

Evaluation of a Sustainable Bigadiç Civil Architecture and its Landscape: Architectural Typology and Building Physics

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Abstract: Most building technicians in the past were familiar with the climate in which they were building. However, a building designer was aware of ways that could benefit from more precise information regarding climate, so rigorous climate analysis is necessary. They could convert the advantage of climatic features of place by opting for appropriate building shapes, location, orientation and the use of appropriate building materials. This study has used climate data sheet, Mahoney tables and Building Bioclimatic chart to formulate strategies for building design. This paper identifies climatic considerations as an integral part of building orientation in Bigadiç, in Balıkesir, Turkey.

Key words: Sustainable architecture • Bigadiç • Building typology • Vernacular architecture

INTRODUCTION

A remarkable feature of vernacular architecture is the use of local building materials to construct housing using passive energy that is requiring no extra energy. In other words, vernacular architecture provides the local inhabitants with a comfortable living environment, while at the same time, having minimum impact on the natural environment [1]. The term “vernacular architecture” is used to refer to traditional buildings that were designed and built in accordance with the local climate and culture. Much research done has been carried out on vernacular architecture, mostly from humanities or social science perspectives, very little are from an environmental engineering angle. The vernacular studies both social science perspectives and environmental engineering angle are very important, especially having traditional architecture such as Bigadiç settlements.

A holistic approach that considers the role of the environment as a major one, within the limits of the resources available can be easily observed in the vernacular architecture of Bigadiç. Traditionally designed buildings are often considered as the predecessors of modern bioclimatic design [2]. They display embodied experience of building with relationship between building

and climate by the way of implying a logical analysis, the considering main principles and a rational using of resources. These buildings will be studied as models of environmentally responsive and sustainable architecture.

The aim of this paper is to evaluate the vernacular settlement of Bigadiç, in terms of its architectural typology and building physics.

Bigadiç vernacular settlement has functions as a living organism. It has meaning that inherently sustainability through the use of various bioclimatic concepts applied in its original construction integrated with the its topographic area usage. The subsequent analysis is comprised of two major parts: 1) a study concerning the evolution of the built environment (typological analysis, site planning, construction materials and techniques); and, 2) an evaluation of specific vernacular dwelling types and their response to climate, based on passive design principles that are responsible for the bioclimatic character of the settlement.

Bioclimatic Design Concept and Building Physics: Bioclimatic design must attempts to integrate the building with its surroundings such as climatic conditions, techniques and materials available in the region. Moreover, bioclimatic design relies on building physics,

which is the ability and knowledge of how to allow sunlight, heat and airflow through the building envelope when necessary, at certain moments of each day and month of the year [3].

The vernacular architecture of Bigadiç is named as bioclimatic concepts, aspects of Building Orientation and Form, Building Envelope and Materials and the strong relationship between site, climate and building that made him aware of the consequences of bioclimatic design choices.

Bigadiç: A Turkey Vernacular Settlement in Balıkesir

Location and History: Bigadiç is a mountainous village located in Balıkesir, in mainland Turkey, 36 km South of Balıkesir with approximately 49957 inhabitants. Most of the houses date back to the second half of the 19th century and. They have totally replaced older structures or been added to older house-cores [4].

Climatic Data: The energy conscious building aims to optimise the use of passive solar energy, natural ventilation and natural light to create a comfortable and energy efficient working environment.

It is important to consider the local climate during the first stage of building design. In a buildings, the shape and the orientation of the building should be first considered considering the climate of the area, the wind, the temperature, amount of rainfall and relative humidity. Air temperature reaches maximum of 32.0 C and minimum of 4.5°C [5]. The summer months have an average temperature of 24.0°C, while the winter months have an average temperature of 6°C. The annual average temperature is about 15°C and the relative humidity varies from 50% to 76%.

Mahoney Indicators: The climatic data has been incorporated in the Mahoney Tables which provide preliminary design recommendations. They are grouped under eight headings: layout, spacing, air movement, openings, position of openings, protection of openings, walls and roofs. The following is a summary of the recommendations for Bigadic: a) Layout: buildings oriented on an east-west axis to reduce sun exposure; b) Spacing: compact planning; c) Air movement: rooms single and double-banked with temporary means for wind passage; d) Openings: medium-sized openings, 20-40% of wall area; e) Position of openings: openings in north and south walls at body height on windward elevation, as well as including openings in internal walls; f) Protection of openings: protection from direct sunlight; g) Walls: high mass; and h) Roofs: high mass [6].

Analysis of the Built Environment: Bigadiç's vernacular architecture is ancient settlement and elegant structure morphologically and structurally with a unique landscape pattern. The buildings are built according to the principles of traditional Turkish house. It is believed that the house is continuation of social life.

This study examines the most important architectural forms found in village that plays a significant role in the evolution of vernacular architecture in Bigadiç and which are subject to preservation. The collected data which are measured, sketched and observed by authors is the outcome relating to the energy aspects of the buildings.

Typological Analysis: In Bigadiç town, certain types of Turkish dwellings are introduced. Effects of the community structure are seen in architectural space. In Bigadic town, there are clarity in the general layout of the dwellings both in its architectural synthesis as well as in its structural formation; the building envelope is simple, clear and easy to grasp.

Building materials of Anatolian houses varies by region. The tradition of building stone is especially common in the vicinity of the Marmara Region. The building envelope of the traditional building at Bigadic was being designed with high insulation levels, such as stone and timber.

Turkish house plan types by Sedat Hakkı Eldem divided into four groups [7].

1. Non-court plan type, 2.Exterior courtyard plan type, 3.Inner courtyard plan type, 4.Central courtyard plan type

According to this grouping, all the houses in the district has the courtyard plan type. The classification and typological analysis is based on functional characteristics, i.e. use-patterns and variations of the basic form (Table 1).

Site Planning: Bigadic town developed in response to orientation and topography (Fig. 1). It has a clear-cut organization that defines the use of space and determines the distinction between public and private areas. Dwellings are detached with extensive courtyards and sinuous streets of varying shape, width and position (flat, inclined or stepped with stone path) that connect buildings to one another (Fig. 2). There are harmony between relationships and size ratios between streets and houses. The human scale is indication of the settlement dimension.

Detached dwellings of compact geometry and single or double blanked extensive "sofa" are designed considering climate conditions The connection through

Table 1: Typological analysis

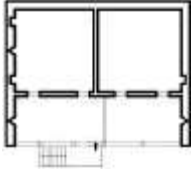
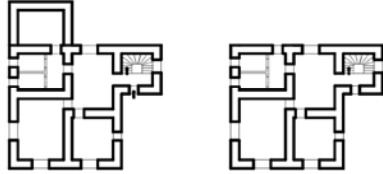
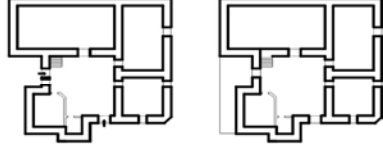
Types of Architectural typology dwellings	
Plan scheme	Description
<p>Kasım Atak House</p> 	<p>One storey All activities take place in one room. The ground floor is used as fabric weaving work shop. It is known as “Tokat house type” “Tokat house type” is used as a home-type plateau “Tokat house type” was square or rectangular planned houses constructed with unification of the pine logs. Roof of the house was covered with wooden or barren earth. Its walls were plastered with mud mixed with straw.</p>
<p>Yüzbaşı Şevket Gürsel House</p> 	<p>Two stories unit The ground floor and the first floor are used as residence. It is divided into three rooms separated by a corridor. Bedrooms are private spaces. The house plan was drawn by Military Officer Sevket Gürsel. For this reason, the building reflects the architectural features of military barracks House plan is in the form of inverted L. Corners and window frames of the building were emphasized with white stone. Ceiling, floor and doors were wooden. An exterior stone staircase leads to the first floor.</p>
<p>Hacı Süleymanlar House</p> 	<p>Two stories unit The structure has exterior courtyard plan type The ground and first floor are used as residence. Sofa is a place surrounded by rooms. The top floor of wooden stairs is wooden cover. When wooden cover closed, the connection is cut with the upper floor. It reflects the properties of a typical residence of Turks. Housing was 18th century structure. There are located two spaces traversed in each other in the northeast of the building.</p>



Fig. 1: Plan of the settlement



Fig. 3: Broad-leaved trees close to the garden providing shade during the summer.



Fig. 2: Dwellings detached with sinuous streets

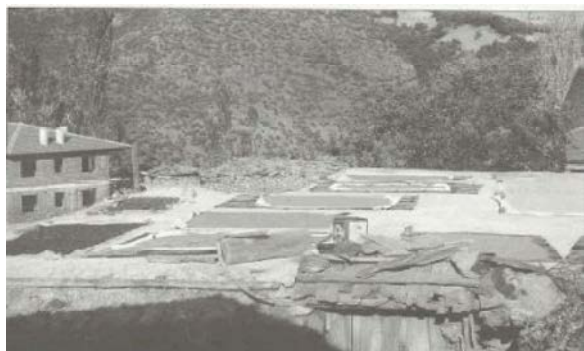


Fig. 4. Private Terrace of Kasım Atak House

the garden is provided by “sofa”. Gardens provide shady and cool places that become the main living units of the summer months. The use of gardens along with their landscape features (trees, flowerbeds, broad-leaved trees, soft ground surfaces) and their appropriate placing serves as an additional climate modifier, ensuring human comfort both indoors and outdoors [8] (Figs. 3 and 4).

Spatial organization highlights the rich visuality in the central-hall space, as the functional, architectural spatial and visual focal point of the house. The choice of movements within the house and the garden is under control as spatially [9].

The outdoor activities are pleasant spaces where take place almost throughout the year. Terraces are turned into a space where are been dried of foods like wheat, plums, crop and onion. (Fig. 5). Harmony and interdependence between dwellings and gardens-terraces is developed. Large and tall adobe/stone walls define the boundaries between public and private spaces (Fig. 6). Their shape, size and location vary according to the tall walls of the boundaries of each site by which they are defined. There is one plan layouts identified: with entrances through the garden.

Returning to Bigadiç's rural character, domestic gardens and terrace is becoming clear area. The garden space is essential to provide with a refuge within their home and even the garden space itself is a refuge.

Construction Materials and Techniques: The used building materials used are brick material and crushed stone. White stones and green stones used in construction are the local material. The most common building method in Bigadiç has stone or brick construction as an uniform construction (Fig. 7).

The main building material used for constructing the load-bearing walls of the dwellings was stone. Topography is the most plentiful resource in the region. For this reason, The local stone is often used that is obtained from the region. White-colored stone was obtained from Işıklar village. Green Stone used in construction was obtained from Abdikırı region.

Building facades rolled up with mud-brick, recently were plastered with cement. Upper cover of the building is soil structure. The wood of “Davulga Tree” [10], is placed on wooden roof beams. The wood of “Davulga Tree” is covered with earth. “Davulga Tree” in the region have been used because of robustness. Today, the roofs of the buildings have pitched roof covered with tile.



Fig. 5: Extensive tall walls



Fig. 6: Bigadiç's single manner of construction



Fig. 7: Genel view of Bigadiç

The structures hidden in the high garden walls, are two floors above the ground floor. Overhangs and balconies are located above the ground floor. Overhangs and balconies are supported by wooden consoles from the bottom.

The structure called “timber frame” are the light construction that is built up the wooden floor. The empty spaces from construction were filled with bits of wood, cane, seaweed or shavings. The walls are covered by plaster. This application make them looking like ordinary walls despite their being extremely light.



Fig. 8: Tradional Bigadiç settlement

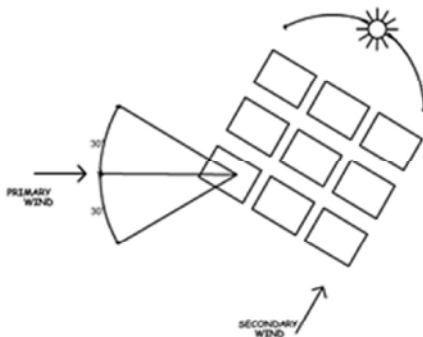


Fig. 9: Street layout considering sun and wind movement

Ceilings of the houses in the region, has the original ceiling decorations. “Kundekari technique” [11] contains elements created with floral decorations of the ceiling. “Kundekari technique”, applied to the period of Anatolian Seljuks, is a difficult wood decorative art. Kundekari technique means that the timber insertion technique. It is the most original ceiling decoration in the region. “Kundekari technique”, applied to a hard wooden decoration is the art of the Anatolian Seljuk period.

The roofs were most often four pitched, such as oak, juniper, pine and cypress. There are cupboards on the walls of the rooms. The empty space between the ceiling and the cupboards provides natural ventilation.

Evaluation

Architectural Typology and Building Physics: Vernacular dwellings of Bigadiç are evaluated in terms of building physics criteria solar geometry, thermal mass, heat transfer, air movement and solar geometry.

The design strategies are formulated considering the comfort analysis and preliminary recommendations from Mahoney tables [6]. Following are the specific design recommendations for Bigadiç (Fig. 8):

- Street layout
- Securing neighborhood sunshine
- Building orientation
- Building structure
- Roof design
- Windows and ventilation
- Shading devices
- Courtyard option

Moreover, the evaluation is based on the design variables proposed by Mahoney. These are: a) the layout of the buildings (orientation in relation to sun and wind, aspect ratio); b) spacing (site planning); c) air movement; d) openings (size-position, protection); and e) building envelope (walls: construction materials-thickness, roof construction detailing) [12].

Street Layout: Orientation and layout of streets have significant effects on sun and wind in buildings.

To maximize cross ventilation and air movement in streets, dwellings in Bigadiç are oriented towards 30 degree south-west axis. Major street orientation within the angle of approximately 20-30 degree on either direction of the prevailing breezes is recommended highly importance (Fig. 9).

The term “aspect ratio” is used to denote the ratio of the longer dimension of a rectangular plan to the shorter. The N/W and S/E walls are longer than the N/E and S/W and the “aspect ratio” varies from 1.0 to 2.0.

Securing Neighborhood Sunshine: Solar radiation in winter months is necessary for buildings. The organization of open spaces is an ideal approaches for streets.

The another approaches are solar utilization at maximum density and is to elongate of buildings in the east-west direction and in the north-south direction. This placement allows to collect sun to buildings facing north and with this type planning type, buildings will not allow to shade on each other. Because of the topography or pre-existing conditions, do not east-west orientation in many streets but several variations of open space layouts to solar access are seen in Figs. 10, 11 and 12.

Air Movement: The natural ventilation are provided with appropriate placement of the rooms. The openings of door and window are advantage to get breeze through their sizes in relation to the size of the room.

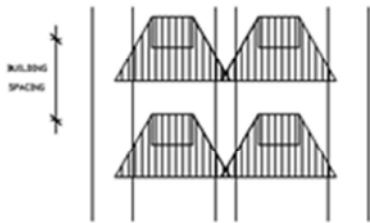


Fig. 10: East-west lot arrangements

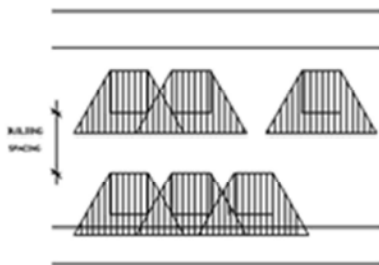


Fig. 11: North-south lot arrangements

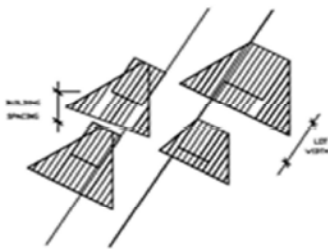


Fig. 12: Non cardinal streets, lot arrangements

Openings: Size-position of openings: Openings of door and window are placed according to sun orientation, topography, views and wind patterns. Buildings have mostly single banked building orientation. Cross ventilation as good is provided by double banked building orientation. Thus, optimum views, natural lighting and cooling, ventilation are achieved with suitable building orientation, design and geometry of the openings and their configuration of juxtaposed. There are several South/East openings relatively big sized, whereas those facing North/West are fewer and of small sized. There are small number windows of small size facing south-west and several openings in the north-eastern façades. In addition, their placement on a 30° north-east axis, in the direction of the wind, provided with natural ventilation from prevailing breezes in summer. The sizes of the openings of door and window were relatively small in relation to room area and the ratio between their width and length is about 1/2.

Protection of the openings: Protection of the openings of door and window from solar radiation is important. Especially, during summer the protection is also achieved with the use of shading devices, such as metal and wooden external lattices that permit the dwelling to be fully shaded during the summer. At the same time, in winter, the building is exposed to solar radiation fully. Such devices are lattices, curtains, vertical shafts, external horizontal shades.







Open spaces, such as balconies with various forms as an architectural components are bulky volumes changing the amending the existing air inner space, creating shade on the sun-warmed facades and protecting building from rain effect. They are usually south and east direction oriented, providing a thermal refuge and a place of transition from inwards to outwards. The respective wide of the balconies must be 1.00-1.50 meters to provide for outdoor functions. Some balconies are covered by a roof that is angled from the roof to best reduce solar admittance.

Building Envelope:

Walls: Thick walls are the most common external walls and are made of stone. The wall section has a thickness of 0.60-0.70cm and a low U-value ($U=0,0336W/m^2K$); hence it serves as a good insulator[13]. The heat storage time of these walls is high; they store heat during the daytime and radiate it into the room at night when the outside temperature is below the comfort range. [14]. The light colored surfaces of the façades are used as a mechanism for the protection of the high thermal mass walls against solar radiation as they absorb less heat in summer, thus preventing the rise of internal temperatures.

Roofs: With the use of high thermal capacity vertical envelopes, physical comfort condition is provided ($K = 1.5$) [15] Table II evaluates all types of dwellings as their layout, spacing, air movement, openings and building envelope (Table 2). Dwellings are oriented in direction on a 30° north-east axis to provide maximum environmental comfort as the elements of sunshine, light, air and indoor temperatures suggested by the Mahoney Tables. All types of dwellings use compact geometry as much as possible, which provides maximum volume with minimum area exposed to the sun and to maximize heat storage. Moreover, the buildings are organized as detached dwellings with extensive courtyards suggested in the Mahoney Tables. The extensive garden walls that define

Table 2: Evaluation of the Bigadiç's architectural typology

Types of residence	Layout		Spacing Site planning	Air movement Plan layout	Openings		Building envelope	
	Orientation	Aspect ratio			Size-Position	Protection	Walls	Roofs
1a			Detached Extensive "sofa"	Single Blanked	N:10% S: 23% E:10% W:13%	External metal window railings Balcony at the Southside	Stone walls of high thermal mass	Rooms of medium thermal mass
1b			Detached Extensive "sofa"	Single Blanked	SW:10% NE: - NW:10% SE:10%	Balcony at the Northwest External wooden shutters	Stone +timber walls of high thermal mass	Rooms of medium thermal mass
1c			Detached Extensive "sofa"	Double blanked axial corridor	N:32% S: 10% E:19% W:4%	External wood lattice at the east side Balcony at the Northside	Adobe Stone walls of high thermal mass	Rooms of medium ther mal mass
1d			Detached Extensive "sofa"	Single Blanked	NE:20% SW:8% SE:- NW:-	Balcony at the Northwest External wooden shutters	Adobe Stone walls of high thermal mass	Rooms of medium thermal mass
1e			Detached Extensive "Sofa"	Single Blanked	NE:15% S: 20% E:9% W:10%		Adobe Stone walls of high thermal mass	Rooms of medium thermal mass
1f			Detached Extensive "Sofa"	Single Blanked	NE:- S: 88% E:2.5% W:-		Mud plastered stone walls of thermal mass	Rooms of medium thermal mass

the boundaries between public and private spaces seem to function as continuous wind fences, especially during winter. The Mahoney Tables suggest double-banked rooms providing wind passage.

Contrary to this suggestion, some floor plan of the dwellings is single-banked (in width of a room), but, some floor plan of the dwellings is double-banked (in width of two room) having an axial corridor for wind passage.

Bigadiç: A Sustainable Turkish Vernacular Settlement: Really, Bigadiç dwellings have maintained its qualities for centuries proposing sustainable construction techniques. The building materials are well professional choices aiming at sustainability.

Therefore, the vernacular architecture of Bigadiç can be defined as sustainable. The criteria leading to such a sustainable vernacular settlement are: 1) design recommendations, which minimize the adverse environmental effects in building; 2) use of materials with low maintenance and energy efficiency; 3) selection of building materials that provide thermal comfort; 4) use of natural resources; 5) reduction of energy consumption by maximizing passive thermal comfort; 8) improvement of environmental quality; and 9) provision for comfortable living spaces. [16]

Such an understanding of vernacular architecture may serve as a model for sustainable design responsibility to climate, energy use and notions of environmental quality [17].

CONCLUSION

Bigadiç town is a vernacular Turkish settlement that takes advantage of its climate through the appropriate application of design elements and building technology for energy preservation as well for ensuring comfortable dwelling conditions.

The Bigadiç dwellings are good example of climatic building design in a hot dry climate, with the thermal insulation and heat capacity of the building envelope, shading of the buildings by each other against solar radiation, small size window and door openings and ventilation holes for winter.

Many early period building constructors were aware of the impacts of wind and sun factor. They were aware of that what kind of building planning could destroy the negative effect of sun and wind that will improve the building microclimate. This paper is concerned with the fundamental practise of sustainability to understand of traditional building behaviour. It is evaluated that the specific vernacular dwelling types and their responsibility to climate based on design principles could be adapted to current architectural practice in the area. The relationship is evaluated among site, building and climate in order to optimize sustainability concept in the past. The secrets about durable, compatible, elegant, reliable and eco-efficient buildings are revealed in particular Bigadiç settlement. It can be presumed that these vernacular characteristics considering the climatic benefits are been

generated by society who had lived in there. But most of the people have recently moved into new buildings having heavily on mechanical systems to provide thermal comfort. According to them, the new buildings are not as comfortable as the traditional ones.

Therefore, they can form design recommendations that could be incorporated into current architectural practices in the area. The dwellings of Bigadiç demonstrate an economical use of local resources and responsive to climatic conditions using low-energy design principles that provide human comfort. One of them is timber material that is been harvested regularly from İpliklar and Abdikırı village. These design principles are consistent with the form, orientation and materiality of the buildings. Their combination of engineering and architecture reveals an aesthetic quality. These design principles are consistent with the form, orientation and materiality of the buildings. Their combination of engineering and architecture reveals an aesthetic quality. This study provides to our learning about sustainable building tradition with examples.

Bigadiç houses which were used as dwellings in the past, are now being used mostly as dwellings.. Most of these houses are in desolate positions. The local inhabitants are very friendly, but not prosperous and cultured enough to conserve or provide the hygienic services of the houses. For continuity of Bigadiç rural settlements, its traditional architecture typology is important. There is a need to new formation processes in rural settlements. For this, firstly, there is a need understanding the formation process of the existing traditional ecological and sustainable settlement. Secondly, it must be determined that this traditional structure how will continue and the router frame how will be created.

The thresholds should be addressed determining spatial patterns and sustainable development of settlement for Bigadiç settlement. In this context, the physical thresholds and its natural boundaries (topography, other) should be considered determining continuation of Bigadiç rural settlements. "Eco-centric planning" approach should be adopted and continued in Bigadiç settlement where is hosting the natural resources and is extremely important. Ecologically based planning means that dealt with there is a relationship among natural resources, human life functions and its user as a holistic approach. This approach envisages ecological spatial structure taking into climatic data account, sensitive to the natural environment.

In Bigadiç settlement, the basic unit of traditional structure constitutes buildings and surrounding it an open or semi-open areas. Buildings and open spaces surrounding it are privacy spaces created with taking into consideration the climatic data. Courtyard incorporates many functions as life, garden, open spaces. Open fields serve to vital activities in the area of social and cultural life also. Open spaces, as a venue for a gathering of the family, serve different formations and environments as wedding, engagement, requiring to be together. These areas also may be without walls, as high courtyard walls that require privacy, are separated by a low wall or fence. The size of indoor and outdoor areas in construction parcel, their distribution, positions, orientations and functions depending on the sun angle, plays a role in determining the nature of the ecological structure of traditional tissue.

Most of the times, the relationship between structure and road evolving according to topography, has a decisive role in the formation of traditional tissue. Bigadiç settlement is in form of sparse, open, less dense structure in the islands which are large gaps in the settlement tissue affected by the type of tissue in the climate. This type of tissue allows maksimum benefit to buildings to take beneficial effects of sun and wind.

The boundaries between building and road converts to the building parcel permeable or introverted character. For example, the high courtyard walls prevent to appearing activities from outside. In contrast, low-level courtyard or fence with does not form an enclosure between the interior parcel and road.

Bigadiç traditional settlement, with natural construction, local materials and local production system has a structure that implements building orientation, sparse structure, occupancy-space balance.

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