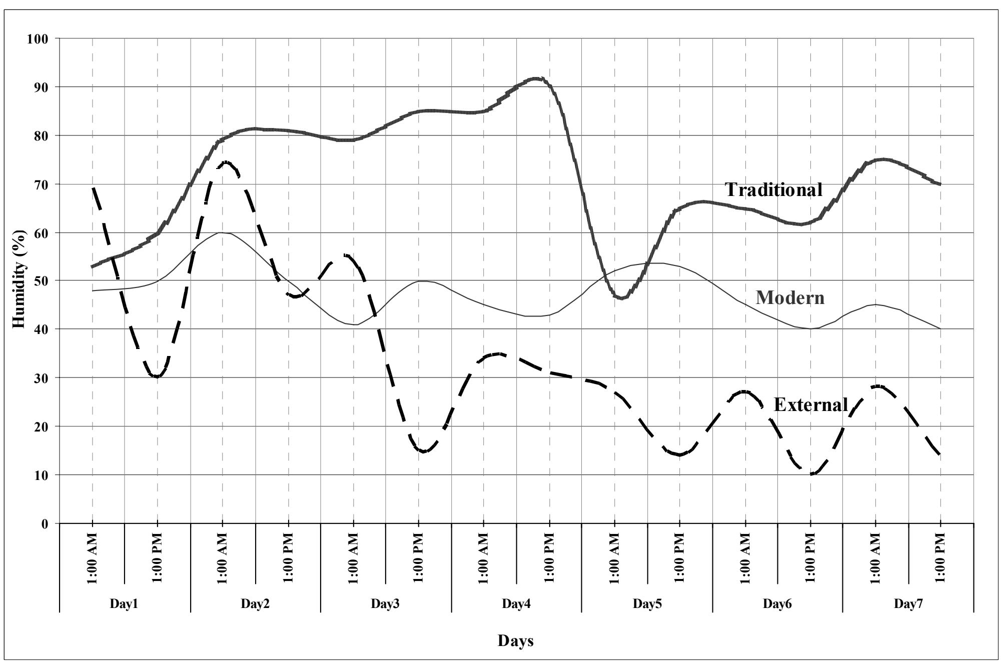


Figure 5.2 Humidity data for Tripoli during one week in July.

ii) Data during winter:

Figures 5.3 and 5.4 represent the ranges of internal and external temperature and humidity at 1:00am and 1:00pm during one week in January for both types in Tripoli.

Figure 5.3 shows the differential in indoors temperature readings for both types. The readings of the traditional house are close to the range for human comfort; as opposed to the contemporary houses were the temperature range is low which provides uncomfortable states of the house that in fact was caused for the same reasons mentioned previously in Figure 5.1.

Figure 5.4 shows the differential range of the three humidity readings. Referring to bio-climatic chart (Figure 2.1), the traditional house shows a small potential of offering a comfort thermal condition to the occupants.

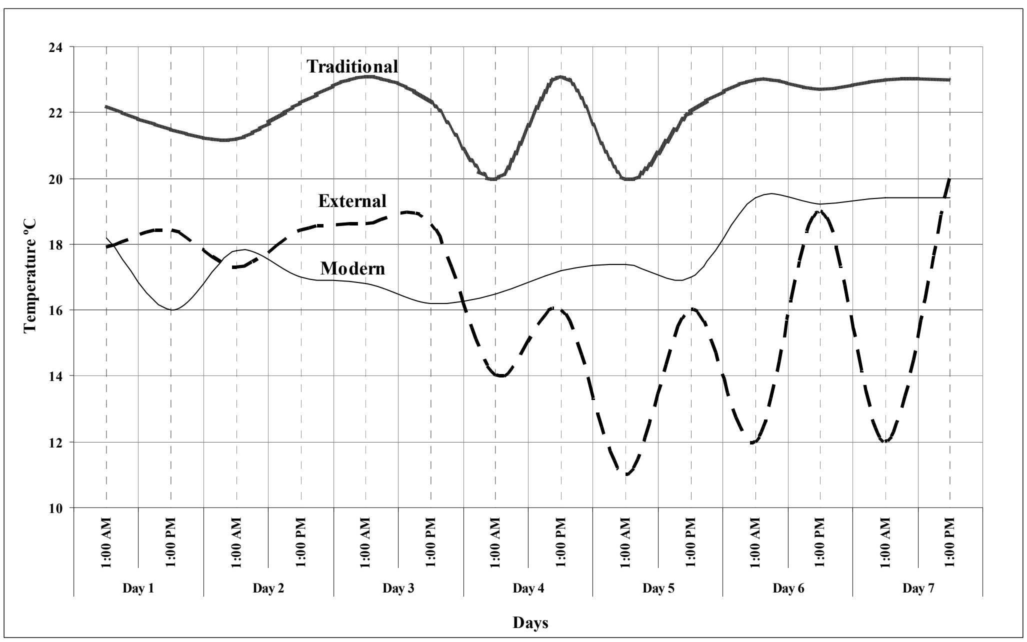


Figure 5.3 Temperature data for Tripoli during one week in January.

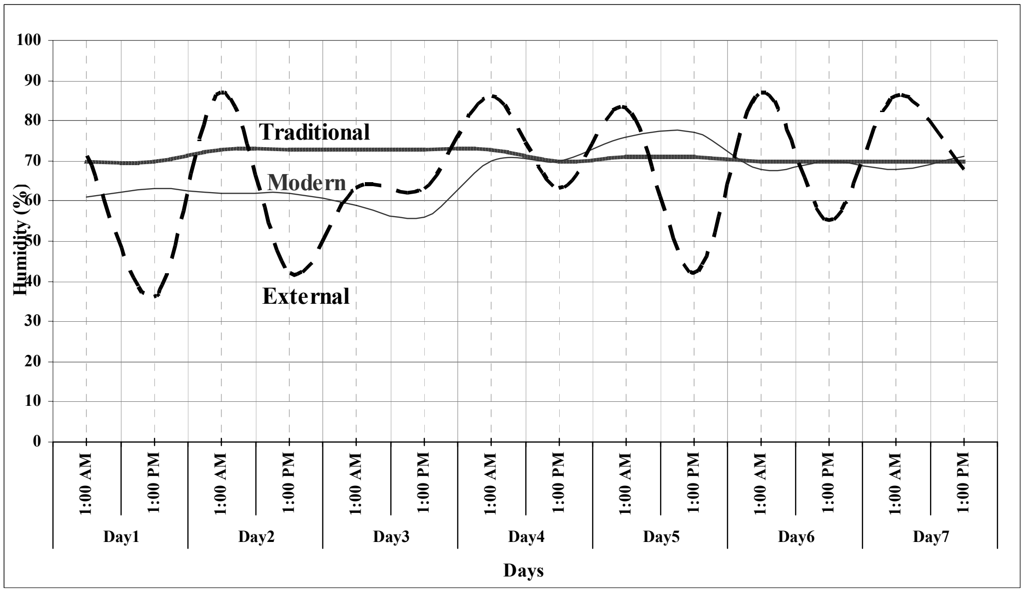


Figure 5.4 Humidity data for Tripoli during one week in January.

5.1.2 Temperature and humidity data of Gharyan

Results drawn from the tabular data were as follow.

i) Data during summer:

Figures 5.5 and 5.6 present the ranges of the internal and external temperature and humidity at 1:00am and 1:00pm during one week in July for both types in Gharyan.

Figure 5.5 shows that the majority readings of indoor temperature for the traditional house are approximately constant, and were within the range for human comfort in this zone. That is because of many reasons such as; the house was completely dug underground, isolated to a high extent from external environment, made of natural local materials and the house style was appropriate for the local climate.

On the other hand, the majority indoor readings of the contemporary houses comparing to the outdoor was quite close at some points, and sometimes the indoor temperature became higher than the outdoor temperature, that indicates the uncomfortable states of the house, which was caused for the same reasons mentioned previously in Figure 5.1. Figure 5.6 shows that the majority of humidity readings of the traditional house are approximately constant around 70%, which indicate the house is within the comfort zone. On the other hand, for the contemporary one Figures 5.5 and 5.6 resulted that the house during night time in most days was within the comfort zone; as apposite to day time were the house is not within the comfort zone.

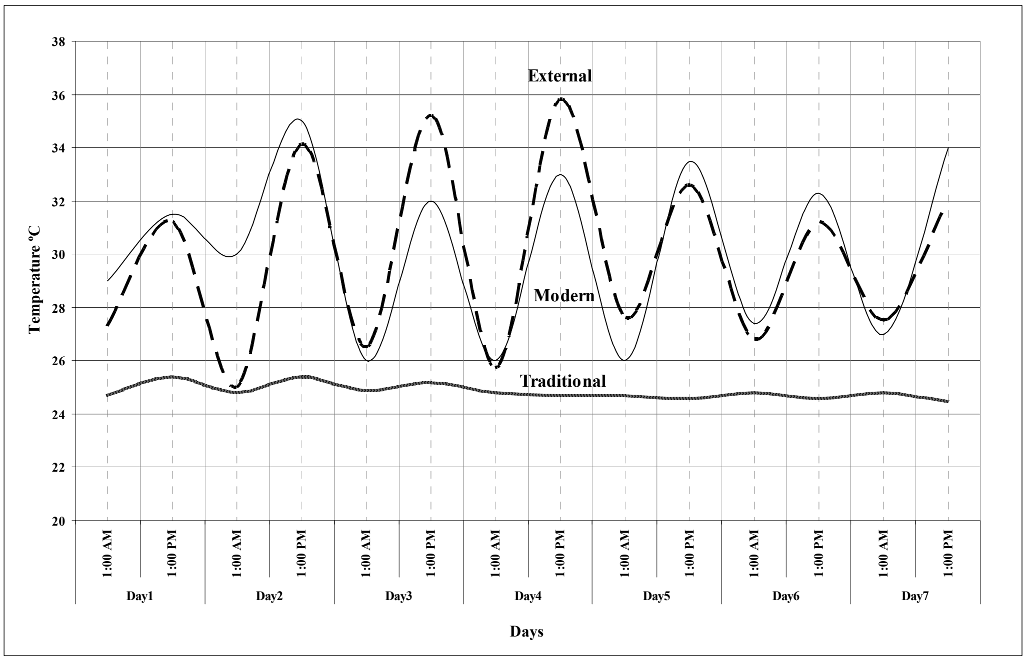


Figure 5.5 Temperature data for Gharyan during one week in July.

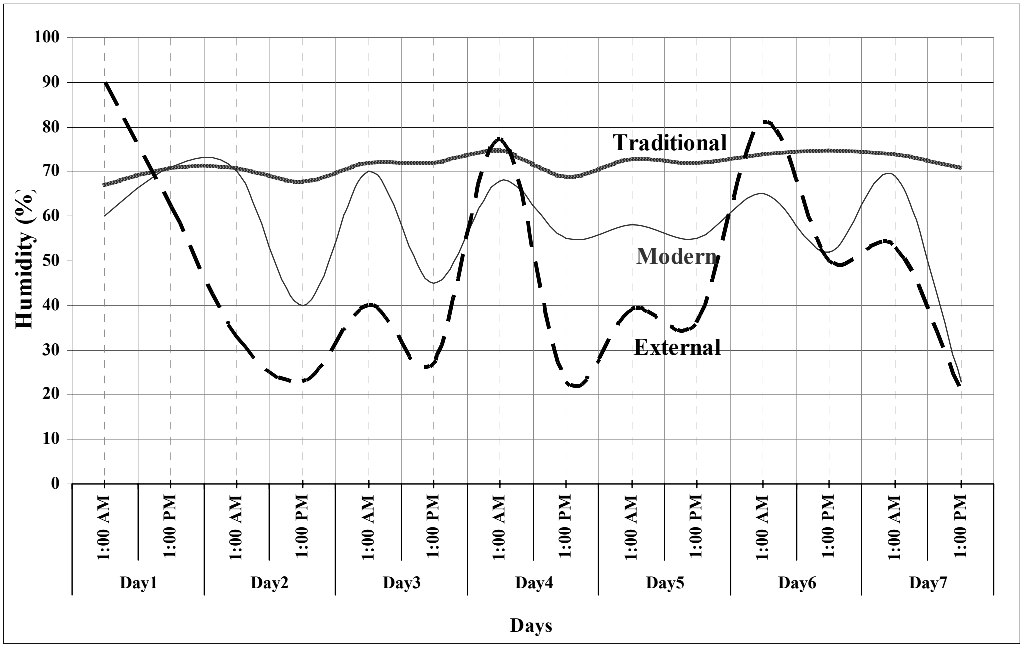


Figure 5.6 Humidity data for Gharyan during one week in July.

ii) Data during winter:

Figures 5.7 and 5.8 represent the ranges of internal and external temperatures and humidity at 1:00am and 1:00pm during one week in January for both styles in Gharyan. Figure 5.7 shows the same differential range between the outdoor and indoor temperature of the modern and traditional house. Most readings of indoor temperature for the traditional house are approximately constant, and it is warmer than the contemporary house, that is also leads to what was mentioned in the summer part in Figure 5.5. Figure 5.7 shows when the temperature is at the highest peak level which is at recorded at day time, the thermal comfort of indoor weather for the traditional house is within the comfort human level; but the range became a little bit lower during night times, which became slightly out of the comfort zone. On the other hand, readings of the contemporary houses were out of the comfort zone during the whole winter season, according the temperature and humidity figures and the bio-climatic chart.

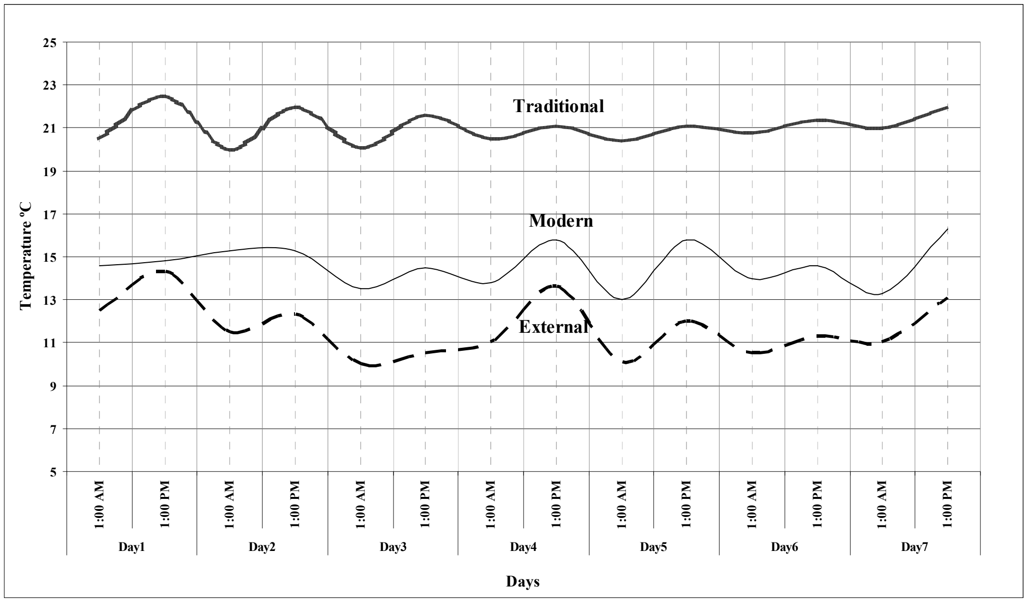


Figure 5.7 Temperature data for Gharyan during one week in January.

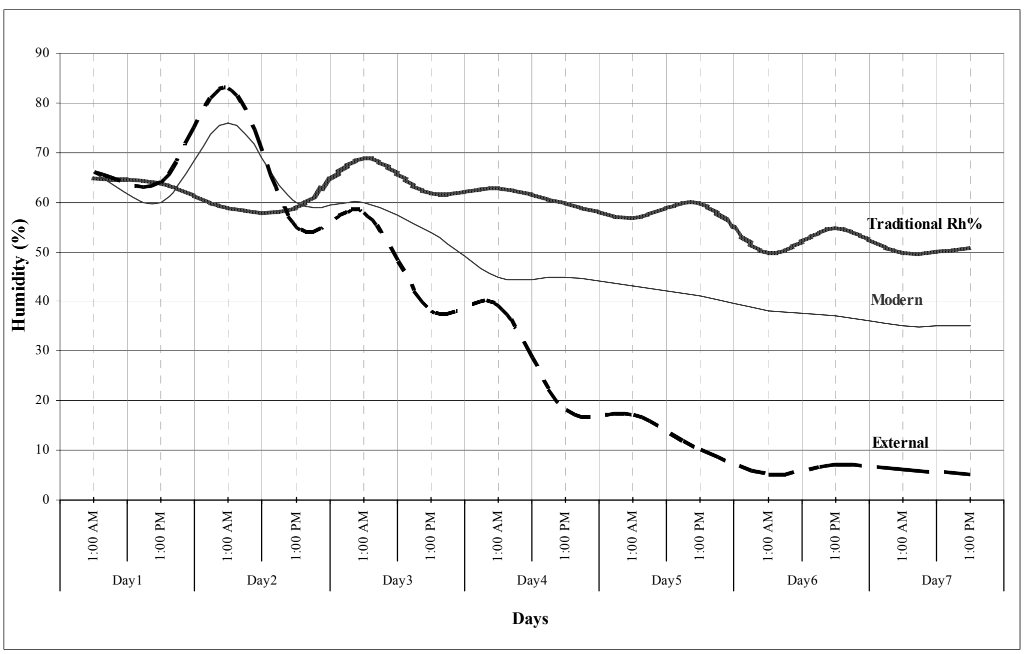


Figure 5.8 Humidity data for Gharyan during one week in January.

5.1.3 Temperature and humidity data of Ghadames

Results drawn from the tabular data were as follow.

i) Data during summer:

Figures 5.9 and 5.10 represent the ranges of internal and external temperature and humidity at 1:00am and 1:00pm during one week in January for both types in Ghadames. From the figures and the bio-climatic chart it was found out that the traditional house's readings are taking a moderate curve line for temperature and humidity; in other words it is providing a stable climate inside the house; as opposite to the contemporary house, were the high and low peaks of the readings are also higher than that of the traditional house. Comparing with the external readings, this resulted in that both houses are not in the comfort zone for humans.

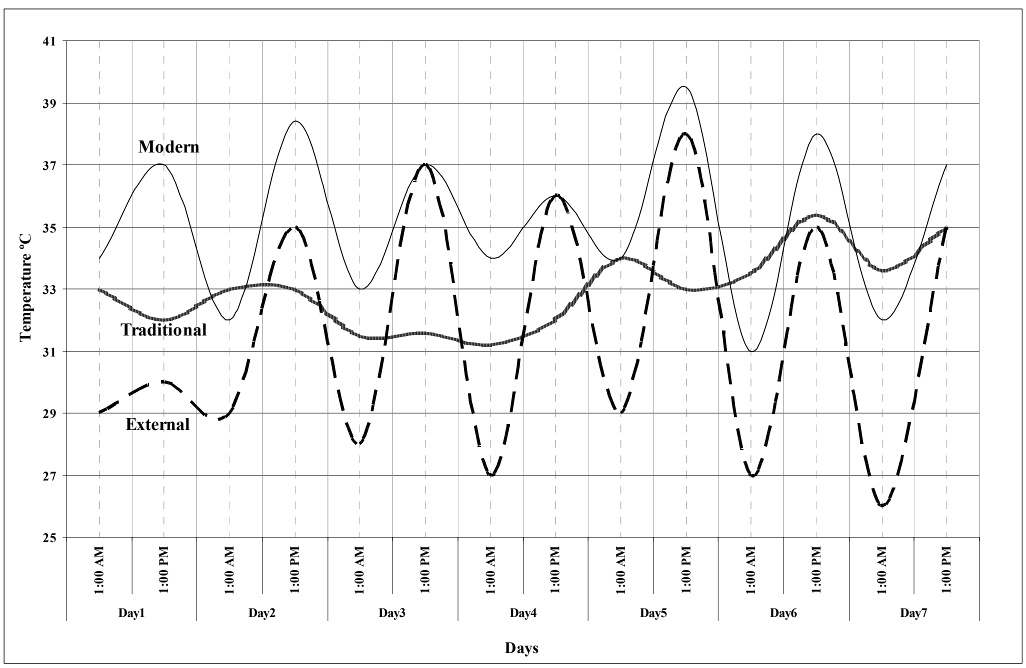


Figure 5.9 Temperature data for Ghadames during one week in July.

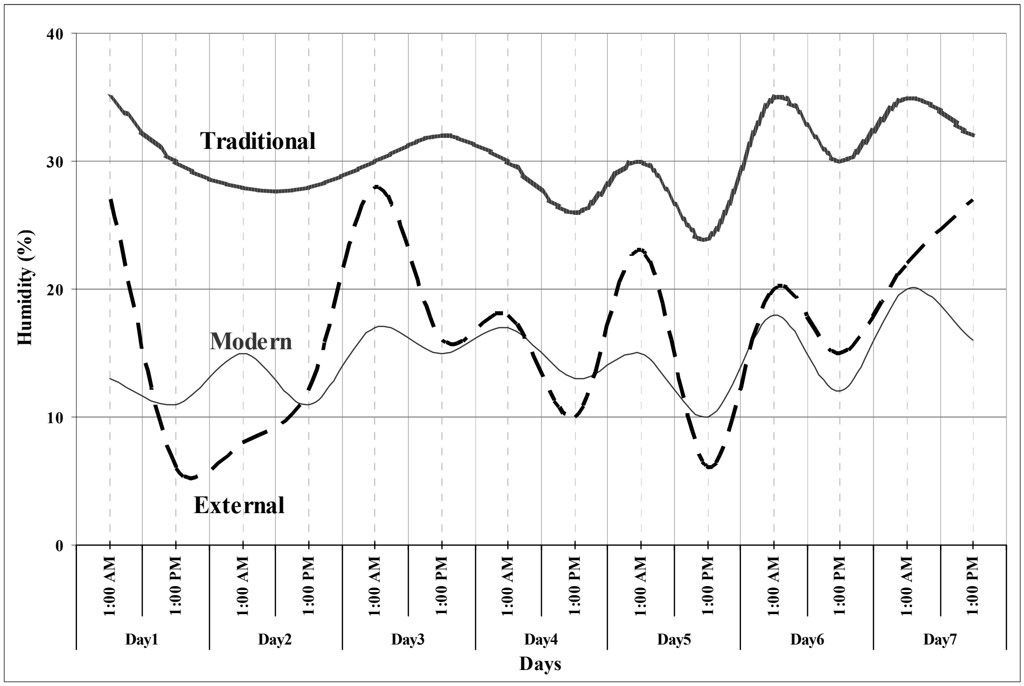


Figure 5.10 Humidity data for Ghadames during one week in July.

ii) Data during winter:

Figures 5.11 and 5.12 represent the ranges of internal and external temperature and humidity at 1:00am and 1:00pm during one week in January for both types in Ghadames.

The different ranges of temperature readings between day and night time are noticed in Figure 5.11 for both houses. The traditional house's range was between (8ºC-15ºC); at the same time, the range of the contemporary house was between (6.5ºC-14ºC); both types' ranges were close. On the other hand, both houses show a moderate stable humidity curve line as shown in Figure 5.12; but unfortunately the two types were not within the comfort zone.

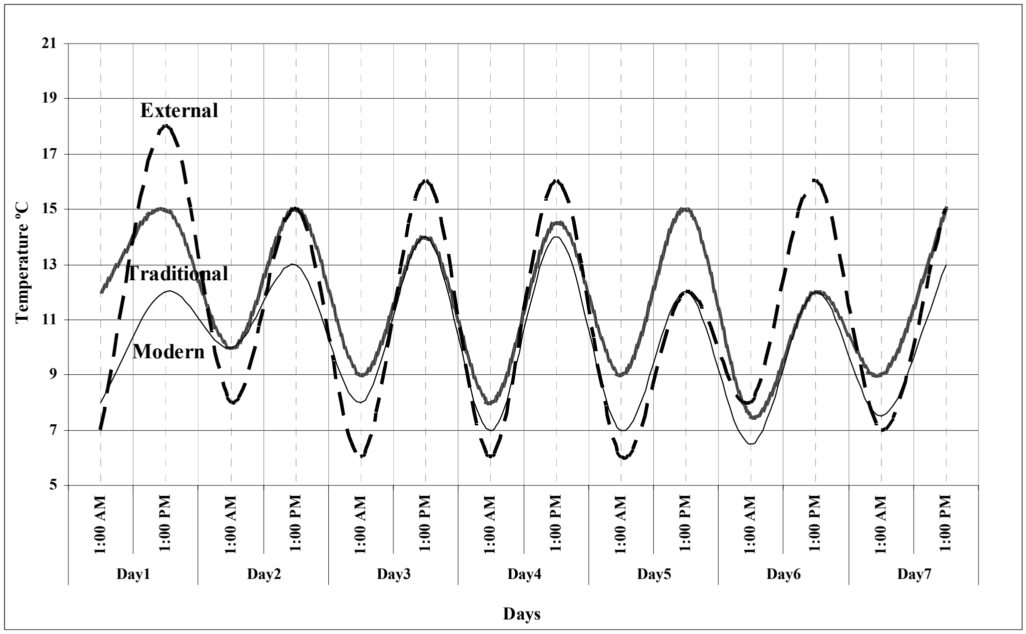


Figure 5.11 Temperature data for Ghadames during one week in January.

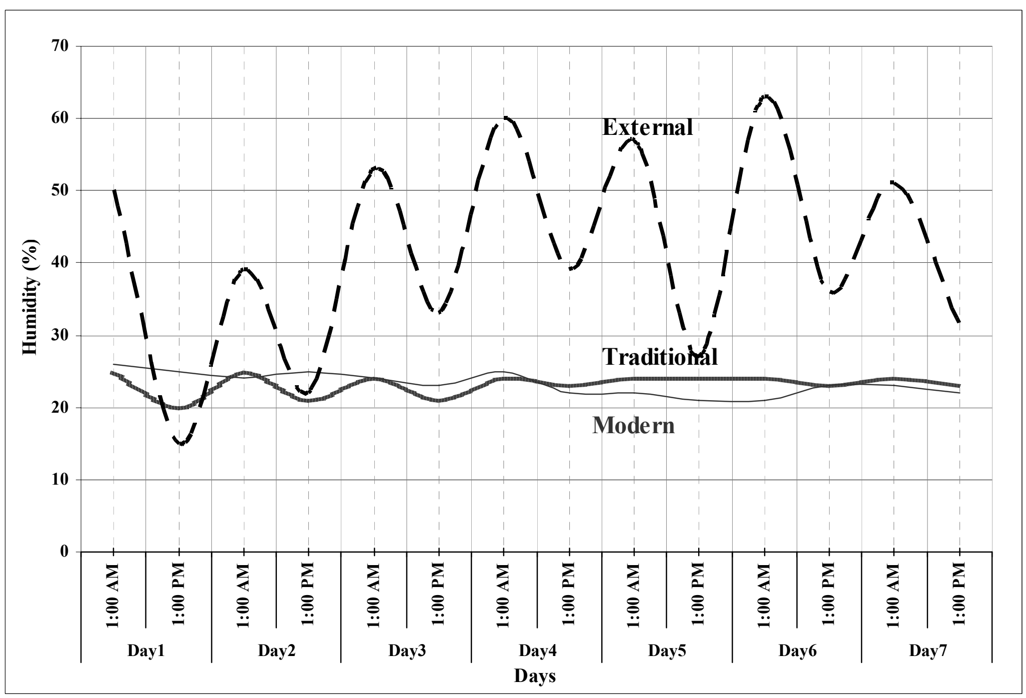


Figure 5.12 Humidity data for Ghadames during one week in January.

Generally, the temperature and humidity data resulted in that the traditional house of Gharyan provides the comfort level for human were the readings are approximately constant during the whole year even in recent days. On the other hand, the traditional house of Ghadames still struggling to keep differences even if it is lower than the modern one, but unfortunately it did not achieve the comfort level for human, where the readings are extremely low. Lastly, the traditional house of Tripoli was the worse in the three comparisons.

On the other side, the contemporary houses of the three cities have approximately the same temperature results, which did not achieve the comfort level for human, during summer or winter season, because of the many reasons mentioned in section 4.1.

5.2 Informal interviews

As mentioned earlier in the methodology, Section 3.2.2, questions were asked about particular features of the houses. The informal interviews focused on traditional houses generally, and particularly on the plumbing system, the cooling system, how the people built there houses and how often they used to do repairing and renovation work for their houses. The answers are summarized under the following headings.

a) Building methods

Methods of building methods differ from one city to another. In Tripoli, there were many ways of building; one of them is called locally *"Darab Elbab"*. This way used only rubble stone with lime mortar and clay. In this type of construction a form work was made with wooden planks in which the rubble stone was filled along layer by layer with the clay and then compacted to form the walls. In other places bearing walls were constructed from lime and sandstone which is commonly found in the old city of Tripoli.

In the old city of Ghadames, all houses were constructed from mud brick. Bricks were manually made in site by mixing many types of soil available on site, which are known locally as *"black and white soil"*, with animal excreta. The walls of the house were built in stages: after every four to five layers of brick are completed, the wall is left for few days to dry; thereafter, new layers are added to the previous layers. According to the old people interviewed this way provides more strength to the structure of house.

b) Sewage system and water drainage of the house

Most traditional houses in Tripoli and Ghadames are still using septic tanks. In the troglodytes people used to make the courtyard in two levels, the upper level which surrounds the inner lower courtyard is compacted earth and is used as a pavement or a terrace for the occupants; and the lower level which is composed of loose earth is dug to absorb all water, especially in rainy seasons, also some times the occupants put some insects as worms which are known to make the ground soft by increasing its porosity, and therefore, the rain water will be absorbed more easily.

c) Type of cooling system

In the old city of Tripoli -in the past- people used to put some kind of sea plants brought from the sea on the roofs. These plants help in providing cool air to the house. Also some times they used to put wet pieces of fabric or/and water jars as cooling devices. This system is used also in troglodytes of Gharyan.

5.3 Questionnaire Data

Results drawn from the tabular data were as follow. The questionnaire was distributed to a representative sample of people who had experienced living in both types of building. A comparative analysis was done for the modern and traditional houses in the three cities, from many aspects and presented in tabular form.

5.3.1 Particular of occupants:

a) The **ages** of the respondees ranged from 30 to over 60, such that 23% were between 30 to 40 years old, 26% were between 41 and 50, 36% were between 51 and 60 and 14% were older than 60 years of age.

b) Concerning the **education** level of the respondees, it was found that the majority were educated people; 53% held university degrees and 38% had finished high school. On the other hand, the percentage of respondees with little or no education was quite low; 1.5% and 5% respectively. As majority of the respondees held university degrees and their ages ranged between 41 and 50 years, they appeared to be more aware of the importance of this research and took care to diligently answer all questions.

c) Concerning the **occupation** of the respondees, it was noticed from the results that, in Gharyan and Ghadames the employment rate were 46% and 44% respectively while that in Tripoli was low, at 21%. On the other hand, craftsmanship in Tripoli had the higher percentage at 42%, as opposed to Gharyan with 19% and Ghadames with 25%. This indicated that traditional crafts were still popular in Tripoli.

5.3.2 Particular of occupancy in both types of houses:

a) Majority of respondees spent more than 10 years in both houses. (Q. 2.1-6.1)
b) The number of families living in one house ranged from 1 to 9, while this situation was different from one city to another, it also depended on the type of the house. The results showed that:
   - 81% of the traditional houses in Ghadames had one family.
   - 62% of the traditional houses in Gharyan had up to three families.

On the other side, 88% of contemporary houses in the three cities had one family. (Q. 2.2-6.2)

c) The total number of occupants living in the same house ranged from 3 to 35 people, the results showed that: (Q. 2.3-6.3)

- 50% of traditional houses in the three cities had from 5-10 people.
- 73% of contemporary houses in the three cities had from 5-10 people.
- 38% of traditional houses in the three cities had more than 10 people.
- 17% of contemporary houses in the three cities had more than 10 people.

5.3.3 Particulars of the layout for both types of houses:

a) The total number of stories ranged from 1 up to 4 levels. It is resulted that the traditional houses of Gharyan consist only of 1 level, in Tripoli ranged from 1-2 levels and in Ghadames all traditional houses had multiple stories about 4 levels. On the other hand, contemporary houses in the three cities have variety in stories. (Q. 2.4-6.4)

b) According to the questionnaire the traditional houses for Tripoli and Ghadames consist of many rooms, varied in size and function for each room. As opposed to Gharyan, which consist only of one big room for all activities. On the other hand, contemporary houses in the three cities have a big variety in room size and number, depended on the design of the house. (Q. 2.5-6.5)

c) Concerning the rooms' classification in the house from both types; it is clarified that the **traditional houses** of **Tripoli** and **Ghadames** included large number of rooms which contained many activities, such as bed rooms, guest room, living room and storage room. What it is noticed from the questionnaire's results; that the traditional houses of **Ghadames** has the highest range of storage spaces comprising of about 25% from house's floor area. As opposed to traditional houses of **Gharyan**, which have one room that is divided into the sleeping and living areas, where all daily activities of the family including eating area and the craft work shop. On the other hand, the rooms' classification in the **contemporary houses,** had a big variety in rooms number, classified into many activities, such as bed rooms, guest room, living room and storage room. (Q. 2.6-6.6)

d) In the traditional houses of **Tripoli**, where the rooms are rectangular shape approximately, the average room measures 2m to 4m wide, by 5m to 8m long. In the traditional houses of **Ghadames**, where the rooms are small in area, the average room measures - except the living area- is 1.5m to 2.5m wide, by 3m to8m long. The living room is large compared to the other rooms of the house; the average dimension of the room is 4 × 6m to 6 × 7m. In the traditional houses of **Gharyan**, where the one room dug into the ground represent the whole house for each family, and contain all life's activity; the average room's dimension is 3m to 4m wide and 8m to10m long.

On the other hand, the contemporary houses, the rooms' sizes and classification depend on the house design in the three cities. What is interested in this part of study, a comparison between traditional houses and contemporary houses of Gharyan, from living in one big room with all daily activities, to be transformed to houses containing several rooms each with its certain job or activity. (Q. 2.7-6.7)

e) Windows do not exist at all in traditional houses of **Gharyan**; while in **Tripoli** 50% of the houses have widows with a variety in their sizes, these sizes depends on the level where they exits at and most of windows overlooked the courtyard. In **Ghadames,** about 44% of houses have windows, that are located on the upper floors only and extremely small sizes, for climatic and social concerns; and most of windows overlooked the central room –living room-. In the contemporary houses**,** there is a big variety in windows sizes, depending on the house's design. (Q. 2.11, 2.12 and 6.11)

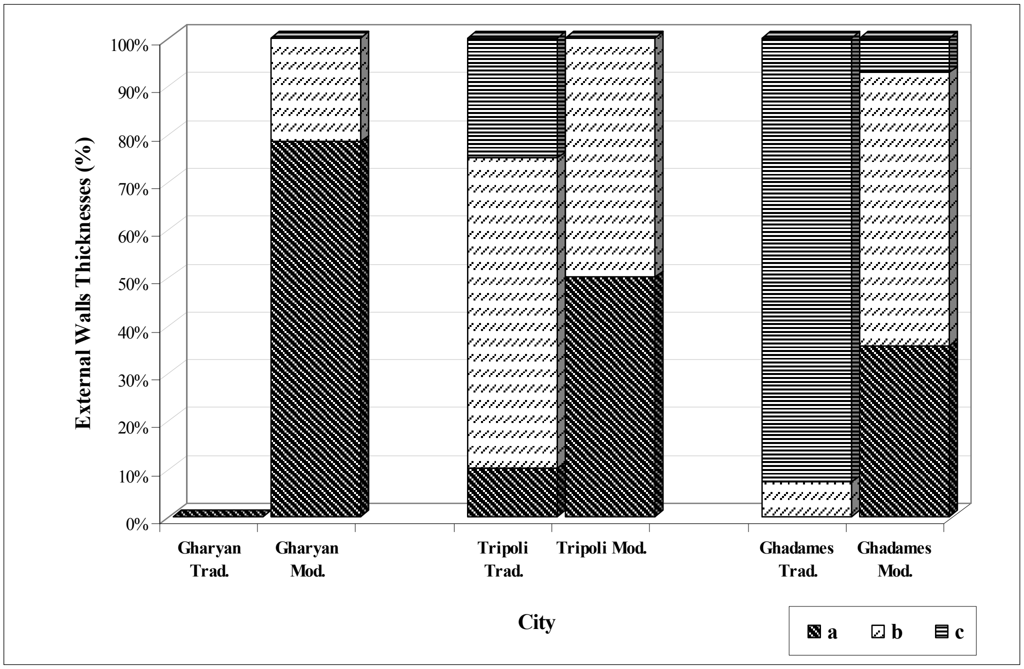
f) Most houses in both types have auxiliary spaces. These spaces are considered as indoor and outdoor, such as storage areas, animal sheds, cooking areas, *etc.* (Q. 2.15, 2.16, 6.14, 6.15 and 6.16)

g) About 30% of the respondees had bought their contemporary houses and 70% of respondees had built their own houses, 15% of them had used readymade design and 55% had used personalized design. On the other hand most traditional houses were owned by their lords. (Q. 6.17-6.18)

h) From questionnaire, it was resulted that only 35% of the respondees had modified their **traditional houses**. The modification works were done to enlarge the house, or to change function of some of the rooms and to cover the courtyard. The modifications were done for many reasons such as, lack of privacy, unsuitability of design for social life, *etc.* On the other hand, the results survey shows that 45.5% of the selected sample had modified their **contemporary houses.** The modifications were done for the same reason mentioned in the traditional houses part. (Q. 2.18, 2.19, 2.20, 6.19, 6.20, and 6.21)

5.3.4 Particulars of the structure in both types of houses:

a) All traditional houses have the same feature of thick external walls; they ranged from 50 to 80cm and some times to 100cm. In contemporary houses the average thicknesses of the external walls is 30cm, and about 40 to 45cm, in few cases, as double wall in the three cities. Figure 5.13 shows the average thicknesses of houses from both types in each city. As illustrated from the figure traditional houses of Gharyan have a special situation as been dug in the ground. Concerning the thickness of internal walls, there were minor differences between the traditional and contemporary houses, in other words, the internal walls are less in thickness than the external ones, except in the traditional houses of Ghadames were both walls the inner and outer mostly with the same thicknesses. (Q. 2.8, 6.8, 2.9 and 6.9)

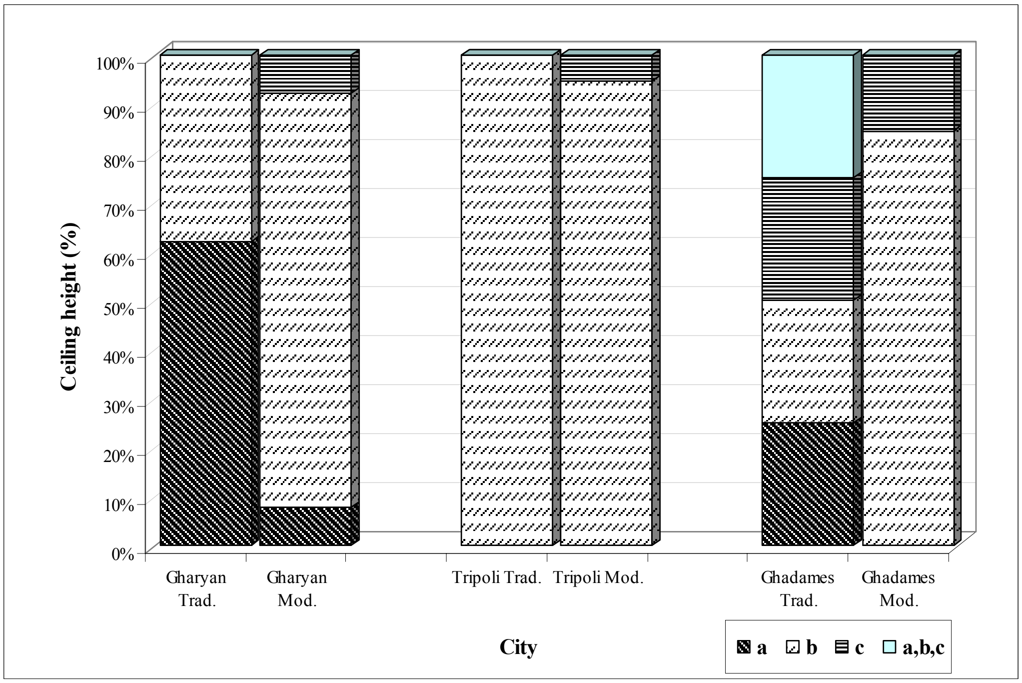


* a= 30cm, b=40cm, 50<c<80 cm and 100<d<150 cm

Figure 5.13 Average thicknesses of external walls of the house in both types.

b) Concerning height of ceilings in traditional houses, they ranged from 2.5 to 7.0m, as presented in Figure 5.14. It is clear from the figure that traditional houses of Ghadames have variety of heights, unlike houses in Tripoli and Gharyan. (Q. 2.10-6.10)

c) Tables 5.1 and 5.2 show the construction materials used in the walls and roofs in both types of houses.



* 2.5<a<3.0 m, 3.5<b<4.0 m and 4.5<c<7.0 m

Figure 5.14 Ceiling heights of both types in each city.

Table 5.1 Typical walls in both types of houses. (Q. 2.13-6.12)

	Main building material	**Binding material**	**Plastering material**	**Additional material**
Tripoli Traditional	Lime stone	Lime / Cement mortar	Lime / Mortar cement	Steel bar between spans
Gharyan Traditional	Sand stone / Rubble stone	Mud / Cement mortar	(Gypsum / Cement) mortar	-
Ghadames Traditional	Mud brick / Volcanic rocks	Mud / Cement mortar	Lime / Gypsum	Lintel wood for fenestration
Contemporary in Libya	Masonry units	Cement mortar	Cement mortar	Reinforced beams for lintel

Table 5.2 Typical roofs and ceilings in both types of houses. (Q. 2.14-6.13)

	Main building material	Binding material	Plastering material	Additional material
Tripoli Traditional	Lime stone / Timber	Lime / Cement mortar	Lime / Mortar cement	Steel bar between spans
Gharyan Traditional	Rubble stone / Olive branches	Mud / Cement mortar	(Gypsum / Cement) mortar	-
Ghadames Traditional	Rubble stone / palm branches	Mud / Cement mortar	Lime / Gypsum	-
Contemporary in Libya	Hollow clay pots / Pre-cast tie beams	Cement mortar	Cement mortar	Pre-cast tie beams

5.3.5 Particulars of utilities in both types of houses:

a) Figure 5.15 shows availability of electricity; water supply and sewage system in both types of houses; and 90% of traditional houses have utilities, existed recently. (Q. 3.1, 3.2, 3.3, 7.1, 7.2, 7.3 and 3.8)

b) Concerning the water sources in **traditional houses**, it was found that the sources are different from city to another. In **Gharyan** about 73% of houses depend on underground rain storages tanks (*Majin*); in **Tripoli** about 35% of houses depend on well water and in **Ghadames** about 78% of houses depend on spring water from "*Ain Al-faras*". On the other hand, it was found a variety of sources also used in **contemporary houses,** about 80% houses of **Ghadames**, 70% houses of **Tripoli** and 23% in **Gharyan** depend on city water supply; and 31% in **Gharyan** depend on rain water. (Q. 3.5-7.5)

c) Concerning natural lighting and ventilation in both types of houses are illustrated in Figures 5.16 and 5.17. It is noticed from both figures, 88%

respondees of contemporary houses were satisfied and considered the amount natural light ventilation as “good”. On the other hand, most traditional houses respondees considered the amount natural light ventilation as “fair”, except in Tripoli were respondees give a good degree for ventilation level. (Q. 3.6, 3.7, 7.6 and 7.7)

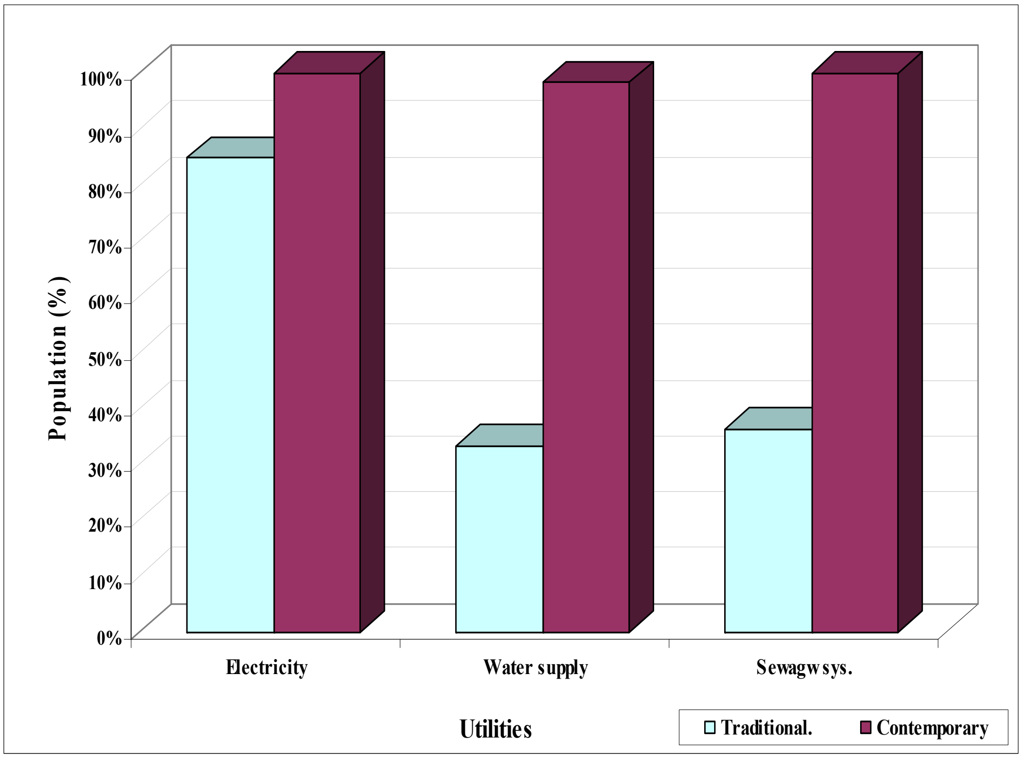


Figure 5.15 Availability of electricity, water supply and sewage system.

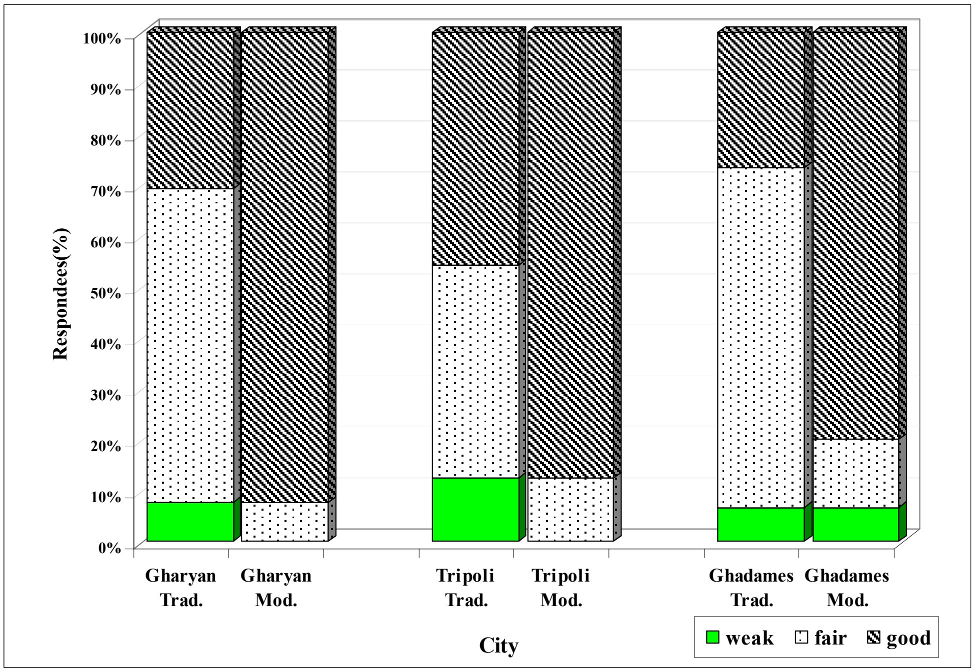


Figure 5.16 Level of natural light in both types of houses.

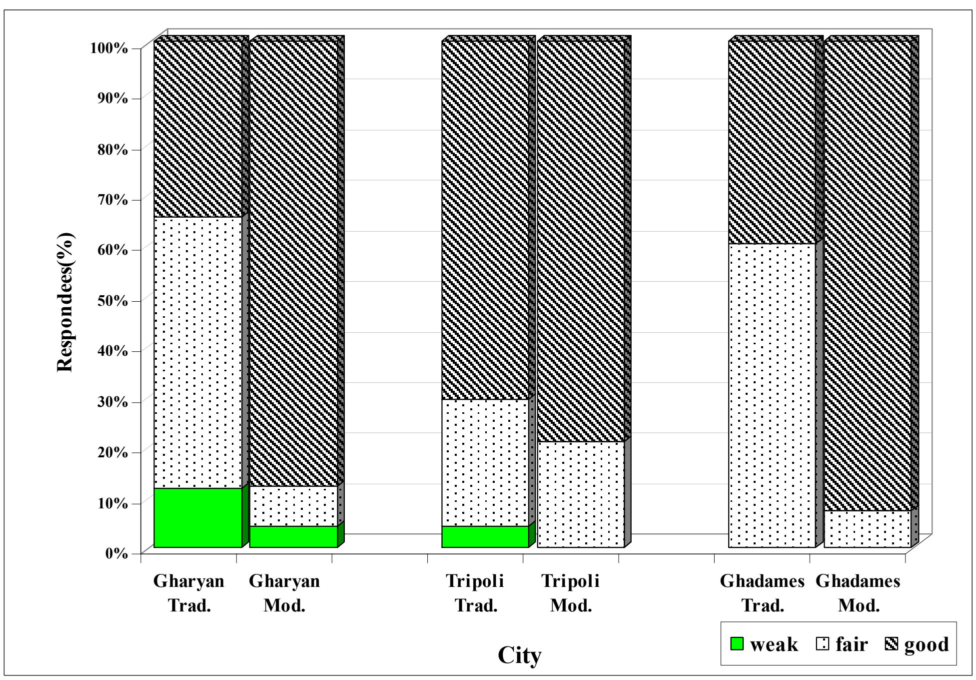


Figure 5.17 Level of natural ventilation in both types of houses.

5.3.6 Particular of energy consumption in both types of houses:

The estimated cost of energy consumption in contemporary houses comparing to the traditional houses is illustreted in Figure 5.18. (Q. 5.1)

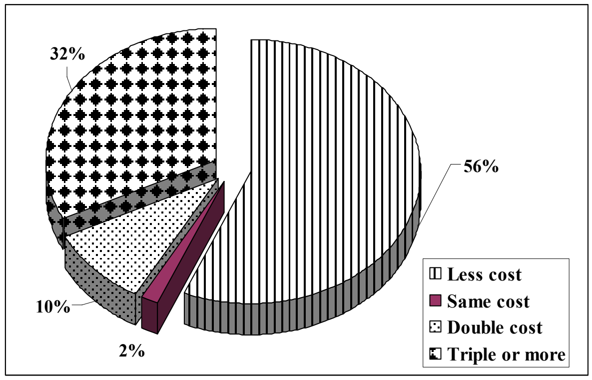


Figure 5.18 Energy consumption of traditional houses comparing to contemporary ones.

5.3.7 Particulars of environmental behavior and thermal comfort:

a) Respondees' opinion of the comfort level of their traditional houses regarding climate comfort comparing with their contemporary houses is illustrated in Figure 5.19. (Q. 4.1)

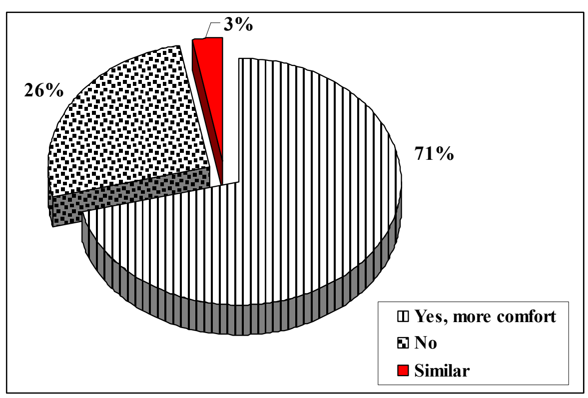


Figure 5.19 Comfort level in both type of houses.

b) The reasons of differences between the traditional and modern houses with regard to climatic comfort can be listed in (Q. 4.2):
   - 49% for design of the house
   - 33% for construction materials
   - 10% for size of the house
   - 8% of respondees stated that there are not any differences in comfort level.

c) The used cooling and heating systems in both types of houses as listed in Tables 5.3 and 5.4.

Table 5.3 Comparison between the used cooling systems for both types of houses (Q. 4.3-8.1)

Traditional house	Contemporary house
Hand-held fans	Mechanical air-conditioning
Electrical fans	Electrical fans

Table 5.4 Comparison between the used heating systems for both types of houses (Q. 4.4-8.2)

Traditional house	Contemporary house
Cordwood and Coal	Electrical boilers
Gas heating	Mechanical air-conditioning

5.3.8 Particular of respondees opinion of their houses in both types:

a) The major reasons for abandoning the traditional style in building, and adopting the modern style is listed as 67% was achieving for better sanitary facilities and utilities at the first stage and 33% was that the modern ones are fashionable and have more prestige value. (Q. 4.5)

b) The advantages of traditional house were ranked as the following according to the most important as the respondees stated (Q. 4.6-8.3):
   i) Simplicity of the house's design
   ii) Providing strong social relationship
   iii) The house was economic, no huge depletion in energy and financial resources.
   iv) the usage of local construction materials and the personal

   The results of contemporary houses were ranked as the following according to the most important as the respondees stated:
   i) Good sanitary system
   ii) Fashionable
   iii) Provide privacy
   iv) Flexibility in changing and modification

c) The disadvantages of traditional house were ranked as the following according to the most important as the respondees stated (Q. 4.7-8.4):
   i) Lack availability of sanitary system and utilities
   ii) Not fashionable, and do not provide requirements of recent life.
   iii) Lack of privacy because many families are living in the same house

   The results of the contemporary houses were ranked as the following according to the most important as the respondees stated:
   i) Costly in buying and in constructing
   ii) Weakens social relationship
   iii) Using unsuitable construction materials for the local environment
   iv) Complicated in construction
   v) Not comfort climatically
   vi) Other disadvantages as: using unsuitable design regarding to local environment, the difficulty in providing construction materials and do not have a local identity of each region.

d) Tables 5.5 and 5.6 show the respondees' opinions of their traditional and contemporary houses, listed in an arrangement according to the importance's of the variables, in a comparison with what the occupants like and dislike in the their houses.

Table 5.5 What the respondees like and dislike in their traditional houses.
(Q. 8.5-8.6)

Rank	Variables (Indices)	(%)
1	Strong social bonds	60
2	Simplicity	40
3	Good thermal comfort	35
4	Economic	19
5	Psychological rustiness	17.5
6	Good design style	11
7	Have a local identity	9.5
8	Usage of local building materials	5
9	Good natural lighting & ventilation	3
10	Easy accessibility to the different rooms	3
11	Easy to built	1.6
12	No dead spaces in the house	1.6
13	Every thing about the house	1.6
14	Nothing in house	1.6

Rank	Variables(Indices)	(%)
1	No privacy	66
2	Unsuitable design for social life	21
3	Do not consists of rooms (as in Gharyan)	16
4	Sanitary problems	13
5	Unsuitable for large (extended) families	10
6	Not fashionable	6.5
7	Lacking of natural lighting & ventilation	5
8	The continuous maintenance	5
9	Dusty	5
10	Nothing wrong with the house	3
11	Humidity	3
12	Unsafe in rainy season (as in Gharyan)	1.6
13	Cold in winter	1.6
14	Not economic	1.6

Table 5.6 What the respondees like and dislike in their contemporary houses.
(Q. 8.7-8.8)

Rank	Variables (Indices)	(%)
1	Suitable design for social life	57
2	Quietness	35
3	Fashionable	25
4	Good sanitary system	18
5	Privacy	18
6	Big in size	15
7	Every thing about the house	15
8	Good natural lighting & ventilation	7
9	Good thermal comfort	7
10	Availability of green surfaces	5
11	Suitable for large Families	3
12	Flexible in modifications	3
13	Small in size (i.e. flat system)	1.6
14	Nothing in house	1.6

Rank	Variables(Indices)	(%)
1	Expensive	34.5
2	Uncomforted climatically	31
3	Weak social bonds	17
4	Not economic	15.5
5	Unsuitable design style	15.5
6	Huge in size	14
7	The modern construction material not good in quality	10
8	privacy	9
9	Lack of facilities in high rise buildings	3.5
10	Every thing about the house	3.5
11	Weak maintaining and facilities	2
12	Nothing wrong with the house	2
13	No identity	2

e) Majority of respondees about 69%, prefer to live in houses with a mix of both styles, *i.e.* advantages of the traditional bio-climatic house and modern facilities of the contemporary house; 20% of respondees stated that they will ignore living again in traditional style, and never think of returning back. On the other hand, the respondees who declared that they would like to return and live in traditional house were low, about 9%. As it is understood from the results, most people agree of improving the traditional house to be compatible with recent modern life. Some people suggest of using the local features of the houses in each region on the modern houses' design, and other think of using mechanical methods to cover the courtyard with a mobile roof. (Q. 8.9)

f) 59% of the respondees stated that traditional house is a heritage of the country; while 11% said that it was the best for the local environment of Libya; and 6% commented that it became history. (Q. 8.10)

g) The level of satisfaction of the occupants to their houses concerning to several variables of both styles, for each city. Table 5.7 shows the satisfaction percentages of the respondees, regarding to certain variables. (Q. 8.11) .As noticed from Table 5.7, the respondees are satisfied with their contemporary houses regarding to: rooms' sizes, rooms' distribution, No. of rooms, windows' sizes, level of natural lighting and ventilation, their personal privacy, No. of stories, sanitary facilities and utilities such as electricity and water supply. At the same time, they are dissatisfied with their traditional houses regarding to the previous points.

On the other hand, the respondees are satisfied with their traditional houses regarding to: the architectural style of the house, construction materials, energy consumption and the thermal comfort of the house. Meanwhile, they are dissatisfied with their contemporary houses regarding to the previous points.

h) The occupants' opinion of the perfect house design were listed according to the respondees' impotents level (Q. 8.12):

1) Providing green areas
2) Improving the local construction materials to be implemented in practice
3) Suitable design for social life and traditional family manners
4) Providing good sanitary facilities, utilities, water drains and good natural lighting and ventilation
5) Simplicity in design
6) Suitable design for the local environment such as: increasing walls and floors thicknesses, providing good insulation materials
7) Returning the traditional identity and taking the benefits of the style
8) Procession for the development of the era

9) Providing privacy
10) Cost consideration
11) The use of solar energy
12) Living at the suburb areas

Table 5.7 Satisfaction ratio of the respondees.

	The traditional house			The modern house		
	Satisfied	**Moderately satisfied**	**Dis-satisfied**	**Satisfied**	**Moderately satisfied**	**Dis-satisfied**
Size of the rooms	23%	53%	23%	**66%**	34%	0%
House layout	33%	31%	36%	**57%**	36%	7%
No. of the rooms	39%	37.5%	23%	**64%**	29%	7%
Size of the windows	14%	22.5%	61%	**75%**	20%	5%
Natural light	44%	37%	19%	**73%**	19%	8.5%
Ventilation	37%	46%	17%	**68%**	25%	7%
Privacy	32%	20%	48%	**78%**	12%	10%
No. of stories	47%	35%	18%	**53%**	28%	19%
Sanitary Facilities	6%	17%	78%	**86%**	10%	3.5%
Utilities (electricity, water supply)	11%	46%	43%	**75%**	23%	2%
Architectural Style	**53%**	33%	15%	37%	56%	7%
Construction materials	**64%**	29%	8%	24.5%	49%	26%
Energy consumption	**73%**	25%	2%	11%	28%	61%
Thermal comfort	**68%**	28%	3%	21%	46%	33%

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study is based on the fact that the old prevailing form of construction in Libya was heavily related to the local environment for each region being the ruling climate or availability of local building materials. These circumstances are considered the main reasons of obvious differences in the traditional prevailing building scheme for each district of the case study, including the coastal regions, represented by Tripoli, the mountainous regions, represented by Gharyan or the desert regions, represented by Ghadames, whereas, on the other hand, the contemporary building scheme exploits the unified concrete skeleton system in all the regions within the country, without taking into account the specific climatic circumstances for each region.

In this thesis, a comparison between traditional and modern dwellings was carried out in the three previously mentioned cities was carried out based on the architectural design, the construction materials, the structural system, the thickness of the walls and the height of the ceilings. Furthermore, indoor temperatures and humidity were compared with outdoor data. Also, a comprehensive questionnaire was distributed to a representative sample of people who occupied for a long period both types of dwellings. Following is the conclusion which resulted from this study:

6.1.1 Traditional Dwellings

The research helped in arriving at some important and useful conclusions about the characteristics of the abandoned traditional buildings in the three cities, and the reasons that made them more comfortable to live in, with the minimum need for artificial air conditioning or heating, compared to modern buildings where life is quite hard without heating in the winter and air-conditioning in the summer.

a) Tripoli represents the coastal region of the study. The architectural and structural designs were closely studied. The main characteristic distinguishing the Tripoli dwelling was the central open court which has a climatic function through refreshing the air and providing privacy, since most of the windows and doors open into it. The house is usually consisted of two floors and it has high ceilings and bearing walls of thickness 50 ~ 80cm, built from lime stones, which is an available and common material in this region of the country.

b) Gharyan represents the mountainous region of the study. The traditional dwelling in Gharyan is distinctively underground dwelling. In shortage of building materials in this region, the people resorted to excavating their houses one level beneath ground level, with a low height ceiling. The house particularity is the limitation of structural elements in some houses or even absence of such elements in others, except of the upper entrance to the house, which is the only built part of the dwelling.

c) Ghadames represents the desert region of the study. The traditional house in Ghadames has the particularity of being consisted of many floors, up to four floors. In addition, it has the characteristic of having thick retaining walls completely built of mud bricks of thickness 45 ~ 55cm, in addition to the rarity of openings opening on the outside, except for an opening in the uppermost ceiling in the house, which is a main opening necessary for lighting and airing.

6.1.2 Contemporary Houses

The predominant modern scheme for residential buildings is the concrete skeletons houses, of which non-retaining walls built from hollow masonry blocks and limestone blocks. The thickness of the walls is considered small in comparison with the traditional houses, whereas the thickness ranges from 25 ~ 30cm. This method of building is unified in all regions of Libya, without taking into consideration the climatic circumstances for each region. In addition, these houses ignore the cultural heritage of the country, as innovated building schemes not carrying the local identity are being recently introduced.

Additionally the outdoors conditions such as: sand-storms in some areas or salt and humidity in coastal areas create problem of corrosion, which increases maintenance expenses on such equipments as well as reduce their life. Also, there is a dearth of technicians to service these equipments, as well as spare parts, which aggravate the maintenance problem. Hence, as mentioned before, adapting the contemporary style of housing and totally abandoning the traditional style was not completely appropriate for Libya.

The questionnaire which had been distributed showed that the traditional houses residents had immigrated from their dwellings and adopted the concrete houses mainly for reasons of convoying with the modern era, obtaining better sanitary and electricity utilities and the lack of privacy in these traditional houses where usually more than one family live within. This immigration has lead to negative results mainly neglecting these traditional houses which caused some of these houses to collapse creating a defect in the general city weave of the old city. Due to the bad situation of the houses adjacent to those which had collapsed, the owners were obliged to undertake restoration procedures using renovated materials such as hollow concrete blocks and cement mortar, which are incompatible with the original materials which were used to construct the house.

6.1.3 Thermal Comfort

From wide discussions with citizens who had once lived in the traditional houses and had moved into the modern houses, it turned out that in most cases the traditional houses provided a big amount of thermal comfort for the residents, as they were relatively cold in the summer and warm in the winter without the need of using the current air-conditioning systems, which is currently available in nearly every modern house.

Temperature and humidity data was taken inside the houses of both styles for each region for comparison and to know the extent of reliability of the traditional houses in providing the thermal comfort as was previously well-known for. The results showed that the underground houses in Gharyan are the best in favor of the thermal comfort inside the house. The reasons were previously discussed in the division of discussion & analysis in Chapter 4 of this study.

The results of the temperature & humidity data showed that the traditional house in Ghadames is much better than the modern house, but it does not provide the thermal comfort for its residents, since the temperature inside it is high in the summer and low in the winter. The result of the traditional house in Tripoli did not differ than the modern house in respect of the thermal comfort, especially in the summer season. The reasons of the climatic inconsistency had been previously discussed in Chapter 5 of this thesis.

As for the contemporary houses, all of them are cooler in the winter and warmer in the summer than the traditional houses, which make usage of artificial air-conditioning a necessity, especially in the summer. Living in absence of such artificial air-conditioning is very difficult. Also, some houses use electrical fans for cooling in the summer, but lately, this method is not being used anymore because of its inefficiency. In addition, oil & kerosene heaters are also being used for warming.

Others use coal heaters which has many serious disadvantages. The heating system using hot water as that used in Turkey does not exist in Libya

6.1.4 Cost and Energy Consumption

As previously mentioned, the inconsistency of the contemporary concrete houses as to the climatic circumstances has lead to negative results, represented mainly in the inability of these houses to provide thermal comfort for their residents, leading to the demand of using artificial air-conditioning methods which in turn causes huge consumption of energy and waste of financial resources. The distributed questionnaire showed that the modern houses consume more than twice as much energy and money as the traditional ones. Another disadvantage of the modern houses in respect of energy and financial resources is their high cost of buying or building, adding to that the difficulty and complexity of the building process. For these reasons a small group of people have built their own houses using local materials due to the obvious difference between their cost and that of the modern building materials, for example: the cost of the mud bricks units is 20% lower than that of modern concrete masonry units as used in contemporary houses. (For an example, Tuneen village to the west of Ghadames).

6.2 RECOMMENDATIONS

a) This study is not considered as an invitation to return back to the traditional building style and abandoning the contemporary living schemes. It can be recommended to benefit from the traditional types which have proved to be successful, and trying to make it compatible with the present circumstances in a manner which guarantees the optimum usage of available local resources, reducing energy and money consumption and improving and developing the modern houses, for which abandoning it is an unrealistic matter, in order to comply with the environmental and climatic circumstances of the country.

The preservation of the traditional buildings and renovating them by the same local materials besides improving it workability and performance, which will serve and rich the country culture.

b) Improving the properties of the local construction materials, and facilitate its productivity, marking and transferring; to provide an appropriate construction materials to the local environment, and reduce the high cost of the construction operation.

c) Also, the authorities have to be aware of the invasion of the western architecture in the Libyan cities, which is threatening the local architectural heritage and identity with disappearance.

d) It is recommended that this study is to be extended in the future in a way that covers a wider and more comprehensive survey for other regions in Libya, e.g. applying the same study to the eastern region, whereas this study was applied to the western region. Benghazi represents the coastal regions, Albayda represents the mountainous region and finally, Alkofra represents the desert region, in order to enrich the research and information encyclopedia of Libya.

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APPENDIX A

TEMPERATURE AND HUMIDITY DATA ON THE CASE STUDIES

The temperature and humidity data are presented into tabular format, representing data during one week in both season summer and winter, illustrated as the following.

Table A.1 Temperature data for Tripoli during one week in July.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	29.5	31	29.8
	01:00 pm	32	32.2	35
Day2	01:00 am	29.8	31	30.6
	01:00 pm	30.8	31.8	31.9
Day3	01:00 am	31.5	31.7	33
	01:00 pm	33.9	29.8	41
Day4	01:00 am	32	29.8	36
	01:00 pm	32	29.8	36
Day5	01:00 am	32.2	30.2	33.4
	01:00 pm	32.5	32.2	34.7
Day6	01:00 am	30.2	30	30.3
	01:00 pm	31	29.9	31
Day7	01:00 am	30.1	29	29.9
	01:00 pm	30.5	29.4	31.2

Table A.2 Humidity data for Tripoli during one week in July.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	53	48	69
	01:00 pm	60	50	30
Day2	01:00 am	79	60	74
	01:00 pm	81	50	47
Day3	01:00 am	79	41	54
	01:00 pm	85	50	15
Day4	01:00 am	85	45	34
	01:00 pm	90	43	31
Day5	01:00 am	47	52	27
	01:00 pm	65	53	14
Day6	01:00 am	65	45	27
	01:00 pm	62	40	10
Day7	01:00 am	75	45	28
	01:00 pm	70	40	14

Table A.3 Temperature data for Tripoli during one week in January.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	22.2	18.2	17.9
	01:00 pm	21.5	16	18.4
Day2	01:00 am	21.2	17.8	17.3
	01:00 pm	22.3	17	18.4
Day3	01:00 am	23.1	16.8	18.6
	01:00 pm	22.3	16.2	18.6
Day4	01:00 am	20	16.5	14
	01:00 pm	23.1	17.2	16
Day5	01:00 am	20	17.4	11
	01:00 pm	22	17	16
Day6	01:00 am	23	19.4	12
	01:00 pm	22.7	19.2	19
Day7	01:00 am	23	19.4	12
	01:00 pm	23	19.4	20

Table A.4 Humidity data for Tripoli during one week in January.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	70	61	71
	01:00 pm	70	63	36
Day2	01:00 am	73	62	87
	01:00 pm	73	62	42
Day3	01:00 am	73	59	63
	01:00 pm	73	56	63
Day4	01:00 am	73	70	86
	01:00 pm	70	70	63
Day5	01:00 am	71	76	83
	01:00 pm	71	77	42
Day6	01:00 am	70	68	87
	01:00 pm	70	70	55
Day7	01:00 am	70	68	86
	01:00 pm	70	71	68

Table A.5 Temperature data for Gharyan during one week in July.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	24.7	29	27.3
	01:00 pm	25.4	31.5	31.2
Day2	01:00 am	24.8	30	25
	01:00 pm	25.4	35	34.1
Day3	01:00 am	24.9	26	26.5
	01:00 pm	25.2	32	35.2
Day4	01:00 am	24.8	26	25.7
	01:00 pm	24.7	33	35.8
Day5	01:00 am	24.7	26	27.6
	01:00 pm	24.6	33.5	32.6
Day6	01:00 am	24.8	27.4	26.8
	01:00 pm	24.6	32.3	31.2
Day7	01:00 am	24.8	27	27.5
	01:00 pm	24.5	34	32

Table A.6 Humidity data for Gharyan during one week in July.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	67	60	90
	01:00 pm	71	71	62
Day2	01:00 am	71	70	33
	01:00 pm	68	40	23
Day3	01:00 am	72	70	40
	01:00 pm	72	45	27
Day4	01:00 am	75	68	77
	01:00 pm	69	55	23
Day5	01:00 am	73	58	39
	01:00 pm	72	55	36
Day6	01:00 am	74	65	81
	01:00 pm	75	52	50
Day7	01:00 am	74	69	53
	01:00 pm	71	23	20

Table A.7 Temperature data for Gharyan during one week in January.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	20.5	14.6	12.5
	01:00 pm	22.5	14.8	14.3
Day2	01:00 am	20	15.3	11.5
	01:00 pm	22	15.3	12.3
Day3	01:00 am	20.1	13.5	10
	01:00 pm	21.6	14.5	10.5
Day4	01:00 am	20.5	13.8	11
	01:00 pm	21.1	15.8	13.6
Day5	01:00 am	20.4	13	10.1
	01:00 pm	21.1	15.8	12
Day6	01:00 am	20.8	14	10.5
	01:00 pm	21.4	14.6	11.3
Day7	01:00 am	21	13.3	11
	01:00 pm	22	16.3	13.1

Table A.8 Humidity data for Gharyan during one week in January.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	65	66	66
	01:00 pm	64	60	64
Day2	01:00 am	59	76	83
	01:00 pm	59	60	55
Day3	01:00 am	69	60	58
	01:00 pm	62	54	38
Day4	01:00 am	63	45	39
	01:00 pm	60	45	18
Day5	01:00 am	57	43	17
	01:00 pm	60	41	10
Day6	01:00 am	50	38	5
	01:00 pm	55	37	7
Day7	01:00 am	50	35	6
	01:00 pm	51	35	5

Table A.9 Temperature data for Ghadames during one week in July.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	33	34	29
	01:00 pm	32	37	30
Day2	01:00 am	33	32	29
	01:00 pm	33	38.4	35
Day3	01:00 am	31.5	33	28
	01:00 pm	31.6	37	37
Day4	01:00 am	31.2	34	27
	01:00 pm	32	36	36
Day5	01:00 am	34	34	29
	01:00 pm	33	39.5	38
Day6	01:00 am	33.5	31	27
	01:00 pm	35.4	38	35
Day7	01:00 am	33.6	32	26
	01:00 pm	35	37	35

Table A.10 Humidity data for Ghadames during one week in July.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	35	13	27
	01:00 pm	30	11	6
Day2	01:00 am	28	15	8
	01:00 pm	28	11	12
Day3	01:00 am	30	17	28
	01:00 pm	32	15	16
Day4	01:00 am	30	17	18
	01:00 pm	26	13	10
Day5	01:00 am	30	15	23
	01:00 pm	24	10	6
Day6	01:00 am	35	18	20
	01:00 pm	30	12	15
Day7	01:00 am	35	20	22
	01:00 pm	32	16	27

Table A.11 Temperature data for Ghadames during one week in January.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	12	8	7
	01:00 pm	15	12	18
Day2	01:00 am	10	10	8
	01:00 pm	15	13	15
Day3	01:00 am	9	8	6
	01:00 pm	14	14	16
Day4	01:00 am	8	7	6
	01:00 pm	14.5	14	16
Day5	01:00 am	9	7	6
	01:00 pm	15	12	12
Day6	01:00 am	7.5	6.5	8
	01:00 pm	12	12	16
Day7	01:00 am	9	7.5	7
	01:00 pm	15	13	15

Table A.12 Humidity data for Ghadames during one week in January.

Frequency	Time	Traditional	Modern	External
Day1	01:00 am	25	26	50
	01:00 pm	20	25	15
Day2	01:00 am	25	24	39
	01:00 pm	21	25	22
Day3	01:00 am	24	24	53
	01:00 pm	21	23	33
Day4	01:00 am	24	25	60
	01:00 pm	23	22	39
Day5	01:00 am	24	22	57
	01:00 pm	24	21	27
Day6	01:00 am	24	21	63
	01:00 pm	23	23	36
Day7	01:00 am	24	23	51
	01:00 pm	23	22	31

APPENDIX B

QUESTIONNAIRE

B.1 A questionnaire about bio-climatic architecture in Libya

Introduction:

This questionnaire has been prepared by Arch. Nahla A. Elwefati, graduate student at the Middle East Technical University in Ankara, Turkey, as a part of Master thesis in Architecture, Building Sciences Division. The thesis focuses on conducting a study to compare environmental comfort in traditional and contemporary architecture of three Libyan cities; namely, Tripoli, Gharyan and Ghadames.

This questionnaire is forwarded to people who lived for long periods in both traditional buildings in the past and modern concrete houses at present. The researcher appreciates giving part of your time to answer the questionnaire, and she welcomes any additional queries about the details of the subject. The researcher ensures that the information provided by you, will be treated as confidential data, and will be used for the purposes of scientific research only.

Please put the sign (✓) in the appropriate box:

1. General Information:

1.1 City: …..

1.2 Age group: ☐ 30-40 ☐ 41-50 ☐ 51-60 ☐ Over 60

1.3 Level of education: ☐ Elementary ☐ High School ☐ University ☐ Uneducated

1.4 Occupation: ☐ Craftsman ☐ Employee ☐ Business ☐ Unemployed

2. Information on Traditional House:

2.1 For how long you lived in the traditional house:

☐ Less than 5 years ☐ 5-10 years ☐ more than 10 years

2.2 How many families were living in the same house:

☐ One family ☐ Two families ☐ Three families

☐ More than three families (please mention the number of families)

2.3 What was the total number of occupants in the house:

☐ Less than 5 ☐ 5-10

☐ More than 10 people (please mention the number of families)

2.4 How many stories were there in the house: ………

2.5 How many rooms were there in the house: ……

2.6 Rooms classification:

☐ Guest room ☐ Living room ☐ Bed room

☐ …………… ☐ …………… ☐ ……………

2.7 How much was the average size of the rooms (*e.g.* 3m × 4m):

☐ Guest room (…m × …m) ☐ Living room (…m × …m)

☐ Bed room (…m × …m) ☐ ……….……………

☐ ……………………….. ☐ ………………..……

2.8 How much was the average thickness of the internal walls:

☐ 20 cm ☐ 30 cm ☐ ……. cm

2.9 How much was the average thickness of the external walls:

☐ 30 cm ☐ 40 cm ☐ ……. cm

2.10 How much was the average ceiling height:

☐ 3.5 m ☐ 3.5-4.00 m ☐ ……. m

2.11 Were there any windows overlooking the street (on the façade):

☐ Yes ☐ No

2.12 If the answer is yes, do you classify the sizes of the widows as:

☐ Small (50cm×70cm) ☐ Medium (100cm×140cm)

☐ Larger than (100cm×140cm)

2.13 Construction materials used in the walls (more than one answer is possible):

☐ Mud brick ☐ Lime stone ☐ Volcanic stone ☐ Timber

☐ Cement mortar ☐ Other ……………………………

2.14 Construction materials used for roof slabs (more than one answer is possible):

☐ Mud brick ☐ Lime stone ☐ Concrete ☐ Timber

☐ Cement mortar ☐ Other ……………………………

2.15 Were there any auxiliary spaces in the house (such as store, stable, etc.):

☐ Yes ☐ No

2.16 If the answer is yes, were these spaces:

☐ Inside the house ☐ Attached to the house

2.17 Other auxiliaries spaces: ……………………………………..

2.18 Were there any kind of modifications/ changes in the house after it was built:

☐ Yes ☐ No (satisfied by what was in the house originally)

2.19 If the answer is yes, were the changes made by:

☐ Roofing the courtyard ☐ Adding new rooms

☐ Changing function of rooms ☐ Other type of modifications ………

2.20 Were the changes done because of:

☐ Lack of privacy ☐ Unsuitability of design for social life

☐ Incompatibility of the house to the family size

☐ Weather conditions ☐ Other reasons …………………..

<u>3. Utilities in the Traditional House:</u>

3.1 Availability of electricity: ☐ Yes ☐ No

3.2 Availability of water supply: ☐ Yes ☐ No

3.3 Availability of sewage system: ☐ Yes ☐ No

3.4 Other utilities available: …………………………………

3.5 Source of water: ☐ City water supply ☐ Well ☐ Fountain

☐ Spring ☐ Other ………………….

3.6 Level of natural lighting: ☐ Weak ☐ Fair ☐ Good

3.7 Level of natural ventilation: ☐ Weak ☐ Fair ☐ Good

3.8 Were these utilities there when the house was built:

☐ Yes ☐ No

☐ Added later ☐ Existed partly

4. Environmental Comfort Level in the Traditional House:

4.1 Comparing to modern houses, do you think the traditional houses are more comfortable with regard to climatic comfort (warm in winter, cool in summer):

☐ Yes ☐ No ☐ Similar

4.2 In your opinion, what are the reasons of differences between the traditional and modern houses with regard to climatic comfort:

☐ No difference ☐ Construction materials ☐ Size of the house

☐ Design of the house ☐ Other ………………………………..

4.3 What system was used for cooling in summer:

☐ Hand-held fans ☐ Electric fans

☐ Nothing exist ☐ Other …………………………..

4.4 What system was used for heating in winter:

☐ Cordwood heating ☐ Gas heating ☐ Coal heating

☐ No heating ☐ Other …………………………..

4.5 In your opinion, what are the major reasons for abandoning the traditional style in building, and adopting the modern style:

☐ The modern ones are more comfortable

☐ They are fashionable/ have more prestige value

☐ Sanitary utilities are much better

☐ Other …………………………….

4.6 In your opinion, the advantages of the traditional house are that they:

☐ Provide climatic comfort ☐ Are low cost

☐ Use local construction material ☐ Are simple

☐ Provide strong social relationships

☐ Have special characters that distinguish them from other styles of traditional houses in other parts of the country.

☐ Other ……………………………

4.7 In your opinion, the disadvantages of the traditional house are that they have:

☐ Problems of sanitary utilities.

☐ Lack of prestige value (not fashionable)

☐ Lack of privacy because many families are living in the same house

☐ Other ………………………………………

<u>5. The Energy Consumption in the Traditional house:</u>

5.1 How do you estimate the cost of energy consumption in modern houses comparing to the traditional houses:

☐ Less cost ☐ Same cost

☐ Double cost ☐ Treble or more cost

<u>6. Information on Modern House:</u>

6.1 For how long have you lived in the modern house:

☐ Less than 5 years ☐ 5-10 years ☐ more than 10 years

6.2 How many families are living in the same house:

☐ One family ☐ Two families ☐ Three families

☐ More than three families (please mention the number of families)

6.3 What is the total number of occupants in the house:

☐ Less than 5 ☐ 5-10 ☐ more than 10 people: ……

6.4 How many stories were there in the house: ………

6.5 How many rooms were there in the house: ……

6.6 Rooms classification:

☐ Guest room ☐ Living room ☐ Bed room

☐ …………… ☐ …………… ☐ ……………

6.7 What is the average size of rooms (*e.g.* 3m × 4m):

☐ Guest room (…m × …m) ☐ Living room (…m × …m)

☐ Bed room (…m × …m) ☐ ……….……………

6.8 How much is the average thickness of the internal walls:

☐ 20 cm ☐ 30 cm ☐ ……. cm

6.9 How much is the average thickness of the external walls:

☐ 30 cm ☐ 40 cm ☐ ……. cm

6.10 How much is the average ceiling height:

☐ 3.00 ☐3.00-3.5 m ☐ ……. m

6.11 What is the size of the windows on the facade:

☐ Small (100cm×100cm) ☐ Medium (200cm×220cm)

☐ Larger than (200cm×220cm)

6.12 Construction materials used in the walls (you can choose more than one answer):

☐ Concrete masonry units ☐ Bricks ☐ Cement mortar

☐ Lime stone blocks ☐ Other ……………………………

6.13 Construction materials used for roof slabs (can choose more than one answer):

☐ Bricks ☐ Concrete ☐ Precast tie beams

☐ Cement mortar ☐ Other ……………………………

6.14 Are there auxiliary spaces, in the house (storage, outdoor kitchen, stable …etc): ☐ Yes ☐ No

6.15 If the answer is yes, are there special ovens for cooking: ☐ Yes ☐ No

6.16 Are there animals: ☐ Yes ☐ No

6.17 Was the house: ☐ Bought ☐ Built by the owner

6.18 If the house had been built personally, did you make use of:

☐ Readymade design ☐ Personalized design

6.19 Is there any kind of modifications done to the house:

☐ Yes ☐ No

6.20 If the answer is yes, what kind of modifications:

☐ Adding new rooms ☐ Changing function of rooms

☐ Other type of modifications ……………………………………

6.21 Were the modifications done because of:

☐ Lack of privacy ☐ Unsuitability of design for social life

☐ Incompatibility of the house to the family size

☐ Weather conditions ☐ Other reasons …………………..

7. Utilities of the Modern House:

7.1 Availability of electricity: ☐ Yes ☐ No

7.2 Availability of water supply: ☐ Yes ☐ No

7.3 Availability of sewage system: ☐ Yes ☐ No

7.4 Other utilities available: …………………………………

7.5 Source of water: ☐ City water supply ☐ Well ☐ Fountain

☐ Spring ☐ Other ………………….

7.6 Level of natural lighting: ☐ Weak ☐ Fair ☐ Good

7.7 Level of natural ventilation: ☐ Weak ☐ Fair ☐ Good

8. Environmental Comfort Level of The Modern House:

8.1 What system is used for cooling in summer:

☐ Air conditioning ☐ Electrical fan

☐ Other …………………………..

8.2 What system is used for of heating in winter:

☐ Air conditioning ☐ Electrical boilers

☐ Other …………………………..

8.3 In your opinion, the advantages of the modern house are:

☐ Fashionable ☐ Provides privacy

☐ Availability of sewage systems, and sanitary utilities.

☐ Flexibility in modifications and additions.

☐ Other …………………………..

8.4 In your opinion, the disadvantages of the modern house are:

☐ Does not provides climatic comfort ☐ Weak social relations

☐ Complicated in construction ☐ Costly in building and selling

☐ Unsuitable construction materials for local environment

☐ Other …………………………..

8.5 What do you like in your traditional house:

…......…………………………………………………………………

8.6 What do you do not like in your traditional house:

…......…………………………………………………………………

8.7 What do you like in your modern house:

…......…………………………………………………………………

8.8 What do you do not like in your modern house:

…......…………………………………………………………………

8.9 If you could choose between the modern and the traditional style, what would you choose (give a reason please):

☐ Return back to traditional style as it is.

…......…………………………………………………………………

☐ Ignore the traditional style, and never think of returning back.

…......…………………………………………………………………………

☐ Mix between the two styles, by making use of the advantages of the traditional style and make it applicable in the modern style. In this case what are your suggestions:

…......…………………………………………………………………………

☐ Other choices you would like to add:

…......…………………………………………………………………………

8.10 What is your opinion about the traditional houses:

☐ It was the best for our local environment in comparison to our recent houses.

☐ It is a heritage; we have to protect it from vanishing.

☐ It was just a stage of life and it in history now.

8.11 How much you are satisfied with your traditional and modern house:

	The traditional house			**The modern house**		
	Satisfied	**Moderately satisfied**	**Dis-satisfied**	**Satisfied**	**Moderately satisfied**	**Dis-satisfied**
Size of the rooms						
House layout						
No. of the rooms						
Size of the windows						
Natural light						
Ventilation						
Privacy						
No. of stories						
Sanitary Facilities						
Utilities (electricity, water supply)						
Architectural Style						
Construction materials						
Energy consumption						
Thermal comfort						

8.12 If you have the chance to build your house or modify it, how would you describe the perfect design, which provides environmental comfort and fits your requirements?

…......…………………………………………………………………………

…......…………………………………………………………………………

Thank you for your precious time and for answering the questionnaire

✱ For any questions please call the researcher, and you are welcome to do so any time: Telephone no: ……………………… E-mail:……………………………..

B.2 Questionnaire results

Table B.1 Results on the layout in both types for each city.

Nos. of question	Questions	Answers	Traditional house (%)			Contemporary house (%)		
			Tripoli	Gharyan	Ghadames	Tripoli	Gharyan	Ghadames
Q. 2.1 and 6.1	Total years spent in the house,	> 5years	16	8	-	4	-	-
		< 10 years	17	40	6	13	4	-
		5-10 years	67	52	94	83	96	100
Q. 2.2 and 6.2	No. of families in same house	1 Family	50	27	81	87	96	73
		2 Families	12	11	13	13	4	20
		# 3 families	38	62	6	-	-	7
Q. 2.3 and 6.3	Total occupants in same house	> 5 people	17	8	13	17	12	-
		5-10 people	38	54	62	54	80	87
		< 10 people	45	38	25	29	8	13
Q. 2.4 and 6.4	No. of stories in the house	a=1 level,	33	-	-	33	42	-
		b=2 levels,	62	-	13	62	48	20
		c#3 levels	5	-	87	5	10	80
Q. 2.5 and 6.5	No. of rooms in the house	a<4 rooms,	28	22	6	14	17	13
		4<b<6 rooms,	55	52	81	79	72	87
		c#7 rooms	17	26	13	7	11	-
Q. 2.6 and 6.6	Rooms classification		See Section 5.3.3 (c)					
Q. 2.7 and 6.7	Average rooms sizes		See Section 5.3.3 (d)					
Q. 2.8 and 6.8	Average thickness of internal walls	a=20cm,	50	-	-	94	-	93
		b=30cm,	44	11	8	6	-	7
		c#40 cm	6	89	93	-	-	-
Q. 2.9 and 6.9	Average thickness of external walls	a=30cm,	10	-	-	50	78	36
		b=40cm,	65	-	7	50	22	57
		c#50 cm	25	-	93	-	-	7
Q. 2.10 and 6.10	Average thickness of ceiling height	2.5<a<3.0 m,	-	62	33	-	8	-
		3.5<b<4.0 m,	100	38	33	95	84	85
		4.5<c<7.0 m	-	-	34	5	8	15
Q. 2.11	Presents of windows overlooking the street	Yes	-	50	44			
		No	-	50	56			
Q. 2.12 and 6.11	Window sizes	a=Small	9	-	100	-	-	47
		b=Medium,	73	-	-	46	85	40
		c=Larger	18	-	-	54	15	13

Table B.1 cont'd

Q. 2.13 and 6.12	Construction materials used in the walls		See Section 5.3.4 (c)					
Q. 2.14 and 6.13	Construction materials used in the roofs and ceilings		See Section 5.3.4 (c)					
Q. 2.15 and 6.14	Availability for auxiliary spaces	Yes No	50 50	88 12	19 81	37 63	38 62	20 80
Q. 2.16	Location auxiliary spaces	- Inside - Attached	92 8	43 57	100 -			
Q. 6.15	Availability of especial ovens	Yes No				89 11	40 60	100 -
Q. 6.16	Availability of animals	Yes No				33 67	60 40	33 67
Q. 6.17	Was the house	- Bought - Built				42 58	4 96	53 47
Q. 6.18	If the house was built, was it done by	- Readymade - Personalized				21 79	29 71	14 86
Q. 2.18 and 6.19	Modification done to the house	Yes No	33 67	38 62	31 69	35 65	50 50	56 44
Q. 2.19 and 6.20	Types of modification	- Roofing - Adding - Changing - Other	See Section 5.3.3 (f)					
Q. 2.20 and 6.21	Reason of modification	- Lack of privacy - Unsuitability - Weather - Other	See Section 5.3.3 (f)					

Table B.2 Results of the utilities in both styles in each city.

Nos. of question	Questions	Answers	Traditional house (%)			Contemporary house (%)		
			Tripoli	Gharyan	Ghadames	Tripoli	Gharyan	Ghadames
Q. 3.1 and 7.1	Availability of electricity	Yes No	96 4	65 35	100 -	100 -	100 -	100 -
Q. 3.2 and 7.2	Availability of water supply	Yes No	62 38	27 73	93 7	100 -	100 -	93 7
Q. 3.3 and 7.3	Availability of sewage system	Yes No	75 25	19 81	100 -	100 -	100 -	100 -
Q. 3.5 and 7.5	Source of water	- City water - Well - Fountain - Spring	See Section 5.3.5 (b)					
Q. 3.6 and 7.6	Level of natural lighting	- Weak - Fair - Good	12 42 46	8 61 31	7 66 27	- 12 88	- 8 92	7 13 80
Q. 3.7 and 7.7	Level of natural ventilation	- Weak - Fair - Good	4 25 71	12 53 35	- 60 40	- 21 79	4 8 88	- 7 93
Q. 3.8	Presents of utilities in traditional house	- Yes - No - Added later - Existed partly	74 - 22 4	35 13 35 17	77 8 15 -			

Table B.3 Results of the environmental behavior and thermal comfort in both styles in each city.

Nos. of question	Questions	Answers	Traditional house (%)			Contemporary house (%)		
			Tripoli	Gharyan	Ghadames	Tripoli	Gharyan	Ghadames
Q. 4.1	Were traditional houses more comfortable than modern ones	- Yes - No - Similar	42 50 8	85 15 -	94 6 -			
Q. 4.2	Reason which make traditional houses more comfortable than modern ones	- No difference - Construction materials - House size - Housedesign	See Section 5.3.7 (b)					
Q. 4.3 and 8.1 / Q. 4.4 and 8.2	The used cooling and heating system		See Section 5.3.7 (c)					

Table B.4 Comparative results of the energy consumption in both styles in each city.

Nos. of question	Questions	Answers	Traditional house (%)			Contemporary house (%)		
			Tripoli	Gharyan	Ghadames	Tripoli	Gharyan	Ghadames
Q. 5.1	Estimated cost comparing to contemporary	a=Less cost, b= Same cost, c=Double cost, d=Treble	45 5 14 36	58 - 11 31	63 - 6 31			

B.3 Row data of the questionnaire

Table B.5 Respondees of Gharyan city (Mountainous area).

Case #	City	Q 1.2	Q 1.3	Q 1.4	Q 2.1	Q 2.2	Q 2.3	Q 2.4	Q 2.5	Q 2.6	Q 2.7	Q 2.8	Q 2.9	Q 2.10	Q 2.11	Q 2.12	Q 2.13	Q 2.14
1	Gharyan	a	c	b	a	c	b	-	a	a		c	-	a	-	-	-	b
2	Gharyan	b	b	b	b	d	d	-	b	a		d	-	a	-	-	-	0
3	Gharyan	a	c	b	b	b	b	-	b	a,b,c		c	-	a	-	-	-	b,d
4	Gharyan	b	c	0	c	a	b	-	0	a		0	-	0	-	-	-	0
5	Gharyan	c	b	d	b	d	b	-	c	a		0	-	0	-	-	-	0
6	Gharyan	c	b	a	b	a	b	-	b	a		c	-	b	-	-	-	c
7	Gharyan	d	c	b	c	c	b	-	b	a		d	-	a	-	-	-	a,b
8	Gharyan	b	b	a	b	a	a	-	a	a		c	-	b	-	-	-	b,e
9	Gharyan	b	c	b	b	a	b	-	a	a		c	-	a	-	-	-	0
10	Gharyan	c	c	b	c	a	b	-	0	a		0	-	a	-	-	-	b
11	Gharyan	d	a	c	c	c	d	-	b	a		e	-	a	-	-	-	a
12	Gharyan	a	c	d	0	c	b	-	b	a		b	-	a	-	-	-	a,d
13	Gharyan	c	b	b	b	c	b	-	b	a		e	-	b	-	-	-	a
14	Gharyan	a	b	b	b	a	a	-	a	a		c	-	b	-	-	-	a,b,c,e
15	Gharyan	b	c	b	b	d	d	-	d	a		0	-	0	-	-	-	0
16	Gharyan	c	c	a	c	e	d	-	c	a		0	-	a	-	-	-	a
17	Gharyan	d	b	0	c	c	c	-	0	a		0	-	0	-	-	-	d
18	Gharyan	a	b	b	c	a	b	-	a	a		c	-	b	-	-	-	c
19	Gharyan	a	c	a	a	b	b	-	b	a		c	-	a	-	-	-	d
20	Gharyan	d	a	d	c	d	b	-	c	a		0	-	a	-	-	-	d
21	Gharyan	d	b	e	c	c	c	-	b	a,b		b	-	0	-	-	-	a,b
22	Gharyan	c	0	d	c	c	c	-	b	0		c	-	b	-	-	-	natural
23	Gharyan	c	b	d	c	c	c	-	b	a		d	-	a	-	-	-	0
24	Gharyan	b	c	b	b	e	d	-	d	a		d	-	b	-	-	-	0
25	Gharyan	c	c	b	c	d	d	-	c	a		c	-	a	-	-	-	0
66	Gharyan	c	b	a	c	b	b	-	b	a		c	-	b	-	-	-	e,f

Table B.5 cont'd

Case #	City	Q 2.15	Q 2.16	Q 2.17	Q 2.18	Q 2.19	Q 2.20	Q 3.1	Q 3.2	Q 3.3	Q 3.4	Q 3.5	Q 3.6	Q 3.7	Q 3.8	Q 4.1
1	Gharyan	a	b	-	a	b,c	d	b	b	b	-	c	b	a	c	a
2	Gharyan	b	-	-	b	-	-	b	b	b	-	b	b	b	a	a
3	Gharyan	a	b	-	a	b	a	a	b	b	-	c	a	a	c	a
4	Gharyan	a	b	-	a	b	a	a	a	b	-	a	c	c	d	a
5	Gharyan	b	-	-	b		0	b	b	b	-	c	b	b	c	a
6	Gharyan	a	b	-	a	a,d	a,b,c	a	b	a	-	a	b	a	a	a
7	Gharyan	a	a	-	b		-	a	a	b	-	d	b	c	d	b
8	Gharyan	a	b	-	a	b	a	a	b	b	-	c	b	b	c	a
9	Gharyan	a	a	-	b		-	a	a	b	-	c	c	c	a	a
10	Gharyan	a	a	-	b		-	a	b	b	-	c	b	b	b	a
11	Gharyan	a	a	kitchen	b		-	b	b	b	-	c	c	c	0	a
12	Gharyan	b	-	-	b		-	a	b	b	-	c	b	b	a	a
13	Gharyan	a	a	stable	b		-	b	b	b	-	c	b	b	a	a
14	Gharyan	a	b	-	a	b,c	b	a	a	a	-	a,b	c	b	a	a
15	Gharyan	a	b	water/seeds storage	b		-	a	b	b	-	c	a	b	c	a
16	Gharyan	a	b	gest r./wc	b		-	a	a	b	-	c	c	c	0	a
17	Gharyan	a	b	gest r.	b		-	b	b	b	-	d	b	b	b	b
18	Gharyan	a	b	-	a	b,c	c	a	b	a	-	c	c	c	c	b
19	Gharyan	a	b	-	b		-	a	a	a	-	c	b	b	c	b
20	Gharyan	a	a	gest r.	a	b	b	b	b	b	-	c	b	b	a	a
21	Gharyan	a	a	-	b		-	a	a	a	-	c	c	c	d	a
22	Gharyan	a	b	-	b		-	a	b	b	-	c	c	c	d	a
23	Gharyan	a	a	gest r.	b		-	b	b	b	-	c	b	b	0	a
24	Gharyan	a	a	gest r./stable	a	b	c	a	b	b	-	c,d	b	b	c,d	a
25	Gharyan	a	b	-	b		-	b	b	b	-	c	b	b	b	a
66	Gharyan	a	a	-	a	a	g	a	b	b	-	c	b	c	a	a

Table B.5 cont'd

Case #	City	Q 4.2	Q 4.3	Q 4.4	Q 4.5	Q 4.6	Q 4.7	Q 5.1	Q 6.1	Q 6.2	Q 6.3	Q 6.4	Q 6.5	Q 6.6	Q 6.7	Q 6.8	Q 6.9	Q 6.10
1	Gharyan	b	c	c	b	c,d	a	c	c	a	b	b	b	a,b,c,d		-	a	b
2	Gharyan	d	c	c	b	a,b,d	a,b,c	a	c	a	b	b	b	a,b,c		-	a	b
3	Gharyan	b,d	a	a	b,c	a,c,d,e	a,b,c	d	c	a	b	a	b	a,b,c		-	a	b
4	Gharyan	d	a,b	c	b,c	b,d,f	a	a	c	a	b	0	0	a,b,c		-	a	b
5	Gharyan	0	a	a,b,c	b,c	a,b,c	b	d	c	a	b	b	b	a,b,c,d		-	0	c
6	Gharyan	b,d	b	b,c	a,b,c,d	a,b,c,d	a,b,c	a	c	a	b	0	b	a,b,c,d,e,f		-	a	c
7	Gharyan	b	c	a	b,c	c	a	d	c	a	b	b	8	a,b,c		-	b	a
8	Gharyan	b	a	c	c	b	b	d	c	a	a	a	0	a,b,c		-	b	b
9	Gharyan	b,d	c	a	b	b	b	a	c	a	b	a	b	a,b,c		-	a	b
10	Gharyan	b	c	c	b	c	a	a	c	a	b	a	a	a,b,c		-	b	b
11	Gharyan	d	c	a	c	a,d	b	d	c	a	b	c	b	a,b,c,d		-	a	b
12	Gharyan	d	0	0	c	d,f	b	a	c	a	b	b	b	a,b,c,d		-	a	b
13	Gharyan	b,d	c	a	b,c	a,d	b,c	d	c	a	b	b	0	a,b,c,d,e,f		-	a	b
14	Gharyan	c	0	b,c	a,b,c,d	a,b,c,d,e,f	a,b,c	a	c	a	b	0	0	a,b,c		-	a	b
15	Gharyan	b	c	0	b	a,b,c,e	a,b,c	a	c	b	c	a	c	a,b,c		-	b	b
16	Gharyan	d	c	d	b	f	b	a	c	a	b	a	b	a,b,c		-	a	b
17	Gharyan	d	c	a	b,c	d,e,f	a,b,c	c	c	a	b	0	b	a,b.c.d		-	0	b
18	Gharyan	b	b	b	a,b,c,d	b,c,d	a,b,c	d	c	a	b	a	a	a,b,c,d		-	b	b
19	Gharyan	d	b	a	a	a	b	a	c	a	b	b	0	a,b,c,d		-	a	b
20	Gharyan	b	a	a,b,c	b,c,d	a,d,f	b,c	d	c	a	c	c	a	a,b,c		-	a	a
21	Gharyan	b	c	a	a,c	d	a	a	b	a	a	0	0	a,b,c		-	a	b
22	Gharyan	b	a	a,b	a,c	b,d	b,c	a	c	a	b	a	b	a,b,c		-	a	b
23	Gharyan	d	c	a,c	a	a,b,c,d,e,f	a,c,d	a	c	a	b	b	0	a,b,c,d		-	a	b
24	Gharyan	d	c	d	a,d	a,c,e,g,h	a,d	a	c	a	b	b	c	a,b,c,d.e		-	a	b
25	Gharyan	d	c	a	b,c	d	b	a	c	a	a	b	b	a,b,c		-	a	b
66	Gharyan	b	b	b	b	b,d	a,b	c	c	a	b	a	0	a,b,c		0	0	b

Table B.5 cont'd

Case #	City	Q 6.11	Q 6.12	Q 6.13	Q 6.14	Q 6.15	Q 6.16	Q 6.17	Q 6.18	Q 6.19	Q 6.20	Q 6.21	Q 7.1	Q 7.2	Q 7.3	Q 7.4	Q 7.5
1	Gharyan	b	b	a,d	a	b	a	b	a	a	c	c	a	a	a	-	b
2	Gharyan	b	c,d,e	a	a	a	b	a	-	a	b	b	a	a	a	-	a
3	Gharyan	b	b	b	b	-	-	b	b	b		-	a	a	a	-	a,c
4	Gharyan	b	e	b	a	b	a	b	b	b		-	a	a	a	-	d
5	Gharyan	b	e	b	a	b	a	b	b	a	c	c	a	a	a	-	c
6	Gharyan	c	e	b	b	-	-	b	b	a	c,d	a,b,d	a	a	a	-	c
7	Gharyan	b	a,b,c,d	b,d	b	-	-	b	b	b		-	a	a	a	-	a
8	Gharyan	b	e	a	a	b	a	b	b	a	b	b	a	a	a	-	a,c
9	Gharyan	b	b,c,d	b,d	b	-	-	b	b	b		-	a	a	a	-	a
10	Gharyan	b	e	a	b	-	-	b	a	b		-	a	a	a	-	c
11	Gharyan	c	b,c,d	b	a	a	b	b	b	b		-	a	a	a	-	a
12	Gharyan	b	b,c,d	b,d	b	a	b	b	a	b		-	a	a	a	-	a
13	Gharyan	c	b,c,d	b,d	b	-	-	b	b	b		-	a	a	a	-	a,b
14	Gharyan	b	b,c,d	a,d	b	-	-	b	a	a	a	d	a	a	a	-	b
15	Gharyan	c	b,d	a,b	b	-	-	b	b	a	b	b	a	a	a	-	a,c
16	Gharyan	b	a,b,c,d	a	b	-	-	b	b	b		-	a	a	a	-	a,c
17	Gharyan	b	a,b,c,d,e	b,c,d	a	b	a	0	b	a	b,c	c,d	a	a	a	-	a,c
18	Gharyan	b	b	b	b	-	-	b	a	b		-	a	a	a	-	c
19	Gharyan	b	b,c,d	a	b	-	-	b	b	b		-	a	a	a	-	a,c
20	Gharyan	b	b,d	a,b,c	b	-	-	b	b	a	b,c	b,c	a	a	a	-	b,c
21	Gharyan	b	a,c,d	b	a	a	b	b	b	b		-	a	a	a	-	c
22	Gharyan	b	b,c,d,e	b	a	b	a	b	b	a	c	c	a	a	a	-	c
23	Gharyan	b	e	b	a	b	a	b	b	a	b	b	a	a	a	-	a
24	Gharyan	b	b,c,d,e	a,b	b	-	-	b	b	a	d	e	a	a	a	-	c
25	Gharyan	b	b,c,d	a,b,c,d	b	-	-	b	a	a	c	b	a	a	a	-	c
66	Gharyan	b	a,c,d	b,d	b	-	-	b	b	b		-	a	a	a	-	b,c

Table B.5 cont'd

Case #	City	Q 7.6	Q 7.7	Q 8.1	Q 8.2	Q 8.3	Q 8.4	Q 8.5	Q 8.6	Q 8.7	Q 8.8	Q 8.9	Q 8.10	Q 8.11-1	Q 8.11-2	Q 8.11-3
1	Gharyan	c	b	b	a	b	d	d	l	a	e	a	b	c	c	b
2	Gharyan	b	c	a	a	a,b,c	a,d	e,f	-	d,h	b,d	b	b	b	d	b
3	Gharyan	c	c	a	a,b	a,b	c,d,e	f	d	d	b	c	a,b	c	c	c
4	Gharyan	c	c	b	a,c	a	b,d,e	d	d	j	a,c	c	a,b	b	a	d
5	Gharyan	c	c	a,b	a,b	a,b,c	a,b,d,f	a,f	d	a	b,c,d	c	a,b	a	a	a
6	Gharyan	c	c	a,b	a,b	a,b,c,d	a,b,c,d,e	a,c,d,f,h	d,f,h,i	a,c,d,e,h,i	c,d	c,d	c	b	c	a
7	Gharyan	c	c	a	b	b	d	a,d,f	c,d	c,d,f,g,h	l,c	b	c	d	d	d
8	Gharyan	c	c	a	b	a	a,b,c,d,e	a,c,d	d,h	c,d,g	c	b	c	d	d	d
9	Gharyan	c	c	a	a	b	a	a,b,f	d	f,g	b,d	b	b	a	b	b
10	Gharyan	c	c	a	a	b	d	b	d	0	f	c	b	a	b	d
11	Gharyan	c	c	a,b	a,b	b	c,d	c,d	b,c,d	b,c,d	c	b	b	a	a	a
12	Gharyan	c	c	c	a,c	b	b,d,e	a,d	d	j	f	e	b	b	c	c
13	Gharyan	c	c	a	a,b	b,d	a,c,d	a,d	d	d	f	b	b	a	b	c
14	Gharyan	c	c	a.b	a,b	a,b,d	a,d	f	d,e	a,d,e,f,h	b,c,d	c	b	d	d	d
15	Gharyan	c	c	b	c	a,b	a,b,d,e	f,g	d,e	a,d,k	b,c	c	c	c	c	c
16	Gharyan	c	c	a	b	d	d,e	a,c	i	0	b	a	a	a	a	a
17	Gharyan	c	c	a,b	a,b	b,c,d	a,b,c,d,e	f	d	j	b,d	a	a,b,c	b	c	b
18	Gharyan	c	c	a	a	a,b,c	b,c,d	a,d,f	a,h	a,f	b,c	a,c	a	d	d	d
19	Gharyan	c	0	a,b	a,b	c	b,d	0	0	0	0	c	b	a	a	a
20	Gharyan	c	c	a,b	a	a,b,c,d	a,d,e	c,d,f	d,e,g	a,d,h	b,c	c	b	c	c	b
21	Gharyan	c	c	a	b	a,b,c	c,d	a,b,d	c,d	j	0	c	b	b	c	b
22	Gharyan	c	c	a	a	b,c,d	c,d	d,f	d,e	a,d,h	0	c	b	d	d	d
23	Gharyan	c	c	b	d	a,c,d	a,d	a,c,d,f	c,d,l	a,c,d,k	a,c	c,d	b	b	d	c
24	Gharyan	c	a	a	b,c	a,c	a,e	c,f,i	c,d,l	b,c,d,h,l	a,b,c	c	b	b	d	c
25	Gharyan	c	c	a	a	b	c,d	d	c,d	d	c	c	b	b	b	b
66	Gharyan	b	b	a,b	a,b	a	c,e	g	n	a	p	b,d	a	b	c	b

Table B.5 cont'd

Case #	City	Q 8.11-4	Q 8.11-5	Q 8.11-6	Q 8.11-7	Q 8.11-8	Q 8.11-9	Q 8.11-10	Q 8.11-11	Q 8.11-12	Q 8.11-13	Q 8.11-14	Q 8.11-15
1	Gharyan	c	a	b	b	d	c	c	c	c	a	a	e
2	Gharyan	c	c	b	b	-	c	b	d	d	b	a	h
3	Gharyan	c	c	c	c	d	c	c	a	a	a	a	e
4	Gharyan	d	c	a	a	d	d	a	a	b	a	a	f
5	Gharyan	d	a	b	b	d	c	b	d	a	a	a	e
6	Gharyan	a	c	c	c	b	c	c	a	c	a	a	f
7	Gharyan	d	d	d	d	d	d	d	d	d	d	d	e
8	Gharyan	d	d	d	d	d	d	d	d	d	d	d	h
9	Gharyan	d	d	a	a	d	d	d	d	b	d	a	f
10	Gharyan	c	a	b	b	d	c	b	d	d	a	b	f
11	Gharyan	c	c	c	c	d	c	c	a	a	a	a	e
12	Gharyan	c	c	b	b	d	c	a	b	b	a	a	e
13	Gharyan	c	c	c	c	d	c	c	a	b	a	a	f
14	Gharyan	d	d	d	d	d	d	d	d	d	d	d	h
15	Gharyan	c	c	c	c	d	c	c	b	c	a	a	e
16	Gharyan	d	a	a	a	d	b	b	a	a	a	a	e
17	Gharyan	b	c	b	b	d	d	d	d	d	d	a	f
18	Gharyan	d	d	d	d	d	d	d	d	d	d	d	e
19	Gharyan	b	b	a	a	d	c	b	b	b	a	a	e
20	Gharyan	d	c	a	a	d	c	b	a	c	a	a	e
21	Gharyan	c	b	b	b	d	c	b	b	b	b	b	e
22	Gharyan	d	d	d	d	d	d	d	d	d	d	d	h
23	Gharyan	d	b	b	b	d	c	c	a	b	a	a	e
24	Gharyan	d	d	b	b	d	d	d	a	c	a	a	e
25	Gharyan	d	d	b	b	d	d	d	d	d	d	b	e
66	Gharyan	c	c	b	b	b	c	c	a	c	b	b	e

Table B.5 cont'd

Case #	City	Q 8.11-16	Q 8.11-17	Q 8.11-18	Q 8.11-19	Q 8.11-20	Q 8.11-21	Q 8.11-22	Q 8.11-23	Q 8.11-24	Q 8.11-25	Q 8.11-26	Q 8.11-27	Q 8.11-28
1	Gharyan	e	e	f	g	e	e	f	e	e	g	e	g	g
2	Gharyan	h	h	h	h	h	h	h	h	h	h	h	h	h
3	Gharyan	e	e	e	e	e	e	h	e	e	g	g	g	g
4	Gharyan	e	e	e	e	e	e	e	h	h	g	e	g	e
5	Gharyan	e	e	e	e	e	e	h	e	e	h	g	g	g
6	Gharyan	g	f	e	e	e	e	e	e	f	g	f	g	g
7	Gharyan	e	e	e	e	e	e	g	e	e	e	e	g	f
8	Gharyan	h	h	h	h	h	h	h	h	h	h	h	h	h
9	Gharyan	h	h	e	h	e	e	f	e	h	f	h	f	f
10	Gharyan	g	h	h	e	e	e	h	e	f	f	h	f	h
11	Gharyan	e	e	e	e	e	e	e	e	e	e	e	g	g
12	Gharyan	f	f	f	e	e	h	h	e	e	h	f	f	f
13	Gharyan	e	e	e	e	e	e	e	e	e	g	e	g	g
14	Gharyan	h	h	h	h	h	h	h	h	h	h	h	h	h
15	Gharyan	e	e	e	e	e	e	e	e	e	g	e	g	g
16	Gharyan	e	e	e	e	e	e	f	e	e	f	f	g	g
17	Gharyan	f	f	f	e	e	e	f	f	f	f	f	g	h
18	Gharyan	e	e	e	e	e	f	g	e	f	h	e	g	f
19	Gharyan	e	e	e	e	e	e	e	e	e	e	e	f	f
20	Gharyan	f	e	e	e	e	e	g	e	e	g	e	g	g
21	Gharyan	f	e	e	f	e	e	f	e	e	e	f	e	f
22	Gharyan	h	h	h	h	h	h	h	h	h	h	h	h	h
23	Gharyan	e	e	h	e	e	e	f	e	e	f	e	g	f
24	Gharyan	e	e	e	f	e	e	h	e	e	f	e	f	f
25	Gharyan	f	f	f	h	e	e	f	f	f	h	f	h	f
66	Gharyan	e	f	e	g	f	e	e	f	f	e	f	f	f

Table B.6 Respondees of Tripoli city (Coastal area).

Case #	City	Q 1.2	Q 1.3	Q 1.4	Q 2.1	Q 2.2	Q 2.3	Q 2.4	Q 2.5	Q 2.6	Q 2.7	Q 2.8	Q 2.9	Q 2.10	Q 2.11	Q 2.12	Q 2.13	Q 2.14
26	Tripoli	c	b	0	c	c	c	a	0	b,c		b	b	b	b	-	a,d,f	a,d
27	Tripoli	b	c	0	a	c	c	b	b	b,d		0	c	b	a	b	a	a,d
28	Tripoli	b	c	0	c	c	c	b	b	a,b,c		b	b	b	b	-	d,f	d
29	Tripoli	d	d	d	c	d	c	a	b	a,b		b	b	b	b	-	a,b,d	a,d
30	Tripoli	a	c	b	c	a	a	0	b	a,b,c		a	c	b	b	-	a,d,f	d
31	Tripoli	a	c	b	c	a	b	0	0	a,b,c		0	0	0	0	-	0	0
32	Tripoli	b	c	b	a	a	a	0	a	b,c		a	b	b	a	b	a	a,d
33	Tripoli	c	b	a	c	a	b	a	a	b,c		b	b	b	b	-	d,f	0
34	Tripoli	d	c	a	c	c	d	a	b	a,b,c		a	b	b	b	-	a,e	b,d
35	Tripoli	c	c	a	b	e	d	b	c	b		b	b	b	b	-	c,d	c,d
36	Tripoli	a	c	a	b	b	b	b	0	a,b,c,d		b	b	0	a	b	a	d
37	Tripoli	a	c	a	a	a	b	b	a	a,b,c		0	0	0	a	b	a,b	d
38	Tripoli	b	c	a	c	a	b	b	0	a,b,c		a	b	b	a	c	0	f
39	Tripoli	c	b	a	c	c	c	b	0	a,b,c		a	a	b	a	a	a	a,d
40	Tripoli	d	c	a	c	a	a	b	a	a,b,c		a	a	b	b	-	a,b	a,d
41	Tripoli	c	c	a	c	a	b	b	b	a,b,c		b	b	b	a	b	a,d	a,d
42	Tripoli	c	c	b	c	b	c	b	b	b,c		0	c	b	a	b	a	d
43	Tripoli	a	c	c	a	a	b	b	b	a,b,c		0	0	b	a	b,c	a,e	a,e
44	Tripoli	0	b	b	b	a	a	a	0	a,b		a	b	b	b	-	a	a
45	Tripoli	c	b	c	c	a	b	a	a	b,c		b	c	b	b	-	a,f	a,d,f,g
46	Tripoli	b	b	d	c	a	b	a	b	a,b		a	b	b	b	-	a	a,d
47	Tripoli	a	b	a	c	b	c	c	d	b,c		0	0	0	a	c	a	a,d
48	Tripoli	c	c	0	b	c	c	b	b	b,c		c	c	b	0	-	-	b
49	Tripoli	b	0	d	c	c	c	b	d	a,b,c		a	b	b	a	b	e	d,e

Table B.6 cont'd

Case #	City	Q 2.15	Q 2.16	Q 2.17	Q 2.18	Q 2.19	Q 2.20	Q 3.1	Q 3.2	Q 3.3	Q 3.4	Q 3.5	Q 3.6	Q 3.7	Q 3.8	Q 4.1	Q 4.2	Q 4.3
26	Tripoli	b	-	-	b		-	a	b	a	-	b	b	b	a	b	d	a
27	Tripoli	b	-	-	b		-	a	b	b	-	b	b	c	a	b	a	a
28	Tripoli	a	a	-	b		-	a	a	a	-	a,b,c	b	c	c,d	a	d	a
29	Tripoli	b	-	-	b		-	a	b	a	-	b,c,e	c	c	a	a	d	a
30	Tripoli	a	a	-	b		-	a	b	a	-	b	c	b	c	b	a	a
31	Tripoli	b	-	-	b		-	b	b	b	-	b	c	c	c	b	d	a,b
32	Tripoli	a	a	-	a	a	c,d	a	b	b	-	a	a	a	a	c	b,c	a,b
33	Tripoli	b	-	-	b		-	a	a	a	-	a,b	b	b	a	a	d	a
34	Tripoli	a	a	kitchen	b		-	a	a	a	-	a	c	c	a	b	c	a,b
35	Tripoli	b	-	-	b		-	a	b	a	-	a	a	b	a	b	d	a
36	Tripoli	a	a	-	a	c,d	b,e	a	b	b	-	b,c	b	c	a	a	b,c	a,d
37	Tripoli	a	a	-	a	c	c	a	a	a	-	b	b	c	a	a	b,c	a
38	Tripoli	b	-	-	a	a	0	a	a	a	-	a,b	c	c	a	b	d	b
39	Tripoli	a	a	-	a	b	a	a	a	a	-	a	c	c	a	a	c	b
40	Tripoli	b	-	-	b		-	a	a	b	-	b,c	a	c	a	b	b	c
41	Tripoli	a	a	-	b		-	a	a	a	-	b,c	c	c	a	a	b,d	a
42	Tripoli	a	a	-	b		-	a	a	a	-	a,b,c	c	c	a	a	b,d	a
43	Tripoli	a	b	-	a	a,c	a	a	a	a	-	0	c	b	c	b	d	b
44	Tripoli	b	-	-	a	c	c,d	a	a	a	-	b	c	c	a	c	c	a
45	Tripoli	b	-	-	a	a,d	e	a	a	a	-	a,b	c	c	a	a	b,c,d	c
46	Tripoli	b	-	-	b		-	a	a	a	-	b	b	c	a	a	d	c
47	Tripoli	a	a	-	b		-	a	a	a	-	a	b	c	c	b	a	b
48	Tripoli	a	a	-	b		-	a	b	b	street light	b	b	c	0	b	b,d	a,e
49	Tripoli	b	-	-	b		-	a	a	a	-	c	b	b	c	b	b,c	a,b

Table B.6 cont'd

Case #	City	Q 4.4	Q 4.5	Q 4.6	Q 4.7	Q 5.1	Q 6.1	Q 6.2	Q 6.3	Q 6.4	Q 6.5	Q 6.6	Q 6.7	Q 6.8	Q 6.9	Q 6.10	Q 6.11	Q 6.12
26	Tripoli	a,b	c	c,d,e	a	d	c	a	b	a	b	a,b,c,d		a	b	b	b	a,b
27	Tripoli	b,d	b	a	c	d	c	a	c	a	0	a,b,c		a	a	b	b	c,d,e
28	Tripoli	c	c	d	c	a	c	a	b	a	b	a,b,c		a	a	b	b	b,c
29	Tripoli	a	c	b,d	b	d	c	a	b	a	b	a,b,c		a	a	b	c	b,c,d
30	Tripoli	b	b,c	c,f	b	b	b	a	b	a	b	a,b,c,		a	a	b	b	b,c
31	Tripoli	b	c	b,e	b	c	c	a	c	b	c	0		0	0	0	c	b,c
32	Tripoli	b	a,b,c,d	c--	a	c	c	b	c	0	0	a,b,c		a	b	0	c	c
33	Tripoli	c	c	b,d	c	0	c	a	b	a	b	a,b,c		a	b	0	b	b
34	Tripoli	b,c	b	b,c,d,e,f	c	d	c	a	c	b	b	a,b,c		a	a	b	c	b,c
35	Tripoli	b,c	c	b,c,d,e	b,c	a	c	a	b	b	0	a,b,c		a	b	b	b	b,c,d
36	Tripoli	b,c	b,c	b,f	b	a	c	b	b	c	0	a,b,c		a	0	b	c	b,c
37	Tripoli	b,c	b,c	b,f	b	a	b	a	b	b	a	a,b,c		0	0	0	b	a,b
38	Tripoli	e	b	b	a	c	c	a	b	a	b	a,b,c		a	b	b	c	e
39	Tripoli	b	b	b	c	d	c	b	c	a	0	a,b,c		a	b	b	c	a,b
40	Tripoli	c	a	d	a	d	c	a	b	a	b	a,b,c		a	b	b	c	c,d,e
41	Tripoli	b,c	d	b,c	b	a	c	a	a	a	a	a,b,c		0	a	b	c	a,b,c,d
42	Tripoli	c	b	a,b,c,d,e	0	a	c	a	a	b	0	a,b,c,e		a	b	b	b	a,b,c,d
43	Tripoli	b	a	f	b	0	c	a	a	a	b	a,b,c		0	0	0	c	b,c
44	Tripoli	b,c	a	f	a	a	c	a	b	b	0	a,b,c		a	a	b	b	b,c
45	Tripoli	d,f	b,c,e	a,b,c,e,f,h	c	d	b	a	a	a	b	a,b,c		b	b	c	c	c,d,f
46	Tripoli	c	a	d	a	a	c	a	c	b	0	a,b,c		0	0	b	b	0
47	Tripoli	b	c,f	g,h	b,e	a	a	a	c	a	b	a,b,c		0	0	b	c	0
48	Tripoli	a,c	b,c	a,c,e	b,c	a	c	a	b	c	0	a,b,c		a	a	b	b	b,c
49	Tripoli	b,c	a,b	c,d,e,f	b,c	d	c	a	b	b	0	a,b,c		a	a	b	c	a,b,c,d

Table B.6 cont'd

Case #	City	Q 6.13	Q 6.14	Q 6.15	Q 6.16	Q 6.17	Q 6.18	Q 6.19	Q 6.20	Q 6.21	Q 7.1	Q 7.2	Q 7.3	Q 7.4	Q 7.5	Q 7.6
26	Tripoli	c	a	a	b	a	-	b		-	a	a	a	-	a	c
27	Tripoli	a	a	a	a	b	b	b		-	a	a	a	-	a	c
28	Tripoli	b,d	b	-	-	a	-	b		-	a	a	a	-	a	c
29	Tripoli	c	b	-	-	a	-	0		-	a	a	a	-	a	c
30	Tripoli	b,c,d	a	a	b	b	b	a	c	d	a	a	a	communication sys	b	c
31	Tripoli	b,d	a	a	a	b	b	b		-	a	a	a	-	a	c
32	Tripoli	b,c	a	a	b	b	b	a	b,c	b	a	a	a	-	a	c
33	Tripoli	a	a	a	b	a	-	b		-	a	a	a	-	a	b
34	Tripoli	b	a	0	b	a	-	a	b,c	b,c	a	a	a	garaj	0	c
35	Tripoli	c,d	a	a	b	b	b	a	b,c	b	a	a	a	-	a,c	b
36	Tripoli	b,d	b	-	-	b	a	b		-	a	a	a	-	a	c
37	Tripoli	b,d	b	-	-	b	b	b		-	a	a	a	-	a,b	c
38	Tripoli	c	b	-	-	a	-	a	c	c	a	a	a	-	a	c
39	Tripoli	a,c	b	-	-	a	-	b		-	a	a	a	-	a	c
40	Tripoli	a,b	b	-	-	a	-	b		-	a	a	a	-	a	c
41	Tripoli	c,d	b	-	-	b	a	b		-	a	a	a	-	a	b
42	Tripoli	b	b	-	-	b	b	b		-	a	a	a	-	a,c	c
43	Tripoli	a	b	-	-	b	b	b		-	a	a	a	-	a	c
44	Tripoli	b,c,d	b	-	-	b	a	a	b	f	a	a	a	-	a	c
45	Tripoli	c,d	b	-	-	a	-	b		-	a	a	a	gaz	a	c
46	Tripoli	a	b	-	-	b	b	b		-	a	a	a	-	a,b	c
47	Tripoli	0	b	-	-	a	-	a	d	b	a	a	a	-	a	c
48	Tripoli	d	b	-	-	b	b	b		-	a	a	a	-	a,c	c
49	Tripoli	b,c,d	a	a	0	b	b	a	c	b	a	a	a	-	a,b	c

Table B.6 cont'd

Case#	City	Q 7.7	Q 8.1	Q 8.2	Q 8.3	Q 8.4	Q 8.5	Q 8.6	Q 8.7	Q 8.8	Q 8.9	Q 8.10	Q 8.11-1	Q 8.11-2	Q 8.11-3	Q 8.11-4	Q 8.11-5
26	Tripoli	c	a	a	a,d	c,d	a,c,d	d,e	d,h	f,g	c	b	c	b	c	c	b
27	Tripoli	c	b	a	b	d	a,d,j	d	h,m	b	c	b	b	c	a	c	d
28	Tripoli	b	a	a	b,d	c,d,e	d,k,l	e,m	d,h	e	a	a,b	a	d	a	b	c
29	Tripoli	b	b	b	b	c,d	d,j,k	d	g,f	h	c,d	b	a	c	b	c	b
30	Tripoli	c	b	a	b,c,d	d,e	a,d,m	d	d,l	a,d	c	b	b	a	b	c	b
31	Tripoli	c	a	a	a,b	d,e	a,j,m	d	a,d	j	c	b	a	a	b	a	d
32	Tripoli	c	a	b	a,b,c	e	n	e	c,d	h	c	b	b	a	a	a	a
33	Tripoli	b	a	a	b	a,d	d,k	m,n	d,f,n	f,g	c	b	b	c	b	c	c
34	Tripoli	c	a	a,b	a,d	b,c,d	d,j,k	a,k	a,g,h	b,e	c	a,b	b	d	b	c	c
35	Tripoli	b	a	a	a,d	b,c,d	a,d	a,e,h	h,I,m	I,j	c	b	c	c	a	b	c
36	Tripoli	c	b	a	a,b,d	c,d	k,m	d	d,h	e	c	b	b	a	d	b	a
37	Tripoli	c	a	a,b	b,c,d	d,e	a,d,j	d,e	d,f,l	a,d,k	c	b	b	b	b	c	b
38	Tripoli	c	a	b	a	d	l	0	o	0	c	b	b	c	a	c	a
39	Tripoli	c	a	a	a	c	d,j,k	q	p	h,n	a	a	a	b	a	c	c
40	Tripoli	c	a	a	b	c	d	d	q	h	b	b	b	c	c	c	c
41	Tripoli	b	a	a	b	c,d	l,m	j	h	h	c	b	b	b	a	b	c
42	Tripoli	c	a	b	d	a,b,c,d,e	d,j	j	h	c	c	a	b	a	b	b	a
43	Tripoli	c	a	b	a,b,d	d	m	j	h,r	h	c	a,b	b	b	b	d	b
44	Tripoli	c	a	a	a,b,c,d	b,d	a,b,k.j	q	a,h,p	0	b,d	b	b	b	c	b	c
45	Tripoli	c	b	a,c	a,b,c,d	a,d	p	j	s	o	a	a	b	a	a	a	a
46	Tripoli	c	a	b	a	d	q	s	j	p	b,c	b	a	c	c	c	c
47	Tripoli	c	c	a	b,d	f	f	m	j	p	b	b	a	c	a	a	a
48	Tripoli	c	a	b	b,d	b,d	a,d,f,g,m	e,n	h	h,q,r	c,d	a,b	c	b	d	a	c
49	Tripoli	c	a,b	a,b	a,b,c,d	b.c.d	c,d	a,b	a,d,g,o	b,e	b	b	b	c	b	b	b

Table B.6 cont'd

Case #	City	Q 8.11-6	Q 8.11-7	Q 8.11-8	Q 8.11-9	Q 8.11-10	Q 8.11-11	Q 8.11-12	Q 8.11-13	Q 8.11-14	Q 8.11-15	Q 8.11-16	Q 8.11-17
26	Tripoli	a	a	c	c	b	a	a	b	a	f	f	e
27	Tripoli	a	a	a	b	b	a	b	a	a	e	e	e
28	Tripoli	a	b	b	b	b	a	a	b	a	h	h	h
29	Tripoli	a	a	c	c	c	a	a	b	a	e	e	e
30	Tripoli	a	b	b	c	b	a	b	b	b	e	f	e
31	Tripoli	a	a	b	c	c	b	a	d	b	f	f	f
32	Tripoli	a	a	c	a	a	c	a	a	b	e	f	f
33	Tripoli	a	a	b	c	b	a	a	b	c	f	f	f
34	Tripoli	b	b	c	c	c	a	d	a	a	e	e	e
35	Tripoli	b	b	b	a	b	b	a	a	b	e	e	e
36	Tripoli	a	a	b	b	b	d	a	d	b	f	f	g
37	Tripoli	a	b	b	c	b	b	b	a	b	e	e	e
38	Tripoli	a	a	a	b	a	b	c	b	c	e	f	e
39	Tripoli	a	a	a	b	a	a	b	b	a	e	e	g
40	Tripoli	b	b	a	c	c	b	b	c	b	f	f	g
41	Tripoli	a	a	a	c	d	a	a	a	a	e	f	f
42	Tripoli	a	a	a	a	a	a	a	a	a	e	e	e
43	Tripoli	b	b	d	c	b	a	a	d	b	f	g	f
44	Tripoli	b	c	c	c	b	c	b	a	a	e	e	f
45	Tripoli	a	a	d	b	b	b	b	a	a	f	f	f
46	Tripoli	a	a	d	b	b	c	b	d	b	f	e	e
47	Tripoli	a	a	a	c	b	b	a	d	b	e	e	f
48	Tripoli	a	a	b	c	c	a	a	a	a	f	e	h
49	Tripoli	b	b	c	c	b	b	c	a	b	e	e	e

Table B.6 cont'd

Case #	City	Q 8.11-18	Q 8.11-19	Q 8.11-20	Q 8.11-21	Q 8.11-22	Q 8.11-23	Q 8.11-24	Q 8.11-25	Q 8.11-26	Q 8.11-27	Q 8.11-28
26	Tripoli	f	e	g	g	g	e	e	f	f	g	f
27	Tripoli	e	h	g	g	e	e	e	g	f	g	g
28	Tripoli	h	h	h	h	h	h	h	h	h	h	h
29	Tripoli	f	e	g	f	g	e	e	f	f	g	g
30	Tripoli	e	e	e	e	f	e	f	g	e	f	f
31	Tripoli	e	e	e	e	f	e	e	f	f	h	f
32	Tripoli	c	c	c	c	e	c	c	f	f	f	f
33	Tripoli	e	f	f	f	g	f	e	f	f	g	f
34	Tripoli	e	e	e	e	e	e	e	h	e	g	e
35	Tripoli	e	e	e	f	e	f	f	f	e	g	f
36	Tripoli	g	h	f	f	h	e	e	h	f	h	f
37	Tripoli	e	e	e	e	e	e	f	f	e	f	f
38	Tripoli	e	e	g	f	f	e	e	f	f	g	e
39	Tripoli	e	e	e	e	g	e	e	e	f	e	e
40	Tripoli	e	g	f	f	g	e	f	f	f	g	f
41	Tripoli	e	e	f	f	g	e	h	f	f	e	g
42	Tripoli	e	f	e	f	e	e	e	f	f	f	f
43	Tripoli	h	f	f	f	h	e	e	f	f	h	f
44	Tripoli	e	e	e	f	e	e	e	e	e	f	e
45	Tripoli	f	f	f	h	f	e	e	e	f	g	g
46	Tripoli	e	e	f	e	e	e	e	e	e	e	e
47	Tripoli	e	e	e	e	h	e	e	f	f	h	a
48	Tripoli	e	e	e	e	e	e	e	g	f	g	g
49	Tripoli	e	e	e	e	e	e	e	e	e	g	e

Table B.7 Respondees of Ghadames city (Desert area).

Case #	City	Q 1.2	Q 1.3	Q 1.4	Q 2.1	Q 2.2	Q 2.3	Q 2.4	Q 2.5	Q 2.6	Q 2.7	Q 2.8	Q 2.9	Q 2.10	Q 2.11	Q 2.12	Q 2.13	Q 2.14
50	Ghadames	b	b	b	c	a	b	c	b	b,c,d		c	c	a,b,c	a	a	a,b,g	d
51	Ghadames	c	c	0	c	b	c	c	a	b,c,d		c	c	a,b,c	b	-	a,d,g	a,d
52	Ghadames	a	a	b	c	a	b	c	b	b,d		c	c	c	a	a	a,b	d
53	Ghadames	c	b	c	c	a	a	c	b	b,c,d		c	d	a	b	-	a	d
54	Ghadames	c	c	a	c	a	b	b	b	b,c		c	c	c	a	a	a	d
55	Ghadames	d	b	c	c	a	b	c	b	b,c,d		c	b	a	b	-	a,d	a,d
56	Ghadames	c	c	a	c	c	c	c	b	b,d		d	c	a,b,c	a	a	a,b,g	a,d
57	Ghadames	b	c	a	c	b	b	c	b	a,b,c,d		d	d	a	a	a	a,g	d
58	Ghadames	a	b	b	c	a	b	b	b	b,c		c	c	b	b	-	a,b	a,d
59	Ghadames	c	c	a	c	a	b	0	b	b,c,d		c	c	a,b,c	b	-	a,g	d,g
60	Ghadames	a	c	b	c	a	b	c	b	b,d		0	0	0	b	-	a	d
61	Ghadames	b	c	b	c	a	a	c	c	b,c,d		d	d	c	a	a	a,b,d	a,d
62	Ghadames	c	c	0	c	a	c	c	b	b,d		c	c	0	b	-	a,b,d	d,g
63	Ghadames	b	b	b	c	a	c	c	b	b,d		0	0	0	b	-	a,b,d,e	0
64	Ghadames	b	b	d	b	a	b	c	b	b,c,d		c	c	b	b	-	a,b	d,g
65	Ghadames	c	b	b	c	a	b	c	c	b,c,d		b	c	b	a	a	a,b	d,g

Table B.7 cont'd

Case #	City	Q 2.15	Q 2.16	Q 2.17	Q 2.18	Q 2.19	Q 2.20	Q 3.1	Q 3.2	Q 3.3	Q 3.4	Q 3.5	Q 3.6	Q 3.7	Q 3.8	Q 4.1	Q 4.2	Q 4.3
50	Ghadames	a	a	-	b		-	a	b	a	-	d	b	b	a	a	b,d,e	a
51	Ghadames	a	a	-	b		-	a	b	b	-	e	b	c	a	a	b,e	a
52	Ghadames	b	-	-	b		-	a	b	b	-	d	b	b	a	a	b,d	a
53	Ghadames	b	-	-	a	d	c	a	b	b	-	0	b	b	c	a	b,d	a
54	Ghadames	b	-	-	b		-	a	b	b	-	0	c	c	b	a	b	a
55	Ghadames	b	-	-	b		-	a	b	b	-	d	b	b	a	a	b,c,d	a,b
56	Ghadames	b	-	-	b		-	a	b	b	-	d	b	b	a	a	b,d	a
57	Ghadames	b	-	-	b		-	a	b	b	-	d	a	b	a	a	b,d	b
58	Ghadames	b	-	-	a	b,c	b,c	a	b	b	-	d	b	b	a	a	b,d	b
59	Ghadames	b	-	-	b		-	a	b	b	-	0	b	b	a	a	b,d	a
60	Ghadames	b	-	-	b		-	a	b	b	-	a,d	c	c	a	a	b,d	a,b
6a	Ghadames	b	-	-	b		-	a	b	b	-	0	0	0	0	a	b	a
62	Ghadames	a	a	-	a	c	a	a	b	b	-	0	c	c	c	a	b,c,d	a,b
63	Ghadames	b	-	-	a	b,c	b,c	a	b	b	-	d	c	c	a	a	b,c,d	a
64	Ghadames	b	-	-	a	c	b	a	b	b	-	0	b	c	0	b	b,c,d	c
65	Ghadames	b	-	-	b		-	a	b	b	-	0	b	b	0	a	b,c,d	c

Table B.7 cont'd

Case #	City	Q 4.4	Q 4.5	Q 4.6	Q 4.7	Q 5.1	Q 6.1	Q 6.2	Q 6.3	Q 6.4	Q 6.5	Q 6.6	Q 6.7	Q 6.8	Q 6.9	Q 6.10	Q 6.11	Q 6.12
50	Ghadames	a,b	a,c	a,b,c,e,f	b,d	a	c	a	b	b	b	a,b,c,d		a	b	b	b	b,c,d,e
51	Ghadames	a	b	c	a	a	c	b	b	a	b	a,b,c		a	a	b	b	b
52	Ghadames	a	b,c	a,b,c,d,e,f	a,b	a	c	a	b	b	b	a,b,c		a	b	b	a	b,c,d,e,f
53	Ghadames	a	b,c	c,e,f	a,b	d	c	b	c	b	b	a,b,c,d		b	b	4	0	b,c,e,f
54	Ghadames	a	b,c	b,c,e	a,b	a	c	a	b	b	b	a,b,c		a	b	b	a	b,c,e
55	Ghadames	a,b	b,c	a,b,c,e,f	b	d	c	a	b	b	b	a,b		a	a	b	a	b,c,e,f
56	Ghadames	a,b	b,c	a,b,c,e,f	a,b	a	c	c	b	b	a	a,b,c		a	b	4	b	a,b,c,d,e,f
57	Ghadames	a,b	a,c	d	a,b	a	c	b	b	a	b	a,b,c,d		a	b	b	a	b
58	Ghadames	a,b	a,b,c	a,c,e,f	b	d	c	a	b	b	8	a,b,c		a	a	b	a	b,c,d,e,f
59	Ghadames	a	c	c,d,e	a	d	c	a	b	b	b	a,b,c,d		a	b	b	o	b,e,f
60	Ghadames	b	c	a,b	b	a	c	a	b	b	a	b,c		0	0	0	a	b
6a	Ghadames	a	a,c	a,b,c,d,e,f	b	a	c	a	b	0	b	a,b,d		a	c	b	b	b,c,e,f
62	Ghadames	a,b	c	b,e,f	b	e	c	0	c	b	b	a,b,c		a	b	0	b	b,c,e,f
63	Ghadames	a	b,c	a,b,c,d,e,f	b	0	c	a	b	a	b	a,b,c		0	0	0	b	c,e
64	Ghadames	b,c	a,c	a,c,d,f	b	a	c	a	b	b	b	a,b,c,d		a	a	b	c	b,c,d
65	Ghadames	b,c	a,c	a,c,d,e,f	b	a	c	a	b	b	b	a,b,c		a	a	b	c	b,c,d

Table B.7 cont'd

Case #	City	Q 6.13	Q 6.14	Q 6.15	Q 6.16	Q 6.17	Q 6.18	Q 6.19	Q 6.20	Q 6.21	Q 7.1	Q 7.2	Q 7.3	Q 7.4	Q 7.5	Q 7.6	Q 7.7	Q 8.1
50	Ghadames	c	b	-	-	a	-	a	d	e	a	a	a	-	a	c	c	a,b
51	Ghadames	0	a	a	b	b	b	a	b	a	a	a	a	-	a	a	0	a,b
52	Ghadames	c	a	a	b	a	-	b		-	a	a	a	-	a	c	c	a,b
53	Ghadames	c	b	-	-	b	a	a	b	d	a	a	a	-	a	c	c	a,b
54	Ghadames	c	b	-	-	a	-	a	b	c	a	a	a	-	a	c	c	a,b
55	Ghadames	c	b	-	-	b	b	a	c	d	a	a	a	-	a	c	c	a,b
56	Ghadames	c	b	-	-	a	-	b		-	a	a	a	-	a	c	c	b
57	Ghadames	c	b	-	-	b	b	b		-	a	a	a	-	a	b	c	b
58	Ghadames	c	b	-	-	b	b	b		-	0	0	0	-	0	0	0	a,b
59	Ghadames	c	b	-	-	a	-	a	b	0	a	a	a	-	a	c	c	a
60	Ghadames	c	b	-	-	a	-	a	b	b	a	a	a	-	a	c	b	a
6a	Ghadames	c	a	-	-	a	-	b		-	a	a	a	-	a	c	c	a,b
62	Ghadames	c	b	-	-	0	-	a	c	d	a	a	a	-	a	c	c	a
63	Ghadames	c	b	-	-	a	-	a	b	b,c	a	b	a	-	a,c	c	c	a,b
64	Ghadames	b,d	0	-	-	b	b	b		-	a	a	a	-	a,c	c	c	a
65	Ghadames	b	b	-	-	b	b	b		-	a	a	a	-	a,c	b	c	a

Table B.7 cont'd

Case #	City	Q 8.2	Q 8.3	Q 8.4	Q 8.5	Q 8.6	Q 8.7	Q 8.8	Q 8.9	Q 8.10	Q 8.11-1	Q 8.11-2	Q 8.11-3	Q 8.11-4	Q 8.11-5
50	Ghadames	a,b	a,b,c	a,c,d,e	a,d	d,h	a,i	l	c	0	c	a	a	c	d
51	Ghadames	a	b	c,d,e,f,g	a,d,j	o	d	b	c	b	a	a	a	b	c
52	Ghadames	b	a,b,d	a,b,c,d,g	d,f,k	d	b,c,d,h	b,c,e	c	a,b	c	b	a	c	c
53	Ghadames	a,b	a,b	c,d,e,f,g	a,c,d,f,g	c,d	c,d	e	a,c	a,b	b	a	a	d	d
54	Ghadames	a	a,b,c	b,c,d,e,f,g	a,d	d,h	c,d	e	c	a,b	b	b	a	a	a
55	Ghadames	a	a,b,c,d	c,d,e,g	d,f	d	d	0	b	b	b	b	a	d	a
56	Ghadames	b	a,b	a,c,d,e,f,g,h	c,d,f,g	b,c,d,h	b,c,d	a,b,c,e	c,d	a,b	b	a	a	c	a
57	Ghadames	b	b	b,d,g	d,k	a,d	d,h,m	b	c	b	c	c	b	c	d
58	Ghadames	a	a,b,d	a,b,c,d,g	f	d	g,h	b	b	a,b	c	b	c	c	c
59	Ghadames	b	b	a,b,c,d,e,f	a,c,g	d,h	d,f,g	b,d	c	b	c	a	b	c	d
60	Ghadames	a	b	b,d,g	0	0	0	0	c	a	b	b	b	d	a
6a	Ghadames	a	a,b,d	b,c,d,e,g	d,f	d,h,p	d,g,m	c,e,f	b	b	b	c	c	c	a
62	Ghadames	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	Ghadames	c	a,b	a,b,c,d,e,f	a,d,g	d	d	c	0	a,b	b	b	b	b	d
64	Ghadames	a	a,b,c	b,c,d	m,o	d	f,g	f,m	c	b	c	a	c	c	a
65	Ghadames	a	b	d	f,h,o	d,h	d,g	m	c	a,b	c	a	a	c	b

Table B.7 cont'd

Case #	City	Q 8.11-6	Q 8.11-7	Q 8.11-8	Q 8.11-9	Q 8.11-10	Q 8.11-11	Q 8.11-12	Q 8.11-13	Q 8.11-14	Q 8.11-15	Q 8.11-16	Q 8.11-17
50	Ghadames	b	b	d	c	b	b	b	a	a	e	e	e
51	Ghadames	b	b	d	b	c	a	a	b	a	f	g	f
52	Ghadames	c	c	a	c	c	a	a	a	a	e	e	e
53	Ghadames	a	a	a	c	c	a	a	a	a	e	e	e
54	Ghadames	b	b	a	c	b	a	a	a	a	e	e	e
55	Ghadames	c	c	a	c	c	a	a	a	a	e	e	e
56	Ghadames	b	b	a	c	c	b	a	a	a	h	h	h
57	Ghadames	c	d	d	c	c	d	b	b	b	f	f	e
58	Ghadames	c	b	b	c	c	a	a	a	a	e	e	e
59	Ghadames	c	b	d	c	c	a	b	a	a	f	f	e
60	Ghadames	a	b	a	c	b	a	a	a	a	f	f	g
6a	Ghadames	c	c	b	c	b	a	a	b	a	e	e	e
62	Ghadames	0	0	0	0	0	0	0	0	0	0	0	0
63	Ghadames	a	a	a	d	d	a	a	a	a	f	f	f
64	Ghadames	b	c	a	c	c	b	a	a	b	e	f	f
65	Ghadames	d	b	a	c	c	a	a	a	a	e	f	e

Table B.7 cont'd

Case #	City	Q 8.11-18	Q 8.11-19	Q 8.11-20	Q 8.11-21	Q 8.11-22	Q 8.11-23	Q 8.11-24	Q 8.11-25	Q 8.11-26	Q 8.11-27	Q 8.11-28
50	Ghadames	e	h	e	e	e	e	e	f	f	f	g
51	Ghadames	f	g	e	f	h	g	f	g	f	g	e
52	Ghadames	e	e	e	e	e	e	e	g	g	g	g
53	Ghadames	e	h	f	f	f	e	e	g	f	g	f
54	Ghadames	c	e	e	e	e	e	e	f	e	f	g
55	Ghadames	e	e	e	e	h	e	e	e	e	g	e
56	Ghadames	h	h	h	h	h	h	h	h	h	h	h
57	Ghadames	f	h	f	f	h	f	e	e	f	f	f
58	Ghadames	e	e	e	e	e	e	e	f	f	g	f
59	Ghadames	e	h	e	e	h	e	e	f	f	g	g
60	Ghadames	f	e	f	g	e	e	f	f	f	g	f
6a	Ghadames	e	e	e	e	f	e	e	e	e	e	f
62	Ghadames	0	0	0	0	0	0	0	0	0	0	0
63	Ghadames	f	h	e	e	e	e	f	g	g	g	g
64	Ghadames	e	e	e	e	e	e	e	f	f	f	e
65	Ghadames	e	e	e	e	e	e	e	f	f	e	e