International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 10 (2017) pp. 2162-2170

Principles of Sustainable Architecture in Sistan Architecture (Case Study: Ghale Nov Village)

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Abstract
Studies show that more than half of Iran is made of desert areas with hot and dry climate. In addition to hot and dry climate, the Sistan region has dust storms known as wind of 120 days. In spite of the severe climatic conditions, Sistan has been a situation for different civilizations since ancient times, and the people of this region are well adapted to harsh conditions and have achieved appropriate solutions in vernacular architecture. Vernacular architecture of Ghale Nov Village, as one of the villages in Sistan, is derived from the identity and culture of the people in the region. People in this region try to achieve comfort through the use of natural resources, without indiscriminate use of energy, and prevention of environmental pollution. Hence, this study aims to investigate the unique architectural features of Ghale Nov Village in Sistan and introduce a model of renewable and sustainable energy in the region. The present study investigates the impact of climatic and geographical conditions of the Sistan region on the formation architectural fabric of Ghale Nov Village to achieve sustainable development through the potential of existing climate in the region using field study through written sources, and the descriptive -analytical method.

Keywords: sustainable architecture, Ghale Nov Village, Sistan, climate, building materials

INTRODUCTION

There is a significant difference between most regions of the world in terms of local and regional features. Thus, the regions require different facilities which must be considered in the architecture in order that the architectural pattern is based on special features of the region and becomes sustainable, resulting in the sustainable development of the region. Thus, vernacular architecture is paving the way to meet the needs of the region through the selection and use of the capabilities of each region. According to global warming and climate changes because of an increase in greenhouse gas emissions, an immediate action seems necessary to avoid the consequences of risks for future generations (hanan & sharles, 2011). According to sustainable development and sustainable architecture, each building must interact with its surrounding natural environment. Many years ago, Iranian residents used sustainable architecture with special skills to use energy and natural resources, especially sun and wind, in coordination with the climate. These measures are also evident, not only for environmental sustainability, but also for other aspects such as social and economic sustainability (hashemkhani zolfani & zavadkas, 2013).

In spite of overall similarities, the warm and dry areas of Iran have special climatic conditions. Proposing one model is not possible for all regions to achieve environmental sustainability. In this regard, each region should be investigated to achieve specific solutions. In addition to hot and dry climate, the Sistan region is affected by strong winds. The combination of the climate and cultural features, this region has achieved a special architecture which is notable. Hence, the aim of this study is to investigate principles of sustainable architecture in Ghale Nov Village of Sistan.

RESEARCH QUESTIONS

Answering the following questions is the foundation for this research:

1. What are the principles of sustainable architecture?
2. Is the vernacular architecture of Ghale Nov Village consistent with the principles of sustainable architecture?
3. What are sustainable principles used in the architecture of Ghale Nov Village?
4. What are building elements associated with the principles of sustainable architecture in the context of Ghale Nov Village?

RESEARCH METHODOLOGY

The architecture of the Sistan region was investigated in terms of construction based on the dry and hot climate, and sustainable conditions through proposing the definition of concepts, such as sustainability and its relation to the construction and architecture, and climatic features of Ghale Nov Village. Building typology (i.e. housing in each region) indicate that the region is affected by environmental, cultural, and climatic factors. Data were collected using field studies as well as the library, documentation and statistical resources. The data were analyzed using the descriptive -analytical method.

What is Sustainability?

The word “sustainability” is etymologically derived from the Latin word sustinere, to hold (from tenere –hold; keep; comprehend; represent; support). Sustainability was used to refer to the means of being resourceful in such a way that things may be sustained/continued in the future by generations to come.

Sustainable Development and Sustainable Architecture

The term “sustainable development” was used in the mid-70s after the oil crisis of 1973. Serious discussion was started after

the crisis. The culmination of this discussion was in the World Conference on Sustainable Development in1992, also known as the Rio de Janeiro Earth Summit. A resolution was issued to provide guidelines for the sustainable development of countries in the world, and all countries were required to comply with this resolution (Zand and linear Race, 2010). The most important definition for the sustainable development in Rio Conference was as follows: development which meets the needs of current generations without compromising the ability of future generations to meet their own needs.

Sustainable development is the development which continuously meets the needs of the human being with regard to the ability of future generations and quality of life. The concept of sustainable development can be considered as the continuation development in the context of financial, natural and human resources to provide sustainable human development as well as the economic, social and cultural development. The improvement at these levels based on the rights of future generations and social justice, and with the aim of sustainable development (Poormokhtar, 2011).

The concept of sustainability is defined as a solution for dealing with many of these problems. Architects, owners and users of buildings can minimize the environmental consequences of urban growth through the selection of environmentally appropriate materials, using a process of ecological design, and attention to the use of buildings; For example, people can control domestic climatic features and inner workings of the building, energy consumption by impressing factors such as the implementation of construction, shape and orientation of the buildings (Ali Naghi Zadeh and Afshari, 2011). This point is considered as the beginning for the creation of sustainable buildings.

Getting ideas for ecological and sustainable architecture is possible through considering vernacular architecture in the past.

Sustainable design is a three-way interaction between architecture, nature, and user. Thus, the sustainable design rules in relation to buildings can be divided into three subdivisions:

- Resource economics
- Designing life cycle
- Human design (ibid, 2011)

Table 1: Diagram of the principles of sustainable design

Principles		
Resource economics	life cycle design	Human design

Table 2: Diagram of sustainable design objectives

Objectives		
Preserving natural conditions	Before construction	Energy conservation
Designing for human comfort	During construction	Water conservation
	After construction	material conservation

Resource economics are rules and guidelines to maintain natural resources as the input of architecture. In other words, it is defined as reducing, reusing, and recycling natural resources. The purpose of designing lifecycle is to increase the shelf life of buildings and reduce their negative impact on the nature. This purpose can be achieved through analyzing the process of building and estimating its effect on the environment. Human designing also focuses on the interaction between man and nature. It aims to reduce the negative effects and increase positive interactions of humans with nature.

Vernacular Architecture

The first name given to this phenomenon was "Spontaneous Architecture" by Pagone. The term "spontaneous" does not mean "random", it means "natural" (Alpagonolo, 2005). This architecture traditionally refers to forms based on the needs and limitations of local residents (Oktari, 2007). It is commonly known as architecture without architects (Amini, 2012). It can be considered as any type of architecture that belongs to a specific location (Bani Masoud, 2008).

Introduction of Sistan and Micro-Climate

According to climatic statistics, one of the warm and dry regions of Iran is Sistan and Baluchistan. Sistan and Baluchistan are two distinct regions in the province. They are historically, socially and culturally different from each other (Afshar Sistani, 2004).

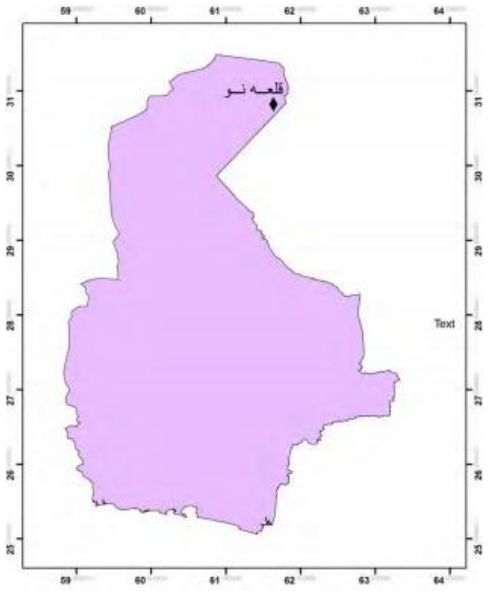

Figure 1: Location of Sistan and Baluchestan in Iran

Figure 2: Location of Sistan and Ghale Nov Village in Sistan and Baluchistan

The term "Zaranj" is the oldest name of Sistan and Zabulistan in the inscriptions of Darius. After the Arab conquest of Iran, the province became known as Sijistan/Sistan. Now, Sistan includes Zabul and the surrounding areas. Sistan was first a land with hills of sand dunes and marine sediments. A part of this land was in the path of the river. After reducing the water of the river, the area of the land around it was extended and a large area for living was formed (Malikzada, 2001).
Sistan is located in south east of Iran and north of Sistan-Baluchestan Province. The Sistan region has a middle desert climate. According to the classification proposed by coupons, Austrian scientist, and corrective recommendations of Russell, American scientist, this region has a very warm and dry desert climate with long summer.

Table 3: climatic feature of Sistan region (National Center for Atmospheric Research in Sistan-Baluchistan province, group of climatological droughts, 2003)

Region (city)	Climate	Average yearly temperature	average yearly rainfall	average yearly humidity	average yearly number of frost days	average yearly number of days above 35 degrees
Sistan (Zabul)	**Warm and dry**	**22.3 ° C**	**59mm**	**39**	**17**	**155**

Table 4: Climatic zoning of Sistan region (National Center for Atmospheric Research in Sistan-Baluchistan province, group of climatological droughts, 2003)

Climatic zoning methods						
Region (city)	Domarten dryness index	Ivanov moisture factor	Hypothermic Factor	Emberger method	Coupon method	Multivariate statistical methods
Sistan (Zabul)	Dry climate	Desert climate	Desert climate	Desert climate	Temperate desert	semi-arid

Sistan is also known as the land of wind because this region is windy in most days of the year. The Sistan region has dust storms known as wind of 120 days because of western high pressure air masses and the air pressure difference between the Afghanistan and Sistan plain as the aggravating factor of this flow. In winter, the wind periodically blows, but in the spring and summer it constantly blows. It starts to blow from early June to late September for four months, which is equivalent to 120 days.

Introduction and Overview of Ghale Nov Village Context

Ghale Nov Village is a part of the rural district "Naruee" in Zabol city. This village is located about 26 kilometers southeast of Zabul city. The latitude and the longitude of Ghale Nov Village are 30° 48' S and 61° 38'E, respectively. The village height is 480 meters above sea level at the lowest point and 510 meters at the highest point.
As seen in the aerial photograph, the village is located on a hillside because of geographical and climatic conditions related to its location. The reason for the formation of the village in this specific area is presented as follows:
A) Geographical reasons: Existence of Helmand River and surface water sources near the village play a significant role in shaping and positioning of the village because most of the people in the village are farmers and the agriculture is heavily dependent on the water of this river.
B) Climatic reasons: The hillside on which the village is located plays the role of a wind shelter because of dust storms and wind of 120 days.

Figure 3: Aerial map of Ghale Nov Village on the hillside

Most passages are located in the direction of the prevailing winds from the northwest to the southeast. Weak deviation from the wind direction has a positive effect on reducing the property of wind channelization. The ongoing change of directions was used to create sub-passages instead of passages perpendicular to the wind direction. Passages perpendicular to the wind are short and slim to avoid the chaos caused by air, and soil clogging the passage (Taste, 2003:1382). In the main passage that leads to the mosque, the existence of open spaces in large numbers along the way and interfering with passages aligned with the wind prevents the soil from clogging the passages.

Figure 5: North-South orientation of Ghale Nov Village with respect to the climate and northwest prevailing winds

Figure 4: Orientation of passages in Ghale *Nov* Village

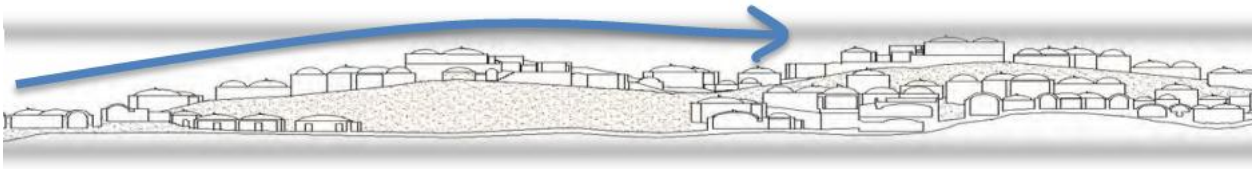

Figure 6: longitudinal section of the village and the location of houses on the hillside with respect to the prevailing wind

Ghale Nov Village is located on the slope of a hill, and consequently the buildings are constructed. In the village, passages follow the natural slope, and if necessary two-storey buildings are constructed. In this region, there is no possibility to construct building basement because of the high levels of groundwater. The general form of the village is like a stepped village, such as Masouleh in Gilan province, but the roof of the houses is not used as a passage because of gentler slope of the land. Since the buildings are not constructed at the same level, they are useful for the wind.

Evaluation of residential buildings of Ghale Nov Village

In this section, climatic, and spatial-functional features of residential buildings are presented to investigate sustainable concepts.

Climatic Features

Climatic feature is one of the most important factors that affect the construction of rural housing in the Sistan region. Traditional rural buildings in the Sistan region inhibit harsh climatic conditions through the implementation of interesting and effective solutions. They use the adjusted conditions in the best way to create a more comfortable and balanced environment. One-sided wind towers, factories, and porches are elements that adjust climatic conditions in the houses. The special structure of domes is very effective in reducing roof temperature because the domes are always exposed to the wind. The climatic features of residential buildings in Ghale Nov Village can be categorized as follows:

1. The plan of buildings is compact as much as possible, and their external surface is relatively low compared to their volume. The density and compactness of house plans minimize the heat transfer and significantly prevents heat loss in winter and summer.

2. Most buildings are constructed in dense contexts and very compact complexes. Thus, the maximum shade is created on the outer surface.
3. External surfaces are covered with thatch to further reduce heat generated through the sun in the walls.
4. The number and size of windows of buildings have been minimized to prevent the rays reflected from the surface ground. Awning is installed around windows and in the upper part of the walls where the niche is placed. Windows are made of wood (tamarisk, willow and mulberry).
5. The building orientation is south or southeast. It is the best ordination to control and minimize the influence of the sun's radiant heat into the building in the afternoon (Panahi, 2006). The building form in Sistan is cubic and their south and north sides are bigger than the east-west ones. Two-floor buildings are preferred over one-floor buildings because they have better defenses against extreme climatic conditions. Sistan has domed buildings with the yard and the door of the rooms is open into the yard. In winter, south-facing rooms are used and in summer, north-facing rooms are used. Thus, the location is consistent with the climate.

Impact of Wind on Architecture

Since the 120-day wind direction which is from north-east to south-west plays a decisive role in the life of Sistani people, Sistan vernacular architecture is based on principles and indicators consistent with the climate of the region. The most advantage of this approach is that it is consistent with wind as the prevailing climatic phenomenon. The most important elements considered in the vernacular architecture of the region are as follows: Ventilation: it is made in three forms: "Kelk", "Sorak", "grid vents".

Kelk: it is the local term for the indigenous windward in the Sistan region. It has a square plan with a maximum size of 0.5 by 0.5 meters on a domed roof. This kind of windward is one-way and in the desirable direction of the wind. This windward is closed in winter to prevent the entry of cold wind into the building (Heidari et al, 2014).

Figure 7: Indigenous Windward of Sistan (Kelk)

With the wind passes through the spherical surface of the roof, the wind friction on the surface is reduced, the wind speed on the domed roof increases, and the pressure on the apex of the dome is reduced, resulting in the air entry into the building more quickly. The outlet of the windward is attached to the ceiling of the room; thus, there is no channel or vertical body in line with the height of the room.

Sorak: it is ventilation that is embedded in the wall. Air inlet and outlet duct are embedded in the wall at a certain angle to break wind power, and enter air into the interior space slowly, resulting in the reduction of the dust ingress. Sistani architects were invented Sorak. In addition to reducing the wind speed, air conditioning can be created through accumulation of thorny bushes in the exterior part of the room. Sistani people have designed a natural cooler known as "Kharkhaneh" by accumulation of thorny bushes outside the window and pouring water on them. It reduces the amount of heat in the interior space of the room.

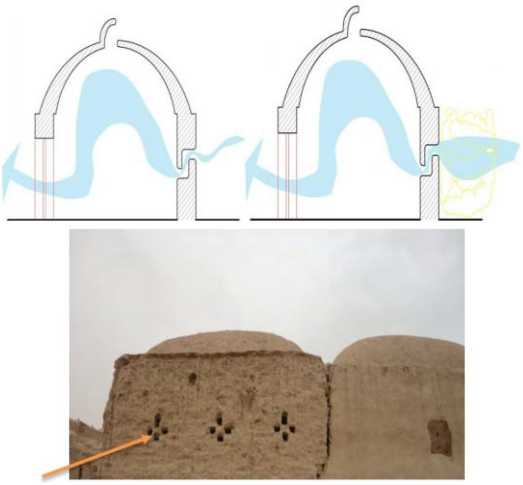

Figure 8: Sorak

Grid vents: Using the grid vents in the northern front directly leads air and reduces the temperature of the environment in warm seasons. These vents regulate the air inside the room. In addition to passing the light and air, the vents regulate air through blocking some of the openings or opening the blocked ones (Ibid, 2014).

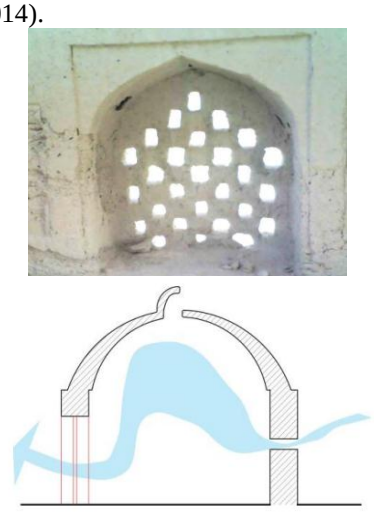

Figure 9: Grid Vents

Terrace: It is an enclosed space without a roof located between the rooms. This space is used in Sistan rural houses. In this space, the living space is located on the top floor, and the livestock space is located on the bottom floor. Terrace is usually used for family members' sitting in the afternoon and sleeping at night, leading to pleasant spaces to benefit from wind energy.

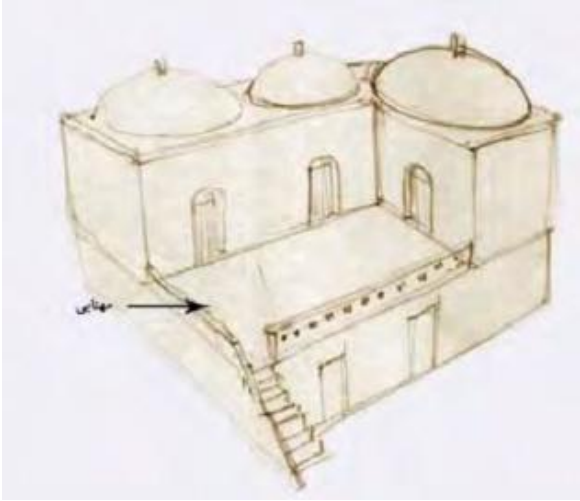

Figure 10: Position of Terrace in rural housing

Physical Features of Rural Buildings

If we consider "body" as the physical manifestation of housing, and the most objective and material topics in assessment, analysis and planning of housing (Gol Mohammadi, 2011), we will see that the architects are interested in the implementation of appropriate methods in housing design based on the local climate.

Building materials: materials used in vernacular architecture of Sistan are raw clay brick and mud. Softness and stickiness of clay soil enable the buildings not to use the imported materials. According to the shortage of stone in Sistan, all measures taken in architecture focus on using local materials, resulting in considerable self-sufficiency for the Sistan architecture.

Figure 11 - Using raw clay brick and mud as local materials

Construction Process of Domed Houses: the construction of mud houses is one of the architectural wonders in the desert areas of Sistan. A suitable piece of land with clay soil is selected to build a house that often occurs in late spring and during the summer. A local group called Hashar (including a group of men among neighbors and relatives) is formed to assist in the construction of houses. After preparing the suitable soil, clay brick making is done by skilled people. In this step, the map is run on the ground and the foundation is filled with hot mud. Then, the walls are built with a diameter of 90 cm using the raw clay brick. The bricks are cubic with a dimension of 25 * 25 cm. The wall thickness includes three bricks.

In Sistan, the roofs are domed. Thus, a part of the roof is placed in the shade during the day and less heat is stored. Making the roof with the size of openings is as follows:

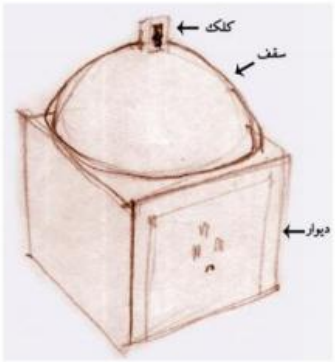

Figure 14: The main components of Sistan rural housing

Figure 13: brick lining the roof for the opening less than 3 meters

gure 12: brick lining the roof for he opening more than 3 meters

A: If the opening of the roof is three meters, brick lining begins from the two sides, continues in the form of an arc, and ends in the center of the dome.
B: If the opening of the roof is more than three meters, brick lining begins from the four corners of the room and ends in the center of the dome according to the size of the opening diameter. Finally, construction details of the house, such as lining and installation of doors and windows, are performed.

Spatial and Functional Features

The form of rural houses is derived from the material and spiritual needs of residents as well as behavioral patterns (Alalhesabi, 2008). Therefore, one of the significant elements is the impact of the beliefs, customs, and behavior patterns on the formation of residential spaces and courtyard. Most people in Ghale Nov Village are farmers. The context of the houses is severely compressed because of the separation of livelihood from residence in this village. The people's job has caused to have two courtyards. Farmers need a space to put a space for farming tools, wood, and straw as well as a space for the pen and forage of animals.

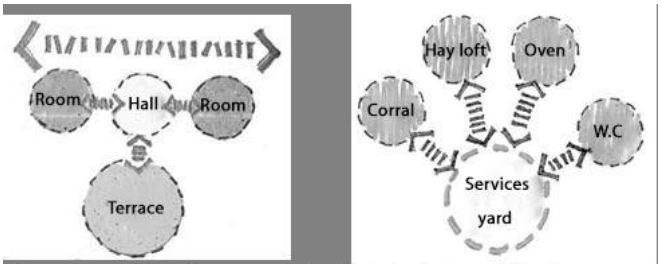

Figure 14: Terrace in living spaces

According to the location of the yard in the residential areas in Ghale Nov Village, we are confronted with two different types of housing: houses on plain and a flat surface, and houses in the vicinity of the hill. The separation of services yard and terrace is an integral part of rural housing that has economic and cultural reasons because this separation creates private yards. Since houses are located on the plains, the separating elements in the yard include a few steps and one-meter walls which are used as terrace in the direction of the wind shelter for sitting in the evening and eating watermelon in the summer (Sarabandi et al., 2011).

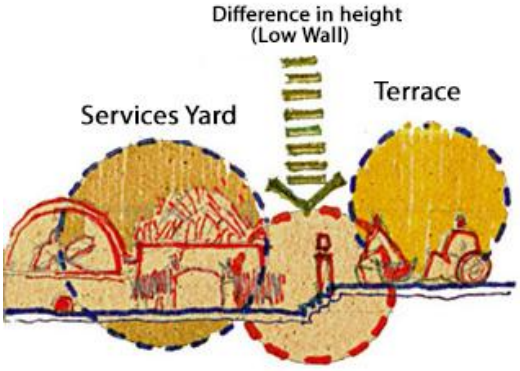

Figure 16: yard of houses located on the plain

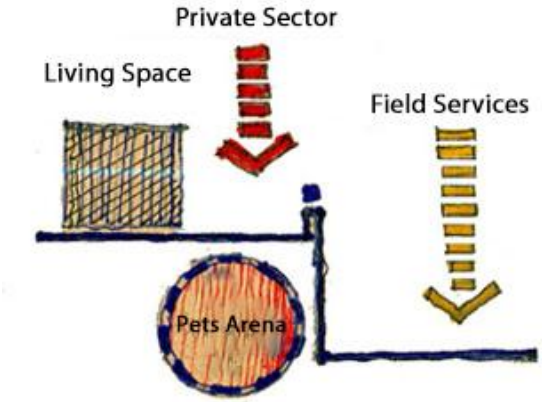

Figure 13: spaces associated with the services yard

In houses located in the vicinity of the hill, the services yard and pets arena are located on the bottom floor, and the living space is located on the first floor (such two-floor houses are called "upstairs" because the bottom floor is a place for animals). The height of the walls in such houses is 1-1.5 meters to form Terrace and the rooms are located around it; thus, a private yard is formed.

Figure 17: relations of spaces in houses of Ghale Nov Village

In spite of the physical differences in the two types of the house, entering the house is the same and indicates the privacy. It includes the main road, the main passage, secondary passages, neighborhoods, entrances, services yard, living space, and rooms. According to the people's beliefs in the village, toilets are separated from the living space of the building.

CONCLUSION

During different periods of history, Ghale Nov Village could be compatible with the climatic constitutions and efficiently use natural forces. People in this village abide by their traditions and use clean energies through the appropriate architecture. The methods used in this village have been shaped based on people's culture and beliefs during different periods of history.

Considering architecture indexes of Ghale Nov Village, this study investigated the compliance of rural vernacular architecture with sustainable architecture. According to the climatic, spatial, and physical features of village buildings, it can be stated that there is an appropriate design in accordance with the principles of sustainable architecture. As displayed in diagram 1, the features included resource economics, life cycle design, and human design. The studied indices are presented as follows:

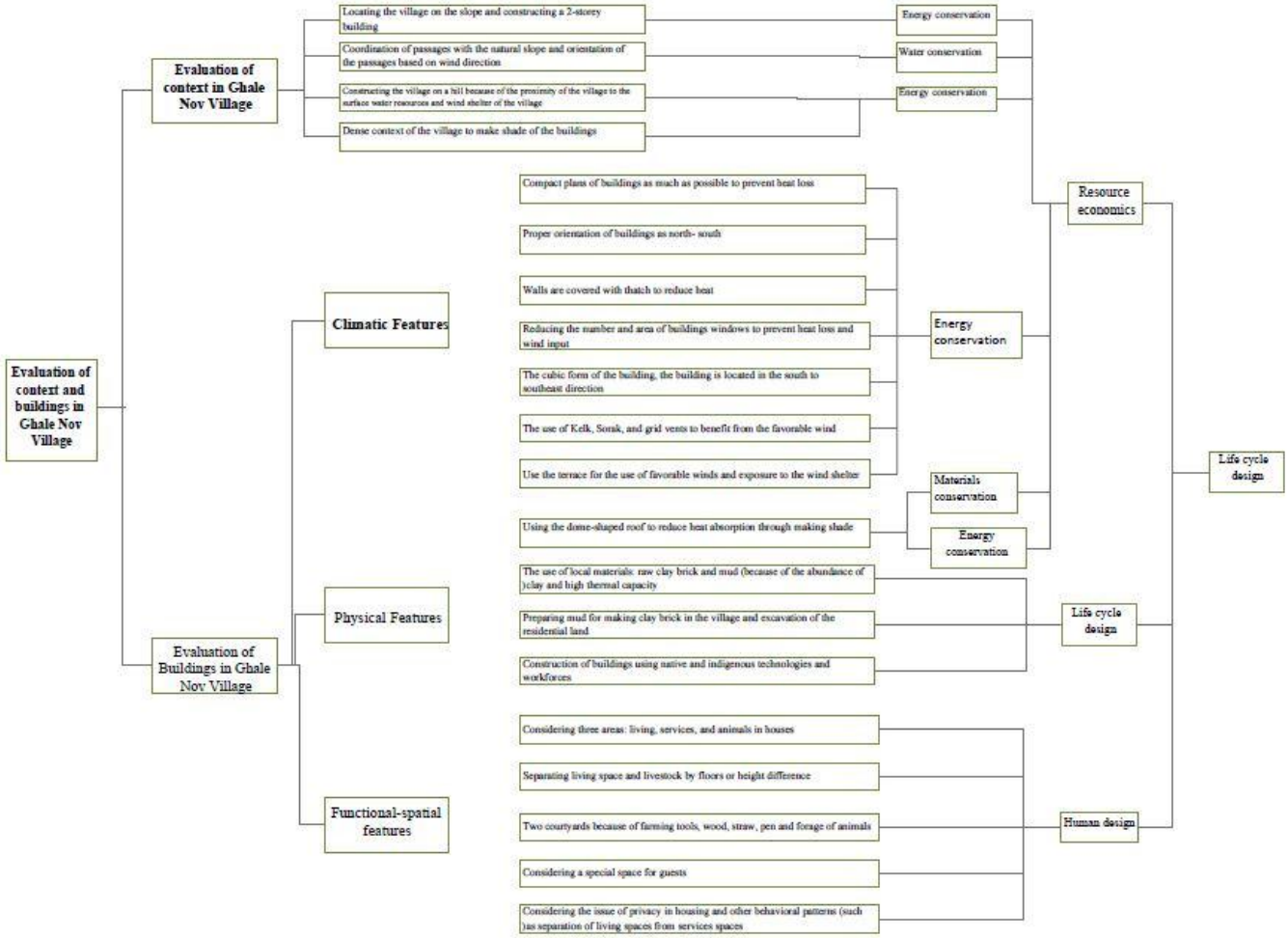

Diagram 1: Comparison the Architecture in Ghale Nov Village and Principles of Sustainable Architecture

1. The establishment of villages on the slopes of the hill as shelter against the wind and the use of surface water resources.
2. The use of compact context with narrow and irregular alleys with high walls in order to create the maximum shade.
3. Proper orientation of buildings as north-south and the reduction of the opening levels based on the sunlight.
4. The use of Kelk, Sorak, and grid vents to benefit from the favorable wind.
5. Using the dome-shaped roof to reduce heat absorption through making shade
6. The use of local materials (raw clay brick and mud)
7. Construction of buildings using native and indigenous technologies and workforces
8. Considering three areas: living, services, and animals in houses
9. Separating living space and livestock by floors or height difference

Finally, it can be concluded that this study can express the rich structure of the architectural fabric in this village to a certain extent. If further research can be done, new and indigenous techniques of architecture and construction are obtained to achieve sustainable principles for this region.

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