Designing a Dwelling Unit in Tripoli – Libya by Using Sustainable Architectural Principles

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Abstract

The modern urban built environment is considered the most energy consuming sector as new forms of construction and services have been applied without complete understanding of their side affects. Therefore, buildings are now dependant mostly on the mechanical equipment to provide comfort. As a consequence, this has led to, firstly, many ecological problems such as the over and misuse of the energy resources, pollution and associated ill-health. Secondly, design without consideration of the local climatic conditions, which can also contributes to loss of identity related specifically to every climatic region, resulting in buildings having the same features all around the world regardless of the cultural, social and physical differences.

In Libya, issues related to this subject are neglected or rarely studied. This paper, therefore, aims to highlight some architectural solutions that contribute to reducing building's energy consumption as well as creating an architecture related to the local environment and place.

It provides an overview of the general architecture principles and a study of the components of environmental design and the architectural treatment for this climatic zone. A model of a house for Libyan family life will be shown in order to give an idea of the application of some sustainable architectural principles taking into consideration the physical, cultural and social differences.

Keywords: Architectural design, Housing, Hot regions, Sustainable architecture, Tripoli- Libya.
1 Introduction

Based on the frightening facts that are emerging about global warming and the other effects of fossil fuel burning, it is generally accepted that buildings of the future should be in better harmony with their environment and should integrate the local influences of the specific climatic regions they are built in. Prior to the modern era, architects and builders had little else other than local materials and natural resources.

Contemporary architecture reveals its similarity in almost every part of the world without any consideration to regional characteristics, in contrast to vernacular architecture which is almost climatically appropriate, where architects and builders traditionally had to design with respect to nature, local climate and materials. They designed their buildings carefully taking in consideration thermal properties of materials and the availability of local resources.

This paper presents passive climatic solutions in vernacular and contemporary architecture. In addition, it provides the principles of sustainable building design and the applications of these principles in designing a dwelling unit in Tripoli- Libya.

2 Sustainable Architecture

The concept of sustainable architecture appeared more or less at the same time as the evolution of the concept of sustainable development. Cofaigh et al., (1996) described sustainable building as those buildings that have minimal detrimental effects on the natural environment, on their immediate surroundings and on the wider regional and global setting. On the other hand, Sherlock (1991: 293) emphasises reductions in the consumption of energy as a step towards sustainability, and argues that the best way for this is "...to reduce our need to travel ... to live in compact cities where everything is close at hand". McDonough (2000) stated that sustainable design is the conception and understanding of environmentally sensitive and responsible expression as a part of the evolving matrix of nature. Roaf et al., (2005) defined the eco-house as a house that is closely connected to the site, society, climate, region and planet.

Accordingly, sustainable architecture can be defined as an architecture that meets human needs and has minimum impact on the natural environment. It is a planned effort at designing a built environment that is energy and ecologically considerate both internally and externally.

Housing has a greater influence upon global and social harmony than any other building type. The importance of the home as a starting point for successful communities has been emphasised by many authors such as Edwards (2000: 7) who stated that "...living in harmony with the environment has become an essential component of the design of homes and neighbourhoods in the third millennium". Gilkinson and Sexton (2007:2) cited the definitions from the sustainable housing project of the British Broadcasting Company (BBC) as
“Sustainable housing is a form of affordable housing that also incorporates environmentally friendly and community based practices. It attempts to reduce the negative impact that homes can have on the environment through choosing better building materials and environmental designs”. Furthermore, in Hilary Armstrong’s interpretation of sustainable housing “…housing is sustainable if everyone has the opportunity of access to a home that is decent; if it promotes social cohesion, well-being and self-dependence” (Edwards 2000: 2).

To achieve sustainable housing in any society, a central role should be given to the importance of sustainable housing. The home as a family unit addresses three different dimensions of well-being, economic development, social welfare and environmental welfare Figure 1.

![Diagram](source.png)

Figure 1: The three dimensions of sustainable housing (Source: Almansuri et al., 2009)

2.1 Sustainable housing design and environmental welfare

McMullan (2002:2) identifies that ‘the built environment is formed by buildings and structures that humans construct in the natural environment’. The impact of contemporary buildings has been highlighted by Enertia Building Systems (2006) as building is the second largest industry in the world after agriculture, and the pollution from heating and cooling of buildings cause the main damage to the environment and grow to be greater than that from cars. The environmental quality of the housing conditions of the residents and residential activities on the ecological system are the major concerns of a sustainable environmental perspective (Emhmed, 2005).

2.2 Sustainable housing design and social and culture welfare

Sustainable communities need to allow families to invest long periods of time in their neighbourhood (Edwards, 2000: 25). The cultural sustainability of housing can be associated to the preservation of housing heritage. The adaptation of residents to the natural habitat, how it changes with time and the progression of technology all reflect the physical form of housing. Therefore, the physical form becomes a part of culture itself. The arrangement of housing’s internal spaces is an outcome of socio-cultural values, customs and practices as well as enhanced
by housing legislation and roles. While the external forms of housing are the result of the availability of building resources, the climatic conditions, the construction capability of the residents and the aesthetics of specific communities over specific periods of time (Chiu, 2004: 5).

To achieve a sustainable and balanced society in housing requires a number of issues to be addressed such as social exclusion, crime and employment opportunities, as well as the usual priorities of energy and environmental performance. The transformation of a culture and the cultural identity of a place represent the lifestyle of a people, as well as the aesthetic and the artistic dimensions of culture. The conservation of residential buildings for aesthetic and heritage values enhances the continuation of a culture (Emhmed, 2005).

2.3 Sustainable housing from an economic perspective

Chiu (2004) stated that there are two fundamentals for housing to be economically sustainable:

1- The benefits to housing providers and producers must be more than or equal to the costs of housing production given the housing demand levels; and
2- The production and consumption processes must be within the environmental capacity to provide and absorb, given the mitigating technology.

The first relates to the operation of the housing sector and the ability of housing consumers to afford quality housing. The second refers to the recognition of the environmental gains and costs of housing activities. To enhance environmentally friendly consumption behaviour, it is essential to understand the central role of affordability, value and habits. Also to mitigate the environmental impact of housing activities and their implication for the financial viability of housing projects, it is important to know the development of technology, building materials and housing designs. (Chiu, 2004: 4).

3 Principles of the Sustainable Architecture

Sustainable design techniques are becoming increasingly important in building design. It should include all kinds of activities and processes that increase the capacity of people or the environment to meet human needs and improve the quality of human life. Many studies have been conducted on the principles of sustainable architecture. Almansuri et al., (2008) and Almansuri et al., (2009B) have summarised the main principles of sustainable architecture as follows:

- **Respect of the user's socio-cultural values.** The variety in architectural form can be seen as a result of a host of social, cultural, economic, physical, and technological variables (Rapaport, 1969);

- **Adapting the climatic conditions.** Sustainable buildings should respect and benefits from local climatic conditions and adapt to the daily and seasonal climatic changes;
- **Energy conservation.** Buildings consume energy not only in their operation, for heating, lighting and cooling, but also in their construction. Construction often requires large amounts of energy for processes ranging from moving earth to welding. Also transportation of the materials used in buildings.

- **The use of local materials.** Using the provided local material will significantly contribute in respecting and enhancing the environmental issues.

- **Respect the location (site conditions).** It is essential to consider that the building design and construction will not have a major effect on the site topography and the surrounding architectural style.

- **Water efficiency.** As water consumption is a serious ecological concern nowadays, it is very important to consider regulating its use and reuse inside and outside buildings.

- **The use of natural light and ventilation.** Building and window design that utilizes natural light and ventilation will lead to conserving electrical lighting energy, shaving peak electric loads, and reducing cooling and heating energy consumption.

- **The studied use of colours.** Colours have physiological and psychological impacts on the human body and in addition to its aesthetic values, it plays a significant role in reducing and reflecting the solar radiation on the external walls.

- **Treatments for ecological problems such as noise pollution.** Noise is like light in its effect on psychological human health, accordingly buildings should be protected from noise sources.

### 3.1 Principles of sustainable housing

Emhmed (2005) added to these general principles of sustainable architecture other sustainable design principles to housing, summarised as follows;

- The dwellings should be compact for less land use; to reduce motorised travel; effective thermal resistance for good microclimatic performance and efficient use of infrastructure and the protection of agricultural land.

- Compact form to provide high density, low-rise buildings.

- Dwelling should be flexible and adaptable to allow for future changes in family organisation.

- Spaces in the dwelling should be multi use at different times of the day.
3.2 Passive design techniques

Many references set the basic passive solar design techniques, for instance, U.S. Department of Energy (2004), Christensen (1994) stated that there are three basic types of passive solar design; direct gain, indirect gain, and isolated gain, and some others give two other types; composite and combined. All of these types explained by Christensen, (1994), Evans (2007) and Roaf et al., (2002) as follows:

- **Direct heat gain**

South facing glass admits solar energy into the house where it strikes directly and indirectly thermal mass materials in the house such as masonry floors and walls Figures 2, 3.

- **Indirect heat gain**

In indirect gain system, thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. There are two types of indirect gain systems:
  - Thermal storage wall systems (The Michell-Trombe wall Figures 4, 5 Evans (2007) explained that ‘Trombe wall’ or ‘ventilated accumulator wall’ achieves a favourable modification of the outdoor conditions in a series of steps, using different thermal properties of glass, surface absorbance and thermal mass in following layers of the construction.
  - Roof pond systems, using water pipes in the roof to heat water in morning and distribute heat in the night Figure 6.
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Figure 4 using the storage wall with close or open windows when necessary

Figure 5 using the Water pipes wall as thermal storage wall

Figure 6 using the water pipes in roof as thermal storage roof

- Isolated system

Isolated gain system has its integral parts separate from the main living area of a house. Examples are a sunroom (solar green house) and a convective loop through an air collector to a storage system in the house Figures 7. It employs a combination of direct gain and indirect gain system features.

Figure 7 direct heat gain to sunroom + indirect heat gain to living room
Combined system:

This system is more flexible than others because it depends on mixing more than one type Figure 8.

Composite system:

This kind depends on using one of the previous systems in addition to using mechanical systems to increase the benefits; it can be by mixing passive and active systems.

Source of Figures (2 to 8) the author after Panchyk (1984)

4 Tripoli- Location and Climate

Tripoli is located in Libya in the Mediterranean Sea. It is situated to the north of the Equator, at longitude 32.56 degree, and latitude 13.15 degrees east of Greenwich as shown in Figure 10 (Amer, 2007).

The weather in coastal region is characterised as hot, humid in the summer season and warm, rainy in the winter season (Shawesh, 2000).

The average humidity in this region is 58% to 65%, which in some years may increase in the summer June to the end of August (Emhemed, 2005).

The average temperature in Tripoli ranges from 30°C in summer to 8°C in winter and in the desert summer temperatures rise to over 50°C, but daytime winter temperatures range between 15 and 20°C, falling below zero at night (Arab.net 2002). The geography and climatic characteristics of Libya have had a
direct effect on housing and urban patterns. This requires special treatment to prevent undesired heat within external and internal housing spaces. In addition to climatic issues, socio-cultural issues have been the main factor dominating the Libyan housing design, the next part explains the importance of these factors in shaping Libyan housing.

4.1 Socio-cultural issues in Libyan society

Religion and socio-cultural values in Libya play a very important role in controlling and directing the behaviour of people within internal and external spaces. Many authors such as (Daza 1986, Shawesh 2000, Emhemed 2005, and Amer 2007) have raised the main Libyan socio-culture factors as follows:

- Privacy in Libyan society is a priority consideration within housing spaces.
- The separations age and sex and guests have long determined the roles played within the family.
- The extended family and elderly people have special and high status in the society.
- The way of life of the Libyan people has many aspects that should be considered in external and internal spaces.
- The way of preparing meals in the kitchen, the need to have storage places and the way of serving food to guests and family members requires more internal spaces.
- Safety and security are priorities to Libyan life.

Although all of these factors are well addressed in the Libyan local traditional architecture, most of them do not exist in contemporary houses. Emhemed (2005) explained that the effect of religion and social interaction on local architecture can be observed in two ways; Islamic religious teaching encourages privacy and modesty, and courtyard houses fulfilled this condition by providing an inward-looking house.

As stated previously the cultural sustainability of housing can be related to the preservation of housing heritage. On the other hand, although contemporary houses have lack of attention to socio-cultural demands and the accepted standards of life, it possesses many advantages such as more comfort, flexibility, privacy, area and possibilities to use new technology. Amer (2007) summarised the advantages of both house types in Table 1.

The opinions of residents and professionals in Tripoli in terms of future housing design have been investigated by Amer (2007) and Almansuri et al., (2009A+B). They identified recommendations for new house design as follows:

- The design should be suitable for geographic location and reflect the local identity and social-culture aspects;
- Combining the advantage of the traditional and contemporary designs;
- Take the courtyard concept as an essential element in design taking in consideration (using appropriate building materials, good proportion, appropriate position, provide movable cover to avoid excess summer heat and winter rain, also, solarium house can be a good solution and a courtyard can be used as a solarium when using moveable covered windows);
- Flexibility and harmony suitable for modern furniture;
- Avoid large windows and provide balconies to provide shading, and for privacy reason, a big part of the balcony can be covered by musharbia.
- Use local building materials with modern technology and new insulation materials;
- Use light colours, which reflect the sun-rays;
- Avoid high rise building;
- The contribution of users in the design process is important to fill the gap between designers and users; and
- Pay attention to economic factors and cost of materials.

<table>
<thead>
<tr>
<th>Advantages of the courtyard</th>
<th>Advantages of contemporary houses</th>
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<tr>
<td>- It provides air movement ventilation;</td>
<td>- They offer different spaces for varied functions such as Arabic and western salons;</td>
</tr>
<tr>
<td>- It provides natural light and shaded area;</td>
<td>- The superior quality of finishing;</td>
</tr>
<tr>
<td>- It provides the privacy, particularly from streets, neighbours and visitors compared with contemporary housing;</td>
<td>- The good arrangement of interior space;</td>
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<tr>
<td>- It is a quiet place, which offers good protection against the passage of heat and the street noise;</td>
<td>- More privacy is offered in terms of separation between brothers and sisters;</td>
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<tr>
<td>- It is a space for family gathering after sunset, it is also used as area for activities during wedding and meeting friends;</td>
<td>- There is greater potential for future extension and adoption than in traditional housing;</td>
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<td>- It allows to children greater safety in terms of their playing areas, where their mother can easily watch them; and</td>
<td>- They are more structurally stable.</td>
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<tr>
<td>- It provides a good relationship within extended families.</td>
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4.2 Housing and building laws in Tripoli

To design a dwelling unit in Tripoli, it is important to understand the building laws in this area, Emmed (2005) clarified that the main components of planning and building legislation that affect housing projects in Libya are land use, streets' width, building height, site coverage and zoning regulations. He translated the Libyan planning and building Act 1969 into English. In this paper, the codes related to private housing that affect the model design are summarized as follows;

Modern legislation requires housing units to stand separate from one another across a specified minimum distance. Buildings should have the following dimensions:

- Yards and setback requirements; The Libyan Planning and Building Act 1969 illustrates the different distances of these setback requirements (front, side and rear), particularly in residential areas, according to the land-use and density of the area as determined in the master plan (the designed model located in zone R2 – single-family residential district low density, 500m² land area).
- Building height limits and number of storeys; maximum number of storeys, according to zoning type area.
- The thickness of the external walls should not be less than 25 cm on the ground floor and 20 cm for the upper floors; and the thickness of the internal walls inside the flats should not be less than 20 cm.

4.3 The application of sustainable methods in private dwellings in Tripoli

From the previous discussion about the new housing design recommendations, this part will provide a model architectural design for a single Libyan family house to meet the following contents;

- Family size more than 6 persons (The average number of Libyan family);
- The land area is about 500m² (suggested by the building laws - council);
- Respect the building laws in Tripoli;
- The model will not seek to provide a detailed design (form and elevations), it is to provide a flexible, applicable aide which can be amended and adapted according to site location, users needs and the creativity of the architect.

Next figures show the model design that includes the main sustainable houses principles for Libyan families in Tripoli. It incorporates vernacular solutions with new technology. More detailed discussion shows in section 4.3.1.
Figure 11: explains the main design concepts

Figure 12: the construction method

Figure 13: Ground floor plan - explains the functions and design concept
Key:
1. Terrace can be change to room in future
2. Living room, has axes to the green house and the courtyard
3. Solarium house space as an extra space to living room
4. Rain water storage
5. Staircase entrance to the family area, basement and the first floor
6. Kitchen and toilets gathered and located in the west side
7. Courtyard in the centre of the house
8. These spaces can be used for Arabic salon guest room, guest bedroom or as an office, also in future when the family leave the first floor for the son or for rent, it can be used as a bed rooms
9. Guest area can be furnished by western salon and dining room
10. This space can be used as an extra toilet or storage area
11. Car parking can be located in the West and shaded by trees

Figure 14 first floor plan and it can be basement plan – explains the flexibility in using the floor for the main family 1 and split it when use it by a new family 2.
Figure 15 shows the roof plan with an explanation of the main features.

4.3.1 Design concepts discussion-how the design meets the criteria

According to the information given in the previous section, and the criteria of sustainable housing, the model concept is designed to meet these criteria in following ways;

Respect of the user’s socio-cultural values; to respect the social culture, the design provides privacy, safety, flexibility and future extension, were the internal spaces have been designed according to its functions, it divided into three main group zones (guest, family and surface zones) (Figure 11, 13 and 14). The model offers the required number of spaces with adequate areas. Basement is used as one of the solutions that can provide extra spaces (It can be used for daily life, work or storage). In addition to that, its constant thermal comfort (Figures 14, 17). Choosing simple construction method can help in reducing cost (Figure 12).
Using passive and active solar energy solutions such as solar panel and greenhouse

Temporary roof cover to provide shading when needed

Termades for external use and future extension, it can be edged by nachi men when needed

Design shading devices according to the orientation

Figure 16: perspectives shows the main external features in the designed model

Figure 17: sectional perspectives shows the relation between the courtyard and other functions

Courtyard, basement, greenhouse, orientation, shading devices, and the use of shade as wind catchers are all important devices in improving thermal comfort in hot regions

Figure 18: shows external wall and windows design

Double-glazing with shuttering and shading devices can protect internal spaces from sun

Courtyard provides good ventilation and lighting to spaces

Cavity double wall or with thermal isolation can increase thermal time lag

Flexibility in spaces which can be used for multi purpose
Adapting the climatic conditions: As mentioned before, Tripoli needs cooling more than heating, accordingly, the main points is to prevent heat temperature to enter the spaces, providing shading and cross ventilation by the following strategies:
- Orienting the spaces to the best orientation. Living room and guest room can be in the north or south (living room is preferred to locate in the south because it can have a solarium house which help in moderate internal temperature). Bed rooms should be located in the east to receive direct sun in the morning while family are not using this rooms, services can be located in the West (Figure 11);
- Provide shading by using trees and shading devices- (vertical shading devices in the East, Horizontal one in South and combined of vertical and horizontal one can be located in the West (Figure 16);
- The thickness of walls which increase time lag or use cavity walls or one of the techniques presented earlier and using double glassing windows with a suitable thickness;
- Use solarium house concept to provide a good environment and prevent a direct heat gain to the living area (Figures 13, 16, and 17);
- Landscape design can help in provide shading by using trees especially in the East side (Figures 13, 14, and 15);
- Use the concept of the courtyard to provide cool air (Figures 13, 17).
- Use the staircase as wind catcher by orient the openings towards the North side (Figures 15, 17).
- Using musharabia in balconies or where necessary to provide privacy, shading and allow cross air (Figure 15).
- To reflect direct sunrise, the best shape of roofs can be curved or bitched and if it is not suitable, roofs should be shaded by shading devices or trees;
- Choose the appropriate design and materials with thermal insulation in walls, roofs and windows (Figure 18);

Energy conservation: In addition to the previous climatic strategies, energy consumption can be reduced by the following strategies;
- Using active solar energy (solar tracker) for hot water and heating spaces (Figures 15);
- Provide good lighting by good windows orientation and size, also choose appropriate internal colour and light colour in the external surfaces;
- Using passive design techniques such as solarium house (Figure 16 and 17);
- Using the provided local material

Respect the location (site conditions): Respect the site location, shape, geography and style by respecting building laws, and using simple structure that can not harm the site features (Figure 12);

The use of natural light and ventilation: the model designed to receive natural light and ventilation and the courtyard helps to increase the amount of lighting
were the windows in external surfaces includes shading devices and *musharabia* (Figures 14, 16, 17 and 18).

**Water efficiency;** to reserve water, the model provides ground storage for rainwater (Figure 13), also gather the services in one side for water supply and sewerage, and recycle the used water in gardens (Figures 11 and 13).

**The studied use of colours;** the model suggested using bright colours in both external walls and roofs. For the interior surfaces the choices can be left to the residents.

**Reduce noise pollution;** can be by trees and spaces orientation also by using sound insulation.

**Flexibility;** the model offers flexible design by the possibility to add spaces when need it (for example using big terraces which can be changed to rooms). Possibility for future extension (a part of the house can be used for new family or for rent). To achieve flexibility, the position of the staircase should have access to inside and outside of the house (Figure 13).

### 5 Conclusion and Future Research

Relationships between man and the natural environment are reflected in housing forms. These forms present a clear identity to a culture, particularly in the early periods when man has a strong connection directly with natural resources.

To be successful in sustainable housing design, the architectural designer should play role in reducing the impact of buildings on the environment. They must consider energy efficient design strategies in the early design stage and should not rely on using simplified analysis, synthesis techniques, and historical examples. Also, building energy simulations are becoming more common in the design of buildings, architects should use it in the early design stage.

The modifications of the indoor conditions in buildings can be achieved by the use of the characteristics of the building skin, building materials, cross-ventilation and the use of available technologies. These demonstrate the potential of the building design to modify the internal conditions through strategies of natural conditioning.

This paper presents; First, the main principles of sustainable housing design with passive design techniques, second, an overview of the case study conditions and the third, the application of sustainable methods in private dwellings in Tripoli. The suggested design did not give a detailed form and elevations, it is a concept design shows the possibilities of designing a dwelling unit taking in consecration most of sustainable housing principles. Accordingly, a suggested concept design aimed to provide flexible guideline and applicable aides which can be amended according to site location, users needs and the creativity of the
The house shows how traditional values can be incorporated into a contemporary design that meets current needs for modern life in Libya.

For future studies, more quantified information to evaluate the inside thermal comfort and energy consumption can be achieved by testing this model using special software such as ECOTECT which be suggested for future studies.

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