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Identifying Sustainability Solutions in the Traditional Houses of Dhamar Architecture

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Abstract

The world is facing numerous issues from environmental pollution, natural disasters resulting, climate change, and the waste of natural resources has focused specific attention on sustainable development. The house design has different characteristics according to the culture and environmental conditions. The study attempts to answer that, is the traditional architecture of Yemen consists of the principles of sustainable architecture. Moreover, what are sustainable solutions used in the traditional architecture of Dhamar houses? This study aims to evaluate the identity of traditional houses in Dhamar city, analyze the positive features that can be developed in sustainable development, and extract solutions of sustainability to improve the environment built in the modern. The methodology consists of literature studies and field observations. It uses a qualitative method that emphasizes identifying the characteristics of traditional architecture in Dhamar and its response to the environment and sustainability through literature and field studies that include observation and then a questionnaire survey of 55 solutions as form questions. The study results show that traditional houses are very friendly to the environment and sustainable based on local resources, with positive design techniques using natural materials from the surrounding environment. The results indicate that both the house owners and architects agree that Yemeni architecture is sustainable. The results show that the first principle is the economic principle, the social principle, and the environmental principle. These research findings will increase insight into the concept of sustainable building design in the future.

Keywords: Sustainability, architecture, sustainable development, Yemen, tradition, Dhamar, tower house

INTRODUCTION

Sustainability is one of the subjects discussed by various fields, which attempts to meet the current needs of societies, without reducing future needs [1]. It is being considered and developed to reduce the effect of the construction on human aspects regarding three topics, social, economic, and environmental [2]. On the other hand, architecture is involved in many life areas related to the three topics, that reflect culture, tradition, and lifestyle. Today, the concept of architectural sustainability is developing and rising in all places of the world. As the importance of sustainable awareness increases, there is a weak response to research on the sustainability of traditional architecture [2].

Traditional architecture is a physical culture closely related to society's visions and ideas. The socio-cultural factors, environmental conditions, and other factors influence the physical expressions of architecture. In general, the main factors influencing traditional architecture include environmental conditions, local materials, construction techniques, and the needs of building occupants. Therefore, sustainability usually uses friendly materials, environments, and technologies [3].

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On the other hand, it is necessary to investigate the building's elements such as the roof, wall, and materials which are also considered important topics for sustainability. In addition, the principles of sustainable architecture should be explained according to the characteristics of traditional architecture. There are several studies regarding the main principles of sustainability including user's socio-cultural values, climatic conditions, energy conservation, use of local materials, site conditions, water efficiency, use of natural light and ventilation, and treatments of ecological problems such as noise pollution [4].

This study investigates the sustainability in traditional Yemeni architecture to raise awareness about sustainability and its benefits to the environment. This section explains the background of sustainability development, sustainability of architecture, and traditional Yemeni architecture. It provides a whole picture of sustainability and traditional architecture to determine the research problem and objectives.

SUSTAINABILITY DEVELOPMENT

The absence of a general definition the sustainability and sustainable development led to multiple approaches for assessing sustainability in the built environment [5]. There are many definitions of the sustainability concept developed to involve giving equal importance to environmental, social, and economic aspects [1]. One of the researchers defined sustainability development to "includes management and correct utilization of natural, financial and human resources to achieve the appropriate patterns of consumption by using technical equipment to eliminate the requirements to be satisfied [6]".

Sustainability means proper management of the availability of local resources and natural energy resources. On the other hand, other methods can be provided using natural resources and local technologies available correctly. Sustainability is supposed to cover long-term costs and create an ideal balance between renewable and non-renewable resources to achieve an economic and environmental balance. In social considerations, sustainability is based on ethical principles recognizing the value of traditions, cultures, human rights, and quality of life [7].

In general, sustainability development focuses on three pillars that are environmental approaches, social approaches, and economic approaches, which can be found in most of the literature [5]. Under those three pillars, many aspects are included for example: minimization of resource consumption, maximization of resource reuse, use of renewable resources and recyclable resources, protection of the natural environment, and creation of a healthy and non-toxic environment. Reduction in resource consumption includes energy, land, water, and materials. In addition, the improvement in indoor environmental quality includes air, thermal, visual quality, acoustic quality, and the management of a healthy built environment based on resource efficiency and environmental principles [8].

Sustainability of Architecture

Sustainable architecture aims to reach its goals in the design of any building with considerations of the environment as well as design consistent with nature. The main goal is to find architectural solutions including the suitability and existence of overtime needs. Designs are supposed to improve long service life, maintain the environment effectively, and benefit and good exploitation of natural energy resources. The performance can be measured through standards including environmental prestige, internal environment, and primary energy source [9].

On the other hand, many studies of sustainability development are carried out by using several criteria and principles for evaluating the performance of architecture. The sustainability principles of architecture include materials produced locally, resources used efficiently, and responsive to climatic conditions. Another principle is socio-cultural involving the building process with social bonds. Finally, adaptability is the assumption borne out by long histories of usage that architecture is remarkably flexible and expandable [10].

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House owners in traditional architecture are involved in contracting and choosing most of the architectural elements and details, to fit mud, stone, and wood into houses and mosques to address cultural identity. Moreover, traditional techniques and local techniques can have an optimistic impact on social and economic sustainability, representing a local identity and values preserved over generations [5].

Old and traditional communities have succeeded in balancing between population increases and the ideal exploitation of environmental resources. Since most traditional buildings are a community built to request promises of the community, this result costs less because depending on available materials and local labor [10].

In general, the objectives of sustainable architecture have been to design with respect to several aspects, use minimum energy, adhere to the local regulations in the design process, apply knowledge and technology to enhance the life cycle, and use renewable resources [6].

Traditional Yemeni Architecture

The Republic of Yemen is in the Asia continent and the Arabian Peninsula. It is situated between latitude 12–40° and 17–26°, and longitude 42–30° and 46–31°. The western mountain ranges represent a large expanse of the country [11].

Yemen has a unique architecture, which survived with almost no change over centuries (Figure 1). The traditional house materials and techniques change from one region to another according to site considerations, social-cultural considerations, geography, climate, and natural land materials. This variety in building design and materials creates independent characteristics for each region.

The building design can be divided into three categories: the southern and western coastal region, the eastern region, and the mountainous region. In the western coastal region, the houses are constructed circularly and gathered as cottages, using a mixture of mud and reed and with a single floor of house design. In the eastern region, the house is square constructed from mud and multi-story houses in this region. In the mountainous region, stone and burnt brick architecture are predominant in the midlands and the central of the highlands, while mud or a combination of mud and stone architecture occurs in the valleys [11].

Figure 1. Traditional architecture of Yemen (Sana'a City).

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The defense factor of house design was not the only consideration, occupation was not situated on agricultural land but was concentrated on above mountains. On the other hand, many buildings with small heights were exposed for occupation, leading to a vertical orientation in traditional architecture. Once the basic concept of tower houses was the main building form, had become the established pattern in Yemeni society. The tower house may well be the most interesting and unique type of house in the region of the Middle East. This kind represents the architectural heritage of Yemen, in both rural and urban environments [12].

The architecture of Yemen is not only a new phenomenon, but it has a long history dating back to centuries before the spread of Islam. The houses may be square or rectangular towers. In building traditional houses in Yemen, local materials such as bricks, mud, and stones have been used for the lower floor of a house and bricks are more often applied for the higher floor [13]. These different types, materials, and construction methods depend on the availability of materials and the climate. The stones decorate the exterior of the building, and the higher floors of houses are built of brick and decorated with gypsum and plaster.

Energy saving depends and its efficiency greatly depends on the style, design of house elements, and building materials. On the other hand, the privacy of the residents is available through the appropriate organization of plans and architectural elements. The windows, "Qamariya" and "Mashrabiyah" provide natural lighting, ventilation, and privacy. The "Qamariya" provides adequate natural lighting, and the "Mashrabiyah" provides ventilation and privacy [13].

RESEARCH PROBLEM

The world faces several issues such as environmental pollution, natural disasters, climate change, and bad use of natural resources; all these have paid particular attention to sustainable development. The extent of development is measured by several criteria, the most important of which are economic growth, optimal exploitation of natural energy sources and resources, as well as maintaining the environmental balance of the atmosphere.

Sustainability themes have developed in recent times by encouraging the use of local materials and improving the quality of life by integrating environmental, social, and economic aspects. Several studies have addressed sustainability issues in architecture in general or in specific but omitted the important role played by this area to minimize the impact on the physical environment. So, the problem is the absence of knowledge regarding the role played by the sustainable design strategy to reduce those impacts.

On the other hand, a lack of consciousness of the principles of traditional Yemeni architecture on sustainable activities needs formulation of a framework set for its components and solutions to use in modern architecture. In addition, the study attempts to answer these questions: Does the traditional architecture of Yemen consist of the principles of sustainable architecture? And what are solutions used in the traditional architecture of houses in old Dhamar?

OBJECTIVES

This research paper is an attempt to explore concepts of sustainability from the experiences of previous people in traditional architecture in Yemen, especially in ancient Dhamar, and to benefit from them in contemporary life and the architectural environment. In addition, the specific objectives are:

- To evaluate the identity of traditional houses in Dhamar city and analyze the positive features.
- To identify indicators of sustainability in traditional Yemeni architecture.
- To analyze the traditional houses in Dhamar as a case study for extracting solutions of sustainability to improve the environment built the modern architecture.

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METHODOLOGY

This paper tries to identify indicators of sustainability in traditional Yemeni architecture for extracting solutions of sustainability to improve the environment built by modern architecture. To achieve the aims, this paper traces the following steps:

- A qualitative method is adapted to emphasize identifying the characteristics of traditional architecture in Dhamar city and its response to the environment and sustainability through field studies and surveys. Field study is carried out by direct observation to record physical conditions of the environment, orientation, and shape of buildings, construction systems, building materials, and other things. In addition, the questionnaires are preliminary prepared and arranged.
- Collecting the necessary data through personal interviews with the occupants of traditional houses in Dhamar and preparing a general list of standards through documentation of the interviews and developing research questionnaires.
- Collect and analyze all types of information and transform qualitative data into quantitative data. In addition, this study also used an analytical method based on the comparison, and evaluation to draw comments for solutions of traditional architecture.
- The results are analyzed and interpreted to understand the sustainability concept in traditional Yemeni architecture and the values of all sustainability principles and solutions, and then the conclusions and recommendations are determined.

TRADITIONAL DHAMARI HOUSE (CASE STUDY)

The traditional houses of Dhamar are built in the form of a vertical tower (Figure 2). Many houses have more than three or four levels, but the largest commonly have five levels. All Streets of the town are generally narrow and surrounded by houses. The house walls were built with approximately 1 m black stone on the lower level, then walls were built with approximately 50 cm stone on the upper level and are built by brick in the end (Figure 3).

The construction materials of tower houses are stone on the ground floor and first floor, and burnt bricks are used on the upper floors. The burnt brick is made from local materials. The roof of each level was constructed from wooden beams installed with 50 cm between one and the others, and then beams are covered by branches and lie layers of earth mud.

Figure 2. Traditional architecture of Old Dhamar.

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Figure 3. House materials in Old Dhamar.

Usually, there is only one outside door at the ground floor level opening into a central entrance hall surrounded by stores and rooms for grain and animals such as cows, and goats.

On the second floor, further storage rooms for food and firewood are located. The reception and guest rooms are located on the second and third floors, and finally, the occupant sleeping rooms are located on the upper floors.

The ground floor contains one of the most important design elements which is a vertical shaft that stretches through all the floors of the house that is used for collecting waste from bathrooms. There is the entrance rectangular hall or “Dihliz” with stores and rooms for animals and cooking wooden. On the first floor, there is a room called “Mahkama” that does not have any windows, only a door and small windows for ventilation.

On the second floor, there is the biggest room used for family and reception of visitors called "Diwan" and used for special functions such as weddings, births, and funerals.

On the roof, there is the "Mafraj", or men’s living, where the householder rests alone or with friends to chew the "Qat" (Figure 3). It is located at the top of a Yemeni house and has three side windows with various colors, which provide an extraordinary breadth of vision in the afternoon.

The structure of the Dhamar house façade consists of the windows that appear in different configurations through organization, shape, and location on the house façade. The openings consist of two parts, the lower part is a window, and the upper part is called "Qamariah".

The ratio varies between the closed and open areas in the facades of the building on each floor in accordance with the functional and structural considerations. Most buildings are used in the first two floors of the services and higher floors for the occupants.

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Figure 4. Main entrance, Mashrabiyah, and Façade elements.

Another façade element is called "Mashrabiat" located above the door on the façade and is structured from wood or brick (Figure 4). It is functionally for the privacy of women and ventilation, in addition to creating shade and regulating temperature such as blinds in windows. Furthermore, many decorative belts separate the floors and are located at the end of the floor, and the decorative belt located at the end of the façade is the largest.

DISCUSSION

The data of this research is collected through observation and interviews with many house owners to identify a solutions list. The survey instruments are developed and translated into the Arabic language for piloting the previous solutions. The findings related to the solutions of traditional houses and elements can be categorized and described as follows.

Environment Solutions

The houses of Dhamar architecture employ a unique sustainable design, in which they do not require mechanisms such as fans, air-conditioners, and coolers. They were planned to reduce cost and energy consumption. Their spaces contribute to sustainability by creating social and economic environmental interaction, materials used are environmentally friendly, and climate following traditional design helps to create an appropriate interaction between humans and activities. The environmental solutions consist of the main parameters as follows.

Energy Conservation

The natural ventilation is well in a staircase and a lobby. Both these areas have cooling boxes, which help to facilitate air flow throughout interior spaces and provide fresh air into other parts of the house. The lobby makes available cool and pleasant indoor situations in the summer months. In addition, house design respects the climate conditions of Dhamar, by applying a traditional thermal system for heating in the cold winter and ventilation in the hot summer. Thus, it creates a moderate and comfortable climate for the entire year.

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Resource Conservation

Traditional architecture has been able to resist weather conditions by using local construction techniques and natural materials from the surrounding environment. Generally, construction materials are mainly made from stones and bricks that act as high thermal elements for storing heat, recycled materials, and local hardwearing materials.

Land End Site Conditions

The site plays a vital role in sustainable design and helps protect a building from extreme sunlight and wind. Any region has a specific way of orienting a building based on the region's climate. On the other hand, the house plan is usually rectangular and divided into compartments, creating a continuous space. There are stairs contained in their facades on small openings for utilizing sunlight and natural ventilation. The houses were designed to respect natural and cultural resources, respond to flexibility and future expansion, and respect land area and location.

Climatic Conditions

The people in Dhamar have much experience in choosing the best direction for the new house and avoiding harsh sunlight. In general, the south direction is the most favored because the weather in the winter is cold, so the need to capture sunlight and temperature is important. The house was designed to orientate service spaces to the north and orientate main spaces to the south and used in the winter. In addition, the openings are designed to be large and toward the sun, exposing and utilizing shadows from windows' umbrellas and shadows of other buildings (Figures 4 and 5).

Ecological Problems

The roofs were built with timber beams and mud because of their lower costs and good thermal performance. In addition, a house's envelope reduces noise pollution of street traffic and prevents dust. On the other hand, the people have experience in recycling bathroom water to use in gardens and recycling solid sewage to use as fertilizer soil (Figure 6).

Economic Solutions

The efficient sustainable architecture aims to minimize energy use as well as the generation of waste. Additionally, it was constructed from natural sustainable materials collected from the location, generating energy from renewable sources. The economic solutions consist of three main parameters as follows.

Figure 5. Houses facades built from stone, brick, and mud.

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Figure 6. Houses surrounded garden (Megshamah).

Figure 7. House built from brick and mud.

Efficient Use of Resources

The traditional architecture of Dhamar was constructed according to the direction of solar radiation and climate conditions. Therefore, appropriate materials, utilizing shades from each area, ventilation, and windows facing the sun, are always considered. They use traditional construction methods, available local materials, and local supplies of materials benefiting from available skills and local labor.

Energy Efficiency

Throughout history, the people of Yemen have employed locally available materials such as stones, bricks, mud, and wood for their houses (Figures 7 and 8). Therefore, the local material is used to treat harsh sunlight, temperature, ventilation, durability, and capacity, especially in the summer. Nevertheless, in the winter, such environmentally friendly solutions help to retain heat, ventilation, and other natural climates.

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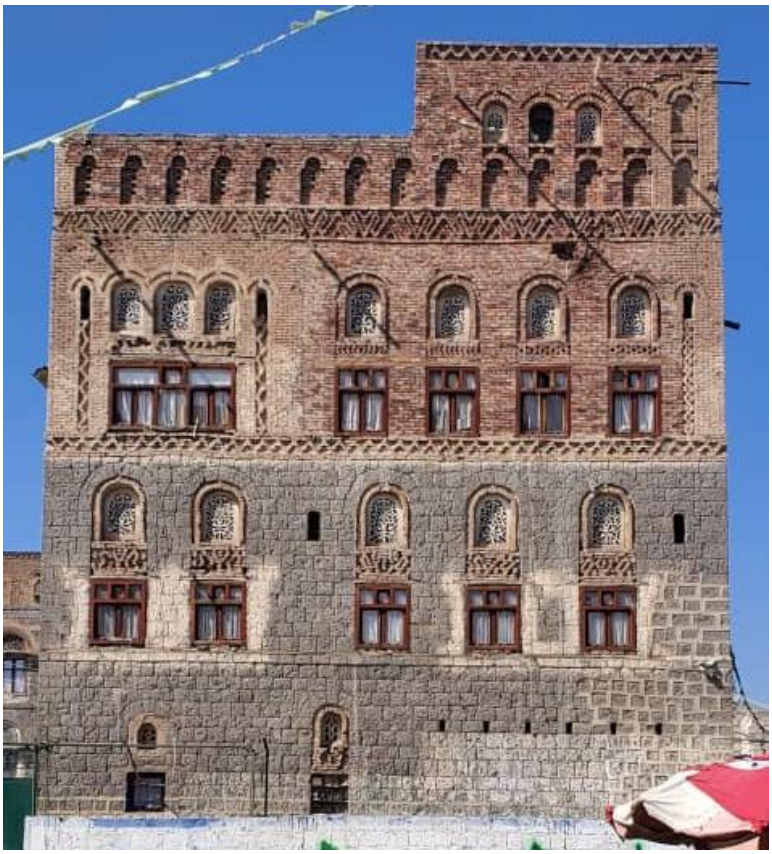

Figure 8. Different types of windows and materials.

Long-term Cost

Natural ventilation has an important role and efficient technique for reducing building cooling energy needs and improving indoor air quality. The building successfully balances environmental requirements and residential comfort by considering the natural environment, energy consumption, and economic conditions. As well, the technology costs can be saved when managed locally, reducing maintenance and repair costs.

Social Solutions

Sustainable architecture is not only to conserve resources or to decrease environmental damage but is a necessity to respond to the needs of societies and to increase the physical and mental comfort of humans. The characteristics of the climate must be considered, human comfort can be maximized in the building and protection from climatic forces. The social solutions consist of three main parameters as follow:

Socio-cultural

Sustainable architecture is considered a necessary thing to respond to the needs of human societies to conserve cultural values and beliefs. The house in Dhamar fits cultural habits, a regional expression of Yemeni culture, the values of Islam, and the cultural identity in façade elements, and reaches high-level privacy between house spaces.

Human Health and Comfort

The walls of the house were built from stones in the lower with small ventilation openings; however, they are built in the upper with large windows for sunlight and ventilation. Several types of ventilation openings are provided, for example, at the entrance lobby at the ground level and small openings located at the top of the entrance door. For the lobbies on other floors, windows with a huge fanlight to let airflow into the rooms are employed.

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Table 1. Sustainability solutions of the traditional houses in Dhamar architecture.

Principles	Sub-Principles	Solutions	House Owner %	Dhamari Architect %	Average Value %
Environmental Principles (86.88%)	Energy conservation (86.42%)	Ventilating staircase and lobby from small openings	85	81	83
		Entering clean air into other parts of the house	86	83	84.5
		Providing cool pleasant indoors in summer in the lobby	89	85	87
		Controlling solar radiation by "Gamariat" and "Mashrabiat"	90	97	93.5
		Inflowing desired wind to all spaces from openings	79	86	82.5
		Using building materials thermal resistance	88	88	88
	Resource conservation (89.7%)	Using locally available materials (brick and stone)	96	94	95
		Using recycled materials (brick and mud)	94	89	91.5
		Consisting of the roof from local wood beams and mud	88	91	89.5
		Using natural and local durable materials	86	92	89
		Constructing vertically because of limited land	81	86	83.5
	Land & site condition (84.4%)	Respecting land area and the location	83	87	85
		Respecting the natural and cultural resources of the site	86	88	87
		Responding to site conditions and neighborhood	85	91	88
		Responding to flexibility and future expansion	76	79	77.5
	Climatic conditions (90.86%)	Utilizing shadows from umbrellas and other buildings	81	88	84.5
		Maximizing openings areas oriented toward the sun	86	85	85.5
		Orientating main spaces to the south and used in winter	91	97	94
		Orientating spaces of services to the north	92	96	94
		Orientating openings toward sun exposure	94	90	92
		Insulating the walls through gypsum and wood frame	87	95	91
		Using thick walls helps to preserve the temperature inside	96	94	95
	Ecological problems (83%)	Reducing house envelope from noise pollution	83	83	83
		Recycling solid sewage to use as fertilizer soil	84	86	85
		Preventing dust by good site and house envelop	77	82	79.5
		Recycling bathroom water to use in gardens	84	71	77.5
		Constructing a roof protects from rainwater	86	94	90
Economics Principles (88.45%)	Efficient use of resources (88%)	Using traditional construction methods is not expensive	94	87	90.5
		Benefiting from the availability of skills and labor locally	94	89	91.5
		Recycling rainwater to supply "Megshamah"	90	81	85.5
		Using local supplies of materials with low energy	89	91	90
		Reducing costs by using available local materials	87	97	92
		Building vertically to solve increased land prices	74	83	78.5

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	Energy efficiency (92.1%)	Reducing energy consumption in activities	90	81	85.5
		Reducing cost by using "Mashkat" for natural light	95	92	93.5
		Reducing cost by using "Shoagis" natural ventilation	92	90	91
		Reducing cost by using "Mashrabiat" for cooling	96	97	96.5
		Utilizing solar energy by doing activities on the surface	95	93	94
	Long-term cost (85.25%)	Reducing maintenance and repair cost	83	83	83
		Using simple construction techniques	88	91	89.5
		Using the ground floor economically as food stores	87	85	86
		Using the ground floor economically as shops to streets	82	83	82.5
Social Principles (87.25%)	***Socio-cultural (93%)***	Fitting of historic and cultural habits in house design	92	92	92
		Fitting of the values of Islam in house design	93	94	93.5
		Maintaining a cultural identity in façade elements	92	95	93.5
		Reaching high-level privacy in house design	91	96	93.5
		Maintaining regional expression of Yemeni culture	92	93	92.5
	Human comfort (88.25%)	Satisfying the level of thermal comfort inside	90	91	90.5
		Insulating sound among spaces and from outside	87	87	87
		Sufficient natural ventilation and airflow in all spaces	88	87	87.5
		Reaching a high level of work and health quality	89	87	88
	Physical Resources (80.5%)	Non-flammable material resistant to fire	80	88	84
		Resisting of natural hazards	82	82	82
		Resisting for crime prevention	74	78	76
		Building above high land to prevent flood disasters	73	87	80

Physical Resources

Solid local materials such as bricks and stones are used for non-flammable material resistance to fire. Dhamar house materials help to control the contrast of temperatures inside and outside the building as well as control of the risks caused by natural resistance and prevent crime, disaster reduction, and flooding.

RESULTS

After the pilot study, the questionnaires were distributed to 16 persons of house owners and 10 architects who live in the traditional houses in Dhamar city through interviews with them to answer questions. They consist of 55 solutions in the form of questions that are categorized under 11 sub-principles and categorized under three main principles called environment, economic, and social principles of sustainability.

Results of the questionnaires conducted indicate that most house owners are satisfied with the traditional environment (86.88%). Furthermore, results indicate that most of the house owners are satisfied with the economy (88.45%). Furthermore, they indicate that most of the house owners are satisfied with the society (87.25%) as shown in Table 1.

In addition, the results show that the first sub-principle is the socio-cultural value (93%), then the second is the energy efficiency value (92.1%) and the third is the climatic conditions value (90.86%).

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The results show that the first solution is reducing costs by using "Mashrabiat" for cooling valued (96.5%). Then, both the using locally available materials (brick and stone), and using thick walls helps to preserve the temperature inside valued (95%), and the utilizing solar energy by doing activities on the surface, the orientating spaces of services to the north, and the orientating main spaces to the south and used in winter valued (94%).

CONCLUSION AND RECOMMENDATION

The study concludes with groups of solutions about how traditional architecture in Dhamar is considered sustainable architecture. The solutions were divided into categories as environmental, economic, and social-cultural solutions. A sustainable design of modern architecture must meet those solutions so that design products can grow economic benefits, protect of environment, encourage cultural identity, maintain natural resources, effectively utilize the natural sources of energy, and protect the user's health.

This study concluded that traditional Yemeni architecture has emerged from its environment and surroundings, being able to overcome environmental problems. It can respond to environmental problems through house design with local materials, techniques, and local expertise. Moreover, Yemeni architecture has proven to be sustainable architecture stemming from its roots in achieving a comfortable environment, through design compatible with human needs and the environment in the orientation of spaces and openings in different facades and has achieved environmental integration for human comfort and the efficient use of energy and local resources.

This study indicates that both the house owners and architects agree that Yemeni architecture especially in Dhamar houses is sustainable architecture and it corresponds with the importance of economic, social, and environmental principles. In addition, the results show that the first principle is the economic principle, the social principle, and the environmental principle.

On the other hand, the study concludes that the traditional house has been influenced by the Islamic contexts, culture, and natural environment. The houses were designed to make the people feel good. Therefore, the high frequency keeps the place socially, culturally, and economically performing well. It is one of the fields in traditional Yemeni architecture studies that needs to be developed.

The study recommends the need to direct architect specialists to carry out special studies that help preserve architectural elements. The study also recommends carrying out studies that help reveal an architectural heritage of Yemen specialized in the field of architecture.

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