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# Sustainable adaptation climate of traditional buildings technologies in the hot dry regions

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**Abstract**

Traditional architecture has been successful in achieving harmony between housing and the environment, which is one of the most important conditions for sustainability. The research tried to study and analyze the traditional architecture to diagnose its importance and ability to solve contemporary problems. In order to achieve this aim, we conduct an empirical study of five regions of the hot dry climate, focusing on the urban fabric and dwelling projects. Analytic studies were performed using computer simulations by Ecotect software. The research concludes the effective indicators in the traditional urban fabric and employed it in many of housing clusters in hot dry regions.
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*Keywords:* Sustainability; adaptation climate; traditional architecture; compact urban fabric; hot dry regions

## 1. Introduction

### *1.1. Sustainability affects all area of human activity*

sustainability is a multi-dimensional, theoretical and practical concept, which balances the suitability of environment and optimal use of energy and natural resources that support our life (Pugh, 2002). It is concerned with creating a conducive urban environment and control the expansion and development operations, which is one of the

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oldest human activities. Since ancient times to until now, man has been associated with the environment and nature. In order to live and survive, he tries to interact with it. Architecture is considered the result of the interaction between man and the environment surrounding him. Traditional architecture is considered synonymous with environmental architecture as man was able to conceptualize, design and construct buildings within their surrounding environment and take advantage of the positive effectives for manifestation of the natural environment.

Traditional architecture generally is a reflection of that architecture within a specific environment, and which was able to configure its own character to preserve its identity. It takes advantage of past experience and the ability to adapt the construction materials to express the local environment and the behavior of society in accordance with the beliefs and local history to integrate with its own natural and climatic factors.

The intelligent adjustment of traditional buildings in accordance with the climatic condition is a pivotal tenant of sustainability in architecture. These traditional formulas represent the accumulated experiences across time, and these experiments are a direct result of the humanitarian needs and extreme climatic conditions. Due to the intense climatic pressures of hot-dry regions and weak balance of the ecological system in it, it becomes necessary to find strategies within the systems that runs from the heart of the environmental problems of these regions. Moreover, to formulate the best design and planning solutions of residential complexes in these regions, it has to assess against the environmental solutions and approve, modify, develop and link with the sustainability principles in order to be adapt to the contemporary requirements [1].

## 2. Principles of sustainable design and planning

The basic principles of urban form design has proposed by (Golany 1983), are generalize as principles designed to practices intended or unintended in many regions, especially hot dry for survival.

### *2.1. Urban gathering*

This principle is applied as a major aspect of urban design. The sustainable urban gathering confirms the sustainable development goals of improving the sense of place, interaction with nature, conservation of energy and resources, reduce the waste on natural environment, improve the distribution of streets and zoning, helps in linking and integrating many components of society to achieve urban sustainability [2].

### *2.2. The convergence of land use*

The convergence in land use to prevent negative voids usually corresponds to the social customs, cultural, ethnic, and religious beliefs, as well as the suitability in the land area. It also helps to create adaptive local climate, since any large vacant land inside the city, can be a source to generate a hot air during the day and cold at night, and provides the opportunity to generate dust. That convergence helps create climatic comfort and suitable recreational use to ensure compatibles land use and continue to promote utilization [3].

### *2.3. Urban harmony*

The diversity of standards helps create the urban harmony of any urban fabric, especially the traditional principles in terms of: (1) An external form of urban fabric which includes a horizontal skyline and the section of the vertical line of it, as the traditional urban fabric is fairly plane level, without any vertical buildings except in Yemen. (2) The pedestrians network in the urban fabric, where the narrow alleys and twists gives the minimum heat exchange so it is working to give shade in the day and cool at nights, and reduces the speed of the external wind movements which reduces the effect of dust and keeps the moisture. (3) Orientation of buildings with relation to the sun cycle and reduce its impact in summer, until ensuring the self-air movement orientation the building toward the prevailing wind. (4) The relationship between land uses assessed against ventilation and reduce the speed of prevailing wind and thermal loads [3].

### *2.4. The compact form*

Compact is focus on the intensity of the relationship between the components, even within a single housing. The traditional city has a compact arrangement for the purpose of protection from the harsh climate, especially in hot-dry regions. This reduces the surfaces that are exposed to the sunlight, and also social psychology. Although compact form reduces privacy, traditional architecture treats that by opening the residential unit on its own internal courtyard and the isolation of the public from private and very private [4].

Golany (1983), identifies three criteria found in traditional architecture, which leads to intelligent and efficient planning climatically:

- Planning of city based on the relationship with the daily movement of the sun on a quarterly basis.
- Alleys shaded throughout the day, which achieved by the right direction and compact urban fabric.
- Narrow alleys keeps cool during the day and warm during the night. Linking parts of the urban fabric in narrow corridors and twisted (alleys) spread between housing groups, not only improves the efficiency of these alleys to maintain low temperature of lows, but also ensure a comfortable air movement. This helps to create a tropical mild climate for the entire urban fabric [5].

### *2.5. Design of the open courtyards*

The open courtyards in the hot dry regions are always small in size and spread. This is for the purpose of avoiding hot or cold air-currents, by always planting and shading. It is determined by interior open courtyards within a single house, or the public courtyards within group houses [4].

The inner courtyards function in the traditional urban fabric in an organized and integrated way across the difference air pressures because of the appearance of the wide sunlight courtyard and narrow shaded courtyard with the shaded alleys. The purpose is to raise the self-dynamic air movement, increase-shaded areas and reduce thermal loads. Additionally, the inclusion of plants and water inside it, increases the effectiveness of these courtyards to the required level of comfort. These spaces constitute integrated environmental system, called streamlined spaces [5].

### *2.6. The streamlined spaces in the traditional urban fabric*

The streamlined space is an integrated system consisting of urban courtyards and alleyways. The internal courtyards operates to moderating the local climate of urban fabric in general, and the single building in particular [1]. The traditional architect use two principles to ensure natural air moving through the integrative streamlined space for the entire traditional city. The first principle depends on the variation in air pressure caused by variations in wind speed, and leads to the flow of air from high pressure area to the low pressure. Air movement due to pressure variation, depends on the (Venturi) action derived process mainly on the phenomenon of the effect (Bernoulli), as a theoretical important framework for understanding how this movement of air due to variation pressure caused by the movement of wind [1]. Bernoulli's theory summarize that the moving fluid pressure can be less by increasing its speed, and the second principle depends on air movement by impacting load. These results from heating the air and ascension to high, as the flow of the air moves to a cooler place, this process may also lead to the so-called the chimney effect. The Chimney effect is when warm air rises and must replace by cooler surrounding air, while their continuous heat source turns into a permanent air movement [6].

#### *2.6.1. Urban public spaces and their role in the streamlined space*

Public spaces in the traditional urban fabric is characterized by appropriate location and standards. These can be integrated with the composition of the mass of the urban environment, which is the most appropriate composition of the natural environment and used to control the utilization of energy and natural resources. The streamlined space starts in public urban realm, which acquires its first significant decrease in the total heat load influential throughout the region. The squares in the traditional urban fabric includes green spaces and water surfaces, while other locations are tiled and customized residential assemblies. This consists of squares of different sizes and spaces some

shaded, others sunny. These specifications are in the open space formation of all the squares and create naturally a clear difference in the pressure. They are imposed by the principles of the difference in temperatures between space for the flowing air currents across the shaded narrow alleys, maneuvering toward the interior sunny and shaded courtyards to create air current for whole traditional urban fabric.

*2.6.2. The role of the alleys in the streamlined space inside the urban fabric*

Alley can have an irregular path in the urban fabric, characterized by narrow or expanded linear pathways. This space creates shade diversification under high-pressure cold, and the air rushes between the spaces of residential buildings overlooking it through clever joints. This helps the alley to strengthen the intensity of air withdrawal, where the air rushes through the refracted entrance. This joint acts as filter for the air that is coming from the alley, as well as being left out of the noisy levels that can be came from alleys and surrounding streets, like a high-resolution system came spontaneously controlled by the life requirements and privacy laws.

*2.6.3. The role of interior courtyards in the streamlined space inside the urban fabric*

The inner and central courtyard is one of the most important features of traditional housing design. All researchers agree on its environmental strategic importance (air movement and the existence of natural light gets shaded spaces of high atmospheric pressure move toward living spaces surrounding the courtyard), with difference in air pressure being one of the basic principles in the building process. When it reaches the dynamics of air 1.4 times more than usual, there is manipulation by pressing air, and this can take advantage of the phenomenon of air movement by the adoption of evaporating cooling system. This is to ensure that during the day, temperatures are less humidity inside the building. This principle is the basic of sustainable design because it has the potential to save energy [1].

## 3. Analysis of the selected projects using Ecotect software

For the empirical study, five traditional cities around the world located in hot dry regions were chosen. We took into consideration there urban fabric and dwelling projects. Based on this we then identified research samples related to climate adaptation of traditional architecture. The five selected projects are:

- A residential neighborhood in the city of Shibam Hadramout.
- A residential neighborhood in the Kadhimiya district - Baghdad.
- A residential neighborhood in Old Damascus.
- A residential neighborhood in the old city of Sana'a.
- Paris village project -Egypt.

For the purpose of choosing a suitable analysis framework through computer simulations, we identify and analyze the effect of solar radiation on the urban fabric and solar control by orientation. In addition, to the impact of types of urban spaces in solarization and shading the impact of the formation of the buildings and urban facades. The analytical parameters applied to the selected projects were: insolation analysis (total radiation, total sunlight hours, average daily PAR) , total incident radiation (original value), and object attributes (total radiation). (total radiation).

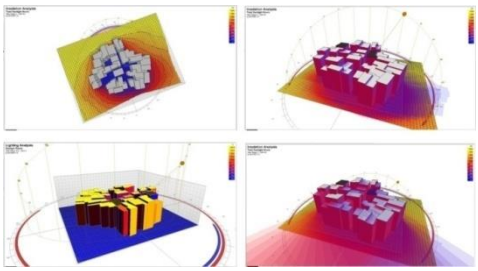

Fig. 1: by using Ecotect analysis of urban fabric in the city of Shibam Hadramout

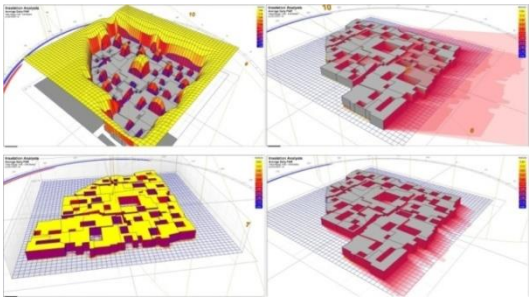

Fig. 2: by using Ecotect analysis of urban fabric in the Kadhimiya district

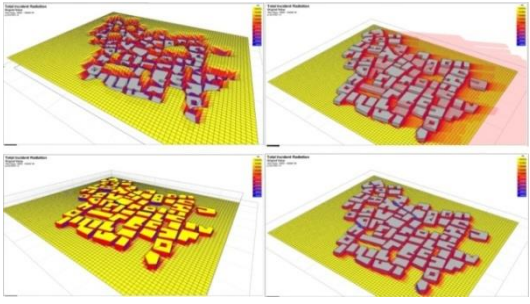

Fig. 3: by using Ecotect analysis of urban fabric in Old Damascus

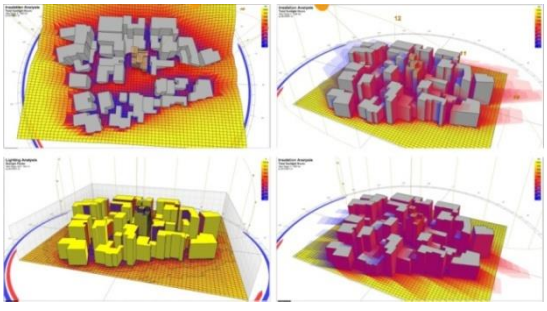

Fig. 4: by using Ecotect analysis of urban fabric in the old city of Sana'a

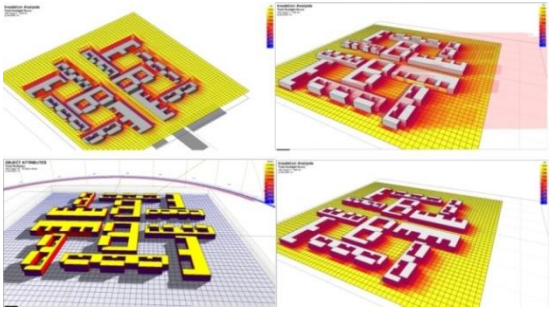

Fig. 5: by using Ecotect analysis of urban fabric in Paris village project

## 4. Discussion of the analysis results

By studying of the five projects, we applied the traditional principles of climate adaptation, using the Ecotect software. The results showed variation and similarities in these projects. All five projects demonstrated the sustainability of the traditional urban fabric. In the first project, a residential neighborhood in the city of Shibam Hadramout, used most of the indicators that we mentioned previously. As it relates to urban fabric, the city uses extreme compaction of urban fabric to reduce and prevent the sunlight insulation from penetrating the streets and narrow alleys. The use of vertical buildings and the diverse functions on different floors provides gradation and diversity in use throughout the day, see Fig.6 (a). Shibam Hadramout city computer simulation results as shown in Fig.1, indicates that by using extreme compaction of the urban fabric, alongside the vertical expansion of buildings, will prevent more than 80% of the hot solar radiation from reaching the streets and alleys throughout most of the day. This will also provide the large shadow areas to create the cold air currents. The buildings are constructed rectangular, with the wide facades toward the south and north. Moreover, multiple floors on the buildings provides more option to maximize the utilization of interior spaces and functions during the day and this is a good solution to the diversity of uses depending on the required thermal comfort. The narrow winding streets and alleys keeps air temperature lower inside the city, and pacify the severe desert wind effects. The horizontal extension of buildings, built in a small area, has achieved the optimal land use exploitation. The second project, residential neighborhood in the Kadhimiya, characterized generally of organic traditional compact fabric. This originates from detached houses, which are separated by narrow alleys, and shaded by extensions from the neighboring houses. In addition, they contain public urban courtyards and an inner courtyard, which is a fully integrated environmental system, see Fig.6 (b).

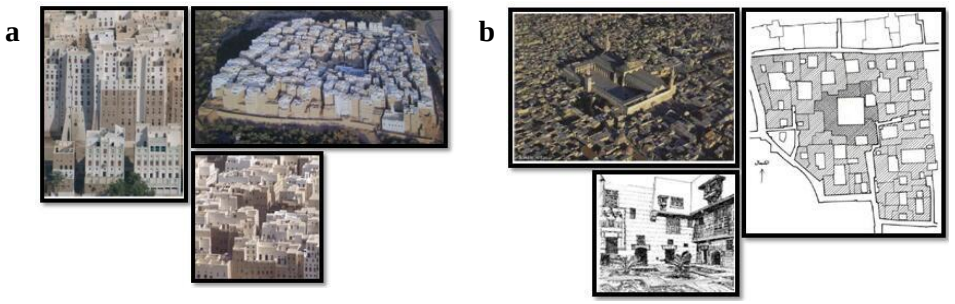


Fig. 6. (a) Shibam Hadramout city; (b) traditional compact fabric of Kadhimiya city.

Based on the results of computer simulation of Kadhimiya city, as shown in Fig.2, the compact traditional urban form is preventing maximum solar radiation from reaching the urban spaces. Approximately 65% shading spaces are provided, and this generates cool air currents. The urban spaces between the buildings are oriented towards the north and this causes them to be shaded most of the day. This analysis (total incident radiation) provides justification to the theoretical knowledge of traditional planners, who believe that is most appropriate to design transport routes and narrow streets from south to north because it provides a large space on building facades.

The third project, a residential neighborhood in Damascus old city, has influenced the planning of Damascus from Islamic influences. The city was transformed from networking style to the traditional compact form. This is characterized by residential units, which are separated by narrow uneven alleys. These alleys typically ends at an urban communal courtyard and the alley is connected from interior courtyard of the house to straight across the corridor. The ground floor is dedicated for public use, therefore, privacy is not required, see Fig.7 (a). The results of the simulation as illustrated in Fig.3, indicates that over 90% of solar radiation is prevented from reaching the street, alleys and urban spaces. This is because the extreme compact of urban fabric and all buildings facades is under shading all day. Furthermore, by using the trees and water basins inside the courtyard to reduce the solar radiation effect, this generates the cool air currents.

The Fourth project is a residential neighborhood in the city of Old Sana'a. The housing in Yemen is quite difference from the previous case studies as are vertically constructed around a common garden (orchard). These

houses, which are characterized by high-rise towers, were designed and constructed to take advantage of the sunlight and natural ventilation. The towers are divided into several floors, so as to maximize the utilization of natural energy, which achieve optimal use of the southern facade. This will ensure that all bedrooms on this side, and services room on the northern facade receive adequate natural light and ventilation, see Fig.7 (b).

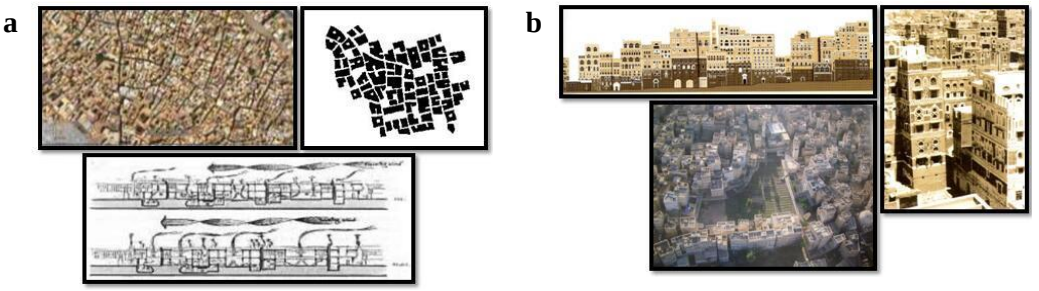


Fig. 7. (a) old City of Damascus; (b) the urban fabric of the old city of Sana'a.

The simulation results illustrated in fig.4, reveals that the urban planning of the Old City of Sana'a is characterized by diversity in urban squares, alleys and streets. There is a gradual difference in the sizes and trends between them, and this creates shading and solarization zones for the purpose of generating more cool air currents. Furthermore, the results proves that orientation is of great importance and should be given special attention, given the effects of the shadows of buildings on each other and the public squares. Shadowing creates a unique system that provides the required shading in summer and solarization in winter with more significance in southern facades.

The Fifth project is located in the Paris Village in Egypt. The village is characterized by traditional compact planning and includes a private courtyard, which is linked by narrow tiled lanes. The old city is pedestrianized, therefore, cars are prevented from accessing. There is also a strict separation of movement between vehicle and pedestrian traffic see Fig.8.

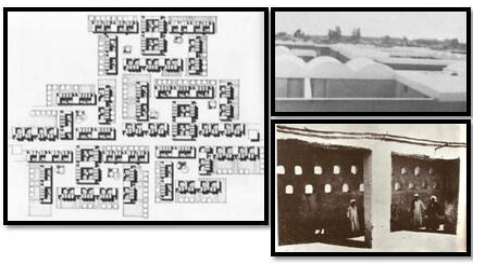

Fig. 8. the urban fabric of Paris Village project.

Based on the results of simulation analysis as illustrated in fig.5, it indicates that the urban fabric of the project dependent on three types of urban spaces: (1) Small courtyards, featuring shading all day from the walls around it and from the trees inside it. (2) The squares between the buildings, featuring a little shading. (3) The narrow streets, for people walking to provide shade from buildings mass. The project has a contemporary, however, the designer takes advantage of the traditional urban form plan principles into its implementation and use an integrated ecological system by inserting the natural elements into to the urban fabric e.g. solar control, so as the maximize optimal use of land.

## 5. Sustainability indicators in the traditional urban fabric

As shown in section four, the results of the simulation analysis proved the effectiveness of all the indicators drawn from the traditional fabric. The empirical study also substantiated varying importance of these indicators in creating sustainability at the level of the urban fabric. We found that the most important indicator in achieving urban sustainability are: (1) The compact urban fabric (2) The orientation of buildings, and the principles of streamlined

space and separation between pedestrians and vehicular traffic. (3) The economy in land use, and integration in the ecosystem and the formation of facades. (4) The nature to urban composition. These factors represent the strategy of sustainable urban planning, where they can be integrated and harmonized with the natural environment, climate and reduce energy consumption. From the above analysis, we highlight the following inferences of sustainability in climate adaptation at the level of the urban fabric:

- Thick compact urban fabric: Urban planning of the city is the first tool that can be used control climate because, the compact city reduces the surface areas prone to environmental conditions. In addition, reducing the ground open areas, and change the width and direction of the streets (alleys), can make building facades shaded by building in the front of it.
- The solar control by orientation: Takes into account the direction of urban courtyards and interior courtyards to the south or south-west, with the protection of surfaces exposed to the sun by protrusions.
- Streamlined space: runs on create air currents tempered local climate in urban fabric, which starts from urban courtyards through alleys and ending with internal courtyards.
- Insertion of nature into the urban fabric (green areas): By introducing the traditional fabric in public courtyards (open urban spaces in addition to private courtyards), elements of water (fountain) and green plants. This will help to reduce the phenomenon of heat islands due to by reducing the tiling area.
- Economy in land use: This can be achieve by stacking land use between structural blocks.
- Integrated Ecosystem: Can be achieve by adopting bio-climate sensitive planning of energy, the adoption of high levels of comfort in the open and closed spaces, adopting economic and ecological constructions materials, and providing social requirements, which are a model for the integration of environmental human.
- The formation of buildings and in particular the urban facade: the traditional compact composition led to the creation of compact facade, which enjoys morphological harmony, and the distinctive character in the formation of urban facade is a shade of some buildings on the others, and so work to create air currents between the shaded and sunny parts due to the difference pressure, where it works on reduce the thermal loads.

## 6. Conclusions

This paper sets out to determine the efficient sustainability indicators of traditional buildings and urban fabric in hot dry regions. This paper presented results which supports the effectiveness of using the traditional climate adaptation systems at the urban fabric and individual building levels. Integration of the principles of sustainability in the principles of traditional architecture will present a dynamic character because of its relationship to the natural environment surrounding on the one hand, and to meet the requirements of the occupants on the other. Traditional architecture is an explicit response to the climatic effects of the natural surroundings. One of the more significant findings to emerge from this study identification of several factors that helped adaptation climate. These includes, compact urban fabric, streamlined space, ecosystem integration, the economy of land use and the streamlining of nature in the urban composition. These factors represent the strategy of sustainable urban planning where there has been integration and harmony with the natural environment, climate and therefore reduce energy consumption.

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