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Sustainable Architecture: Learned Scientific Lessons from Ghadames, a Traditional Libyan City

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ABSTRACT

Specifications exist for architects and other designers to respond to required sustainable architecture. Radford, Williamson and Bennetts (2003:12) note the presence of "checklists of recommended design actions in many books and web sites," adding that, "some green architects, like William McDonough, have set down principles upon which they believe sustainable design should be based." These principles, known as the Hannover Principles, "were developed when McDonough was commissioned by the city of Hanover, Germany, to develop guidelines for design for sustainability for the Expo 2000 World's Fair." (ibid.) Ghadames is a famous Libyan traditional city, located in the desert. It is successful environmentally and demonstrates many principles of sustainable design. This research highlights the physical and social patterns of the ancient city of Ghadames, Libya. These patterns are common to old Islamic cities in the Middle East. This paper also discusses the social and physical aspects of low energy architecture in Ghadames. Furthermore, it presents an outline for upgrading methodology and a proposal for new development, in which grass with palm wood and suitable design technique is displayed as an excellent solution for providing a home. This paper aims to answer the following questions: What are principles of sustainable design in the traditional houses in Ghadames? What are the techniques Libyan builders in Ghadames used that display the Hanover principles? Which may be redeveloped by architects and designers in a newly built environment?

1. Introduction

In the previous periods, before oil was discovered in Libya in the sixties, it was difficult to produce and transport building materials. Libyan builders, as well as other builders, designed their living environment, traditional houses, using existing conditions and materials in various ways, which were successful environmentally, climatically and socially. In Ghryan there was stone, but

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no joint material could withstand strong rain in winter. Without the ability to cut big stone to build a house, digging out a square hole in suitable soil to make a number of rooms in the first lower level was the easy way to have a shelter for the Ghryanies and their animals. In the deserted area of Ghadames, where there is little fear of rain and very little stone, mud was the main building material. The desert city of Ghdames lies at 30.08N latitude near the western border of Libya at an altitude of 326M (Dioxides, 1972). The genius of people who designed and lived in the city has earned it a place in international heritage. The city flourished on important trade routes between north and central Africa. In 1980 the population of old and new Ghdames was 6000 persons. This figure has now increased to about 25000 persons.

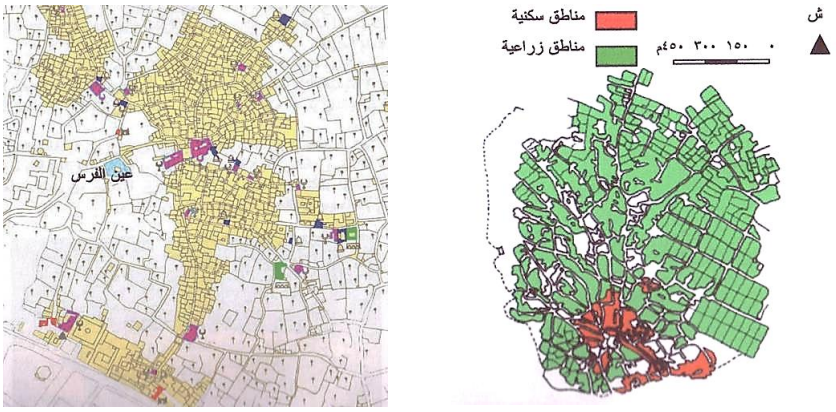

Figure 1: The old city; depicting resident tribes or group

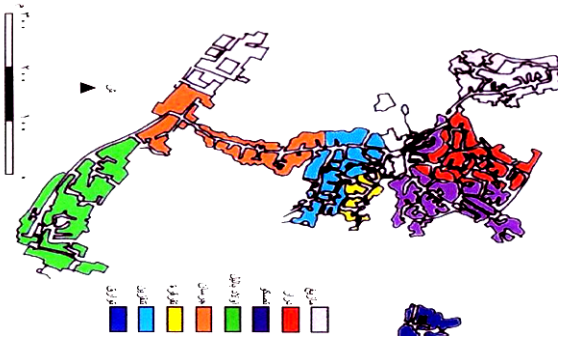

Figure 2: The Growth of the Old City of Ghadames.

2. Learning from the Old City of Ghadames

The public realm of old Ghadames includes mosques, schools, sooq and manufacturing units. Some of the schools near the sooq trained artisans in crafts like leather working. The large open spaces near the city gates were places for dealing in bulk commodities like wholesale agricultural produce, sheep, cattle and carpets. The housing in the private realm of the city consists of mohallahs (places) accommodating different sub-clans. At the micro level of mohallah (place), large parcels of land were allotted to small groups of kinsmen. These people decided among themselves on matters such as internal circulation, open spaces, house design and building over the streets according to their internal social order. A variety of plot sizes housed a mixed population of rich and poor kinsmen.

The circulation system had a hierarchy of main city streets acting as spines of mohallahs (places). There was also a network of cul-de-sacs opening up from the main street. Some of the main streets connected to the city were linear "centers" or sooqs (moll) for commerce, vending and manufacturing (Shibub, 20017). The main mosques, plaza, and hotels are located on the main streets. This system of circulation divides the urban space into public, semi-public and private spaces. Many of the main streets run diagonal to the north-south axis. In Muslim culture, segregation of sexes is a dominant feature of house design. The houses in Ghadames have vertical zoning as a result of climate control as well as a shortage of agriculture land. The ladies' domain is at roof level where the kitchen is also located. They can go from roof to roof by climbing steps built against the parapet walls in Figure 3. The household consisted of patrilineal extended family as in other cities of Libya and the institution of kinship binds as in other cities of Libya. The institution of kinship binds the community together and manifests in the physical patterns of mohallahs (places).

Figure 3: Roof building in Ghadames city

3. Social Aspects

A community builds a settlement to satisfy its socioeconomic and cultural needs. The design and construction have to modulate to the climate in addition to satisfying these needs. The type of dwellings and their clustering follows the behavioral patterns of residents and with the passage of time, life style changes cause changes in behavior patterns. This in turn necessitates a change in dwelling design, layout and links with other urban facilities. These points are illustrated by the architecture of old and new Ghadames city.

For the development of societies and institutions, King (1980) stated, "One can say institutions are the primary design elements of the environment. For the institutions to survive, grow, expand and be part of the culture, there is usually an organizational structure (and buildings) evolved by the society". The residents of different mohallahs in Ghadames were a unique society and were forming a micro scale housing institution. They can be called the forerunners of modern housing

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organizations. There was also a congruence of social and physical patterns with the social organizational structure being eminent in the distribution of water from the spring. There remains an open court between the two main mosques to enhance social contact. The main streets have seats in plazas for people to socialize and rest. The joint ownership of land allotments and the community bond allowed building over the streets and enlargement of a dwelling into neighbors over the street and enlargement of a dwelling into neighbor's lots by building a room into this dwelling. These egalitarian principles extended to agriculture and the distribution of spring water.

4. Physical Aspects

Ghadames is situated at 30.08 N and 9.30 E has a desert climate of Hamadah Al Hamra. Global solar irradiance on horizontal surfaces range between 3-7 kw/hr//sq.m/Day (Hasen, K, 2007). The mean relative humidity is 33%. The mean monthly rainfall is 20 mm and the mean dry bulb temperature in summer is around 45 degrees Celsius. The above climatic indicators require special architectural design and city planning techniques to avoid overheating in summer, Fig 4. When we consider housing in Ghadames we find low energy passive systems have been incorporated into the design. The narrow, sometimes covered, streets provide shaded circulation spaces and at the same time reduce irradiance of walls of the houses. A width to height ratio of 1:2 is a common design feature, giving a vertical obstruction angle of 65 degrees Celsius. During the winter the roof terrace is used for sitting in the sun. The main streets in mohallah (places), run in a diagonal direction to the north-south axis. In this situation the streets will get both sun and shade throughout the year. The main streets are covered at intervals by "sabat" (shelters) rooms built across the street providing shaded spaces for street groups of differing ages. In some of the dark parts of the streets "iumiduct" (bay) types of light wells have been built over the street to provide light and ventilation. The IHVE Guide (Inst & Vent. 1998) explains that when the difference between outdoor and indoor temperature is not more than 10 degrees Celsius the pressure difference "p" between two openings at high and low levels is given by the relationship between (P, H).

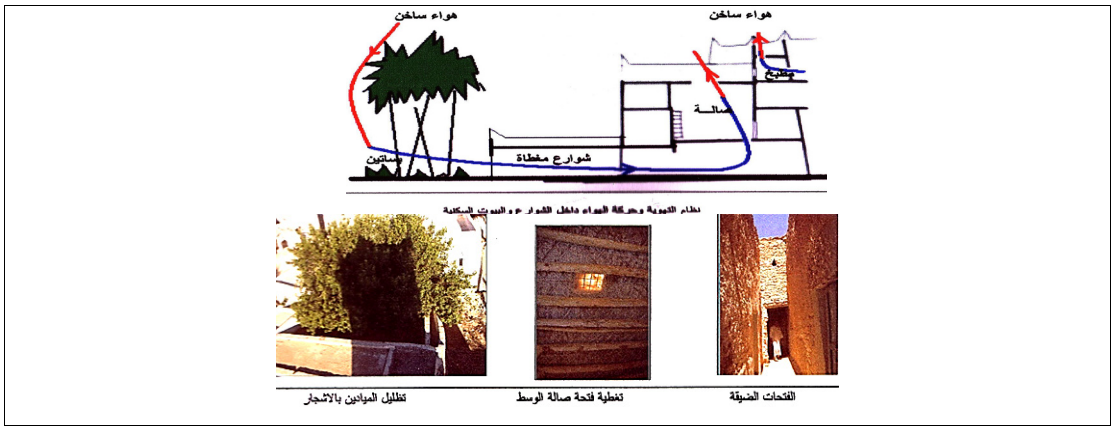

Figure 4: Environmental Concerns and Materials.

The higher opening of the light well is smaller than the lower one to increase the stack effect. These light wells are constructed approximately 15 M apart. The east winds are dominant in the area and therefore the city is built on the west side of agricultural land and date palm gardens as this improves relative humidity. The average wind speed is in the range of 4-6 m/sec. The psychometric chart in Table 1 shows human comfort conditions during the months March, April and October. During the months November to February passive solar heating is needed. For the rest of the year, the high thermal capacity of structures and the clustering of houses are advantageous. The thermal capacity "Q" is expressed by the following relationship:

$$Q=\text{Mass} \times \text{SP. Heat J/Kg C.} \quad (1)$$

Table 1: Temperatures in Ghadames city during a year 2017 (www.world-climate.com)

Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Temperature in °C	10.6	13.2	16.7	21.75	26.2	31.05	31.35	31.15	28.25	22.5	16.4	11.3
Max Temperature in °C	17.6	20.7	24.4	29.7	34.6	39.8	40.3	39.8	36.4	30	23.8	18.2
Min Temperature in °C	3.6	5.7	9	13.8	17.8	22.3	22.4	22.5	20.1	15	9	4.4

The relationship indicates that thermal capacity is directly proportional to mass since the range of specific heat of traditional building material is limited. Adobe and date palm are the local building materials in Ghadames. Figure 3 shows wall and roof sections with thermal conductance values for adobe, stone and concrete (Eben Salah M, A, 1990). The table 2 below gives outdoor and indoor temperature measurements in Ghadames (Hasen, K, 2007:4).

Table 2: Summer Temperatures -- day & night 12 Clock

Summer temp 2016	4/5	1/6	2/6	7/30	7/31	8/28	29 /8
Outdoor temp	22 40:	:23 41	:21 40	: 24 42	:22 41	:25 39	:24 40
Indoor temp modern unit	:32 39	:34 39	:33 37	37 34:	:34 38	:35 38	:36 39
Indoor temp traditional unit	:28 28	:28 28	:28 28	28 28:	:29 29	:29 28	:28 28

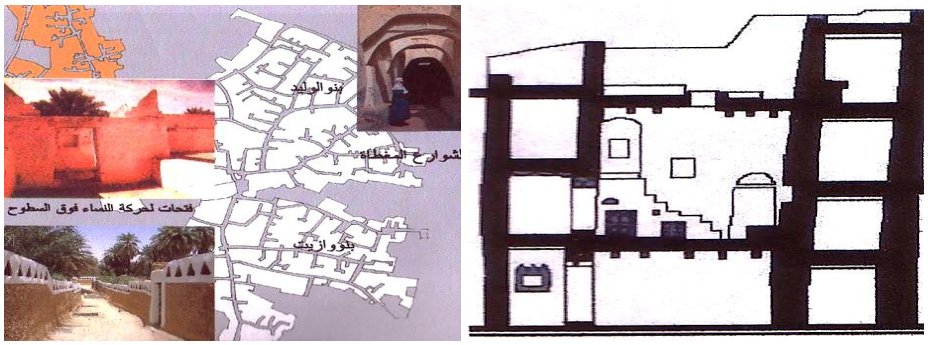

Figure 3: left diagram illustrates the pattern, the right diagram shows the unit

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Table 3: Hanover Principles

No	Hannover Principles	How it was at Ghdames traditional City
1	Insist on rights of humanity and nature to coexist in a healthy, supportive, diverse and sustainable condition.	All the rights of humanity and nature exist.
2	Recognize interdependence. The elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale. Expand design aspects to consider even distant effects.	No negative distant effects; human design is integrated and interacts with and depends upon the natural world
3	Respect relationships between spirit and matter. Consider all aspects of human settlement including community, dwelling, industry, and trade in terms of existing and evolving connections between spiritual and material consciousness.	The pattern of the city and the unity evolves around connections between spiritual and material consciousness, considers all aspects of human settlement including community, dwelling, industry, and trade.
4	Accept responsibility for consequences of design decisions upon human well-being, the viability of natural systems, and their rights to coexist.	All the human activities that affect their well-being are benefited by the viability of natural systems, and their rights to coexist is considered.
5	Create safe objects of long-term value. Do not burden future generations with requirements for maintenance or vigilant administration of potential danger due to careless creation of products, processes, or standards.	Requirements for maintenance or vigilant administration is very low, and there is no potential danger.
6	Eliminate the concept of waste. Evaluate and optimize the full life cycle of products and processes, to approach the state of natural systems, in which there is no waste.	The concept of waste is prevented by the use of natural systems, in which there is little waste. Any waste is reused for agriculture areas.
7	Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate this energy efficiently and safely for responsible use.	The entire city relies on natural energy flows and the design is dependent on the low energy theory.
8	Understand the limitation of design. No human creation lasts forever and no design can solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and a mentor, not an inconvenience to be evaded or controlled.	The design uses the local limited materials, treats nature as a model and a mentor, not as an inconvenience to be evaded or controlled.
9	Seek constant improvement by the sharing of knowledge. Encourage direct and open communication between colleagues, patrons, manufacturers, and users to link long term sustainable considerations with ethical responsibility, and re-establish the integral relationship between natural processes and human activity.	The designers and the builders and the holders are in open communication regarding design and implementation processes.

4.1 Climate control point of view

A terraced house having two common party walls with adjoining owners has less surface area

exposed to the sun and a cold exterior can reach higher densities. The houses in Ghadames generally have dwellings with exposed roofs. Villas, semidetached, terraced and courtyard-type houses have been compared (Mirza, R. H., 1991). The four dwelling types have almost equal floor areas but the villa has the highest exposed area and courtyard-type has the lowest exposed area.

4.2 Sustainability Lessons

It's clear from points 1-4 that Ghdames has different principles of design and it could be a school of sustainable design and development for the desert areas. Table 3 shows the Hanover principles of sustainable design (Radford, Williamson and Bennetts, 2003:12) in the left column and how they are displayed in the Ghadames traditional city on the right.

5. Contribution

The contribution is comprised of upgrading the old city of Ghadames as a tourist attraction and starting new developments on the outskirts of the city. The outline of upgrading methodology is as follows:

A) Aim: the main aim is to tie the developmental goals to the economic goal of tourist trade. The majority of the upgrading is historical conservation with some recycling and change of use in outer areas of the old city. The small motel, Ain al Feris, at the western gate of the city is already catering to tourists.

B) Agencies: the agencies involved in the joint venture will be local government organizations (LGO) and community based organizations (CBO). LGO can provide technical assistance and interactions concerning the supply and delivery of materials. CBO will organize upgrading and tourist services.

C) Finance: the LGO can provide financial support and incentives in the form of credit support to small businesses and cooperatives. The commercial plots can be sold to commercial developers.

D) Program: the upgrading program will pin point action areas in infrastructure, shelter, tourist development etc. A training program for operatives will form part of the upgrading program.

E) Implementation: the implementation can be carried out by CBO through co-operatives. Each successive phase has to be monitored and feed-back considered for the next stage.

6. Conclusion

The new development is needed as a tourist service base. It can be developed as a co-operative housing project. A land parcel in the west of the city can be purchased by a co-operative and

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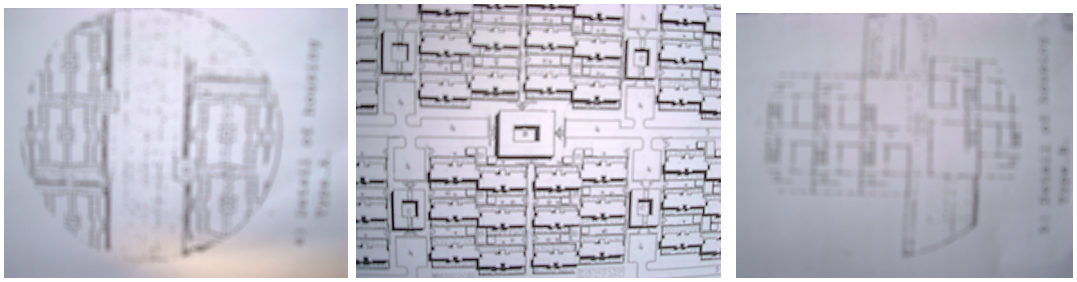
serviced by the government. A sketch of the new development for a community of 7000 persons is shown in Figure 4. The three-story houses link covered pedestrian streets and have a minimum area exposed to the sun. The scale of this model community is close to Dioxides (1972 King A.D. 1980) community class IV. The level of services in the community is as follows:



(A) (B) (C)

Figure 4: Proposal sketch of the new development for a 7000-person community

A-Total area = 64 Ha

B- Housing

Dwelling units =1180

Persons = 6490

Gross Density = 101

C- Land-use

Housing = 30%

Amenities = 13%

Roads = 21%

Parks & Open Spaces = 36% Total = 100%

The social pattern consists of street groups or mohallah (places) of 32 dwelling units for up to 176 persons with its own community center for weddings and other social functions. The covered pedestrian streets provide shaded social gathering space and interaction places. A group of four to six such mohallahs (places) are linked to a services' spine of green pedestrian area; religious and educational buildings; and other community services. The services' spine leads to the district spine of bazaar, retail and manufacturing units. The complete modular community forms a building block of a small town.

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