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Eco-Hotel Design Strategies in Fragile Ecosystems

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Abstract


Tourism, particularly in sensitive and fragile regions with rich heritage, is a vital factor for local sustainable development. However, irresponsible activities within this sector necessitate controlling negative environmental impacts through the design of Ecological Architecture (EA). This research focuses on developing a localized and integrated design framework for eco-hotels in Iran's fragile and sensitive ecosystems. This framework simultaneously addresses two key components: minimizing environmental impacts (reducing the ecological footprint) and maximizing positive social contribution alongside promoting guests' physical and psychological well-being. From an objective standpoint, this study is applied, and methodologically, it employed a mixed approach of content analysis (qualitative) and case study. Data were collected and analyzed through comprehensive literature reviews and comparative case-study analysis. The findings revealed that the sustainability of eco-hotels in Iran is founded upon five core principles (including site selection based on local ecology, material approach, resource management, and emphasis on socio-cultural dimensions). Beyond energy consumption reduction, the success of eco-hotels depends on integrating regenerative components (such as biophilic architecture and attention to indoor environmental quality) to ensure users' psychological comfort. This framework positions the eco-hotel as an engine of local sustainable development, generating significant social and economic added value for host communities while preserving both environmental and cultural heritage. Furthermore, a research gap was identified regarding comprehensive evaluation frameworks for eco-hotels in Iran's fragile ecosystems, warranting further investigation.

Keywords: Sustainable architecture, Eco-hotel, Fragile ecosystem.

1 | Introduction

Tourism, as a major global driver of economic development, plays a pivotal role in the prosperity of mountainous regions. However, the potential for degrading the rich environmental and cultural heritage of these areas necessitates a sustainable approach. Acknowledging the dual benefits and drawbacks of tourism, irresponsible practices have been identified as the primary cause of environmental damage. It mandates that the tourism development framework integrate the principles of Ecological Architecture (EA) and responsible

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traveler education, ensuring that, while preserving natural and cultural capital for future generations, maximum long-term economic and social benefits are achieved.

The development of the tourism industry requires the provision of environmentally compatible accommodation facilities. Eco-hotels, an integral component of sustainable tourism, aim to promote sustainability to preserve the surrounding environment and conserve resources for future generations [1]. These lodgings must implement policies to mitigate their negative impacts on the natural environment.

1.1 | Problem Statement

Architecture, as the foundation of human civilization, finds itself at a crossroads. While modern built environments provide the necessary infrastructure for habitation and the facilitation of social and economic activities, the processes of their construction and operation typically entail high environmental costs. The rapid advancement of technology, despite its undeniable functional advantages, has concurrently led to increased resource consumption, particularly energy, and the intensification of pollution, thereby challenging the ecological balance. It has raised serious concerns among environmental advocates, who emphasize architecture's fundamental role in shaping the planet's path toward sustainability.

The researchers' objective has been to mitigate the negative environmental impact of hotels while meeting the expectations of green consumers who value environmentally friendly products, practices, and policies. Previous studies have indicated that the number of hotels adopting green practices or sustainable strategies is increasing to meet the growing demand for green hotels, as consumers increasingly prioritize environmental protection and seek greater green awareness during their stays [2]. The tourism industry is responsible for 5% of global greenhouse gas Carbon Dioxide (CO₂) emissions, and this figure is projected to increase by 130% by 2050 [3]. The World Tourism Organization (UNWTO) and United Nations Development Programme (UNDP) are actively collaborating with stakeholders to accelerate tourism's contribution to the Sustainable Development Goals (SDGs) through inspiration and engagement.

Investigating environmental strategies for eco-hotel design through a sustainable architecture approach and presenting a proposed design constitute the core issues this research seeks to address. The accommodation facility's design incorporates EA. The application of EA aims to create buildings that are environmentally compatible, maximizing natural potential without compromising aesthetics, reducing waste, conserving energy, and conserving water. Key tourism design strategies adhere to the 3-zero concept: zero kilometer (proximity of local building materials and skills), zero CO₂ (energy management and reduction of greenhouse gas emissions), and zero waste (life-cycle management in construction processes and reuse of building materials) [3]. EA, in this context, manages the tensions inherent in designing sustainable hotels within fragile ecosystems.

The primary research question driving this investigation is: "what strategies are essential for the design of eco-hotels within sensitive and fragile ecosystems?"

The development of tourism complexes necessitates creating spaces that foster human-nature coexistence through an ecotourism approach based on climate-responsive design, the use of clean energy, and local capacities. This realization fosters sustainable tourism and strengthens the local economy. While previous scholarly work has focused on environmentally friendly hotel design and consumer behavior, insufficient attention has been paid to the specific design strategies for eco-hotels in Iran's fragile ecosystems. This study endeavors to bridge this gap by emphasizing the theoretical foundations of sustainable architecture and translating them into practical applications.

1.2 | The Necessity and Importance of Conducting Research

Contemporary tourism, while fostering economic growth, has, through mass tourism, led to the degradation of natural landscapes and fragile ecosystems. This industry also entails substantial energy and resource consumption, and its production processes impose environmental pressures such as greenhouse gas

emissions, pollution of water, soil, and air, noise generation, and excessive exploitation of local resources. To mitigate these adverse environmental effects, hotel management has recently begun adopting eco-friendly practices, and awareness of these issues continues to grow.

This research bridges the gap between theory and practice by translating the principles of eco-hotel design for sensitive ecosystems into practical applications and by highlighting the theoretical foundations of sustainable architecture. The necessity of this study arises from the lack of appropriate design strategies that currently contribute to environmental degradation. The research provides experts and investors with the knowledge and tools required to inaugurate a new era of sustainable hotel design.

1.3 | Research Methodology and Data Collection

Investigating environmental strategies for eco-hotel design, with a focus on sustainable architecture, and presenting a proposed plan are the central problems this research seeks to address. From an objective perspective, this study is applied in nature. The majority of the data was collected through content analysis, with a portion gathered via case study methods. The required information was obtained using library-based and fieldwork methods (questionnaires and predominantly observation), and subsequently analyzed qualitatively using descriptive analysis. Finally, based on the collected information and the analysis of the current situation, a checklist was developed for designing eco-hotels within sensitive ecosystems.

2 | Literature Review and Background Research

In the last five years, sustainable architecture in the hospitality industry has transitioned from being a competitive advantage to an ethical and operational imperative. The focus has shifted from mere resource conservation to the creation of enhanced environmental and social value. Despite the significant ecological footprint of the hospitality sector, evident in substantial energy and water consumption and considerable waste generation, recent literature suggests that hotels can act as local drivers of sustainable development. This literature review aims to augment the existing body of knowledge and deepen the understanding of the current state of this field.

2.1 | Eco-Hotel

Small-scale tourism accommodations established in pristine or environmentally sensitive natural areas, operating under stringent commitments to environmental preservation, respect for host culture, and ensuring the economic sustainability of local communities [4], this term describes hotels and lodging centers characterized by robust environmental policies that mitigate their negative impacts on the surrounding natural environment through effective energy, water, and land efficiency. These establishments constitute the core of sustainable hospitality.

2.2 | Ecotourism

Ecotourism is defined as responsible travel to natural areas that conserves the environment and improves the well-being of local people [5]. It comprises journeys undertaken to experience and appreciate the natural and cultural life in a manner that avoids harming either (i.e., nature or culture). Fundamentally, ecotourism is an ethically managed, nature-based form of tourism that achieves dual objectives: environmental preservation and the enhancement of local community welfare.

2.3 | Fragile Ecosystem

It refers to an ecosystem characterized by high vulnerability, stemming either from its intrinsic structure (such as limited biodiversity, isolation, or a centralized key function) or from high levels of external pressures (such as climate change, over-tourism, or health crises). This inherent vulnerability is coupled with a low potential for resilience against these stressors [6]. In such states, the probability of undesirable, irreversible structural or functional shifts is significantly increased.

2.4 | Domestic Studies

Fallahnejad [7] focused on designing the Candelos accommodation-recreational complex with an approach integrated with its natural context and local culture, utilizing library research. The study's outcome was the creation of a space that, while contemporary, addresses both the functional needs of a hotel and the cultural and indigenous patterns of the region.

Javadi [8] conducted research titled "hotel design with a green architecture approach emphasizing energy consumption reduction in Joybar city." The objective of this research was to identify influential components of green architecture in reducing energy consumption in hotel designs. The research methodology was applied in terms of its purpose. The results indicate that integrating hotel architecture with the regional climate can yield significant energy savings.

Rouhi Zangeneh Kalateh [9] conducted research titled "presenting hotel design strategies with a sustainability approach in cold and dry climates (case study: Torqabeh)." This research involved studies on accommodation centers with a sustainable approach. The outcome of this research is the presentation of strategies for achieving climatic design specific to Torqabeh, aiming to meet the needs of the tourism industry while ensuring adequate attention to environmental considerations.

Hajinia Asbo [10] conducted research titled "design of a 5-star hotel with a green architecture approach in Babol city." This study aimed to create a green hotel building that prevents energy waste and mitigates the negative environmental impacts of construction. This research used library resources and, by examining case studies and climatic factors, proposed solutions for the design of a five-star hotel.

Nobakht [11] conducted research titled "design of an Ecomotel with a sustainable architecture principles approach in Silvana." This research aims to provide Silvana's accommodation and tourism services to users under the designation of an Ecomotel. This study is classified as applied, and its method is documentary-analytical.

Fazli [12] conducted research titled "design of a four-star hotel in Anzali lagoon with an EA approach." The objective of this research is to design a hotel that leverages the region's natural assets to attract tourists, boost economic prosperity, and create employment. According to the results, ecological design must be implemented while preserving the existing texture, maintaining visual harmony, and strengthening local connections.

Vatan Khah Barazandeh [13] conducted research titled "design of an ecotourism lodge with a vernacular and green architecture approach in the Arasbaran region, Kaleybar county." The goal of this research is to examine the impact of the ecotourism lodge on the local economy and livelihoods of the region's villages, and to determine how green architecture influences the preservation of its environment.

Kardgar [14] conducted research titled "design of an intermediate travel accommodation complex with a vernacular architecture approach in the chelav region, Amol." The objective of this research is to modernize the region's vernacular architecture to meet contemporary needs, while ensuring it remains consistent with the area's historical and cultural heritage.

Khojasteh [15] conducted research titled "design of a mountain hotel with a sustainable architecture approach (Baladeh, Yush Village)." This research aims to apply sustainable architecture principles, considering the region's indigenous and cultural characteristics. Methodology: this study employed a mixed-methods approach. Conclusion: the use of indigenous and climatic principles enhances environmental and social sustainability by reducing negative impacts and promoting local interaction.

Sabbaghpour [5] conducted research titled "design of an ecotourism lodge with a social sustainability approach." This study intends to design a socially sustainable ecotourism lodge in Abbasabad county that enhances rural livelihoods while preserving the essential characteristics of tourism accommodations.

2.5 | International Studies

Wang and Hou [16] conducted research titled “architectural design of an ecological and environmentally friendly prototype.” This paper focuses on the design of ecological buildings in mountainous regions. Specifically, it details the design and construction of a sustainable architectural prototype in Mount Zushan, Qinhuangdao city.

Hanjayani and Siahaan [17] researched “Hutinyan Eco-Park Resort hotel (EA).” The objective of the design was to transform the eco-hotel accommodation into a marine tourism destination by understanding the principles of ecotourism.

Maher Hassan Mohamed Elkot [18] conducted research titled “assessment of environmental sustainability of hotel buildings in Siwa.” This study compares hotels built with traditional architecture against concrete examples that are detrimental to local identity. The goal is to preserve Siwa's heritage by aligning architectural design with the surrounding environment.

Yuniati [19] researched “the concept and practices of green hotels in Indonesia.” This article examines several empirical concepts of green hotels. The case study of Yogyakarta illustrates how tourists do not fully grasp the concept of green hotels.

Kitriniaris [20] researched “sustainable hotel design strategies, tourism as a tool for circular bioeconomy in fragile ecosystems.” This research manages the tension between economic development and sustainability to prevent disease outbreaks by proposing specific hotel design strategies for fragile ecosystems.

Jaklin and Sari [1] conducted research titled “the green hotel concept as a model of sustainability.” Green hotels demonstrate the accommodation industry's crucial role in environmental preservation by reducing energy, water, and waste consumption, and by promoting the use of recycled materials. These hotels represent a sustainable paradigm that can generate significant economic, social, and environmental benefits.

Kalfa and Gado [21] conducted a study titled “enhancing hotel sustainability through ecological integration and technology.” This study demonstrates that the convergence of environmental trends and technology significantly reinforces the development of sustainable hotel facilities.

Makoondlall-Chadee and Bokhoree [22] conducted research titled “environmental sustainability in hotels.” By examining Environmental Sustainability Assessments (ESAs) in hotels, this research shows that environmental and socio-economic factors improve hotel business sustainability.

Florivic et al. [23] presented research titled “architectural design in the hospitality industry—contemporary challenges, sustainability approaches, and emotional aspects for tourism competitiveness.” By investigating the architectural process, sustainability, and emotional aspects in Croatian coastal hotels, this article proposes a new model for the competitiveness of the hospitality industry.

Abd Elnaby et al. [24] conducted research titled “methodology for applying sustainable design to achieve energy efficiency in Ecotourism hotels in the Siwa Oasis.” The main objective of this article was to investigate the effect of using local materials on the energy efficiency of hotel buildings in the Siwa Oasis. The results of an applied study indicated that employing these materials improved energy performance by more than 14 percent.

Current studies largely focus on mitigating construction's environmental impacts but lack an integrated, vernacular framework for eco-hotels in fragile ecosystems that adequately addresses both cultural values and environmental sensitivity. Therefore, the development of adaptive design models for specific Iranian ecosystems (such as desert, mountainous, wetland, and mangrove areas) appears essential.

3 | Research Implementation Stages

The hospitality industry has transitioned over the last decade from being a major consumer of resources to a key arena for implementing sustainability principles, given the significant environmental footprint generated

by the high energy and water consumption typical of hotels. By systematically applying sustainable architecture in eco-lodge design, these accommodations can be transformed from agents of degradation into catalysts for local sustainable development. This transformation inherently amplifies the surrounding environment's cultural, social, and economic values.

3.1 | Information Analysis

The initial efforts to apply sustainability principles in construction date back to the early 1990s [25]. Sustainable architecture has since evolved into a global movement dedicated to minimizing a building's environmental impacts throughout its entire life cycle. This research endeavors to extract and formulate sustainable design patterns for eco-hotels through the critical analysis of international case studies.

3.1.1 | Case study investigations

Currently, environmentally conscious hotels are being constructed in Europe, the United States of America, Canada, Australia, Turkey, and other nations. As a general rule, each country maintains its own environmental certification body responsible for formulating standards [26]. By recognizing the imperative of sustainability, hotels have come to understand the need to focus on developing "green" areas. Consequently, numerous resorts are being established in pristine regions, drawing inspiration from an "organic" theme to enhance guest well-being while promoting environmental conservation.

Table 1. Analysis of domestic and international eco-hotels (source: author).











| Domestic | Eco-Hotel Name | Location | Year of Construction | Advantages | Disadvantages | Figure |
|---------------|---------------------------|-------------------|----------------------|--|--|---|
| | Chaldareh | Iran-Tonekabon | 2006 | Placement of cabins among standing forest cover, featuring traditional, climate-responsive architectural design | There is a need for an enhanced sustainability framework encompassing energy, waste, and water resource management. |  |
| | Matinabad | Iran-Natanz | 2010 | Vernacular desert architecture, management of water, energy, and waste resources, and environmental education for guests | Utilization of 30 percent of fossil fuel resources |  |
| | Dorna | Iran-Meshkinshahr | 2014 | Utilization of vernacular materials, harnessing natural vistas, and achieving optimal congruence with the climatic context | The requisite framework for energy management and wastewater treatment strategies to transition into an eco-hotel status |  |
| International | Eco Hotel Butterfly House | Bahia-Brazil | 2013 | The integration of vernacular material utilization, stewardship of water, energy, and waste resources, alongside the provision of environmental education for guests | A substantial carbon footprint, coupled with pronounced vulnerability to climatic shifts |  |

Table 1. Continued.

| Domestic | Eco-Hotel Name | Location | Year of Construction | Advantages | Disadvantages | Figure |
|---------------|----------------------------------|------------|----------------------|--|---|---|
| International | Wilderness Hoanib Skeleton Coast | Namibia | 2014 | Minimalist design, use of natural energy, use of solar energy, and social awareness | Restrictions on waste management, pressure on local wildlife |  |
| | Six Senses Yao Noi | Thailand | 1995 | Minimalist design, utilization of natural energy, use of solar power, and social awareness | Restrictions on waste management, pressure on local wildlife |  |
| | Anantara Bazaruto Island Resort | Mozambique | 2001 | Design in line with the ocean landscape, combining nature with indigenous culture, water, energy, waste management, and marine ecosystem protection | High water and energy consumption, low contribution of residents to the economy |  |
| | Topas | Vietnam | 2003 | Design that is appropriate to the topography of the area, use of local materials, minimal electricity consumption, use of daylight and natural ventilation, waste separation, closed water cycle | The remoteness of the region increases transportation energy consumption. |  |
| | Sápmi Nature Camp | Sweden | 2016 | Use of local materials, minimal utilization of energy resources, emphasis on insulation, and waste management | The remoteness of the region increases transportation energy consumption. |  |
| | La Gree Des Landes -Yves Rocher | France | 2009 | Utilization of renewable energy, water management, waste management, and the implementation of composting | Costly and difficult to insulate old structures. |  |

3.2 | Comparative Model (in Three Analytical Dimensions)

This three-dimensional analytical framework (including environmental, socio-cultural, and technological management dimensions), which is often used in sustainable design strategies, especially in the field of architecture and tourism development, has its roots in the 3P model of sustainability introduced by John Elkington in [27], which includes (people): equivalent to the socio-cultural dimension, (planet): equivalent to the environmental dimension, (profit): which in the context of sustainable design is often replaced by the management/economic/technological dimension to focus on operational efficiency and sustainability.

In the field of sustainable architecture and design, these three dimensions (environmental, social, and economic/technological) have been widely employed by researchers such as David Peters and Ken Yeang.

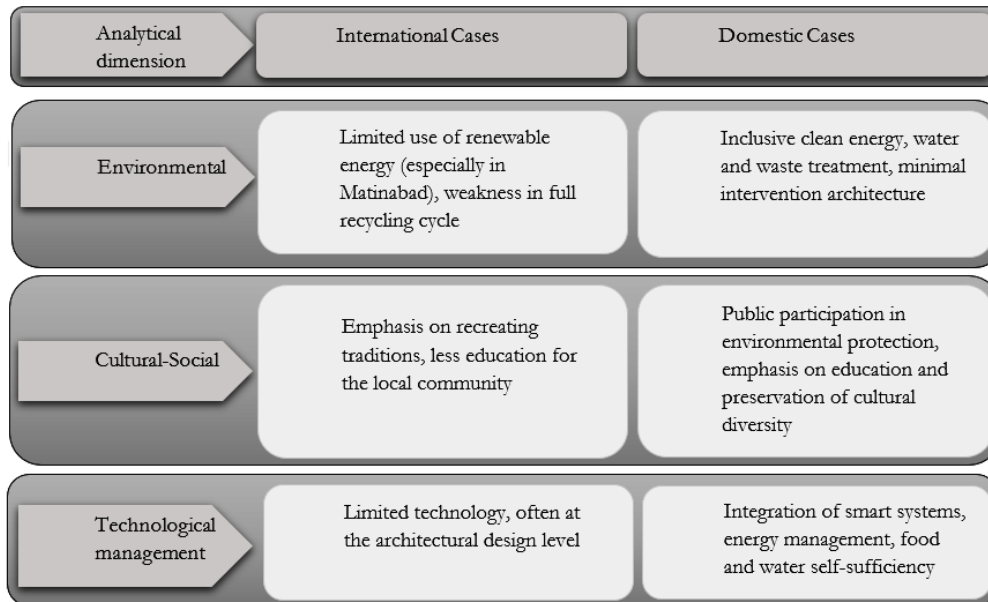


Fig. 1. Comparative pattern (source: author).

4 | Analysis of Findings

This study is a systematic review of the literature on eco-hotel design in sensitive ecosystems to promote environmental sustainability. It aims to identify and categorize design strategies used in the hotel industry. The review clarifies research gaps and offers suggestions to increase sustainability. Finally, this research will yield five central principles for eco-hotel design in sensitive areas of Iran. From the integration of the above findings, five central principles for eco-hotel design in sensitive ecosystems of Iran are extracted.

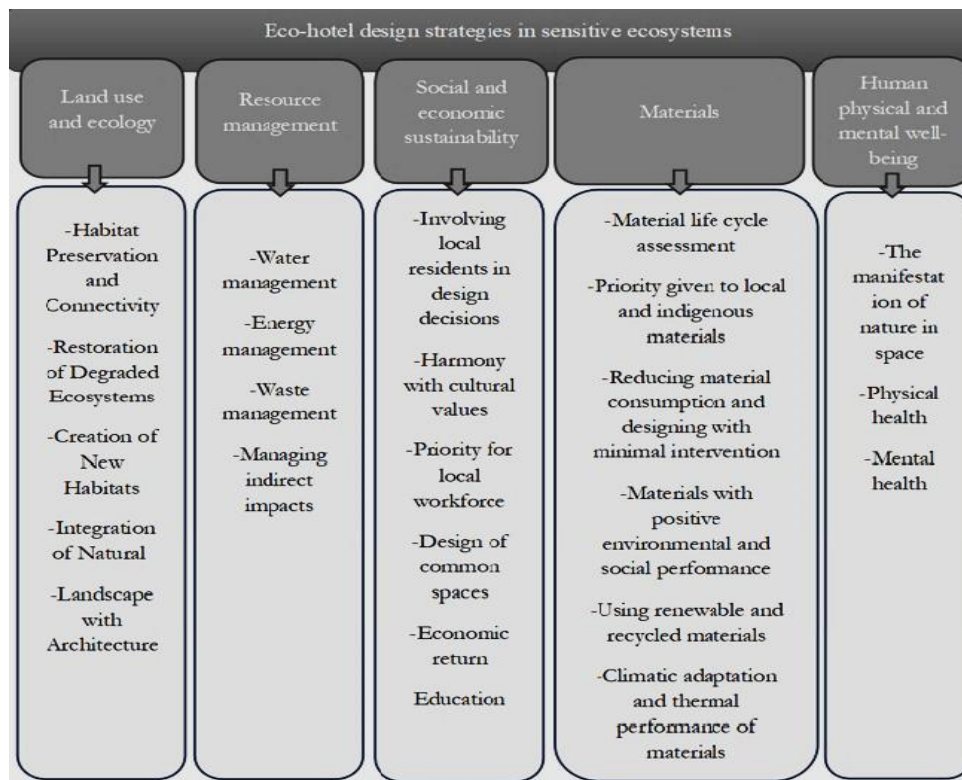


Fig. 2. Eco-hotel design strategies in sensitive ecosystems (source: author).

4.1 | Land Use and Ecology of the Building Site and Surrounding Environment

The selection of an eco-hotel site should be based on a thorough understanding of the site's natural features. This understanding should be deep, multifaceted, and based on scientific data. Careful consideration of

topography (including slope, slope orientation, and drainage patterns), microclimate (including solar radiation, wind speed and direction), natural landscaping (including soil type and geological structure), water resources (including groundwater aquifers, surface runoff pathways, and wetlands), vegetation (including dominant species, age, and health of forests or grasslands), and the presence of wildlife in sensitive ecosystems will help designers determine how to integrate natural elements into the design. In these assessments, the preservation of sensitive and biologically valuable ecosystems (such as endangered habitats or vegetation that plays a key role in carbon sequestration) is an absolute priority.

4.1.1 | Habitat preservation and connectivity

It is vital to maintain the natural flow of life in the sensitive ecosystem surrounding the project. Habitat fragmentation is one of the greatest threats to urban and rural biodiversity. Development boundaries should be determined based on Ecological Sensitivity Mapping. Areas with the highest density of sensitive species or the most important ecosystem functions should be defined as permanent protected areas.

4.1.2 | Restoration of degraded ecosystems

After assessment, it is often determined that part of the site or adjacent areas have been affected by past developments, are subject to pollution, or are at risk of the introduction of non-native species. The architectural design should include a comprehensive ecological restoration program. Native plants are better adapted to local soil and climate, require less water, and, more importantly, form the basis of the local food chain (supporting native insects and birds).

4.1.3 | Creation of new habitats

This architecture is the integration of environmental structures into the building itself: 1) choosing plants that, in addition to being beautiful, create a habitat for beneficial insects such as pollinating bees, 2) incorporating protected spaces into the building structure or incorporating nesting boxes for native birds at appropriate heights is effective, and 3) designing stable ponds or basins that have different depths to host a variety of aquatic animals. These water sources should be maintained without the use of chemicals and using natural filtration (aquatic plants).

4.1.4 | Integration of natural landscape with architecture

The landscape-architecture integration strategy emphasizes visual and functional harmony. This is achieved through: 1) gradual transition: avoiding abrupt boundaries between the building and nature, as this gentle slope helps wildlife adapt to the space, 2) native materials: using local materials with the lowest latent energy to harmonize the visual texture of the building with the environment, and 3) light optimization: using low-intensity, downward and warm lighting (below 3000 Kelvin) to reduce negative impacts on nocturnal insect behavior.

4.2 | Resource Management

Resource management in this context is defined by the model of sustainable artificial ecosystems, which aims to mimic the resource efficiency of natural ecosystems with minimal waste.

4.2.1 | Water management

Water management in sensitive areas is based on two principles:

- I. Demand reduction: this is achieved through the design of very low-consumption infrastructure (e.g., smart faucets and low-flow toilets). This argument is directly linked to reducing pressure on local groundwater or surface water resources.
- II. Advanced treatment and resource recovery: 1) Greywater: treatment by biofiltration systems and direct return for non-potable uses (e.g., irrigation) or toilet flushing, 2) Blackwater: in highly sensitive areas, discharge standards should be zero. This argument requires the use of an MBR method, the output of which is water of a higher quality than the input water required for the natural environment, and 3) Surface runoff

management: instead of piping and rapid discharge, permeable development methods such as rain gardens and green roofs are used to absorb, filter, and return runoff to groundwater aquifers.

4.2.2 | Water management

The goal is to achieve net-zero energy consumption by significantly reducing energy demand.

4.2.2.1 | Climate-responsive design strategies

These strategies represent the first and most essential layer of sustainable design, as they minimize dependence on energy-intensive mechanical systems. They rely heavily on a precise understanding of local climatic conditions, including temperature, wind, solar radiation, and humidity.

Design based on building orientation and form: 1) use of Solar radiation: in cold climates, primary façades should face south to maximize solar heat gain during winter (enhanced solar utilization). In hot climates, efforts are made to minimize east and south façades, as they are subject to strong direct solar exposure, and 2) Surface-to-volume ratio: buildings with a lower surface-to-volume ratio (more compact forms such as cubes) experience less heat loss during winter compared to elongated forms.

Daylight utilization: maximizing the use of natural daylight significantly reduces lighting energy consumption and enhances the visual quality of indoor environments. Key methods include: 1) interior depth control: ensuring adequate daylight penetration into interior spaces (the effective depth is approximately 2 to 2.5 times the window height), 2) light-guiding elements: incorporation of skylights, roof windows, and light-guiding systems that reflect light onto ceilings and distribute it into deeper zones, and 3) window placement: in cold climates, windows should primarily face south to optimize daylight use, while in hot climates, window design must carefully balance daylight admission with shading to avoid glare and direct solar gain.

Solar heat control and shading: this strategy is crucial for reducing cooling loads in warm and temperate climates, 1) horizontal shading devices: block high-angle summer sun while permitting low-angle winter sunlight to enter, 2) vertical shading devices: effective in controlling morning and afternoon sunlight (east and west orientations), and 3) high reflectance materials: application of light-colored coatings on roofs and walls to increase solar reflectance and reduce heat absorption.

4.2.2.1 | Natural ventilation and passive cooling

Cross Ventilation: designing openings on opposite walls to allow natural airflow across the building: 1) stack effect: utilizing pressure and density differences between air at varying heights to create upward airflow, often achieved through wind towers or tall central atria; 2) thermal mass: use of heavy materials such as concrete, brick, or earth that absorb, store, and slowly release heat. In hot climates, these materials absorb heat during the day and release it to the exterior at night.

Renewable energy production: the integration of small-scale solar photovoltaic and wind energy systems is encouraged, ensuring minimal visual and ecological disturbance (e.g., impact on bird populations). In many cases, concentrated solar power with molten salt storage systems for water heating and shallow geothermal systems are preferred. The recovery and reuse of waste heat from cooling or domestic hot water systems to preheat incoming air or water is also an effective strategy for improving overall energy efficiency.

4.2.3 | Waste and raw material management

In environmentally sensitive eco-hotels, waste is regarded as a “system error output”, and the design strategy is fundamentally based on elimination and transformation. Emphasis is placed on source reduction, particularly in packaging and guest consumables, which has proven to be highly effective. All food and organic waste should be processed through composting systems, allowing the recovered material to be returned to regional soils to complete the nutrient cycle. Recyclable materials must be accurately separated and transported off-site for further processing, while non-recyclable materials (such as multilayer plastics) should be minimized to the greatest extent possible.

4.2.4 | Management of indirect impacts

This aspect addresses the hotel's operational impact on surrounding living organisms. In ecologically sensitive areas, the environmental carrying capacity (the maximum number of visitors an area can sustain without vulnerability) serves as the primary determinant for the size and quantity of accommodation units. Generally, the number of units must be severely restricted to prevent human density from exerting undue pressure on wildlife and local resources. Furthermore, by employing precise ecological calculations to determine each guest's proportional resource consumption, the phenomenon of 'environmental pollution through consumption' can be mitigated. A portion of the revenue generated from guest stays must be directly allocated to local initiatives, including wildlife monitoring projects, research on vulnerable species, and habitat preservation.

4.3 | Socio-Economic Sustainability

In eco-hotel design, the social dimension is pivotal to achieving holistic sustainability. A core criterion for sustainability in tourism involves spatial development that not only harmonizes with the natural environment but also demonstrably enhances local community quality of life. Social approaches in this domain concentrate on active community participation, respect for indigenous culture, social equity, and the cultivation of meaningful connections between tourists and residents.

Key social strategies within eco-hotel design encompass:

Resident participation in design decisions: participation, particularly in material selection, lifestyle patterns, and the scope of services offered, fosters a heightened sense of local ownership and facilitates social acceptance of the project.

Alignment with cultural values: the eco-hotel design must be congruent with the region's cultural values, indigenous architectural typologies, and social customs. This Alignment not only exposes tourists to the authentic culture of the location but also prevents the homogenization often observed in standardized tourism spaces.

Prioritization of local labor and enterprises: prioritizing small-scale businesses and employing local labor increases community income, reduces inequality, and strengthens a sustainable economic cycle. Eco-hotels can thus function as catalysts for rural development.

Design of communal spaces: facilities such as indigenous markets, handicraft workshops, and cultural gathering areas create opportunities for dialogue and mutual understanding between tourists and local populations. This interaction serves as a valuable source for cultural learning and reciprocal respect.

Education and knowledge transfer: eco-hotels should serve not merely as accommodations but also as educational hubs, sharing sustainability knowledge with both tourists and the local community. Educational programs concerning natural resource conservation, waste management, and optimal energy utilization contribute to sustainable cultural development.

Economic return on investment: although the initial construction costs for sustainable buildings may be higher, Life Cycle Cost Analysis demonstrates that investment in sustainable design yields significant economic returns, specifically through: 1) savings in operational expenditures, 2) reduction in maintenance and repair costs, and 3) augmentation of property valuation.

4.4 | Materials

The choice of materials in eco-hotel design represents one of the most pivotal sustainable design decisions, as construction materials influence not only the thermal performance and durability of the structure but also carry extensive environmental, social, and economic implications.

4.4.1 | Material life cycle assessment

Environmental assessment of materials—from extraction to final disposal—is of paramount importance in eco-hotel design. Materials must be selected based on a low-energy approach; that is, materials whose production processes are less reliant on fossil fuels and generate minimal pollution. For instance, adobe brick and local stone have lower carbon footprints and greater ecological compatibility than industrial materials such as PVC.

4.4.2 | Prioritization of local and indigenous materials

In eco-hotels, the utilization of local materials plays a crucial role in reducing transportation energy consumption and preserving the region's cultural identity. Sourcing materials from the project site or within a maximum adjacent geographical radius not only decreases the eco-hotel's dependence on external resources but also stimulates local employment and community involvement in the construction process.

4.4.3 | Material reduction and minimal intervention design

Eco-hotel design must be founded upon the principle of “Ecological Minimalism,” meaning structures should be executed with the minimum necessary volume of materials and the least possible alteration to the natural substratum. The use of lightweight structural systems, multifunctional spaces, and modular design can lead to significant reductions in raw material consumption, construction waste, and energy costs. Furthermore, employing easily disassembled and recyclable materials at the end of the building's lifespan is a key component of a closed-loop material cycle.

4.4.4 | Materials with positive environmental and social performance

In sustainable design, the social impact of material selection is as significant as its ecological footprint. Materials must be chosen based on processes that utilize fair labor and non-destructive production methods. Supporting small, local producers and suppliers with recognized environmental certifications can be an integral part of the eco-hotel's social responsibility mandate.

4.4.5 | Implementation of renewable and recycled materials

Priority should be given to materials with short regeneration cycles or derived from recyclable sources. Bamboo, Hemp, Cork, and materials sourced from industrial or agricultural waste streams are examples of renewable, low-carbon materials that can effectively substitute for high-energy conventional materials like steel or plastic in eco-hotel design. This choice not only mitigates CO₂ emissions but also provides educational and cultural value to hotel guests.

4.4.6 | Climatic adaptability and thermal performance of materials

Materials at the eco-hotel must be selected to respond to the site's microclimate, minimizing energy demand for heating and cooling. In hot, arid regions, heavy materials with high thermal mass, such as stone and brick, aid thermal stabilization; in humid climates, lightweight, breathable materials like wood or compressed earth are preferred. The application of natural finishes, bio-based insulation, and reflective coatings represents further climate-adaptive strategies that minimize energy consumption throughout the structure's lifespan.

4.5 | Human Physical and Psychological Well-Being

In eco-hotels located in sensitive regions, the design must prioritize maximizing the positive physiological and psychological effects of nature on humans. These strategies are fundamentally based on Biophilia theory (the innate human affinity for nature) and the concept of natural environment stress-reduction responses.

4.5.1 | Manifestation of nature in space

This approach involves the seamless integration of natural elements into the guest experience through several pathways: 1) controlled natural light: utilizing large glazed surfaces with strategic orientation to capture full-spectrum daylight and its natural temporal variations, while simultaneously mitigating excessive glare and solar

heat gain, 2) natural ventilation and environmental scents: ensuring the flow of fresh, natural air that carries regional olfactory cues (e.g., the scent of earth, post-rain vegetation), which directly influences respiratory stress reduction, 3) water integration in design: incorporating aquatic features (e.g., waterfalls, serene pools) near primary accommodation zones to leverage the calming acoustic properties of water, 4) natural patterns: employing fractal geometries, soft curves, and organic structural forms within the interior design schema, and 5) raw natural materials: showcasing the intrinsic texture of materials to evoke a sense of authenticity and grounding connection to the earth.

4.5.2 | Physical health

This aspect focuses on factors that directly influence the body's physiological functions: 1) Indoor Air Quality (IAQ): exclusive use of materials exhibiting very low or zero volatile organic compounds off-gassing. This argument is critical for ecologically sensitive areas prone to internal contamination. Furthermore, the implementation of plant-based air filtration in common areas proves highly effective, 2) thermal and humidity comfort: (maintaining low diurnal temperature fluctuations). In sensitive settings, internal temperatures must be modulated to minimize reliance on energy-intensive mechanical systems (with an emphasis on optimal relative humidity), and 3) environmental acoustics: designing to attenuate the intrusion of artificial noise (e.g., mechanical system sounds) while enhancing desirable natural auditory inputs (e.g., birdsong, wind).

4.5.3 | Psychological health

This dimension addresses the environment's capacity to alleviate mental fatigue and enhance focus: 1) view corridors: rooms should be designed to provide direct, unobstructed views of pristine natural surroundings, 2) cultural anchoring and refuge: the incorporation of local structures and cultural heritage into the design reinforces a sense of belonging, thereby reducing anxiety associated with unfamiliar environments. The creation of refuge spaces is essential to facilitate opportunities for individual contemplation and solitude. Designing safe, guided trail systems that lead guests into the ecosystem encourages physical activity and deeper immersion.

5 | Conclusion

The present research was conducted to investigate eco-hotel design methodologies within Iran's sensitive and fragile ecosystems. The research process was structured around the study of scientific literature, the analysis of domestic case studies, and the incorporation of findings from international research, ultimately proposing an integrated framework for environmentally adaptive and human-responsive eco-hotel design. The study's findings indicate that designing eco-hotels within Iran's natural settings requires a context-specific, multidimensional approach that integrates ecological, cultural, and functional dimensions in an interactive relationship. Crucial factors in enhancing the environmental performance of such accommodations involve meticulous attention to spatial elements—ranging from material selection to technical details (such as fenestration, building orientation, water treatment systems, and energy recovery). Furthermore, reducing CO₂ emissions and enhancing energy efficiency by selecting materials with low embodied energy and considering the building's life-cycle can significantly contribute to the sustainability of these spaces. Subsequently, the results demonstrate that sustainability is not confined to the ecological sphere alone; it is imperative to address the human and psychological dimensions of the space. Fostering a connection between humans and nature, ensuring high-quality viewsheds, and optimizing internal environmental conditions are factors that directly influence the user's accommodation experience and satisfaction levels. In this light, the eco-hotel can be perceived as more than just a lodging facility; it can be viewed as an integral part of the experience of residing within a natural environment.

Based on the synthesis of the data, a set of overarching principles can be extrapolated across the domains of environmental stewardship, socio-cultural integration, and management for Iranian eco-hotels. However, a review of the domestic literature suggests that a comprehensive approach to systematically integrating sustainable design principles remains underdeveloped. Consequently, the formulation of indigenous

assessment models tailored to Iran's specific climatic and ecological characteristics could pave the way for future research endeavors. Moreover, empirical field studies investigating the impact of ecological design and internal environmental quality on user health and experience would significantly enrich the practical application in this field. Overall, this research underscores the feasibility of integrating environmental sustainability with human well-being in eco-hotel design, thereby providing a vision for the development of responsible tourism congruent with Iran's unique natural and cultural landscape.

Authors' Contributions

All aspects of the research and manuscript preparation were carried out by the author. The author has read and approved the final version of the manuscript.

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Data Availability

All data are included in the text.

Conflict of Interest

The author declares that he does not have any conflict of interest.

Consent for Publication

The author has given consent for the publication of this manuscript.

Ethics Approval and Consent to Participate

This study does not involve any research conducted on human participants or animals.

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