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Evaluation of Match Rate in Construction of Iran's Cold and Mountainous Climate with Environmental Comfort Indicators

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Abstract: *The purpose of this study is to evaluate the parameters of construction physics including form, orientation, the arrangement of activities, openings and materials in six sites of traditional homes in Hamedan and analysis of the effect of physical parameters on thermal comfort. Thus, in order to achieve physical characteristics, each construction is evaluated in terms of designing criteria. Then, the impact of the studied factors during the coldest and hottest days of the year is evaluated through software modeling. The results of the study confirm the role of buildings' physical parameters in optimal energy use. The results indicate that houses with yards have more suitable thermal condition in comparison to houses with gardens. The differences in design, make the houses with yards in the thermal comfort area during warm seasons, and during the cold seasons, they will provide 30 to 40 percent efficiency of the heating energy through radiant energy efficiency.*

Keywords: *Construction physics, thermal comfort, climate-based design, native housing*

INTRODUCTION

In the past, the architecture of each region around the globe was based on its own ecological and cultural principles, and there used to be a deep connection between the design and climate issues. After the "industrial revolution" and the increasing growth of fossil fuel utilization, as well as creation of an "international style of architecture", climate-friendly design skills were gradually ignored, and the gap between inharmonic design and the required comfort conditions was filled by using fossil fuels.

Contemporary buildings are mainly constructed the same way regardless of the mentioned conditions, which indicates the ignorance of environmental coordination, energy requirements and identity (Sozen et al., 2007). Traditional and native buildings in each region are products of the experience and practice of centuries that can be a continuous source of knowledge. Using local and climate-environmentally friendly materials are among the factors that make the architecture identity distinct in each region. The native architecture of each region is a simple example of the region's climate condition, materials, construction methods, lifestyles, traditions and the way people live in a region. Houses are the most original and beautiful example of this.

Researchers have studied various traditional buildings around the world with regard to bioclimatic and environmental architecture. This research is conducted with regarding the issue of traditional architecture's environmental function in two different qualitative and quantitative methods. The qualitative method includes evaluation of the environment and performance of different buildings' materials in dominant climatic conditions. While the quantitative method is based on the measurement of temperature status inside and outside the buildings of the study, which leads to conclusions about the thermal performance of buildings(Ooka et al., 1990).

Using qualitative analysis in this study, we studied the climatic solutions used in native housing, then we obtained the effect of the desired indices by using software modeling and quantitative analysis. At the end, a diagram of the effective indices and their effectiveness is provided which should be considered in the new designing.

2- climate contextualism

During all historical ages, designers were looking to respond to climate conditions, and their first practices were in designing primitive people's housing (Fig. 1). The shelter is the most important dignity to humankind, and it has always been a primary element in the constant struggle of survival to him(Touman, 1990).

Figure (1) The black house, an old house located on Scottish hybrid islands

The local architecture used to have a distinct regional identity prior to the advent of technology and using the energy resources. The first houses were low-energy or non-energy and they depended directly on the climate of the area, and the measures used in their designing guaranteed the survival of the inhabitants, and this has been shown in many ways throughout the world.

Meryl Giness classified the context of architecture to three general subjects including form patterns, activity patterns, and climatic patterns. Form expressions include elements such as space, shape, scale, and proportions, details of materials, texture, and colors. Activity patterns, discovering the site of construction, behavior of individuals and groups are among the factors that can relate the building to its context, and the climatic patterns that affect the materials, colors and openings, the compression of their form shape, the ceilings, etc. (Figure 2).

Touman indicated that climate limitations (weather) are widely accepted as cultural geography. There is no way to deny the role of the climate in architecture. On the other hand, the examination of the difference in the pattern of urban house types in one region e.g. the Persian Gulf region shows that the design style of buildings is more culture-related than climate, hence, for a successful designing, considering cultural and climate-based contextual patterns will be a problem solver for designers (Touman, 1990).

Figure (2) The louver view of Sheikh Isa ibn Ali house, Bahrain

Background of climate based designing

Climate-based designing is a method for reducing the overall energy consumption of a building and the first line of defense against buildings' external climatic factors. In all climates, buildings constructed based on the principles of climate designing will have the lowest need for heating and cooling systems, and instead, they mostly use the natural energy sources of the climate. In other words, climate designing is a response to climatic conditions and features of the site in order to maximize the comfort and health of building for the inhabitants along with reducing energy consumption. The key to this designing is to provide the best suggestions based on the region's climate (Hanan, 2014).

Madhavi found in his field study on a number of native houses in villages of Marikal that they are seeking for climate based designing Marikal is a dry and warm area with low rainfall and seasonal drylands in Telangana region southwest India. Home, a single room for a low-class family, without threatening any functional or climate requirements, slowly transforms itself into a six-room home for a villa (Fig. 3).

Figure (3) Native house with local materials, Marikal country, India

Existing thick walls and ceilings with high thermal capacity, small yards, louvers, and small openings have been created to provide shady spaces and proper use of daylight (Indraganti, 2010). Florina, northwest of Greece has a cold climate, with long, cold, and humid winters, as well as short, warm and dry summers. The typology of traditional houses in Florina is based on three basic elements: Private room (Oda), open (Hayat) and closed space, and public places (Sofa). Private room (Oda) is close to living space with a square plan which all basic functions of living, such as eating, sleeping, and parties are held in it (Oikonomou et al., 2011). The yard is a semi-closed traditional space with a square or rectangular shape that sometimes extends between rooms of the houses by balconies. Widespread use of wood as a local material as decorative and striped column is seen in a large number of decorated windows (Fig. 4).

Figure (4) Native house with local material and wooden windows, Florina, Italy

3- Methodology

The number of old houses with significant architectural and decorative value in Hamedan province is 10 to 15. Selected samples in this research are selected from the buildings under the supervision of the cultural heritage organization of the province with valid documents. In this regard, at first six sites of Hamedan's traditional houses were studied in terms of design factors, including the form of construction, orientation, plan layout, openings and materials, and then through the Ecotect software, we examined the role of the mentioned factors and their impact on designing.

Geographical location

Hamedan is located in 48-degree and 35-minutes east longitude ((48 ° 35'0 "E) and 34 degrees and 46 minutes north latitude (34? 46'0″ N). Hamedan province is one of the western provinces of Iran, which is limited from the north to Zanjan province, the south of Lorestan province, the east to Markazi province, and the west to Kermanshah and Kurdistan provinces. Western mountains - which include the western slopes of the central mountain range of Iran - are in the cold and mountainous climate.

Weather information

According to the reports of the Hamedan-Nojeh synoptic stations, and based on the average of 1976-2003, the maximum absolute air temperature in this province is 36/8 and the minimum absolute is -29.6 and the average temperature is 9.6 degrees Celsius. The warmest months of the year are July and August with a maximum temperature of 35 ° C, and the coldest months of the year, with an average of -25.4 ° C are January and February. Hamadan is one of the coldest provinces in the country with 143 days of freezing during the year.

4- Introducing case examples

Traditional houses in Hamadan are divided into two general groups of gardens and yards. Garden houses are often located in the middle of the site, and houses with yards are in the neighbor to nearby houses. Of the six sample cases investigated, houses of Saberyoon, American, Sharifi, Zarrabi, and Sharafi have yards (Table 1).

(Table 1) Overview of garden and yard houses

Garden houses		Houses with yards	
Nazari		Sharifi	
saberyoon		Zarrabi	
American		Sharafi	

5- Identification of effective factors in designing

The proper designing and building physics in the cold and mountainous climate of Iran follow a number of principles and characteristics which the ultimate goal of them is to use solar energy in building heating, reducing the thermal dissipation of the building and reducing the impact of wind on thermal dissipation.

Givoni indicated that the ability of a building to conserve energy along with the thermal capacity of the material depends on the shape, orientation, density, size of the windows, the color of the building and the measures taken to utilize and protect from solar radiation (Givoni, 1981).

Some of the variables relevant to the buildings' form affecting the heating and cooling needs are form and shape of the building, orientation position, density index or construction compression, and structural properties of the materials. Considering these variable characteristics is important because they determine the energy needs of the building and maintaining it in comfort condition. Optimal architectural designing helps provide the primary conceptual form of reduction in energy consumption of a building, because designing quality has a great influence on the energy performance of a building e.g. the density of buildings has a great influence on the thermal exchange of the building with the outside area(Bekkouche et al., 2013).

Form

Changes in shape and form of the building affect the energy efficiency, even if other features remain unchanged, which means that form is an effective factor in energy demand in the building (Parasonis et al., 2012).

During the tests conducted by Fookin with the goal of achieving the best form as a base of optimization, the introduced solution was the use of spherical form, which despite the limitations of this form for designing, the rectangular prism (cube) is known as the best form of the building. The issue of selecting appropriate dimensions and building geometry was analyzed by Menkhoff and his colleagues and the concept of geometric compression as the quotient of the exterior walls of the building to its volume was introduced(Menkhoffand et al., 1983).

In other words, the quotient of the surface to volume (geometric compression) shows the thermal performance of the spaces. Most of the native studied buildings have different rectangular cube shapes with a length to width ratio ranging from 1/4 to 1/2. Studies indicate that most native houses are two-story buildings and roof height is higher than today's houses, which varies from 3 to 4 meters. Garden houses' roofs are sloping, often foursquare and roofs of houses with yards are flat. The layout of the rooms in the houses with yards, depending on the arrangement of empty and used spaces are divided into groups including one-directional, two-directional, U-shaped and L-shaped. Information about the shape of the studied houses from the aspect of geometry, height, volume, number of floors, type of roof and the deployment of the building are presented in table 2.

(Table 2) Volume and form of Hamedan's traditional houses

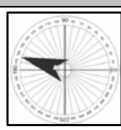
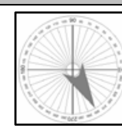
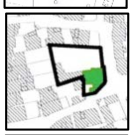
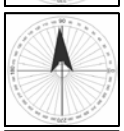
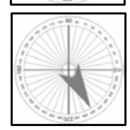
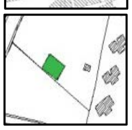
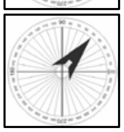
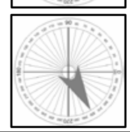
Building name	Nazari	Saberyoon	American	Sharifi	Zarrabi	Sharafi
Geometric form (m)	Rectangle with Height of 67.33 and width of 40.15	Non-geometrical with height of 30 and width of 20	Rectangle with Height of 6.16 and width of 6.10	Rectangle with Height of 6.25 and width of 12	Rectangle with height of 18 and width of 17	Rectangle with Height of 20 and width of 14
Height (m)	35.7	9	8	8.5	8.6	7.6
Surface of floor (m2)	518.5	396	175.96	307.44	774	2781.2
Volume (m3)	3811	3564	1407.68	1844.6	2080.8	1876

Number of floors	Two floors and an establishment of - 55.0 from to the ground	Two floors and an establishment of +40.0 from to the ground	Two floors and an establishment at level of the ground	Two floors and an establishment of - 2.0 from to the ground	Two floors and an establishment at level of the ground	Two floors and an establishment at level of the ground

Orientation

Orientation is among the effective factors in optimal designing of each building, which is determined depending on geometrical latitude and the desired climate. In the studied samples, the orientation of the garden houses was different due to their location on the free site, but houses with yards were oriented toward the southeast with different angles (Table 3).

Table (3) Orientation and deployment of traditional houses in the site

The palace buildings, orientation, and deployment of the building			Buildings with yards, orientation, and deployment of the building		
		Nazari house	Sharifi house		
		Saberyoon house	Zarrabi house		
		American house	Sharafi house		

This orientation allows the building to use before noon sunlight more than afternoon light, and the heat absorption consequently is started earlier. The most suitable orientation for building houses in Hamadan city is shown in yellow color. The best orientation for rotation is 5 degrees to the south east (Fig. 5).

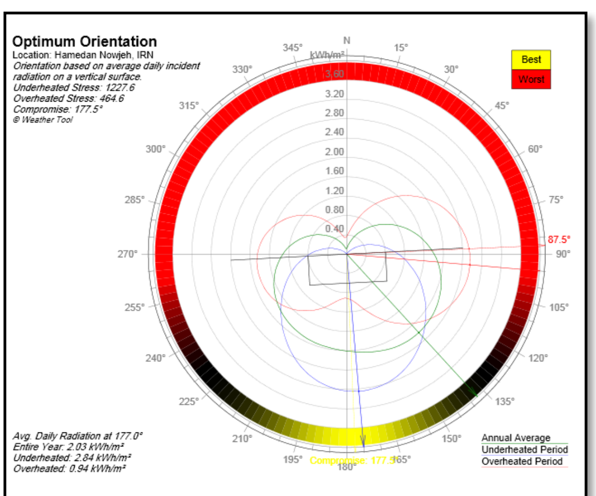


Figure (5) Optimal orientation of the building in Hamedan based on weather information of Nojeh station, Hamedan, Iran.

Materials and the thickness of external walls

In cold climate native houses, the need for high-temperature mass to maintain a longer latency is well understood by local builders. Exterior high thickness walls with local materials such as clay, brick, and rock stones are used. External walls in the studied samples had the thickness between 70 and 130 cm, which creates a thermal resistance of 0.6 to 1.2 m.k / w, which is equal to a 4 cm layer of polystyrene insulation (Table 4).

Table (4) Materials and thickness of the external walls

Palace buildings	**Materials and thickness of exterior walls**	**Buildings with yards**	**Materials and thickness of exterior walls**
Nazari house	Clay and brick, thickness of the outer wall is 150 cm in the ground floor and 100 cm in the first floor	**Sharifi house**	Brick, wood, and cement covering, external wall thickness on both floors is 90 cm
Saberyoon house	Brick, thickness of the outer wall is 70 cm	**Zarrabi house**	Brick with rock stone, outer wall's thickness on both floors is 100 cm
American house	Brick, the thickness of the external wall in both floors in the north-east and south-west view is 100 cm and in the south-east and north-west view is 94 cm.	**Sharafi house**	Brick with rock stone, outer wall's thickness on both floors is 103 cm

Designing openings

The greatest amount of increase in temperature or the highest thermal losses is from openings of the buildings such as windows. Therefore, it is obvious that windows are the main element in the maximum amount of heat transfer between the building and the outside environment(Noh et al., 2001).

Passive design strategies play a key role in providing the optimal use of the solar energy, natural light, and thermal comfort. A common method which has been used is direct absorption method (Eshraghi et al., 2014). In native garden houses, openings are located in four different directions of the building with different proportions. But in houses with yards, the openings are only in the southern view and they occupy about 1/3 of the building's level (Table 5).

Table (5) Location and the ratio of the opening's surface to the view

Building's name	Ratio of opening's surface to the view			
	Northern view	Southern view	Eastern view	Western view
Nazari house	13 %	7 %	10 %	10 %
Saberyoon house	26.5 %	-	-	-
American house	9 %	9 %	2 %	2 %

Sharifi house	-	34 %	-	-
Zarrabi house	-	33 %	-	-
Sharafi house	-	35 %	-	-

Placing activities on the plan

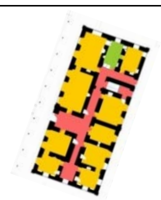
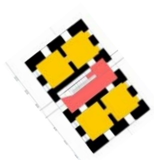
The thermal sensitivity of each space will change along with the type of activity. The type of building, function, and the sensitivity of the inhabitants play an essential role in determining the thermal comfort conditions (LWEC et al., 2011).

Generally, traditional houses have a specific zoning for a variety of activities that are divided according to the amount of heat demand, hours of use, and the rate of efficiency from natural light. The area in traditional homes is divided into living spaces including living rooms and bedrooms, service spaces, including kitchens and warehouse spaces.

In the garden houses, the spaces are focused, winter and summer rooms are not separated, and living spaces are placed facing outdoors for taking advantage of the daylight. In houses with yards, spaces are connected to each other and they are in one row. The part of the building which is faced to the north is used for winter because of possessing the suitable sunlight. In some houses, there is also a summer living room on the south side due to the cool temperature in the warm season. Basement and warehouses in houses with yards are often seen as basements with small windows (Table 6).

Table (6)

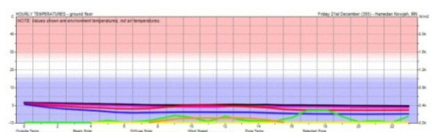
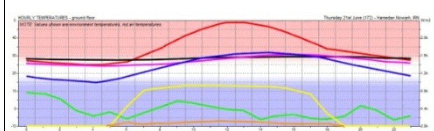
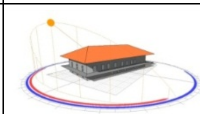
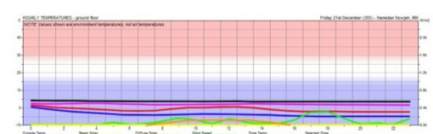
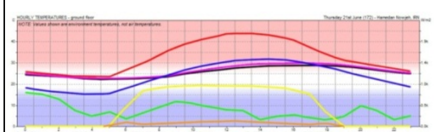
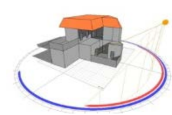
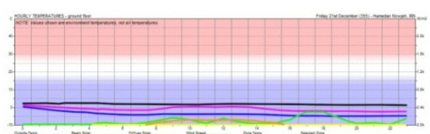
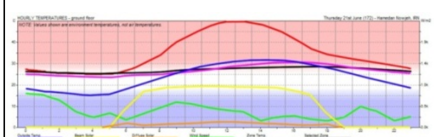
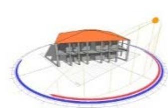
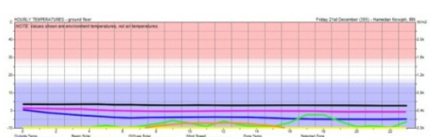
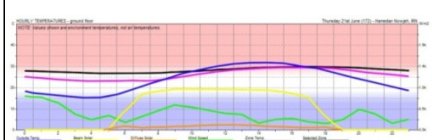
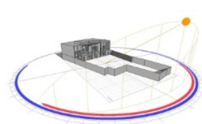
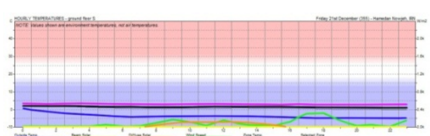
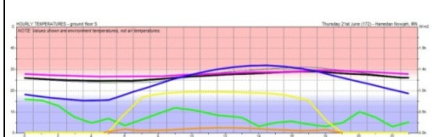
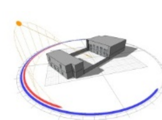
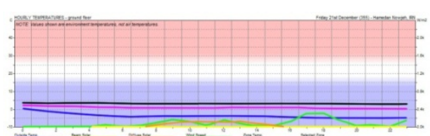
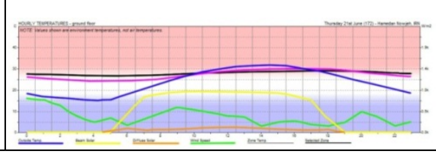
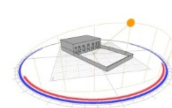
Direction: Living spaces service spaces balcony yard

Palace buildings	Combination of interior spaces on the first floor	Buildings with yards	Combination of interior spaces on first floor
Nazari house		Sharifi house	
Saberyoon house		Zarrabi house	
American house		Sharafi house	

6- The numerical value of the effect of qualitative indices

Simulated models of the houses are considered for the hottest and coldest days of the year (June 21 and December 21) (Table 7). The horizontal axis of the chart shows 24 consecutive hours and the left vertical axis shows the air temperature in Celsius. Each chart represents three thermal ranges, in which, the central white section is the thermal comfort range (temperature between 18 and 27), the blue region indicates under comfort temperature (temperature between 18 to -10) and the red part of the chart indicates the temperatures above the comfort zone (temperature between 27 and 50). In each chart, the blue curve shows outside temperature, the green curve shows wind speed, and the yellow curve shows the solar beam in w / m2. Thermal zones in garden houses consist of three curves for the ground floor, the first floor, and the roof, and for houses with yards, there are two charts indicating the ground floor and the first floor. Sun radiation is 940 w / m2 on July 1 and 130 w / m2 on the first day of January, this amount is about 78% of the radiant energy in the early summer and 10% of the radiant energy in winter's first. Based on the findings, indoor air temperatures at 12 o'clock in the first day of July (outside temperature is 31 C) are between 26 and 27 C, which will be at the ultimate limit of the comfort zone and the need for ventilation and cooling is limited in them. At 12 o'clock of the first day of January (outside air temperature -4 °), the average temperature of indoor spaces is between 0 and 4 degrees, which varies in garden houses and houses with yards. Generally, the average temperature of indoor space in houses with yards is 4 C higher in the cool season than the garden houses in the same conditions. In the analyzed samples, the highest rates were recorded from the homes of Sharafi, Sharifi, and Zarrabi, respectively, and after that, the American and Nazzari houses, and the Saberyoon house are at the lowest level.

Table (7)

Hourly temperature on December 21	Hourly temperature on June 21	Direction toward optimal mode	Building's name
			Nazzari house Saberyoon house American house Sharifi house Zarrabi house Sharafi house
			
			
			
			
			

Hourly temperature of the ground floor, first floor and the roof on June 21 and December 21

Directions: Roof curve ● ground floor curve ● first-floor curve ● outside temperature ●

direct solar radiation   diffused solar radiation   wind speed

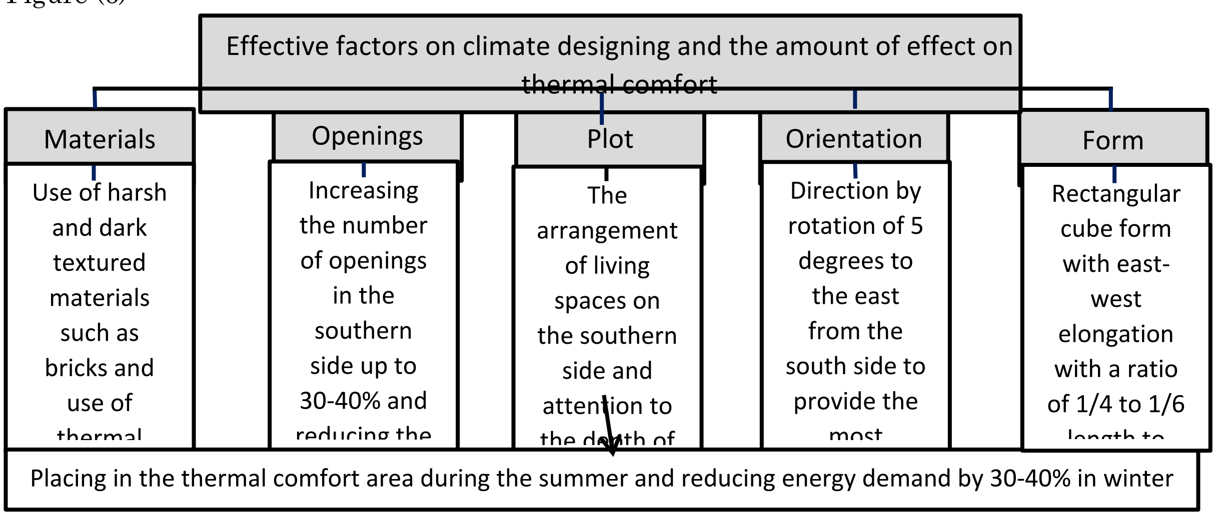
Results

It should be noted that understanding the harmonic architecture with the climate never relies on imitation, in other words, the purpose of this study is not to suggest construction of old-style buildings for today, but to emphasize the importance of energy efficiency, climate awareness and construction of buildings compatible with the environment regarding the advancements in new technology and new materials. The integration of the principles and the various aspects of traditional architecture into a way of adapting to the term "modern native" in modern designing process of buildings is a step towards a sustainable development, and this is the solution that can restore balance and excellence to our architecture in the long run.

Considering the qualitative and quantitative analyses, it seems that houses with yards are more focused on climate and environmental aspects. Therefore, houses with yards including Sharifi, Zarrabi, and Sharafi are in more appropriate thermal comfort zone compared to garden houses including Nazzari, Saberyoon, and Americans during the warm season. In the cold season, the temperature difference between the outside and inside of houses with yards is higher than the similar samples in the garden houses group.

According to the results, a five-index diagram that has been found to be factors for higher energy efficiency of houses with yards in compare to garden houses is provided in figure 6. It should be noted that some of the listed items cannot be implemented in all modern designs, but what's important is that paying attention to any of these factors can lead to creation of various solutions that differ according to the different conditions which can only be achieved by understanding the climatic and cultural characteristics of the region.

Figure (6)



Effective factors in climate designing and their effectiveness in houses with yards

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