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Designing Sustainable and Energy-Efficient Buildings through Biomorphic and Climatic Architectural Strategies

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ABSTRACT

The urgent need for sustainable, energy-efficient, and environmentally responsive buildings has intensified in the face of global climate challenges. This study presents an integrative architectural approach that synthesizes biomorphic and climatic design principles to create energy-efficient structures with minimal ecological impact. A hotel building—serving both residential and recreational functions—is proposed as a case study to demonstrate this dual methodology. The biomorphic design draws inspiration from the growth patterns and natural geometries of trees, incorporating tree trunk cross-sections and bamboo as central elements in both structural planning and façade articulation. Complementarily, climatic design strategies integrate vernacular elements such as shaded porches, internal courtyards, elevated foundations, and regionally appropriate materials to enhance thermal performance. These features promote natural ventilation, reduce reliance on artificial heating and cooling systems, and improve daylight utilization, thereby lowering energy consumption and environmental impact. The resulting architectural framework underscores the potential of bio-inspired and climate-adaptive design strategies in achieving the Sustainable Development Goals. It offers a replicable model for architects and policymakers seeking to develop resilient and livable built environments in a warming world.

1. Introduction

In the context of global environmental degradation and increasing urbanization, architecture must evolve beyond conventional models to embrace sustainability and resilience. Biomorphic architecture—derived from the Greek terms bios (life) and morphe (form)—emphasizes the adaptation of organic, life-inspired forms and systems into architectural design.

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This approach seeks harmony between the built environment and the natural ecosystem by emulating the functional efficiency found in nature.

When combined with climatic architectural strategies—rooted in vernacular traditions and responsive to local environmental conditions—the result is a highly efficient, low-impact design paradigm. These methods collectively aim to optimize thermal comfort, reduce energy dependency, and promote ecological harmony. This paper explores the intersection of these two approaches through the conceptual design of a hotel tailored for mild and humid climates, offering a practical model for future sustainable architectural development.

1.1. Overview

In recent years, particular attention has been paid to biomorphic architecture [1]. Biomorphic is made up of two words: 'Bios' and 'morphic,' both of which are Greek terms that signify 'human life' and 'shape,' respectively [2, 3]. In the scientific realm, however, the concept was enlarged to 'organic Life', which means that a biomorphic shape or object is based on a living organism [4]. Biomorphic with a new insight into nature is one of the best ways to present new and creative ideas in architecture [4]. With this view, understanding nature and its complexities and modeling the form and structure of living beings by observing the laws and proportions of nature, accompanied by brevity, as well as coordination between beauty and function, has met the practical and intuitive needs of the users [4-7]. Biomorphic architecture has three principles including the principle of the use of materials and structures, forms and principles of sustainability [4]. The novel structures and materials can be utilized in biomorphic architecture. Natural formations can be used to make the structure that is aesthetically pleasing and can be applied to the exterior and the interior of the building. The local materials or materials made of lightweight components such as membranes that can satisfy forms curvilinear can be used in biomorphic architecture [4]. The resulting shape in biomorphic architecture is a shape which is similar to a life in nature or is attained by analogy in natural forms. These forms can be original natural life or obtained from its transformation [8]. The development of digital technology has assisted architects to create complex shapes inspired by natural life [9]. Since biomorphic architecture is known as ecological or green architecture, there is a direct relation between this type of architecture and sustainable architecture. Also, biomorphic architecture has the advantage of energy efficiency. In this regard, biomorphic architecture should be constructed with ecological consciousness to create ecologically friendly architecture, so that it is not only exhibited in terms of shape, but also in terms of nature's sustainability [9].

Climatic architecture, in addition to harmonizing with the climate of the region and adapting to a sustainable lifestyle, has also become part of the cultural identity of different parts of the earth [10]. Many people may not be familiar with the climate of the region, but they know the structures of the buildings of that region very well, which is why climate architecture is a lasting cultural heritage [11]. The trend of climate change that has begun in recent decades due to human negligence; it is likely to affect many aspects of human life in the future, including architecture [11]. If the trend of climate change continues in the same way, in the coming years, as the water level rises, the soils of the areas that are now dry will also become wet [12]. Sudden rainfall, extreme temperature fluctuations, scorching heat, and more can cause extensive damage to buildings [9, 13]. Many engineers and architects are planning for possible future changes and believe that in the coming years we need a

special climate architecture that is suitable for unpredictable future conditions [11, 14]. In this regard, the combination of biomorphic and climate architectures can be a practical solution for sustainable architecture and buildings in the future. Consequently, here a novel biomorphic and climate architectures can be applied to design a hotel in a mild and humid climate. According to biomorphic architecture, the form of the hotel is designed based on the growth and form of trees. Moreover, the circular lifelines of trees and bamboo's trunks are used to design the plan of the hotel. By using the climate architecture design approach, the various elements of native architecture such as porch, courtyard, foundation, and native materials are utilized to achieve sustainable architecture of the hotel. These elements lead the optimal air circulation, natural ventilation, and the maximum use of daylight in the building which resulted in significant energy consumption reduction, enhancement of thermal comfort, and minimum impact on the environment.

Biomorphic architecture

Three principles of biomorphic architecture design

Bio Biomorphic design can be seen in different geographical areas at different times. Biomorphic architectural design has three principles, namely form, materials and structures, and sustainability [4].

Form

An important principle in biomorphic design is form. This form creates in the users a feeling of approaching nature and in addition to the association of living beings, with the harmony between beauty and function, also meets the needs of the users. In the design of a residential building, the inspiration of a form is usually the living form and the design of a product based on which the work begins. In this way, form's conceptions of nature are directly related to the purpose of creating pleasure in users, and because they bring with them many hidden, creative, and unforeseen capabilities that exist in natural forms. From another point of view, these forms are full of symbolic elements and signs of identity that open another window in the connection between the user and the biomorphic products [4].

Materials and structures

The form and style of architecture are always closely related to the structure and material systems that are applied in a particular period. The scientific development and training technique gives engineers a great opportunity in which the structure is hardly restricted again in a wide range, in different types of structures in different types of new materials and construction [4]. Biomorphic architecture can be applied through innovative structures and materials. This structure can be made more aesthetically pleasing by using natural formations. The use of structures with organic shapes can be applied to the exterior and interior of the building. This system can mimic the structure and shape of structures that exist in nature because the natural structure has proven its strength. In terms of building materials, architectural biomorphic tend to use native materials or are made of lightweight materials such as membranes and other materials that support complex forms.

Sustainability

Biomorphic architecture is an architecture that considers ecologically themed nature as well as "green architecture". There is a link between organic and sustainable architectural form, but not a reciprocal one. Both of these architectures have in common the stability of the system, that is, because nature has a system for survival. Biomorphic architecture can have the benefits of energy

efficiency, which is the concept of environmental responsibility. The display will be useful for the building itself and the environment for the foreseeable future. Biomorphic architecture must be designed with ecological awareness to create an environmentally friendly architecture, so not only is it presented in terms of shape, but it also offers the sustainability of such a nature [4].

Biomorphic shapes and patterns

"Biomorphic shapes and patterns are symbolic references to contour, patterned, textured, or numerical arrangements that remain in nature" [5]. Biomorphic forms have been evident in a variety of artistic expressions, designs, and structures since the evolution of civilization. Their presence can be seen in the ancient temples of Egypt, India and Rome, and even in most modern designs by the Spanish architect Santiago Calatrava [15]. Due to its mathematical connection in the construction of various forms of buildings and the use of sacred spaces as seen in the temples of India, Greece and Rome through the imitation of natural elements according to the human body [16]. Salingaros in his article on "Applications of the Golden Mean in Architecture" noted: "An important lesson that comes from understanding natural structure is to realize that scales in a natural hierarchy deviate to the smallest dimensions. Natural growth begins on an infinitesimally small scale and develops through a regular hierarchy to the greatest extent [17]. Biomorphic patterns help to create preferential visual environments that are able to enhance residents' cognitive function by helping to minimize stress [5].

Material connection with nature

Natural "materials" are called "material relations with nature." They are suggested as "biomorphic shapes and patterns" [3, 18]. The "matter-to-nature" pattern involves different physiological responses to different elements of natural matter and the effect of a nature-based color spectrum, with green indicating cognitive behavioral improvement properties. Building materials derived from natural materials are similar to their natural state [17]. It has been reported that real modern architecture should not depict colors other than the colors of natural materials [19]. Since the frequency of use of a material in a space should be based on its function [20], given the climate of the region and the abundance of vegetation mentioned in previous chapters for the design and construction of the hotel, natural materials compared to synthetics have taken precedence because human sensory receptors can detect and sense differences between them [20, 21]. Its ability to enhance the creative mood in spaces has benefits for the designer [22-24].

Complexity and order

A space that displays information in the form of complexity is considered attractive to the human mind. It creates a temptation and often acts as a balance between tiredness and boredom. The main purpose of this model is to create a visually productive environment that stimulates a constructive cognitive response [5].

Landscape

In biomorphic architecture, the landscape is also defined as a pattern that provides an unobstructed, unrestricted, open and clear view of an area or large space for planning and monitoring. The idea is to provide residents with a sense of freedom with an inherent sense of safety, security, and control over their non-native environment [17, 25]. It has been reported that in indoor spaces or spaces with high urban density, the landscape is considered as the ability to see one space

through another [26]. It occurs when there is a certain divergence with the option of seeing through the alignment of several spaces.

Shelter

Shelter is another model in biomorphic architecture. Browning, Ryan, and Clancy [5] stated that "shelter is a place to escape from environmental conditions or the mainstream of activity in which one is protected from behind and above the head." An environment that provides a good shelter pattern should enhance the sense of security, the feeling of catabasis that is, retreat or retreat to reduce stress, rebuild, and create an efficient environment for individuals or groups [17, 27]. Moreover, it has been reported that the theory of landscape and shelter is to be able to see your entire surroundings while you are hidden and safe [28]. A quality shelter space has the ability to look unique and stand out from its native environment. It provides a meditative, protective and welcoming environment without creating any unnecessary separation for residents [27-29]. The health benefits of both environments, like landscape and shelter, include perceived stress reduction, boredom, irritability, fatigue, and perceived vulnerability. Perspective is defined as the ability to see from one space to another or a view from an elevated position. [30, 31]

Mystery, temptation and curiosity

Mystery, temptation and curiosity are other biomorphic patterns [7]. Mystery is a spatial state that, with the assurance of more information, is evident from the presence of relatively hidden scenes or other sensory stimuli that encourage one to explore more in the native environment [32-34]. Mystery is a useful model that can be used to modify indoor and outdoor spaces such as corridors, entrances, squares and buffer spaces [34]. Architectural environment for both charm and mystery, paths and transient spaces are next to the entry point of space. Deceptive patterns in the built environment enhance social interaction and support in the innovative team [5, 34].

Danger, fear and awe

Risk or danger can be defined as a combination of threat and related safety [17]. The environment has a way of expressing itself by creating specific boundary parameters as a boundary line, this occurs in an environment that is able to perform several activities in general [35]. For example, at first glance, it evokes fear or danger while looking at a facade that does not have a retaining wall or guide railing, but this design makes people feel safe and forget this fear when they walk in the same space. [36]. Danger can be the result of a reactionary situation created through reflexes as a learned relief and defense mechanism against an alleged danger [37]. Risk is a bold experience that thrills the user and involves two conflicting feelings-fear and pleasure due to our genetic susceptibility to danger.

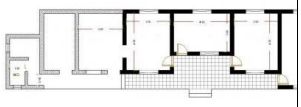
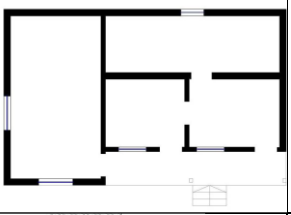
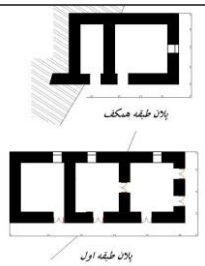
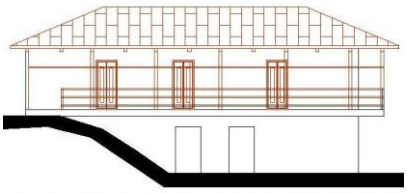
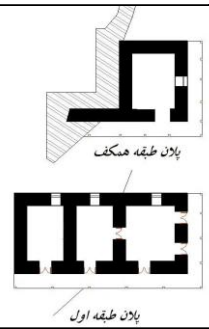
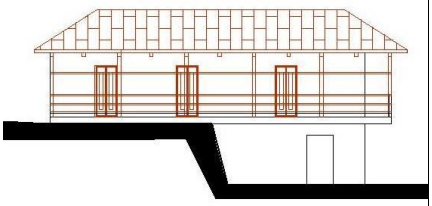
Native and Climate architecture

Architecture is one of the arts that adapts to the culture, customs and climate of each region [38-40]. The indigenous architecture of Mazandaran and the city of Nowshahr is also full of features and characteristics that have originated from the life of the indigenous people and its climate in Iran [41]. Therefore, in order to know the climate architecture of this region, first to analyze the typology of its native buildings and then the important elements affecting the formation of its architecture including extroversion and fragmentation, porch, room and opening, railing, and native materials [42, 43].

Typological analysis

Typology is a method to categorize native houses based on form and plan, spatial relationships, and knowledge of built spaces. In the study and classification of rural houses, it is important to know the factors influencing their construction such as culture, religion, nature and economy [42, 44]. Table 1 has been prepared to study examples of effective factors in the formation of rural housing species in this region.

Table 1
Some examples of architectural typology [44].

No.	Plan	South view	Photograph
1			
2			
3			
4			

Extraversion and disintegration

In rural areas, the areas of residential buildings are scattered and also separated by walls and wooden hedges with low height, which shows the trust and sense of security of the people of this area to those around them (Figure 1(a)) [45]. As a result, a close relationship is achieved between the interior and exterior of the house. Figure 1(b) shows the privacy of houses and the existence of gardens around the building and changes of fences from old style materials to modern style materials. In this climate, cities and villages are completely open and wide, and buildings are separate and distinct from each other (Figure 1(c)) [45]. The scattering of texture and distance between buildings in order to create air circulation in the space between buildings. In this case, air circulation

is easily created between the houses [45]. The most effective way of establishing the building in mild and humid climate for natural ventilation is shown in Figure 1(d).

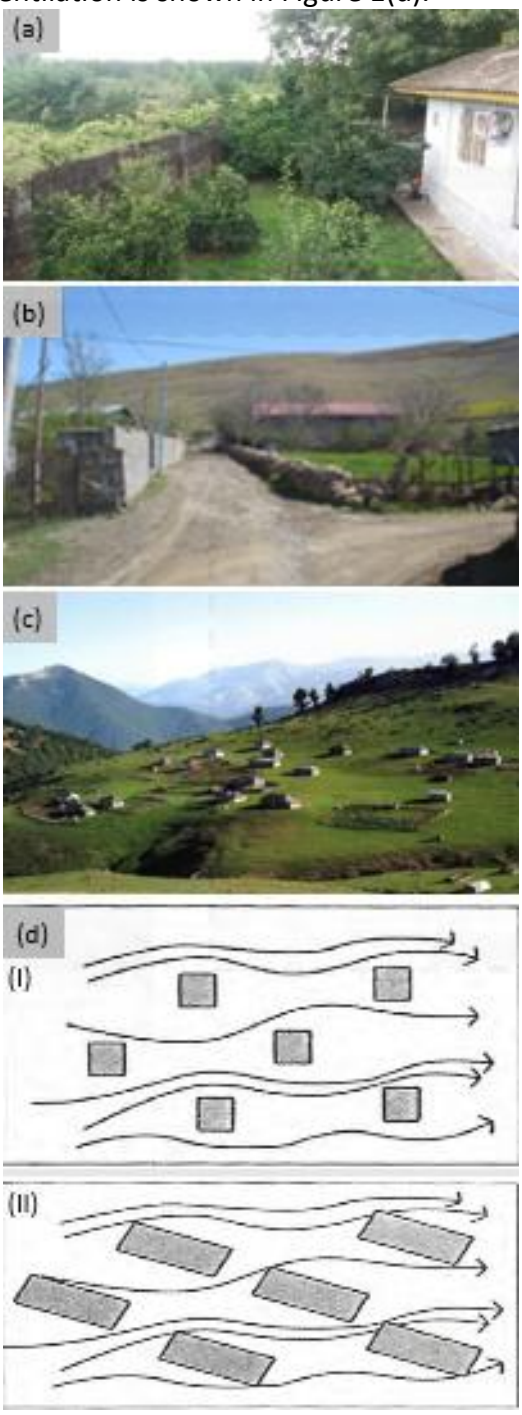


Fig. 1. (a) wooden hedges with low height instead of the building wall, (b) the presence of gardens around the building, (c) the dispersion of texture and distance between buildings, and (d) the most effective way of placing the building in a mild and humid climate for natural ventilation, (I) and (II) show two type of building arrangement in an area [46].

Porch

In mild and humid areas due to high humidity, air circulation should be continuous in and around the building. Therefore, porches are considered in the building to respond to this important.

Depending on the location of each area, there are differences in how it is located [47, 48]. As shown in Figure 2(a), different locations of the porch in relation to the rooms are categorized to three or four-room houses, two-room houses, and one-room houses. The porch is a transparent and intermediate space element from open to closed space, it is located at a higher height than other rooms to have a better view and more air flow [49]. Figure 2(b) shows examples of porch placement in houses in this area.

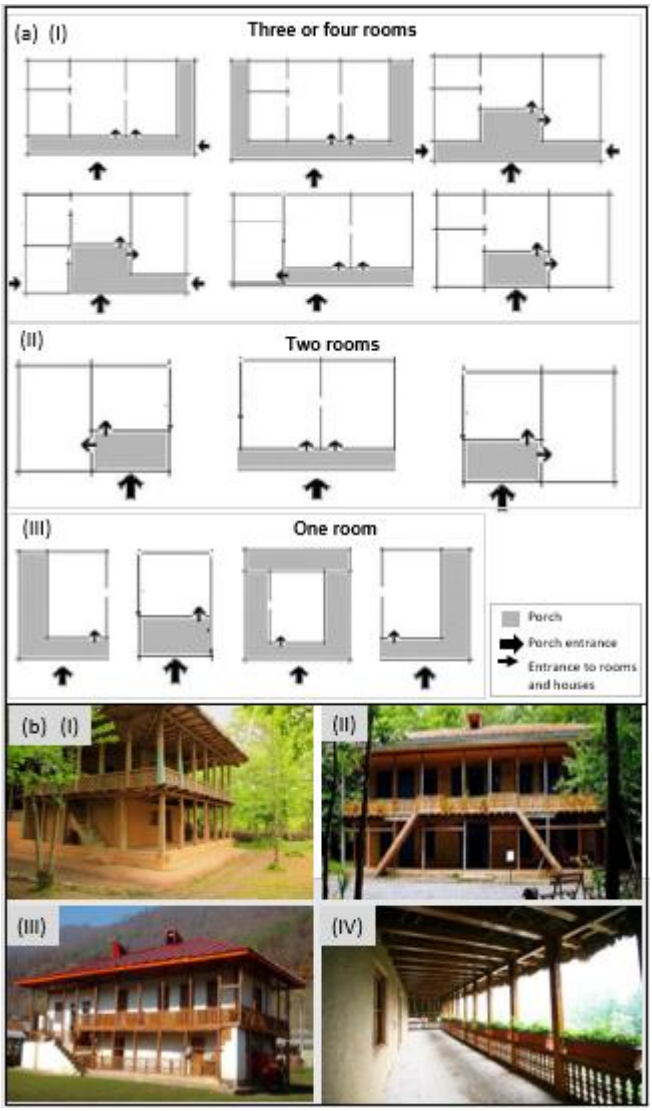


Fig. 2. (a) The location of the porch in several native houses of Mazandaran, (I) three or four-room houses, (II) two-room houses, and (III) one-room houses [50], and (b) examples of placement of porch elements in the houses of this area (I-IV).

Railing

The railing is an effective element in the climate architecture of this region. On the one hand, the semi-transparent design of the railing helps to better circulate the air, and this accelerates the removal of moisture from the building. On the other hand, this semi-transparent design maintains a visual connection with the environment [51, 52]. Figure 3 shows some types of railing and how to place them in the native houses of this area.

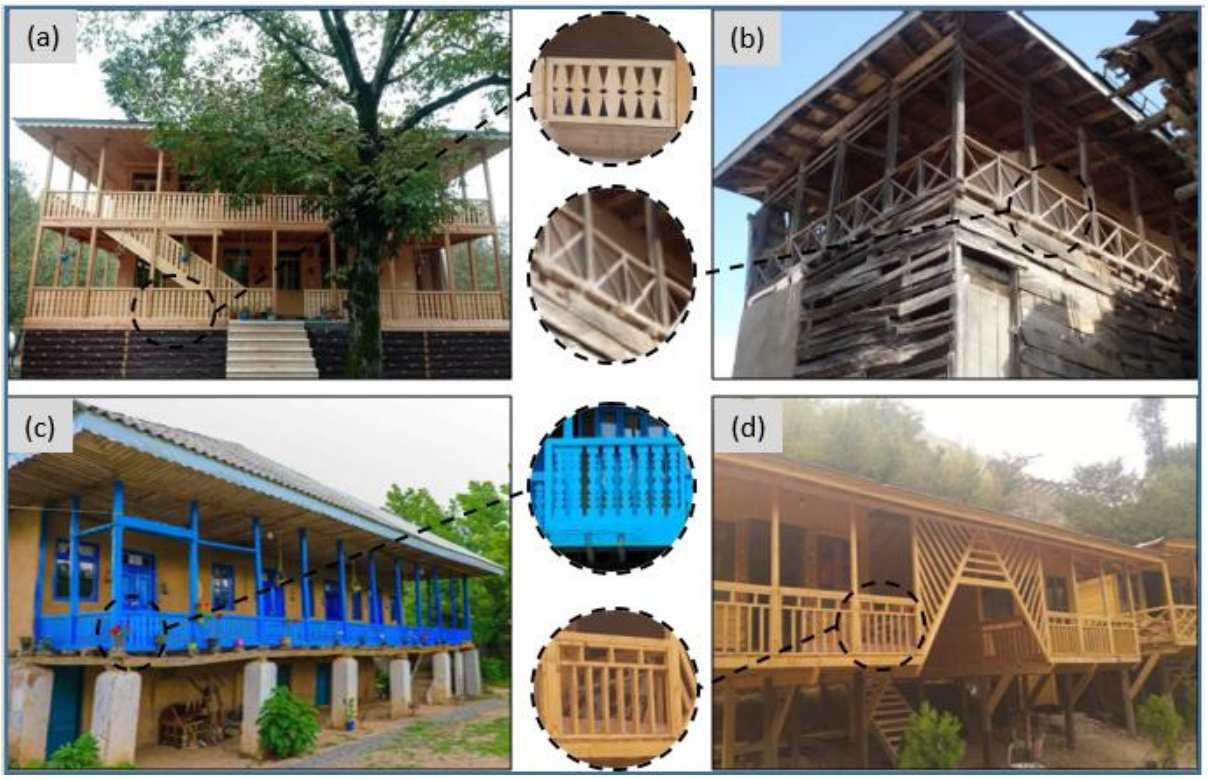


Fig. 3. (a)-(d) Different types of railing and how to place them in the native houses of this area.

Room and opening

In residential buildings, there are rooms behind the porch, which are often used as the main living space in winter. These rooms, which have different dimensions, are used for different uses. Rooms where entrance doors and openings are generally limited in size. Also, the limited number of openings and its dimensions in summer and winter living rooms are more visible in the native buildings of mountain areas, but the number and size of openings are increased in mild and humid area [53]. Figure 4(a) and (b) shows differences in dimensions and type of windows and openings in the rooms of a rural house in plain and mountainous areas schematically and real photographs, respectively.

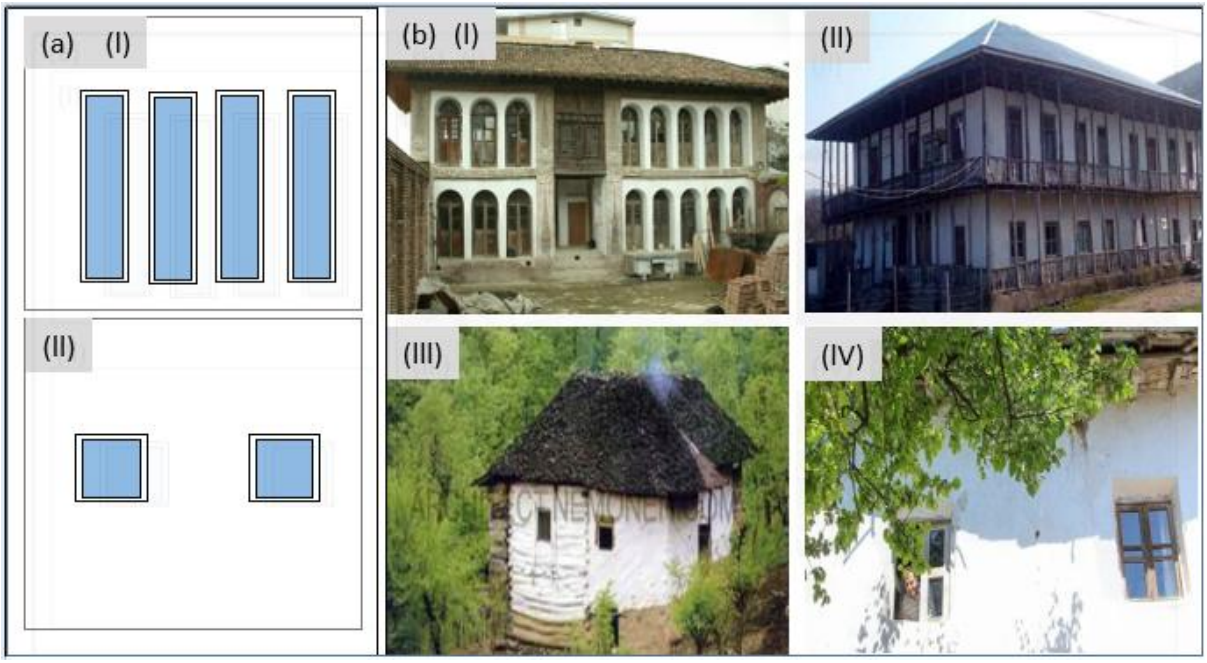


Fig. 4. (a) Differences in dimensions and type of windows and openings in (I) plain area (II) mountainous area, and (b) examples of openings and windows in a rural house in (I, II) plain area and (III, IV) mountainous area.

Foundation

The most common type of traditional building in this area is known as the "Gali Poosh Khaneh", which has a wooden logs roof and a wooden foundation under the building [47]. In very humid areas near the shores, houses are built on wooden foundations to protect the building from excessive ground moisture (Figure 5(a)) [44]. But on the slopes of the mountains, where the humidity is lower, the houses are usually built on the bases of rocks and clay (Figure 5(b)). Another solution that can be seen in some city houses, double wall flooring for the floor of the rooms so that the air flow from the floor wall, causes the evaporation of moisture and ventilation. [52, 54].

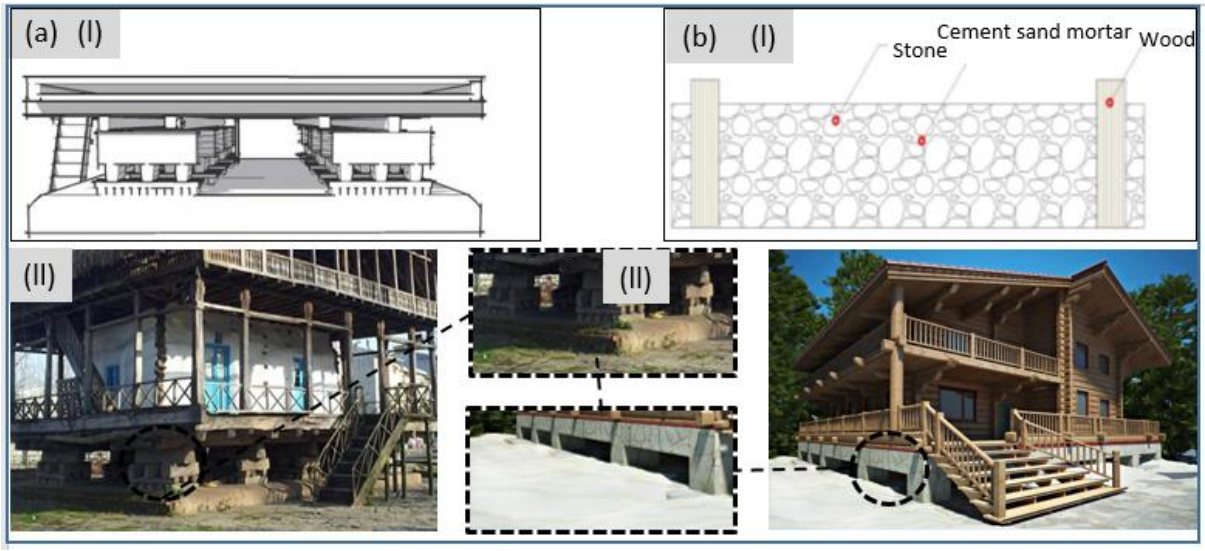


Fig. 5. (a) Wooden foundation, and (b) stone foundation. (I) Schematic of implementation [50], and (II) photograph of implemented foundation in native houses.

Native materials

Other features of the indigenous architecture of the northern regions in general and the study area in particular are the materials used in the buildings [47]. In the slopes and plains, wood is the main material. Also, wooden structures are considered as resistant and flexible structures to deal with earthquakes due to the way they are connected (Figure 6(a)). In mountainous areas, the main materials are stone and clay. As shown in Figure 6(b) and (c), these materials are harmonious and compatible with their environment in terms of perspective. The width of the walls varies according to the climate of the region, less in mild and humid areas and the width of the walls reaches more than one meter in mountainous areas.

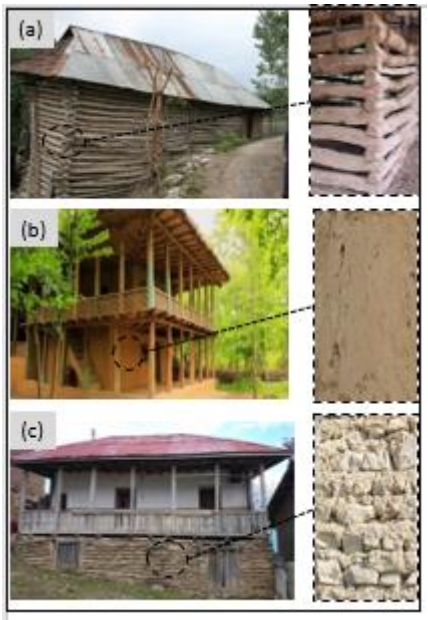


Fig. 6. Use of native materials in the construction of indigenous buildings, (a) wood, (b) clay and mud straw, and (c) stone.

2. Methodology

2.1 Site location of the project

The northern regions of Iran have always been considered as one of the important tourist destinations due to their special geographical location and having many natural attractions [55, 56]. Meanwhile, Mazandaran province and especially Nowshahr city due to its proximity to one of the most important transportation routes of the capital to the north of the country has a special attention among tourists [57, 58]. This province, characterized by climatic and environmental diversity, along with unique natural and cultural attractions, is one of the main tourist destinations in Iran [59]. For this purpose, the geographical and climatic context, various natural, physical and tourism environments of Mazandaran province and Nowshahr city as the most important western city of this province are analyzed and studied. Figure 7(a-c) shows the geographical location of Iran and Mazandaran province, and the divisions of Mazandaran province and the geographical location of Nowshahr city, respectively.

Geographical and climatic context

Mazandaran province in the north of the country and with an area of 23,756 square kilometers covers about 1.46% of the country [57, 60, 61]. The Caspian Sea in the north, Tehran and Alborz and Semnan provinces in the south and Gilan and Golestan provinces in the west and east of the Mazandaran, respectively [58]. Mazandaran, according to the latest divisions of the country, has 22

cities and 57 towns, 57 districts, 132 villages and 3645 settlements [60, 61]. Nowshahr city is one of the most spectacular cities in Mazandaran province due to its special geographical location and proximity to the forest and the sea. This city is located at longitude 51030 degrees north and 36039 degrees east and its area is 1717.5 square kilometers [62]. Nowshahr city is connected to the Caspian Sea from the north, to the Alborz mountain range from the south, to Noor city from the east and to Chalous city from the west. Existence of humidity in the northern slopes of Alborz causes a lot of rainfall [63], which according to the wind direction, two types of climate including mild and humid climate and mountainous climate can be detected in this city [52, 54]. Overall, the average temperature in Nowshahr city in the warmest month of the year is 27.4 ℃ and the average temperature in the coldest month of the year is 8 ℃ [43].

Fig. 7. (a) The geographical location of Iran [64]. (b) the geographical location of Mazandaran province [65], and (c) the divisions of Mazandaran province and the geographical location of Nowshahr city [66].

Tourism attraction

Mazandaran province and Nowshahr city can be considered a very artistic combination of the most beautiful elements in nature, history, architecture and religion, as well as life-giving elements such as excitement and fun. Mazandaran province and Nowshahr city have the highest statistics in

terms of tourist attraction during the years [55]. Examples of their tourism sites are shown in Figure 8.

Fig. 8. Some examples of tourism sites in Mazandaran province, (a) Caspian Sea in the Noor, (b) paddy fields (rice fields), (c) rangeland, (d) Aseman Kuh lake located at peak of Alborz mountain in Lar, (e) Kafer Keli rock houses, Larijan, Damavand mountain, (f) Lar plain, Damavand mountain, (g) Karaj Chalous road, (h) Javarom forest park, (i) Damavand mountain, and (j) Lafoor dam [67].

Vegetation diversity and ecological structure

Caspian forests as broad-leaved and deciduous forests in the form of a relatively narrow strip from Astara to Glidaghi from the coast to more than 2500 meters above sea level cover the northern profile of the Alborz Mountains. These forests have more than 80 species of trees and 50 species of shrubs [68]. Nowshahr city, due to its location on the northern slopes of Alborz Mountain, has a variety of natural vegetation such as rangeland, forest, coastal, agricultural and garden vegetation, which varies according to altitude [69, 70]. Figure 9 illustrates some plant species in Nowshahr city.

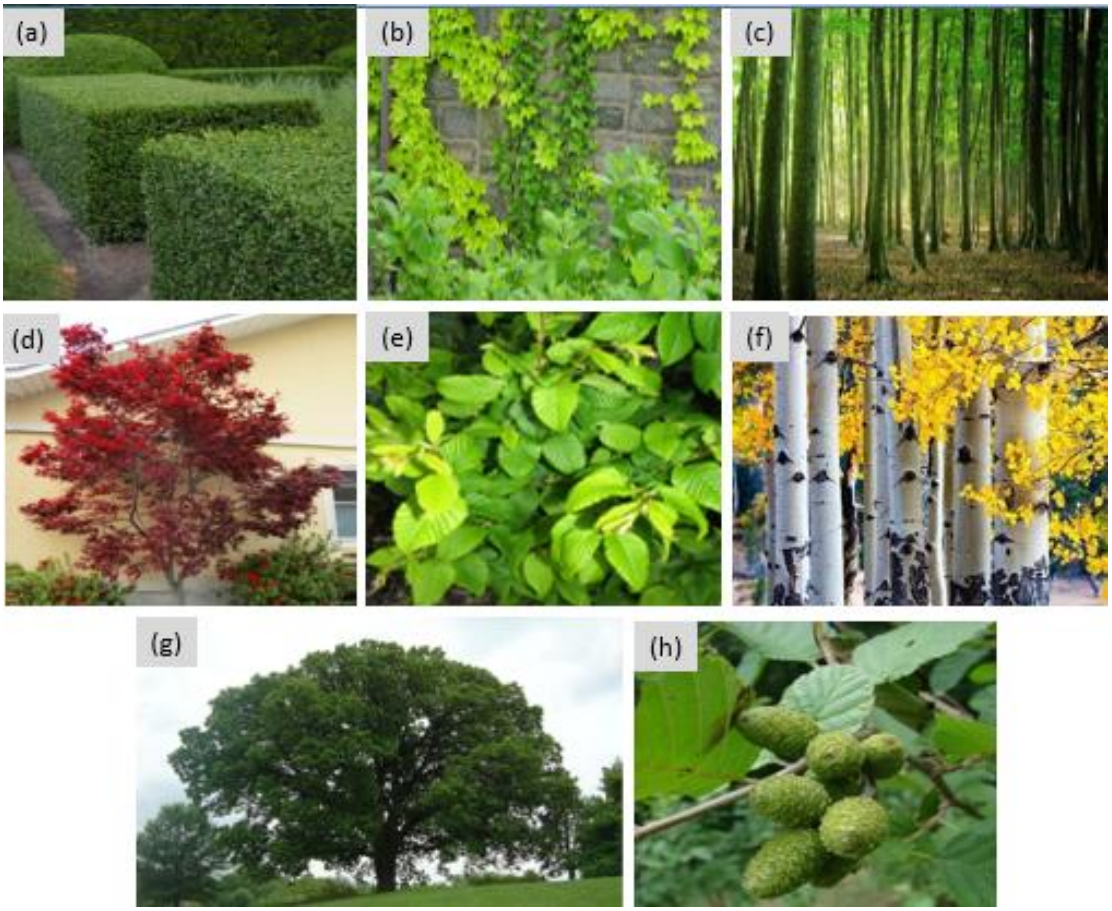


Fig. 9. Plant species of Nowshahr city, (a) boxwood, (b) Persian ivy, (c) beech, (d) maple, € hornbeam, (f) spruce, (g) oak, and (h) alder.

Urban plan and network of access

The central growth of Nowshahr is more naturally and quietly followed by the lower classes. In addition to this effective phenomenon in the discrete development of the city, the existence of agricultural lands and gardens that limit their occupation, becomes another factor in strengthening the disintegration of the city [71]. Nowshahr city has two main routes, ring road and side road. The city belt starts along its southern part and from the connection route to Chalous-Tehran road and continues until approximately the end of the eastern part of the city. The side road, which runs parallel to the Caspian Sea and passes through the central part of the city, is connected to the city of Noor from the east and to the city from the west. Also, these two main routes are connected at the eastern end of the city [72]. Figure 10(a) and (b) shows the first stage of the process of physical growth of the city and the network of roads in Nowshahr, respectively.

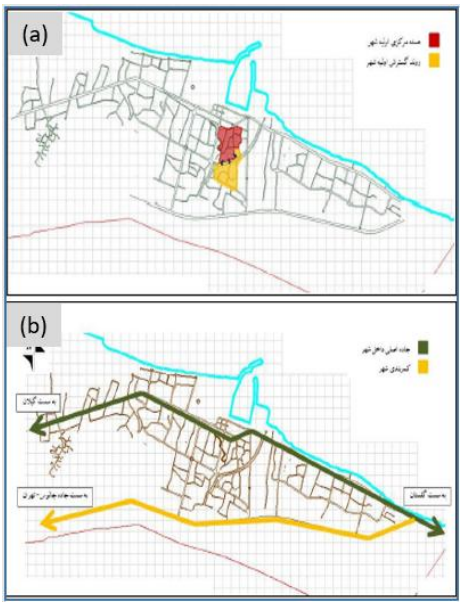


Fig. 10. (a) The first stage of the physical growth process of the city, and (b) Nowshahr city thoroughfares.

Site analysis

From the point of view of experts and planners in the tourism sector, in the development of tourism, it should be borne in mind that concentrating recreational facilities and equipment in places that are not accessible to ordinary people, is incorrect and unpleasant. In order to find a suitable place for the site of hotel, tourists and local citizens were surveyed about the location of the new tourism project using a questionnaire. In the first stage, questions were asked about the proximity of this project to the two natural attractions of the region, namely the forest and the sea.

Table 2.
The desire of users to locate the project at the five proposed points.

	Beach	Close to the sea	Between the sea and the forest area	Close to forest areas	Forest areas
Tourist users	38.00%	30.00%	16.00%	8.00%	8.00%
Native users	21.15%	17.30%	36.35%	7.70%	17.30%
Average	29.75%	23.65%	26.17%	7.85%	12.65%

According to the survey, it is observed that the favorite place of the project from the viewpoints of tourists and native citizens are beach (38.00%) and between the sea and the forest area (36.35%), respectively. Also, as depicted in Table 2, the suitable place for this project is in the beach with the average of 29.75% from both tourists and native citizens. Therefore, the project site is selected in a place near the sea which not only has an easy and fast access to the beach (a distance of less than 700 m) but also benefits from the forest perspective.

In this regard, due to the geographical location of Nowshahr city and the proximity of the forest and the sea therein, a site in the eastern part of Nowshahr city is well visible. Therefore, according to the design conditions, a site was selected in the eastern part of Nowshahr city and outside its center, which is less than 5 km from the center of Nowshahr city. Figure 11(a) shows the location of the site relative to the central parts of the Nowshahr city. Also, as illustrate in Figure 11(b), this site has access to the two main routes of Nowshahr city including side road and city belt and can be accessed from both routes. This site is currently barren, and it is possible to expand and access the route that has

access to forest areas from the south. Aerial image of the current site is shown in Figure 11(c). Also, view from the sea to the surrounding mountains and forests is illustrated in Figure 11(d). In determining the location for the construction of tourist and recreational areas, choosing a site that has less ecological purity and less natural and plant area is certainly a higher priority. At this site, only in some parts there are native tree species, which are shown in Figure 11(e) and (f). Also, in the southern part of the site, there are agricultural and greenhouse lands that need to be considered if the site is expanded. This region alternates throughout the year, under the influence of active systems caused by Siberian meteorology and currents north, northwest and partly west, which bring their moisture, especially moisture from the evaporation of the Caspian Sea to these coasts and highlands. Vegetation spots and the prevailing wind direction of the site are shown in the two sub-panel of Figure 11(g).

Fig. 11. (a) Location of the site in relation to the center of the city, (b) access routes to the site, (c) aerial image of the current situation of the site [73], (d) view from the sea to the surrounding mountains and forests, (e) and (f) some coverage of valuable vegetation on the site, and (g) valuable vegetation spots on the site (I) and the prevailing wind direction (II) [73].

Design process based on biomorphic architecture

Architecture has always been a reflection of the culture and climate of each region and has been defined based on the material and spiritual needs of each nation [38-40], so it can be considered as a new perspective for recreating new ideas and patterns. Accordingly, the study of biomorphic criteria in architecture, methods of nature modeling and the rules and proportions that govern it, and biomorphic criteria in the design of residential spaces are studied in the following. In designing a space based on biomorphs, two basic points are important: (1) formal inspiration from living beings along with simplification of characteristics and factors of inspiration (in this project, tree trunk and use of bamboo plant are considered), and (2) create pleasure in the user (residential and recreational spaces for users). Accordingly, the biomorphic design process steps are as follows:

- Select live creatures
- Identify biological characteristics
- Physical characteristics
- Systematic relationships
- Simplify the desired product to components
- Design a form based on data obtained from a natural source
- Provide observations included in two- and three-dimensional designs [74].

Each steps of biomorphic design process are thoroughly covered in section 3.1 in this work.

Design process based on climate architecture

The formation of climate architecture in any place is derived from the culture, climate and needs that have been formed over time and have been adapted to the conditions of their environment. In the following, the use of native architectural elements such as courtyards, porches, openings, foundation, railings and native materials is described in the present design comprehensively in section 3.2.

Furthermore, different parts of recreational, residential, restaurant, coffee shop, installation, and parking sections are provided in the Table S1-S6 in supplementary information.

3. Result and Discussion

3.1. Design process in biomorphic architecture

3.1.1. Selecting a natural pattern and identifying biological characteristics

The plants and trees in the green area of the design site in Nowshahr city have hundreds of different types of textures that guarantee their biological life. These textures are known as living cells. These cells have different shapes, among them, tree trunks have circular and spherical lines which possess special beauty of form. This unique form results in a new and original design of hotel' form. Also, tree trunks and their radial lifelines have been used to design the project. Figure 12(a) illustrates different forms and components of a tree.

The use of natural materials to minimize environmental impacts has proven to be an effective strategy in the construction industry [55]. Among many natural plants, bamboo has significant potential for use as a sustainable building material due to its fast production capacity, high flexibility, heat resistance, competitive mechanical properties and ease of construction of bamboo structures [75-78]. Bamboo has attracted attention as a sustainable alternative to traditional building materials, including wood, due to its short harvest time , variety of species, as well as high yield [79]. Ability to reach a maximum height of 15-30 meters in 2-4 months and maximum strength in 3-8 years [80, 81]. According to the results of the Life Cycle Assessment (LCA), bamboo is included in the "factor 20", which means that its impact on the environment is 20 times less than modern alternatives [81, 82]. Bamboo plant properties have also been used to cover the hotel façade in this project. Figure 12(b) illustrates different forms and components of a bamboo.

According to section 1.2.1.1, the form of a building inspired from the form of the living creature is directly related to the purpose of creating pleasure in users, and because it brings many hidden, creative, and unforeseen capabilities that exist in natural forms. Also, this form arouses the excitement of the users and leads them to deep emotional reactions. Also, according to section 1.2.1.2, the used natural materials in this design for the exterior and interior of the building can bring more aesthetically pleasing for the users. Also, native materials with low heat capacity wad used in the present design.

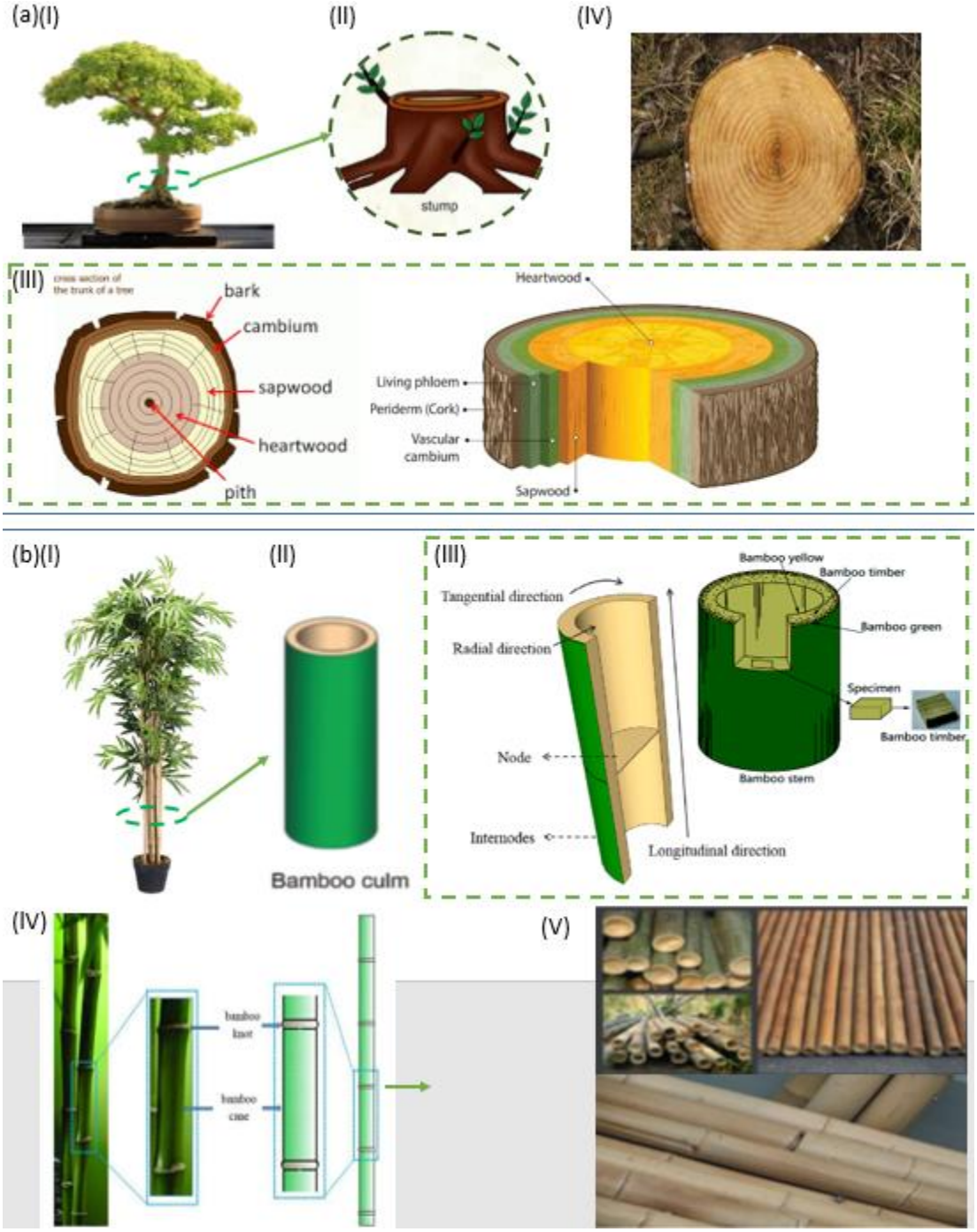


Fig. 12. Different forms and components of (a) a tree, (I)-(IV) [83], and (b) a bamboo, (I)-(V) [18, 84-87].

3.1.2. Physical properties and systematic relationships

In the evaluation of the region, it is observed that in the northern slope of Alborz, the formation of natural components has been formed by the influence of a tensile force towards the sea (Figure 13(a)). This shows the routing of rivers from heights and eventually connecting to the sea or in vegetation. Also, the site is located in a geographical north direction with a slight rotation relative to the mentioned axis. Therefore, in the continuation of the design process, the formation of the form will be transferred to it by the forces of the site, a sense of dynamism and tension, and the form will reach a dynamic and elongated form from a static and fixed state. Furthermore, the overlap of the axes and initial lines of the design with the texture of the ecological value of the site is considered to preserve it (Figure 13(b)). Moreover, the main access lines were defined in order to create an activity node in the center of the site and benefit from areas without special tree and shrub cover to define the uses (Figure 13(c)). Also, the arrangement of the site lines and the location of the uses were placed in a climatic direction, which is shown in Figure 13(d).

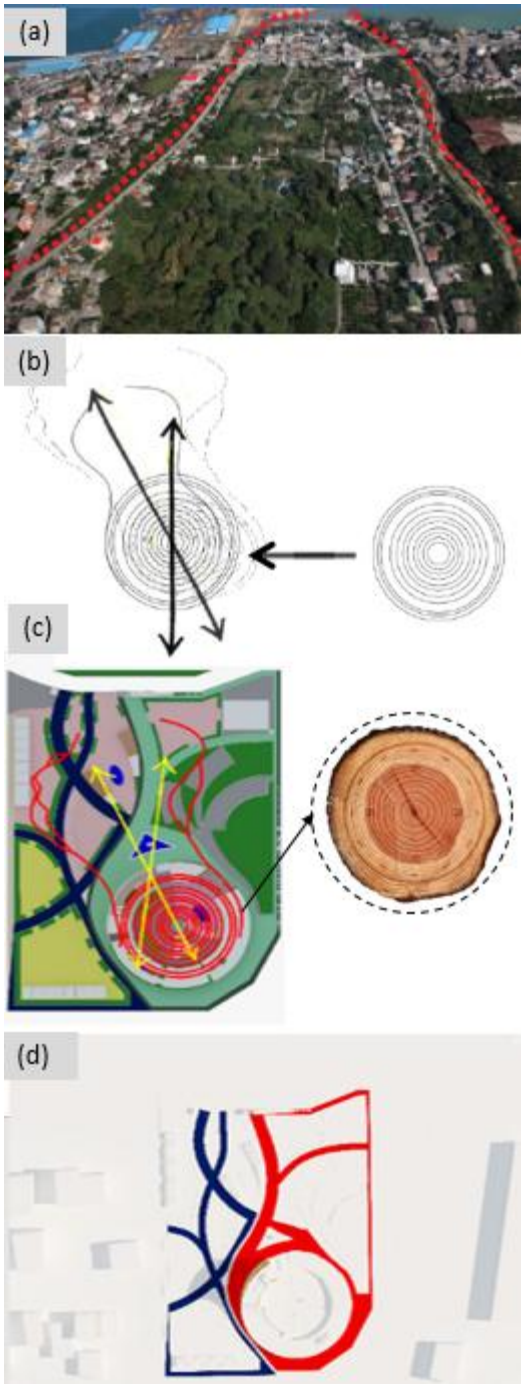


Fig. 13. Attention to the climatic axis in the design process of form formation. (a) Routing rivers from heights and finally connecting to the sea or vegetation [88], (b) overlap of the axes and initial lines of the design with the texture of the ecological value of the site to preserve it, (c) determining the main access lines in order to create an activity node in the center of the site and benefit from areas without special tree and shrub cover, and (d) organizing site lines and locating land uses in a climatic direction.

3.1.3. Simplify the desired form and plan to the components

In the present design, as shown in Figure 14(a) and (b), the use of radial pattern and modeling of the circle of lifeline in the trunks of trees and bamboo is considered to design the main form of the hotel. Also, Figure 14(c) shows creating a gap in the circle, connecting the outside to the inside, and inside of the central yard in the form. This yard is used as a climate yard, climate regulator and

creating air ventilation, which is derived from the circular shape and form of the tree trunk. Also, as shown in Figure (d), the division of recreational, parking and residential uses has been designed by separating multiple entrances in the main ring and circle of the form. The residential and main part of the building moves from the surface to the top by creating suitable views to the sea and the forest by using the southern and northern sun lights in designing the form, like the trunk and the main part of the trees. Location of the residential part and design of the building form for better use of air circulation around the building, control of prevailing winds and use of winds that blow from the forest to the building are shown in Figure 14(e). As illustrated in Figure 14(f), by creating a curvature such as the flow of fluid, the architectural form, like the growth of a plant that starts from the ground and reaches its peak, starts from the entrance of the complex and continues to the end of the form. Also, the use of curved edges drawn from the ground to the end of the form has a more important role compared to the sharp edges and guides the movement of people along them (starts from the entrance of the building and continues to the end of the form.)

As described in section 1.2.2.5, these multiple entrances and various indirect accesses to the building try to hide the information from the visitors to provide the assurance of more information by mystery. Also, creating transparent and semi-transparent surfaces in the facade and surrounding area, as well as the presence of sea and mountains, creates the desire of users to move to explore the environment with curiosity.

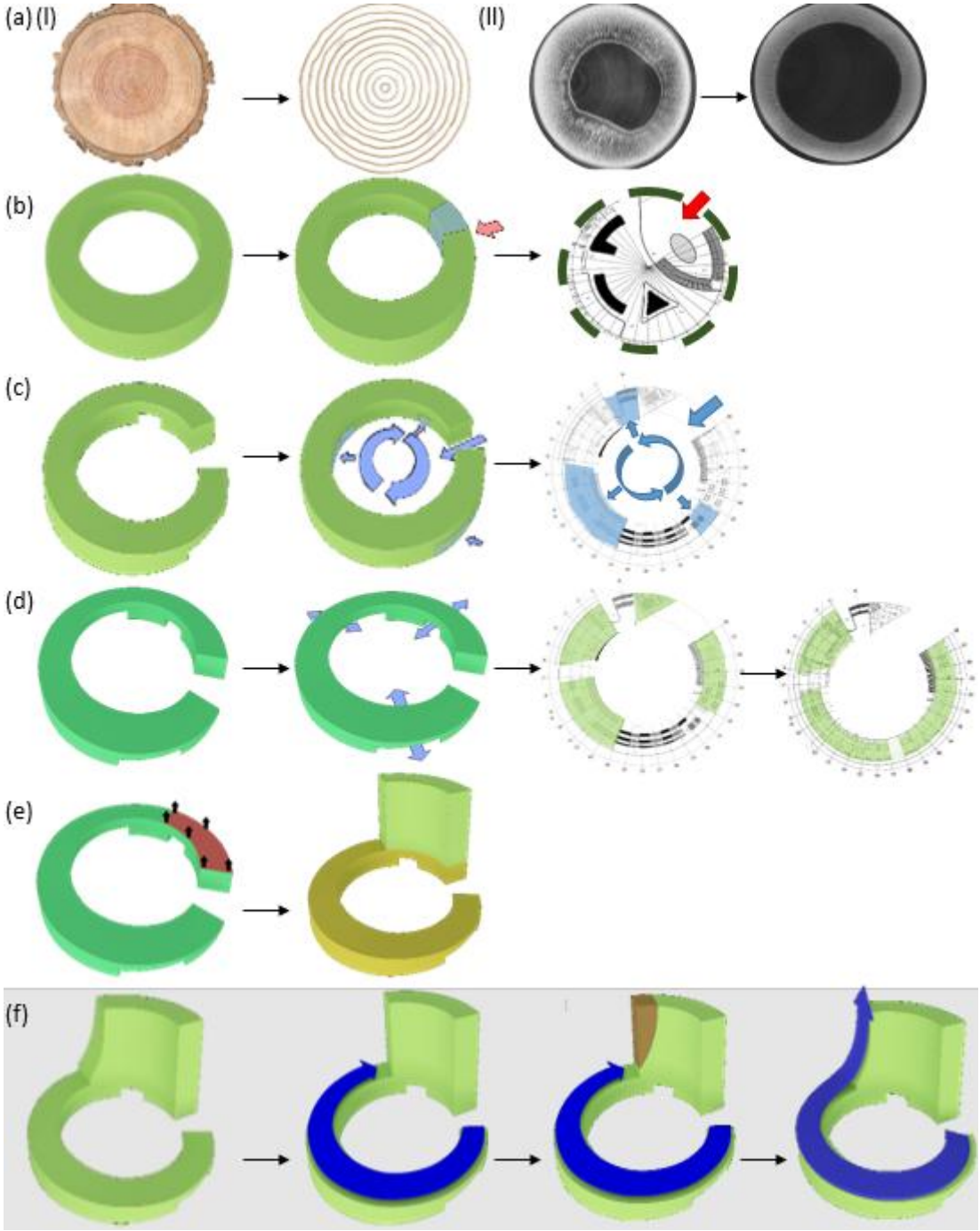


Fig. 14. Simplification of form into components of natural patterns. (a) Using the radial pattern and modeling the circle of the life line in the trunks of trees (I), and Computer tomography (CT) scanning images of morphological features of bamboo (II) [86], (b) designing the main form of the hotel, (c) creating a gap in the circle and connecting the outside to the inside and inside of the central yard in the form, (d) division of recreational, parking and residential uses with separate entrances in the main ring and circle of the form, (e) natural light and location of the main part of the building, the residential part of the building in form, by moving from the ground upwards, and (f) creating a curvature in the main form of the building, which is like the path of fluidity of an architectural form, like the growth of a plant that starts and grows from the ground and reach to the peak.

3.4.1 The use of bamboo in the design

The use of bamboo in present design reduces the weight of building, affects the cognitive function of the user, increases the durability of its usage with cementitious materials, provides ecological and

economic benefits, possess a long lifetime, create the imitation from natural environment , and reduces energy consumption in the building [89]. As shown in Figures 15, bamboo plant is used in the façade, common areas, balconies, and corridors of hotel rooms, and also the colors used in the design and construction of the hotel are derived from the colors of the environment.

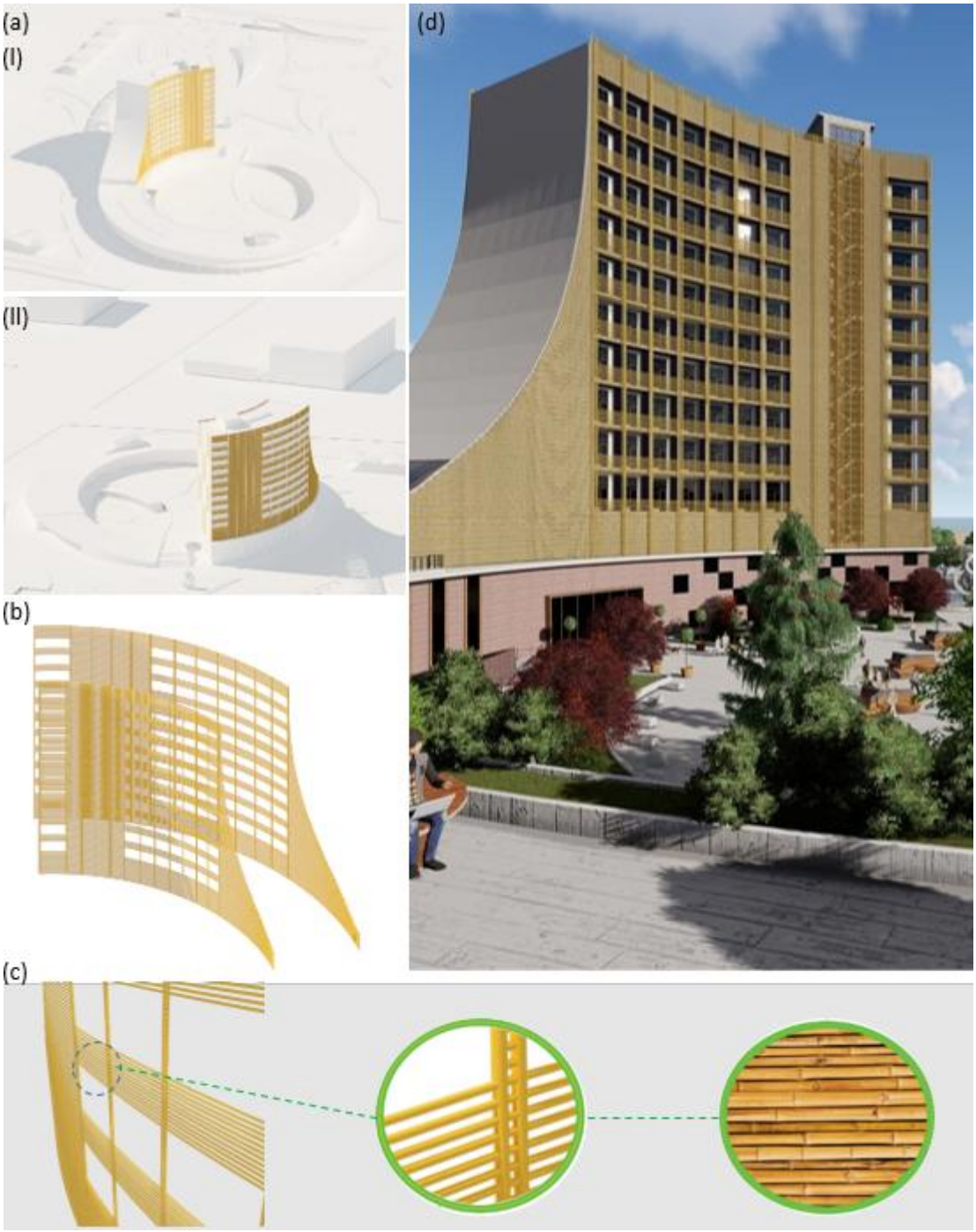


Fig. 15. Use of bamboo in design and façade of the building.

3.1.5 The structure and complexity of the central courtyard

The courtyard is a well-known building form that has been used by many urban civilizations after a long process of trial and error [90]. The traditional houses of many Asian, North African, South

American and European countries have courtyards [91]. Also, the use of courtyards in residential buildings in Iran and other Middle Eastern countries is several centuries old [92]. In the design of this building, by creating a central space or a central courtyard in the center of the building, an activity node has been created to establish the social relations of the users, and the spaces will be located around and directly accessible to it. The yard is used in various type of geometry such as rectangular, square, polygonal and circular in buildings. In the present design [90], as shown in Figure 16(a), a circular shape has been considered for the design of the yard due to its flexible and attractive shape in contemporary architecture. Also, playing with surfaces at different height levels inside the central courtyard provides a good platform to take advantage of the patterns that create air circulation and conditioning (Figure 16(b)). Also, as illustrated in Figure 16(c), multiple entrances and direct and indirect access to defined spaces, allow wind control due to the lack of moisture trapped inside the building in the warm seasons of the year, which is the most important climatic factor. Overview of the yard is shown in Figure 16(d). As described in section 1.2.2.2, a space with complexity and order is attractive to the human mind. The main purpose of this kinds of forms is to create a visually productive environment that stimulates a constructive cognitive response [93, 94]. The central part and the courtyard of the building is created through a pattern and structured hierarchy at different levels, which allow users to communicate with nature that results in visual comfort, thinking, and good feeling in human beings. This connection also reduces stress due to change of focus and increases concentration.

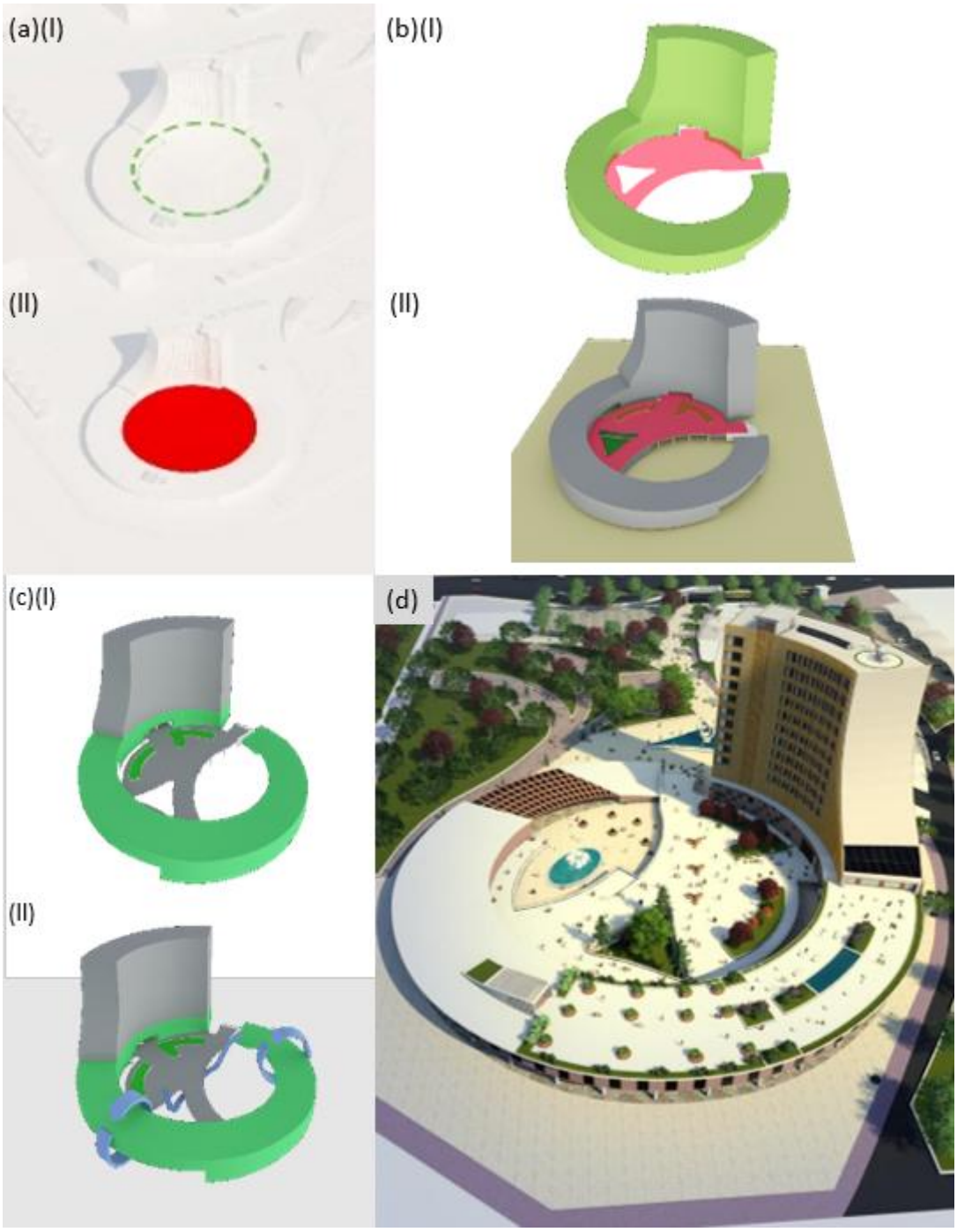


Fig. 16. (a) Select a circular shape to design the yard, (b) play with levels at different heights inside the central courtyard, (c) controlling the wind with multiple entrances inside the yard and building, and (d) overview of the courtyard in the current design.

3.2. Design process in native and climate architecture

3.2.1. Porch and views

The use of semi-transparent spaces or porches in the buildings of this region can be frequently seen for various climatic and functional reasons. Also, the presence of a porch in the building that provides the ability to see one space through another is very important [55-57]. Therefore, as show in Figure 17(a), terraces like the porch form were placed in front of the rooms on both sides of the

building in the present design. These porches prevent rain from reaching the body of the building, access to the open space, and moderate the air in the room. Also, as illustrated in Figure 17(b), the existence of a porch and unrestricted view lead to a suitable and desirable view for the users by creating open and unlimited spaces. It has been reported that this view offers residents a sense of freedom, control over their immediate environment, while enhancing a sense of security for residents [58].

As explained in Section 1.2.2.3, also as shown in Figure 17, the central courtyard creates a landscape by providing open and unlimited spaces in it, while enhancing the sense of security for the residents. The design also tries to help create a qualitative landscape by considering to methods. First, placing the stairs from the facade to the inside as a central shaft with a transparent and semi-transparent facade. Secondly, create a focal length range between 6 m and 30 m where there is enough depth to increase the user experience for walking, cycling and reaching the recreational and sports places of the building as well as exploring the area to visit the sea and the forest. This visual connection with nature also has the ability to optimize the landscape experience with a quality view.

As explained in section 1.2.2.4, Figure 17 is example of landscapes and shelters because the building is in a completely green and open landscape that unobstructed from all ends. Also, by creating space or canopies under the shade of trees, they have created a combination of shelter spaces using different lighting systems and based on the function of the space to use more users instead of one space for the building.

Fig. 17. (a) Placing terraces like the porch pattern to help the thermal comfort of the users and (b) providing a view for the users by creating open and unlimited spaces on the porch.

3.2.2. Openings and natural ventilation

Windows

It has been reported that there is a direct relationship between the volume of ventilated space and the position of the openings and the opening shape, and the proportions of the inlet opening to the outlet opening have a direct effect on airflow behaviour in two-way natural ventilation and can be more effective on air flow velocity [95, 96]. For openings that play the role of ventilation, in order to increase the efficiency of ventilation, it is better that the outlets are reduced, and the inlets are enlarged instead [95]. Moreover, it has been reported that thermal comfort inside the building can be maintained by providing adequate ventilation, which in turn depends on many factors, including the size, position, and proportion of the window [95]. As a result, the form and proportion of the windows in the present design are inspired by the form and proportion of the windows in areas with a mild and humid climate, which is shown in Figure 18(a) and (b).

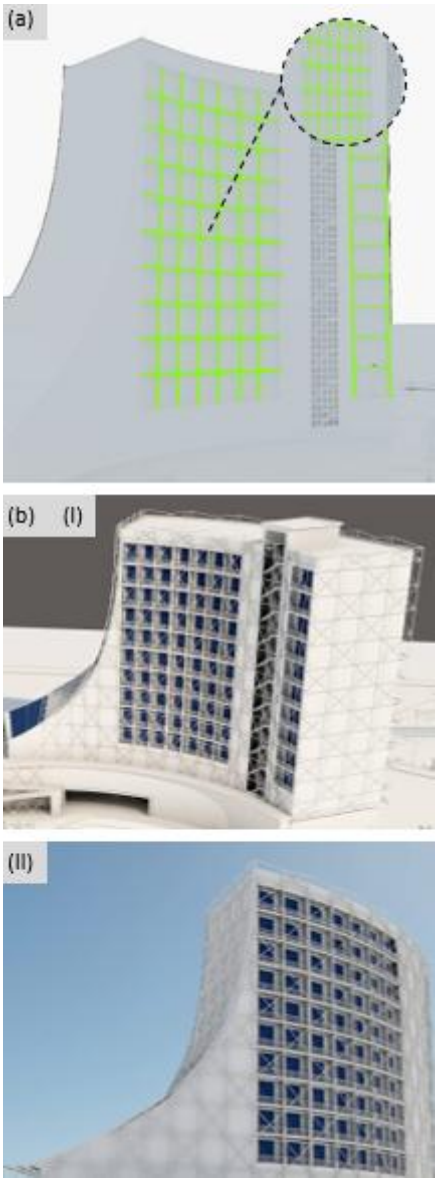


Fig. 18. (a) Illustration of proportions in the design of windows and (b) show windows in the façade of the building.

Obviously, the impact of internal factors on the performance of natural ventilation for residential buildings is of particular importance. Apart from controlling the amount of ventilation by the openings, the type of opening, their composition, the amount of opening, the dimensions and proportions of the opening can have a tremendous impact on the performance of natural ventilation [95]. Examples of the best window placement in this climate are shown in Figure 19(a). As shown in Figure 19(b), when the wind direction and the direction of the two windows are the same, less air circulation can be created in space and the opposite position will cause better circulation. When the wind strikes a body, two dimensions are created: one side in which the space is pressurized (the positive sign is in the Figure) and the side in which the suction is created (the negative sign is in the Figure). The side where the suction is created is a negative side that has no role in receiving the wind and when designing the location of the windows, this point should be taken into account and no wide opening should be placed in it. This side can only contain a window for air to escape and thus participate in the circulation.

Since windows and openings play an important role in natural ventilation [97], so different configurations of windows and openings in the design of the hotel on the north side (facing the sea) and south side (facing the forest) to improve indoor air quality and consequently, thermal comfort inside the building by natural ventilation (Figure 19(c)). This improvement depends on factors such as airflow, indoor and outdoor temperatures, and most importantly opening proportions. Therefore, three types of openings and air flow in the windows are shown in Figure 19(d). By creating a large opening in the wall at the air inlet; cool air enters from below the opening and hot air exits through the opening (Figure 19(d), (I)). Two windows on two different sides of the room, the entry and exit of air according to the direction of wind entry allows optimal ventilation (Figure 19(d), (II)). There are also two separate windows perpendicular to a wall that these small openings close to the ceiling can ensure a minimum of air exchange in a room without significantly increasing the heat (Figure 19(d), (III)) [97].

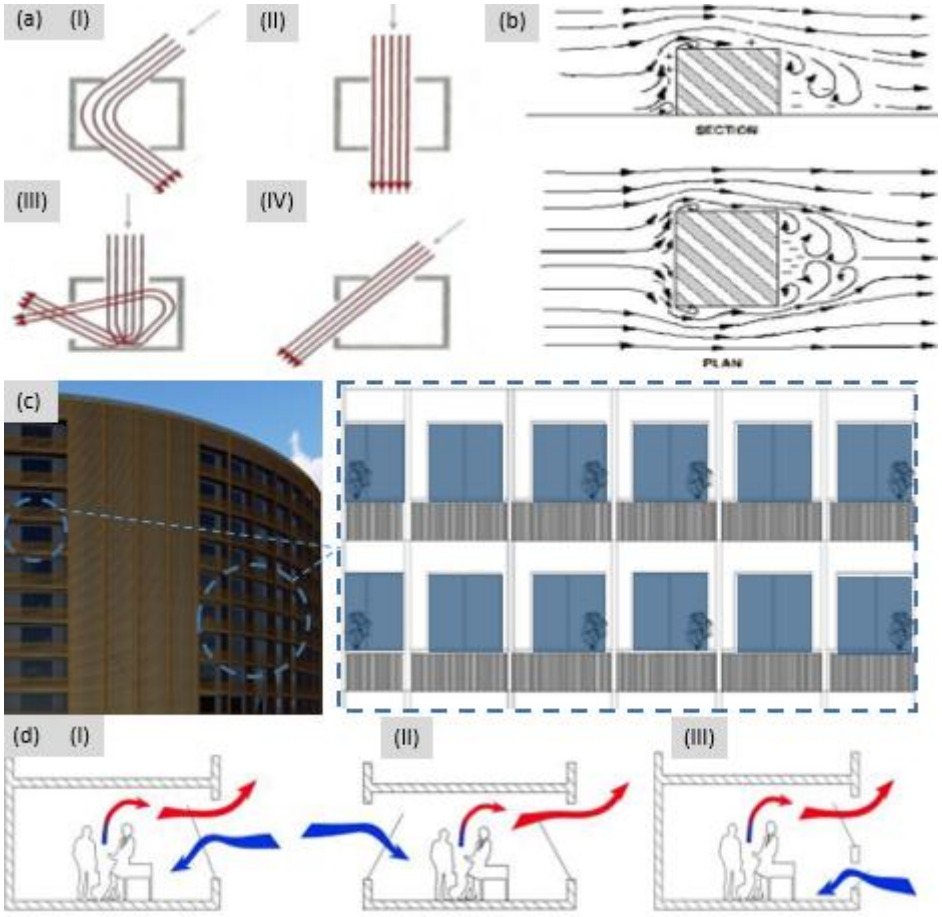


Fig. 19. Enter and exit of the air flow according to the position of the windows. (a) some examples of the best window placement in this climate [46], (b) air circulation and optimal ventilation according to the location of openings [98], (c) different configuration of windows and openings for air flow in the design of the hotel, and (d) create a large opening in the wall at the air inlet (I), two windows on two different sides of the room (II), and two windows are located in the vertical direction of a wall (III) [97].

In order to direct the wind in the desired direction inside the building, the effective factors in directing the flow must be considered, the most important of which are the position of the windows in the facade, the opening position of the windows, the position and shape of the canopies, and other window accessories [99]. In the design of the hotel, as shown in Figure 20(a) and (b), in addition to

observing the proportions in the design, creation of windows with multiple openings on two fronts for air entry and exit, and natural ventilation, blades between the two direction windows is intended to remove hot air from the other side with the circulation that it creates, and consequently strengthens the air circulation.

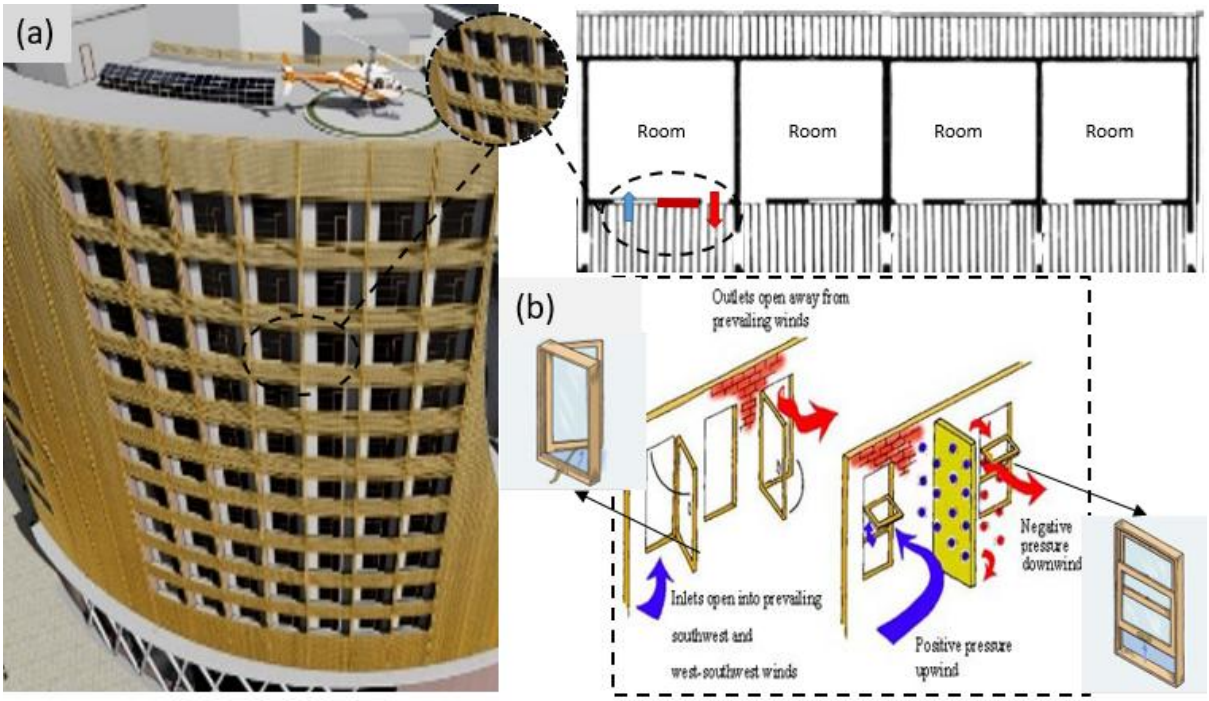


Figure 20. Placing a blade between two windows. (a) The location of the opening and the blades in the design and form of the hotel and (b) the working principle of the blades between the two windows to increase the amount of air entering to the space and rooms or maximum natural ventilation.

Central shaft duct

The duct is responsible for ventilating the building. Especially in cases where there is no ability to create windows in the walls or in a multi-storey building with large and central spaces, the duct performs this task by collecting hot and humid air from the entire building and transferring it to the open air [100]. The end point of the duct leads to the ceiling and lets in and out of the air (Figure 21(a)). In designing the current hotel, an attempt was made to create a central shaft like a duct in the building, in which there are escape stairs and vertical access to the building, as well as a semi-transparent and semi-open space, to transfer air and move hot and cold air. This can result in air conditioning in horizontal accesses (Figure 21(b) and (c)).

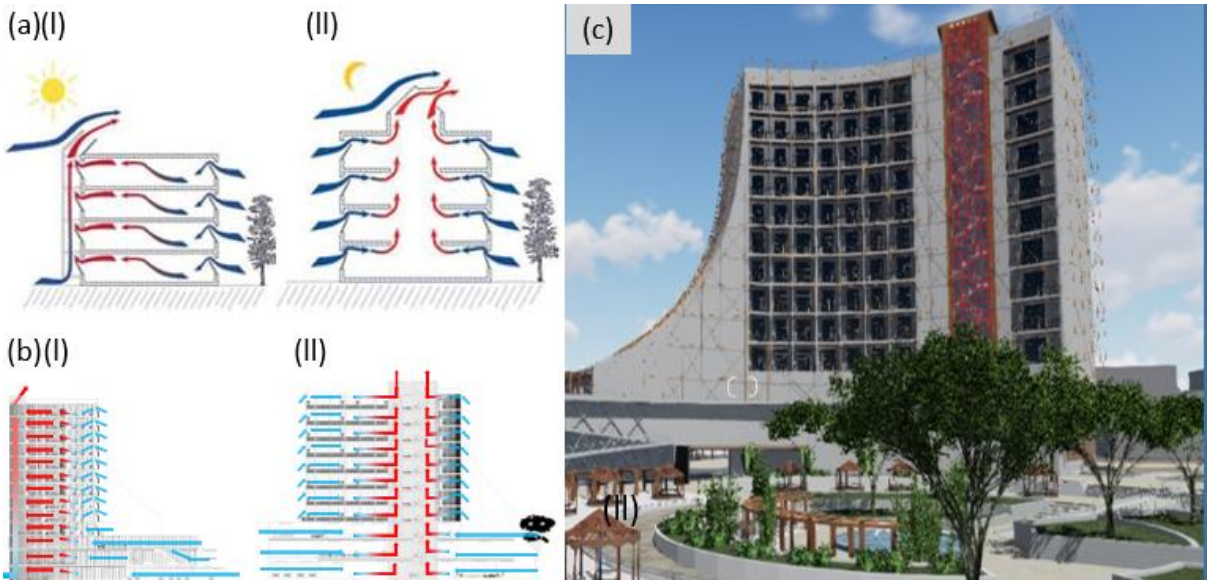


Fig. 21. Collection of hot and humid air from the bottom of the building and their transfer to the open air upwards. (a) An example of the operation of the central shaft, which is responsible for air conditioning in the building [97], (b) the 2D view of our designed central shaft in the hotel and how the central shaft works in collecting hot and humid air from the bottom of the building and transferring it to the open air, and (c) the 3d view of the central shaft in the hotel.

Courtyard

For centuries and until today, the courtyard has been one of the most prominent forms of architecture in hot and dry, and hot and humid climates [90]. The yard is mainly developed in response to climatic needs. Residents of such climates used the courtyard to collect cool air at night and a source of shade during the day (Figure 22(a)) [91]. All aspects of the building yard such as proportion, direction, shape and size, height, shadow control, type and ratio of glaze and thermal mass of the walls should be considered in the design [92]. Therefore, the reasons for designing the yard have been done with the aim of improving energy efficiency in the building as techniques to increase daylight to bring light into the interior space and thus minimize space ventilation by cooling and heating systems and artificial lighting. Therefore, as shown in Figure 22(b), the central courtyard created in the design reduces the penetration of hot and often dusty winds into the rooms. Also, yards with trees, flowers, shrubs and a pond of water create an environment that reduces the air temperature by several degrees [101]. Therefore, in the design of the hotel, despite the central courtyard and the tall plants and trees, the walls of the building and the ground are protected from direct sunlight by creating shade in summer, all of which reduce the temperature of the building (Figure 22(c)) [91]. Also, the location of the building is such that they have access to forest areas from the south, which creates natural ventilation and air circulation, and shows optimal energy performance.

The presence of water in biophilic architecture is also considered as a restorative environment both visually and aurally [102]. Also, water quality determines the degree of human preference for it for remedial environments [103]. Apart from its psychological benefits, water also has the ability to respond to the weather. Figure 22(d) shows the St. Fiachara Garden in Ireland, designed by landscape architect Martin Hullinan. This garden has restorative and recreational properties because it depicts water in its positive aspects. Therefore, it was tried to place the water element in the design and yard of the hotel, to help reduce the temperature through evaporative cooling and improve the thermal comfort of the users (Figure 22(e)).

Fig. 22. The role of the yard in responding to climatic needs. (a) the effect of yard on air conditioning and air circulation, (b) natural elements, i.e. trees, as a barrier to the incoming wind, (c) using vegetation to cool the area and shading the building in the current design of hotel, (d) St. Fiachra's Garden, Ireland by Architect Martin Hallinan [Irish National Stud and Gardens], and (e) Placing the element of water in the design and yard of the hotels.

Railing and native materials

The use of bamboo as a railing element in the form of a semi-transparent element in the design of the hotel, in addition to helping better air circulation, accelerates the removal of moisture from the building. On the other hand, this semi-transparent element maintains the visual connection with the neighbors (Figure 24(a)). Due to the fact that the materials used in this climate must have a small heat capacity, because the temperature fluctuation in this area is very low. Hence, it is not necessary to store thermal energy and most buildings are built with materials with minimum heat capacity. In these areas, also, it is better to use light construction materials. Therefore, wood, which is one of the light materials with low heat capacity (native materials of mild and humid climate) has been used in the design of hotel. Also, the use of wooden designs of windows in this climate and its modernization in the architectural form of the hotel is another point that has been used as a solution to revive the native architecture in designing the form of the hotel (Figure 24(b)).

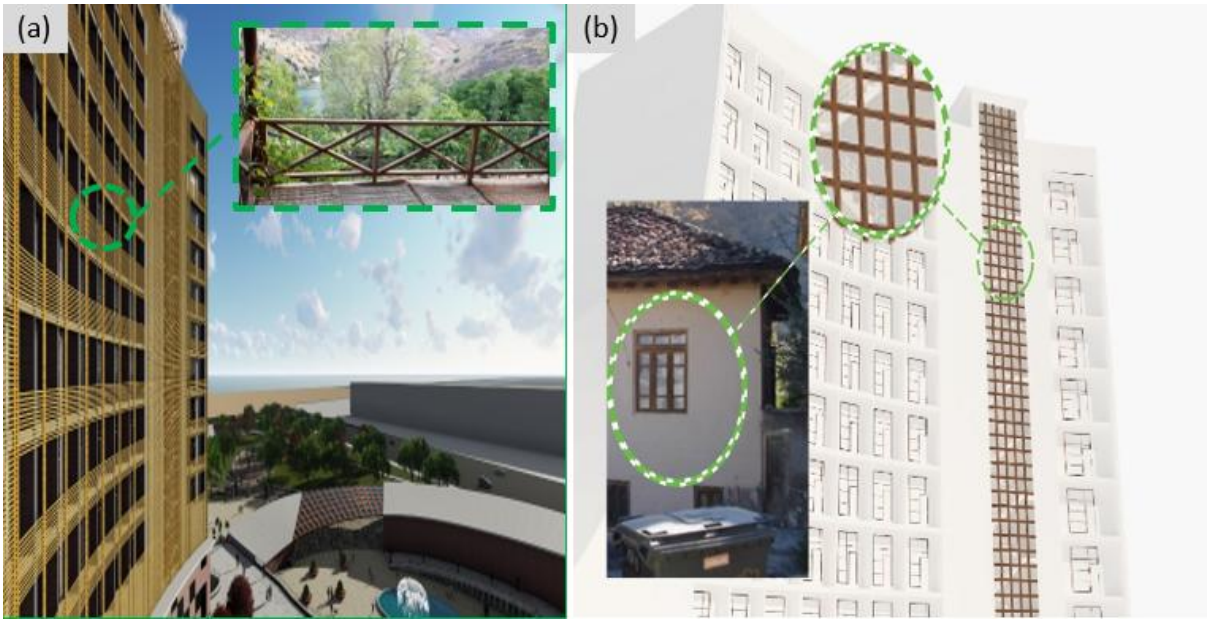


Fig. 24. The use of native materials. (a) The use of bamboo as a railing element in the form of a semi-transparent element in the design of the hotel, and (b) the use of wooden window design as light construction materials in the form and facade of the hotel.

Foundation

As mentioned in the previous sections, a foundation is designed to prevent moisture from penetrating the floor of the building, in which case the building is raised from the floor to allow air to flow between the floor and the ground [50]. Therefore, in designing the hotel, by creating a unique foundation like a platform that extends between the yard and the building, the building is separated from the ground to prevent the penetration of floor moisture into the building. Also, several storey and various functionalities are created on this visible foundation which it results in the air circulation on the floor (Figure 25).

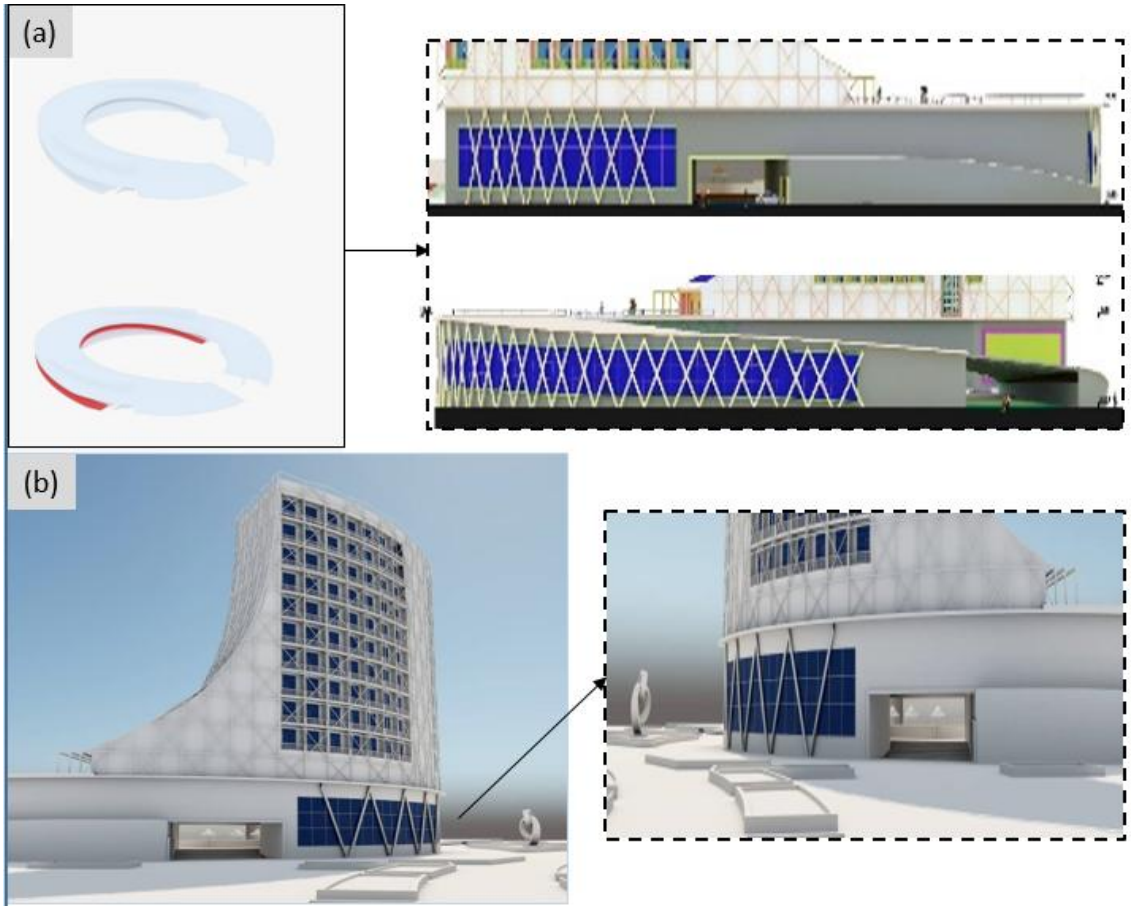


Fig. 25. Creating a space (or foundation) between the floor and the building to prevent the penetration of moisture and air flow.

3.3. 3D views of the design form

The 3D view of the final design of the hotel is illustrated the Figure 26. Also, others 2D and 3D plans and views of the designed building are illustrated in Figure S1-S11.

Fig. 26. 3D view of the final design of hotel.

4. Conclusion

In this paper, a hotel was designed based on the biomorphic and native architecture designs. The form of the hotel was inspired from the growth and form of trees and Bamboo. The hotel was developed like a tree from the ground to upwards. The plan of the hotel was designed based on the trunk of the trees and Bamboo which are circular and radial. This shape was used in the development of the different floors and implementation of the various functionalities. Furthermore, in native architecture design, several native architectural elements such as porch, railway, courtyard, foundation, and native materials were implemented in the design to achieve the sustainable architecture. These native elements resulted in the maximum use of air circulation, natural ventilation and daylight inside the building. Consequently, these results can decrease energy consumption in the building for the heating and cooling systems, and lightings. This framework of design in this work revealed a high potential platform based on biomorphic and native architecture approaches to develop a sustainable building design in future.

Author Contributions

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, X.X. and Y.Y.; methodology, X.X.; software, X.X.; validation, X.X., Y.Y. and Z.Z.; formal analysis, X.X.; investigation, X.X.; resources, X.X.; data curation, X.X.; writing—original draft preparation, X.X.; writing—review and editing, X.X.; visualization, X.X.; supervision, X.X.; project administration, X.X.; funding acquisition, Y.Y. All authors have read and agreed to the published version of the manuscript.” Authorship must be limited to those who have contributed substantially to the work reported.

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Data Availability Statement

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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