Urban planning and architecture of the historic city of Ghadames, Libya: lessons from the past for cities of the future

A. Abufayed[1–3], A. Rghei[4] & A. Aboufayed[5]
[1]*Department of Environment Engineering, AlFateh University, Tripoli, Libya*
[2]*Project for the Rehabilitation of the Old City of Ghadame , Libya*
[3]*UNDP/UNOPS/Secretariat of Tourism, Libya*
[4]*Department of Architecture and Urban Planning, AlAin University, UAE*
[5]*Administrative and Technical Affairs Department, AlFateh University, Tripoli, Libya*

Abstract

Remotely located about 600 km from the Mediterranean sea, the historic city of Ghadames has emerged as the Sahara desert's most important cultural and trade center for many centuries thanks to the outstanding qualities of its urban planning and vernacular architecture. The objective of this paper is to describe these qualities and demonstrate their effectiveness specifically in light of the physical environment constraints and in comparison with the newly built city of Ghadames. Threats to the sustainability of both cities are also defined along with ways to overcome them based on lessons from traditional and new architecture.

1 Introduction

The historic city of Ghadames (HCG), Libya, is located in the Sahara desert. Despite the remote location and arid climate, the HCG has evolved as the Sahara's most important cultural and trade center for many centuries thanks to the extraordinary qualities of its urban planning and vernacular architecture.

The objective of this paper is to describe these qualities and demonstrate their effectiveness and adaptability to modern cities as well. To achieve this objective, the city's historic evolution and significance are presented followed by a

WIT Transactions on The Built Environment, Vol 83, © 2005 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)

description of the physical environment. The urban planning and architectural features are analyzed next. To provide a basis for comparison, the architectural features of the newly built city of Ghadames are presented. Finally, the existing states and threats to sustainability of both cities are presented. These threats may be overcome through understanding and adopting the traditional Ghadamsi approach taking advantage of up-to-date technologies to upgrade materials and methods and giving full consideration to rapid socio-economic changes.

2 City of the past: evolution and significance

2.1 Historic evolution

The HCG has evolved around the eternal Ain AlFaras (AAF) spring. Rock carvings around it indicate that it is pre-historic. It was a Carthaginian/Phoenician province as early as 795 BC. The Romans conquered the city in 19 AC and Latinized its name into Cydamus and the Byzantines occupied it from mid-5th to mid-6th centuries.

It was the Moslem Arabs who have founded the adobe-constructed historic city in existence today; the city's oldest and largest Atiq mosque was erected in 47 AH (667 AD). Ottoman, Italian and later French troops occupied the city during the periods 1551-1912, 1912-1942, and 1945-1956, respectively, when it was turned back reluctantly to newly independent Libya.

2.2 Commercial and cultural significance

Throughout its long history, the HCG has served as a trading center for the caravans linking the Mediterranean to the African markets, well known to the Phoenicians and to the Romans. This role was expanded markedly with the spread and rise of Islam into north and sub-Saharan Africa as the city became also a center of enlightenment and a pilgrimage route for the faithful from the Maghreb. Meanwhile, the city's prosperity was strengthened by agriculture which provided the foodstuff for both residents and the passing caravans.

The city's economic prosperity declined significantly with the decline in caravan trade since the beginning of the 20th century and deteriorated completely during the Italian and French occupation with a marked emigration northwards.

In recognition of its unique vernacular architecture, Ghadames was inscribed in UNESCO's list of World Heritage Sites (WHS) in 1986 as "an outstanding example of a traditional human development which is representative of a culture". In 1999, it was inscribed by the Organization of Heritage Cities (Canada) as a heritage city.

3 Challenging constraints: remoteness and aridity

Urban planning and architecture of the HCG were developed, to a large extent, in response to the constraints posed by location and the physical environment.

3.1 Location

The HCG is remotely but strategically located about 600 kilometers southwest of Tripoli, Libya's capital and only a few kilometers from Tunisia, and Algeria at an elevation of 340-370 m above mean sea level (Fig. 1). It lies practically isolated on the northern edge of the great Sahara desert.

Figure 1: Location of the historic city of Ghadames, Libya.

3.2 Climate

Ghadames lies in the eremitic (arid) climate zone characterized by long hot and dry summers and slightly cold winters as is shown below.

Average daily temperatures vary from 10 to 32 ^{o}C with an annual mean of 22.2 ^{o}C. Extreme high and low daily temperatures means range from 17 to 40 ^{o}C and 4 to 25 ^{o}C, respectively. Absolute maximum and minimum values are 55.2 and - 6.5 ^{o}C, respectively. Large temperature fluctuations can thus be noticed with daily amplitudes reaching 14 - 20 ^{o}C and maximum spans of over 60 ^{o}C.

Ghadames climate is dry with relative humidity ranging from 31 % in August to 56 in January (annual average of 33 %). Extreme values are 67 % and 13 %.

Precipitation is scarce with an annual average of only 32 mm and a maximum monthly of 8 mm. The absolute maximum annual, monthly and daily rates recorded were 182, 66, and 44 mm, respectively.

The sun shines practically daily ranging from 69 % to 88 % and averaging 79 %. Sunlight extends from 7.5 hours in December to 12 hours in July and August.

Northerly to north easterly winds prevail during the summer while westerly winds are prevalent during the winter. Southerly sand laden winds blow in the spring, summer and winter (60, 26 and 14 %, respectively). Wind speeds average 3.5 m/s with a maximum speed of 11 m/s. Wind storms last up to 23 days/year. Because of the low rainfall rates, high sunshine and windstorms, evapo-transpiration rates are very high averaging 2700 mm/year.

4 Overcoming the challenges: sustainable architecture

Sustainable Ghadamsi architecture is realized through a holistic approach to overcoming physical and cultural environments. This approach is reflected in the city's site selection, urban planning and architecture as explained below.

4.1 Site selection

The HCG was sited near AAF and within the 200 ha. almost circular oasis (Figure 2). The city/oasis is bound by a hill rising about 30 m on its south western side. The city was oriented roughly in a NW – SE direction. The oasis consisted of several hundred family plots "farms". Each farm had an adobe fence to provide shading to plants, protection against windstorms, and ensure privacy and security. The oasis was fenced completely limiting access to 7 guarded gates that closed after sunset. The oasis green cover acted as a protective shield with profound impacts on the macro and micro climates. Site selection and city orientation were, therefore, based on quick access to water (AAF) and farms and protection from the harsh climate and strangers.

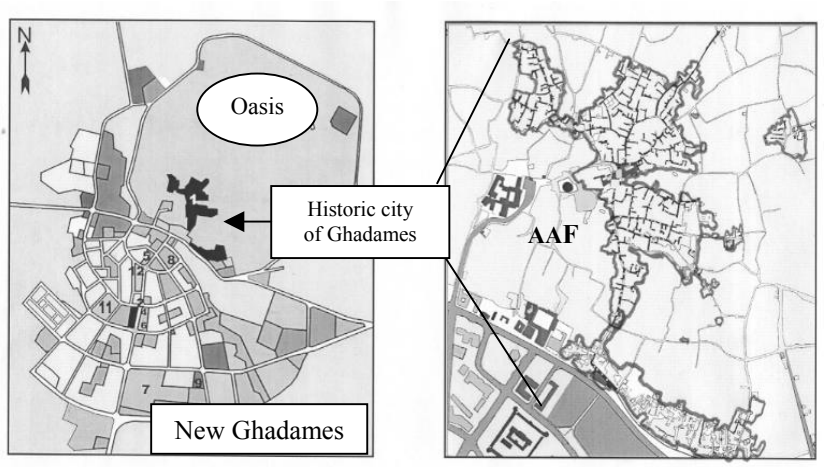

Figure 2: Location of historic city of Ghadames.

4.2 Urban morphology

The HCG is the sum of three concentric interdependent systems, namely, AAF spring (the life support), the city, and the oasis (sustenance); these systems, jointly, form the HCG urban fabric. The urban morphology is characterized by the easily identified and understood form, shape and order of its elements.

4.2.1 Neighborhoods

The city evolved around a nucleus formed near AAF and spread on the south western side of the oasis (Fig. 2). It grew into seven integrated but semi-autonomous neighborhoods "streets" occupying an area of 7.5 ha. Each neighborhood had its own religious and commercial facilities, public squares, gates/entrances and houses which constituted about 80 % of the city's 1700 buildings [1]. Buildings were connected through a complex network consisting of a main street, alleys and passageways (Figure 2). Neighborhoods were linked through streets and alleys but could be separated by inner gates for security. This decentralized arrangement asserted neighborhood's autonomy and equality.

4.2.2 Streets

City streets, alleys and passageways were narrow, dim, curved "winding", had non-uniform dimensions with widths decreasing from about 2 to less than 1 meter (Fig. 3). They were lined with built-in sitting benches "majlis" providing a meeting and resting place for the different age groups with seniors allotted the privileged location near the mosque. To protect against harsh climate, they were covered by buildings. Natural light and ventilation were provided through special shafts that are placed more frequently where use is intensive and omitted in some alleys and passageways to discourage access of intruders. Light thus showed in a natural way both the direction to go and the hierarchy of main streets and passageways.

4.2.3 Houses

Ghadamsi houses were of courtyard plan type with floor areas of 40 to 80 m^2, almost cubical in shape and were of practically identical designs. They were constructed in two main levels; a ground level comprised of the entrance "lobby" and a farming ancillaries store and a first floor comprised of a dry pit latrine and the family room/courtyard where the main rooms are located. The courtyard had a double floor-to-ceiling height and was covered except for a small central opening in the roof to provide natural light and ventilation. A mezzanine floor, reached via two staircases a few steps up along the entrance walls of the courtyard, contained more sleeping rooms and food storage spaces. The living room - the family's resting place and the symbol of their economic/social status - was an artistic masterpiece. Its gypsum plastered whitewashed walls were heavily and brightly decorated. The kitchen was located on the roof terrace to vent smoke directly into the atmosphere. These terraces were also used as public footpaths during the day and as living/sleeping space during the summer nights.

4.3 Building materials and techniques

Adobe (sun-dried mud brick) is the basic material of construction in Ghadames along with stones, gypsum, lime, and palm trunks and leave branches; all of these materials are available in ample supplies locally along with traditional construction skills.

Foundations are made using stone while walls are made of adobe. Arches and vaults are made from gypsum bound "spongy" stones. Roof slabs were

constructed with palm trunk beams cut lengthways in halves, then covered with a mat of palm fronds, a thin layer of palm leaves, a 20-30 cm layer of mud "beaten earth" and a 3-5 cm layer of gypsum plaster.

The inside wall surfaces are plastered with gypsum and covered with lime "whitewash" as are the external walls of some streets and significant buildings, frames of doors and windows, caps of parapets and the stepped triangular finials of the wall corners. Generally, however, external wall surfaces are plastered with adobe mortar or left in their natural state.

Special care and attention are devoted to the collection, preparation, preserving and seasoning of building materials and to the building process itself which is conducted manually. This labor intensive collective process transforms work into social activity while minimizing time and labor costs.

5 Vernacular architecture: features, qualities and values

As can be inferred easily from descriptions above**,** Ghadames' architecture is culturally and environmentally founded; it is inspired and formed by faith and aridity. The unique features, qualities and values of this architecture, summarized below, are perfect reflections of these "additive" inspirations.

1. **Architecture of the veil.** The city is enveloped within a fenced oasis and its own outer walls and access control gates. Building arrangements allow a minimum number of external openings and facades are always oriented inwards giving the city a forceful introvert orientation. It is exclusive to the outside environment through strong defensive measures in order to protect that which is inside, man, family and community; culture. Its buildings, except for the Friday mosques' with towering minarets and domes of mosques and zawias, were hardly distinguishable from the outside. Building façades are equally modest consisting of low windowless walls interrupted only by a single door. A structure's size, shape or function are hidden completely putting emphasis on enclosed space; it "must be experienced by being entered and seen from within" [2]. Additionally, this arrangement, reflects an overwhelming sense of modesty and equality,
2. **A "Covered" city.** Forming a major element in the city's planning, streets, alleys and passageways were extensive, relatively high and covered (Fig. 3), providing easy access, shade and protection against the winds and privacy. Because their roofs are privately owned, repairs are performed freely and more effectively,
3. **Full respect for the human scale.** Structures and spaces' size, orientation, and form are tailored to the human scale. Sizes and dimensions of building, street, and doors, openings, sitting benches, squares, family sleeping rooms and store spaces are but a few of numerous examples to this effect,
4. **Compact urban fabric**. Buildings including houses are built wall-to-wall with other buildings on 3 sides. They are intertwined "keyed" into each other horizontally and vertically thus forming one large conglomerate of private and public buildings making the city one integrated monolithic block with an extended continuous roof. This compact labyrinthine "cluster" arrangement

serves many functions including social connectivity, closeness, structural support, shade and protection against sand-laden winds and intruders,

5. **Moderate vertical expansion**. Buildings expanded vertically to a uniform height of 10 m with the notable exception of public places which are one floor high. This height was intended to save valuable arable land and - being just below palm trees heights - to guarantee maximum protection against windstorms (Fig 4). A third objective, was to maximize population density (> 1000 cap./ha) for economic and social reasons,
6. **Space hierarchy**. City planning was such that spaces including the street/alley network were differentiated in shape and form according to their functions with a distinct gradation from public to semi-public to semi-private to private and sub-gradation (e.g. different functions assigned to each house floor). This hierarchy balanced public and private, material and spiritual, age and gender,
7. **A double circulation system.** Houses are interconnected by common walls, steps, bridges, stairs and doors forming "public footpaths" extending to the roofscape of the entire town to allow women and children to move freely during the daytime hours to visit, socialize, and trade independently away from men (in the ground floor) in line with Islamic traditions,
8. **Identical house designs.** Houses are of an identical design organized around a central covered courtyard - the major distinguishing feature of vernacular architecture - with a clear focus on the interior spaces as opposed to the outside or façade. Unity of the design gives yet another sense of equality and reflects a high level of standardization perfected over many centuries,

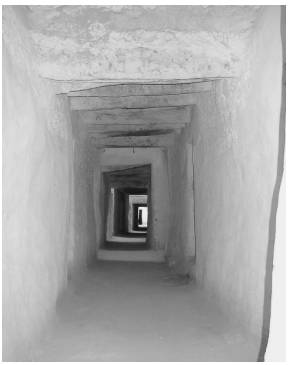

Figure 3: Covered streets.

Figure 4: Unique townscape.

9. **Unique townscape.** The city is enshrined in the oasis. Outer walls, having an almost fortified appearance, give the city a dominating natural brownish color. They are "capped" on top and adorned with stepped finials at corners. Roof terraces, cappings and finials are whitewashed providing an attractive and harmonious townscape. Shorter walls of passageways into the city, squares, mosques and zawias are topped with whitewashed decorative rows of

arched and triangular openings (Fig. 5) while many farm walls are topped with vertical or slightly sloping rows of brick. Inside the city and public buildings, the uniquely shaped Ghadamsi arches provide another local flavor (Fig. 6),

10. **Purposeful use of decoration.** Decoration is used heavily inside houses to give a visual effect of unlimited space, a feeling of weightlessness, and to undermine the role of structural support elements (walls, columns, etc.), in addition to its aesthetic comforting value,
11. **Sensitive design and selection of materials.** Structures are designed to meet cultural and environmental requirements. They are executed using local materials exhibiting suitable thermal properties needed to equalize large temperature fluctuations as will be elaborated later,
12. **City of closeness.** Ghadames residents enjoyed a rare sense of closeness and accessibility both on the social and physical levels. Distances to parts of town or to the farms were short so visiting, shopping and working in the farm were quite easy. Moreover, frequent meeting in numerous social and religious activities brought people in contact and strengthened social bonds further,
13. **Water driven architecture.** Water formed a major component of the townscape with the spring located at the heart of the city and its canals radiating with life within and around the city through an extensive network into the oasis. Water was omnipresent in the daily lives of residents gathered around the spring, performing ablution in canals passing through mosques or around the city or irrigating farm plots in the oasis (Fig. 5). Water supplied moisture, sustained food and construction materials production (palm trunks, etc.), and, along with greenery, improved aesthetics. A scarce commodity, it was valued highly and managed fairly and efficiently [3],
14. **Environmentally sensitive architecture.** Adobe architecture is the product of scarcity of rainfall and cheap durable building materials. It relied completely on local materials which were recycled extensively (adobe), employed natural lighting, ventilation and renewable energy while compactness and other treatments optimized volumes and areas in favor of energy and materials used.

Figure 5: Canal passageway walls.

Figure 6: Unique arches.

6 Overcoming aridity: a numerical proof

The spatial arrangement, functional and structural solutions and materials selection are all geared towards ensuring comfortable macro and micro climates. The effectiveness of these solutions is demonstrated quantitatively below by comparing ambient and indoor temperatures fluctuations inside houses during the summer and winter seasons.

6.1 Thermally resistant structural elements

Use of thermally resistant (insulating) and reflective materials is one of several measures taken to control climate in arid climate zones like Ghadames where thermal resistance should always exceed 4.44 $ft^2.hr.^o$ F/BTU to ensure a comfortable inside climate [4]. The Ghadamsi wall conductivity of 6.2 $ft^2.hr.^o$ F/BTU is comfortably higher than the minimum required indicating good thermal qualities. Because of the large wall thickness, the lag time is 12-15 hours perfectly suited for damping day heat to night [5]. Thermal resistance of roof slabs (30-60 cm thick) is about equal to that of walls; still higher than required. The high parapets provide shade and wind protection while the low adsorption coefficient (0.12-0.4) and a high reflection coefficient (0.8-0.9) of external walls reduce effectively the amount of heat absorbed [5].

6.2 Macro and microclimate conditions

A suitable macroclimate is achieved as the sum of individual compact built-up areas' microclimates with enforcing effects of the farm belt which breaks the winds, filters dust, supplies moisture continuously and acts as an energy buffer dampening sharp fluctuations of the dry barren desert surrounding the oasis. This moisture was pushed gently into the city by the dominantly northern and eastern winds. Streets, being part of buildings, function together as a single, compact structure to keep ambient temperature and humidity at a satisfactory level.

It can be seen from section 3.2 that, in the summer, a relatively large amplitude of 20 ^{o}C exists with an average ambient temperature of about 32 ^{o}C while the temperature inside a traditional house remains constant during the whole week (28 ^{o}C) resulting in an amplitude of 0 ^{o}C. In fact, the temperature inside a traditional house was even lower than the outdoor average [6]. Conversely, ambient temperatures vary from 4 to 25 ^{o}C during the winter while those in an old house, remain practically constant at about 12 ^{o}C.

7 The new city of Ghadames: a contrasting challenge

The new city of Ghadames (NCG) was constructed in the early 1970's within Libya's efforts to raise the population's standards of living. Located on top of a hill only a few meters away from the HCG, it was planned and executed rapidly and to a higher technical standard mostly with expatriate experts employing imported models with little or no respect to the merits of vernacular architecture.

Unlike the HCG neighborhoods, new city streets are paved, wide, uncovered and endless. New housing units with modern "amenities" were larger in size, mostly 2-storey separate plots, had outward facades, more and larger windows, and used mostly non-local building materials. New paving and building materials were less heat resistant and more expensive. New Ghadames - virtually a barren open city - heated and cooled up instantly with magnified effects of blowing winds.

Expectedly, the macro and microclimates of the NCG were inferior to those of HCG. A field study on 9 houses in the HCG and 10 in the NCG indicated that summer temperatures inside the HCG and NCG houses were 28 and 36 ^{o} C, respectively, while ambient air temperature was 46 ^{o} C [7]. This inferiority was a result of several combined factors. Exposed-to-total areas of traditional and modern houses were 0.6 and 2.5, respectively while total area of windows to usable area ratios were 0.008 and 0.12. Building mass to total area ratios were significantly higher for traditional houses (32,000 vs. 1,400 kg/m2). The heat transfer coefficient for traditional houses was only half of that for new ones [6].

8 The HCG today: threatened sustainability

Despite the clear disadvantages of the NCG, however, its modern facilities and services, the less hygienic conditions of a congested HCG and the coincident subsidence of AAF, have led to the gradual exodus of the HCG from 1971 to 1985. The apparent inadaptability of the HCG to running water, sewerage, and vehicular traffic without significant alterations in the design and materials coupled with the residents' desire to modernize made the "physical" abandonment process easier and decidedly irreversible.

Abandonment had tangible impacts on the HCG's social and physical fabrics. Neighborhoods "clans" were torn with families equitably but indiscriminately dispersed throughout an ever expanding new city with boundless streets with subsequent loss of a significant part of the traditional way of life; a way of life that can not be copied or replicated in the new city.

Disuse, neglect and interruption of routine maintenance operations led, subsequently, to the rapid deterioration of the historic city's structures. Today, almost 50 % of the HCG buildings are in poor or collapsed condition [8]. It is a depopulated city used only during the weekly Friday's prayers, or as a haven for residents escaping the torrid summer heat of the NCG, and during the annual 3-day International festival in October. The city's significance and its deteriorated state prompted efforts to rehabilitate it which materialized in 2000. Extensive rehabilitation activities of infrastructure and cultural sites have given new life to the city with notable increases in tourists and private investors [9].

9 Lessons learned: city of the future

Lessons learned from the analysis of the Ghadamsi vernacular architecture are numerous. The major ones are summarized below.

1. Ghadamsi architecture is demonstrably a genuine adaptation to the harsh desert climate. The compact form minimizes exposure to the sun and construction costs while ensuring family privacy and comfort of residents throughout the year.
2. The Ghadamsi approach is holistic unifying design, materials and techniques with cultural and environmental factors to produce a city of unity, harmony and continuity. It utilizes old solutions developed, tested and refined continuously over many centuries by all actors making traditional architecture superior to modern architecture in regard to physical and cultural environments and cost.
3. The HCG remained virtually unaffected by and irresponsive to the rapid socio-economic and technical changes taking place around it for several decades. As a result, it has conserved its authenticity but at the cost of losing its residents.
4. The sustainability of both historic and newly built cities in developing countries is presently being challenged seriously in face of rapid population growth and technical change, fierce competition for available funds, and limited rehabilitation and construction experiences.
5. Understanding the essence of vernacular architecture, upgrading and mass production of local "traditional" building materials and adapting to continuous change are basic steps towards improving the durability and adaptability of historic and newly developed cities better suited for contemporary living but preserving the basic traditional features. Hence, solutions are very site specific.

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