

Original Research Article

The Role of Bio-Aesthetic Components in Predicting the Perceptions of Residential Environment Quality (Case Study: Selected Neighborhoods in Sanandaj City)*

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Abstract

Problem statement: With growing concerns over the quality of residential environments, scholarly efforts have increasingly focused on identifying the factors that shape residents' perceptions of their surroundings. Within this context, the concept of bioaesthetics has gained prominence as a critical dimension influencing environmental perception.

Research objective: This study aims to investigate the extent to which bio-aesthetic components can predict residents' perceptions of residential environment quality.

Research method: Employing an applied purpose, this cross-sectional study utilized a descriptive-correlational approach. The target population consisted of adult residents in the Khosrowabad, Agher Zaman, Qatarchian, and Sartapuleh neighborhoods of Sanandaj. A total of 250 questionnaires were distributed using convenience sampling, from which 214 valid responses were collected. Data were gathered through two researcher-developed instruments: a 49-item scale measuring four dimensions of bioaesthetics perceptual, cognitive, social, and biological and a four-item scale assessing perceived residential environment quality. Content validity was established through expert evaluation, and internal consistency was confirmed via Cronbach's alpha. Data analysis included Pearson correlation coefficients and simultaneous multiple regression.

Conclusion: All four bio-aesthetic components showed significant positive correlations with perceived residential environment quality. The combined model of bio-aesthetic factors significantly predicted 33% of the variance in residential environment quality ($R^2 = 0.33$, $p < 0.001$). Among the components, perceptual, biological, and social aesthetics emerged as significant individual predictors, whereas the cognitive component did not independently predict environmental perception. These findings highlight the pivotal role of bio-aesthetic design especially perceptual and biological dimensions in fostering higher-quality residential environments. Integrating bio-aesthetic principles into environmental design can enhance both resident satisfaction and overall quality of life.

Keywords: *Architectural Aesthetics, Bio-aesthetic, Residential Environment Quality, Environmental Perception, Sanandaj.*

Introduction

Over recent decades, there has been a growing shift in architecture and urban planning toward sustainability

and human-centered paradigms. This evolution has spurred the emergence of innovative approaches aimed at revitalizing the relationship between humans and the natural environment within urban and residential contexts (Kellert, 2015; Beatley, 2011). Among these approaches, bio-aesthetics has gained prominence as a multidisciplinary concept that

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integrates natural components, organic forms, sensory and psychological responses, and environmental sustainability into residential design frameworks (Hung & Chang, 2021; Kaplan, 1995). In this vein, the quality of residential environments whether at the scale of individual dwellings or larger urban neighborhoods has been increasingly acknowledged as a crucial determinant of inhabitants' well-being and satisfaction (Mousavi Sarvinehbaghi & Sadeghi, 2016; Ghomeshi & bin Mohd Jusan, 2013). In Iran, while the country boasts a deep-rooted tradition of vernacular architecture grounded in the harmony between human and environmental elements (Pourjafar & Alavi Balmany, 2012; Ramzy, 2015), recent decades have witnessed a noticeable shift. The rapid pace of modernization, urban sprawl, population growth, and shrinking green spaces have collectively undermined this harmony, leading to a perceptible decline in the aesthetic and experiential quality of many residential settings (Tabatabaei, 2011; Kasravi, 2018). Globally, mounting ecological threats, rising urban pollution, psychological pressures, and diminishing social cohesion have pushed urban design agendas toward biophilic strategies and nature-integrated solutions (Kellert, 2012; Kaplan & Kaplan, 1995; Cushing & Miller, 2019). As a result, a thorough understanding and conceptual development of bio-aesthetics along with empirical evaluation of its influence on residential environment quality has become an essential pursuit within contemporary architecture and urban studies. The significance of bio-aesthetic design extends well beyond superficial visual appeal; it holds the potential to foster physical and mental health benefits (Gray & Birrell, 2014; Hung & Chang, 2021), reinforce place identity and a sense of belonging (Lynch, 1960; Relph, 1976), and promote ecological performance and environmental stewardship (Beatley, 2011; Braungart & McDonough, 2002). Collectively, these dimensions contribute to more resilient, meaningful, and aesthetically enriched residential environments (Ghomeshi et al., 2012; Mousavi Sarvinehbaghi & Sadeghi, 2016; Cushing & Miller, 2019). Nonetheless, despite increasing scholarly engagement, three core challenges continue to shape the discourse surrounding bio-aesthetic research:

1. A lack of clarity regarding the degree to which various bio-aesthetic components influence the perception of residential environment quality.
 2. A shortage of empirical and quantitative studies that analyze the mechanisms through which these components exert their effects.
 3. The integration of bio-aesthetic principles into the design and construction processes of residential environments requires the development of more effective conceptual models and evaluation tools.
- In response to these gaps, the present research aims to investigate the relationship between bio-aesthetic components and perceived residential environment quality, to identify the most effective combination of predictors. Using a descriptive-correlational approach grounded in multiple regression analysis, this study evaluates the impact of four core dimensions of bio-aesthetics—perceptual, cognitive, social, and biological—on residents' perceptions of environmental quality across four historically significant neighborhoods in Sanandaj: Khosrowabad, Qatarchian, Agheh Zaman, and Sartapuleh. From a theoretical perspective, the findings of this research may contribute to the expansion of the academic literature on bio-aesthetics. Practically, the results offer insights for designing residential environments grounded in bio-aesthetic principles, which in turn may enhance the quality of life for urban residents.

Literature Review

A critical survey of the existing body of literature reveals that, while the specific conceptual model explored in this study—namely the integration of bio-aesthetic components with the assessment of perceived residential environment quality at the neighborhood level—has not been comprehensively addressed, a number of related investigations have laid important groundwork in adjacent domains. These studies often explore how natural elements, perceptual responses to environmental aesthetics, and biophilic attributes influence human experiences and environmental quality within residential contexts. Consequently, although the present research introduces a novel and integrative approach, it builds

upon established theoretical and empirical insights. What follows is a review of foundational works that underpin the conceptual structure of this study. One of the earliest and most influential contributions is Edward O. Wilson's Biophilia Hypothesis (1984), which posits that humans have an intrinsic biological tendency to affiliate with nature. This innate affinity, shaped by evolutionary processes, is thought to support both psychological well-being and physiological health. Wilson emphasized that incorporating natural elements into residential settings can enhance emotional balance and life satisfaction. His theory has become foundational in environmental psychology and ecological design, serving as a key argument for integrating nature-oriented strategies in built environments (Wilson, 2016). Complementary to Wilson's framework, Rachel and Stephen Kaplan (1995) developed Attention Restoration Theory (ART), which explains how natural environments contribute to cognitive recovery and mental rejuvenation. According to ART, two types of attention exist: directed attention, which demands effort and can become fatigued, and involuntary attention, which is effortlessly engaged by intrinsically fascinating stimuli, such as those found in nature. Their empirical work demonstrated that environments rich in natural features promote restorative experiences, which in turn influence residents' evaluations of environmental quality and satisfaction (Kaplan & Kaplan, 1995). In a practical extension of these theoretical models, Keller et al. (2014) proposed a comprehensive framework of fourteen biophilic design patterns tailored for application in residential architecture. These patterns fall into three broad categories: direct experiences with nature (e.g., vegetation, water features), indirect representations (e.g., natural materials, colors), and spatial-structural qualities (e.g., refuge, complexity). Their work offers designers actionable principles to improve environmental aesthetics, sensory engagement, and emotional well-being, ultimately enhancing user satisfaction with the built environment. More recently, empirical research by Lee et al. employed structural equation modeling to investigate the role of aesthetic design in fostering emotional connection and well-being in residential neighborhoods. Their results indicated

that aesthetically enriched environments particularly those reflecting natural themes can significantly increase place attachment and contribute to quality of life improvements. These findings support the broader argument that environmental aesthetics, when grounded in natural principles, are critical to shaping positive residential experiences (Lee et al., 2022).

Among domestic investigations, several studies have contributed significantly to the understanding of aesthetic perceptions within urban environments. A notable example is the research by Montazerolhodjah & sharifnejad (2019), titled "Evaluating Physical Indicators Influencing Aesthetic Components in Contemporary Urban Developments (Case Study: Prepared Urban Zones in Yazd)". This study examined how specific physical and spatial characteristics affect aesthetic perception in newly developed urban areas. The results indicated that factors such as the minimization of visual monotony in facades, balanced street widths, and the continuity of built edges significantly influence residents' aesthetic evaluations of their urban surroundings. Similarly, Heydari & Karami (2022), in their study "Analyzing the Role of Urban Landscape Components in Urban Environmental Quality and Citizens' Environmental Behavior (Case Study: Ten Municipal Districts of Karaj)", explored how urban landscape design influences both environmental quality and the pro-environmental behaviors of residents. Their findings emphasized the importance of aesthetic dimensions particularly visual balance, perceived visual quality, and place attachment as key drivers of how citizens perceive and engage with their urban environments. These insights suggest that aesthetic considerations in urban landscape planning not only enhance visual quality but also encourage environmentally responsible behavior. A further contribution comes from Hosseini-Nasab et al. (2022), who conducted a qualitative study titled "Exploring the Aesthetic Dimensions of Residential Facades in Tehran from the Perspective of Neuro-Architecture." Drawing on the principles of neuro-architecture and using content analysis, the researchers identified eleven physical and eight semantic indicators relevant to residential facade aesthetics. Their analysis

revealed that both categories—physical and semantic—play crucial roles in shaping aesthetic experiences. They further classified aesthetic engagement into four distinct perceptual modes: visual, emotional, semantic, and symbolic. In addition, Esmacili et al. (2024) examined the psychological implications of aesthetic experience in their study “The Role of Perceptual-Aesthetic Components of Place in the Mental Health of Residents: Case Study of the Talareh Residential Complex in Gorgan.” Their results demonstrated a statistically significant correlation between aesthetic perception and mental health, indicating that environments rich in perceptual and aesthetic quality can contribute to improved psychological well-being among residents.

Taken together, these national and international studies highlight the substantial influence of bio-aesthetic components—including access to natural light, the integration of greenery, and the use of biophilic design strategies—on residents’ perception of environmental quality. These findings reinforce the theoretical and practical value of nature-integrated design in fostering residential satisfaction and enhancing psychological resilience. However, a clear gap remains in the literature: despite the acknowledgment of nature’s benefits, few studies have undertaken a systematic, component-specific analysis of the relationship between discrete bio-aesthetic elements and residents’ perception of residential environment quality. This underscores the need for further empirical work grounded in a comprehensive and integrated conceptual framework.

Theoretical Foundations

• The concept of residential environment quality

Residential environment quality represents a pivotal dimension in the assessment of living spaces, directly shaping how individuals perceive livability and overall life satisfaction. Rather than being solely determined by the material and spatial attributes of a setting, this concept is profoundly informed by individuals’ perceptions, lived experiences, and spatial interactions (Asadi et al., 2023, 20). Thus, residential environment quality emerges as a multidimensional phenomenon shaped by both observable and perceptual elements.

While housing can be narrowly defined as a physical shelter, a more holistic interpretation extends beyond structural aspects to include a broader range of services, functions, and environmental conditions that contribute to enhanced well-being (ibid. 21). Within this comprehensive framework, the residential environment is understood as a synergistic system in which physical form and surrounding conditions collectively influence the quality of lived experience (Sami & Asadi, 2018, 35). The relationship between a dwelling and its environmental context is so interdependent that evaluating one without the other would render the analysis incomplete (Feijten & Van Ham, 2013, 13). Residential satisfaction, therefore, results from the dynamic convergence of physical infrastructure, social networks, and cultural values (Habibi & Marzban, 2017, 59).

Scholars typically classify the determinants of residential environment quality into two broad categories: objective indicators, which encompass measurable aspects such as urban services, physical safety, green infrastructure, and construction standards; and subjective indicators, which reflect residents’ cognitive evaluations and emotional reactions toward their environment (Ghadiri & Shahrabaki, 2016, 98). Both indicator types interact simultaneously and are necessary for a comprehensive understanding of perceived environmental quality, as neither can offer a complete picture in isolation.

Critically, a neighborhood’s appeal cannot be appraised purely through its tangible features; it is equally contingent upon the users’ sensory and emotional engagement with the space. This underscores the fact that residential quality is not a monolithic or singular metric, but rather a composite concept encompassing multiple interrelated dimensions, each contributing independently and interactively to the way spaces are perceived, evaluated, and experienced.

As conceptualized in Fig. 1, the principal dimensions of residential environment quality include: (1) bio-aesthetic quality, (2) functional-activity quality, (3) semantic-perceptual quality, and (4) environmental quality. These domains form a cohesive and interactive system,

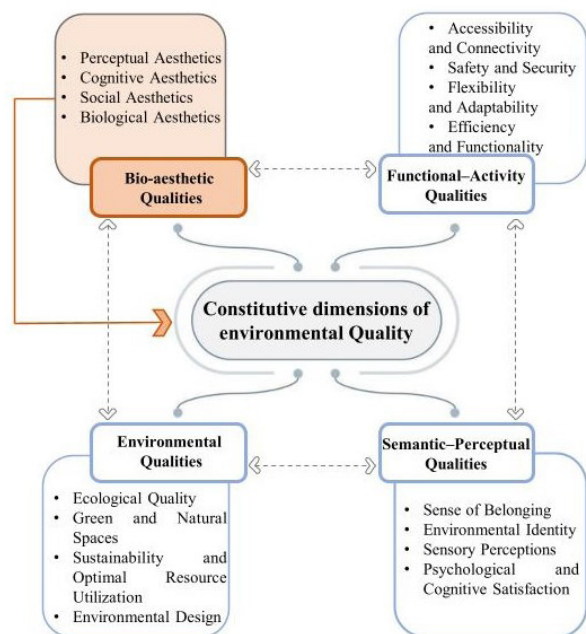


Fig. 1. Dimensions of Residential Environment Quality. Source: Authors.

whereby a comprehensive evaluation of residential quality necessitates simultaneous attention to all facets.

Among these, the bio-aesthetic dimension offers a particularly refined lens for understanding how aesthetic characteristics rooted in nature shape perceptual and experiential responses. It serves as a crucial mediator between the spatial configuration of the built environment and the psychological well-being of its users.

• The concept and nature of bio-aesthetics

Bio-aesthetics represents a contemporary paradigm within architecture and urban design that endeavors to harmonize natural systems—such as organic forms, textures, colors, materials, light, water features, and vegetation—with the perceptual, physical, and symbolic layers of the built environment. Rooted in the intrinsic human affinity toward nature, this approach draws upon evolutionary biology and environmental psychology to underscore the benefits of integrating nature into human living spaces (Kellert, 2015; Hung & Chang, 2021; Cushing & Miller, 2019). The theoretical foundation of bioaesthetics is closely tied to Edward O. Wilson's (1984) seminal Biophilia Hypothesis, which proposes that humans possess a biologically ingrained predisposition to connect with the natural world. Within

this framework, the deliberate inclusion of natural features in architectural design—especially within residential contexts—can foster psychological comfort, boost cognitive performance, and enrich users' aesthetic engagement with space (Kaplan, 1995; Beatley, 2011; Cushing & Miller, 2019, Lowenthal, 1985). While the notion of bio-aesthetics may initially seem limited to the visual application of greenery or biomorphic forms, its true conceptual depth lies in its interdisciplinary and multi-scalar essence. Beyond the superficial, bio-aesthetics engages with a wide spectrum of dimensions, encompassing ecological principles, socio-cultural symbolism, psychological well-being, and even the historical continuity of place-based identity (Gray & Birrell, 2014; Pourjafar & Alavi Balmany, 2012; Mousapour, 2023). It integrates not only the visible beauty of nature but also its structural logic, cyclical patterns, regenerative functions, and its resonance with vernacular traditions and shared cultural memory (Ramzy, 2015; Relph, 1976; Lowenthal, 1985).

• Intersection of bio-aesthetics with related approaches

The concept of bio-aesthetics intersects with several closely aligned theoretical frameworks and design methodologies, each of which contributes distinct yet complementary perspectives to the broader discourse on nature-integrated design. A brief overview of these related paradigms is presented below:

Biophilia and Biophilic Design: Rooted in Wilson's (1984) Biophilia Hypothesis, which argues that humans are biologically predisposed to seek connections with nature, biophilic design operationalizes this theory by promoting strategies that foster natural engagement within architectural settings (Kellert, 2015; Gray & Birrell, 2014). Within this framework, bio-aesthetics functions as the perceptual and sensory manifestation of biophilic principles, translating nature's restorative and emotionally uplifting attributes into spatial experiences that support human well-being.

Biomimicry: Introduced by Benyus (1997), biomimicry entails the imitation of natural systems, patterns, and processes to address design and engineering challenges.

Although predominantly grounded in scientific and technological innovation, biomimicry also influences architectural aesthetics by inspiring biomorphic forms and structures that evoke the complexity and elegance of natural systems, thereby enriching the visual character of the built environment (Ghameshi et al., 2012).

Ecological and Nature-Based Design: These environmentally focused approaches prioritize ecological resilience, the conservation of natural systems, and the minimization of human impact on ecosystems (Beatley, 2011; Mousapour, 2023). While their core emphasis lies in environmental performance and sustainability metrics, bio-aesthetics contributes an essential perceptual dimension, emphasizing that ecological functionality should be visually legible and experientially meaningful through biologically resonant architectural expressions.

Organic Architecture: Rooted in the pioneering work of Frank Lloyd Wright and others, organic architecture promotes the integration of built forms with their natural surroundings through flowing lines, natural materials, and site-sensitive design. Although ideologically aligned with bio-aesthetic values, the bio-aesthetic perspective places greater focus on users' psychological and sensory experiences, aiming to foster emotional engagement and perceptual harmony with the natural elements embedded in architectural form (Kellert, 2015; Cushing & Miller, 2019).

• Distinctions from related concepts and conceptual boundaries

Although bio-aesthetics shares conceptual terrain with various adjacent frameworks, it upholds a unique epistemological and functional identity. The following distinctions delineate its theoretical boundaries in relation to closely related paradigms:

Bio-Aesthetics vs. Formal Aesthetics: While bio-aesthetics acknowledges the importance of visual form and stylistic expression, it does not treat these as isolated design ends. Rather, it embeds them within a broader matrix of ecological functionality and human psychological well-being. In contrast, traditional formal aesthetics tends to prioritize visual impact or compositional elegance as autonomous goals. Bio-

aesthetics, by comparison, seeks to forge a synthesis between aesthetic quality, environmental performance, and human flourishing—advancing a vision of beauty that is as restorative as it is visually compelling (Kellert, 2015).

Bio-Aesthetics vs. Green Design: Green design emphasizes ecological responsibility, typically through strategies such as energy efficiency, carbon footprint reduction, and the use of sustainable materials. While these environmentally protective objectives are foundational, bio-aesthetics surpasses the functional focus of green design by foregrounding the user's sensory and emotional experience of nature-infused spaces. In this regard, the emphasis shifts from minimizing harm to actively cultivating environments that evoke vitality, comfort, and emotional resonance (Gray & Birrell, 2014).

Bio-Aesthetics vs. Organic Architecture: Although both approaches advocate for architectural integration with natural surroundings, they diverge in terms of design priorities. Organic architecture is predominantly concerned with achieving morphological harmony between the built form and its site-specific natural context. Bio-aesthetics, however, extends this concern to include experiential and affective dimensions, such as psychological comfort, emotional bonding with place, and the enhancement of mental health. These human-centered outcomes are explicitly embedded as aesthetic values within the bio-aesthetic design agenda (Kellert, 2015).

Conceptual Scope and Multidimensional Components of Bio-Aesthetics

In light of the reviewed literature and collected sources, bio-aesthetics can be systematically classified as illustrated in Fig. 2 into four main components (perceptual aesthetics, cognitive aesthetics, social aesthetics, and biological aesthetics).

This research adopts an applied orientation and is conducted within a cross-sectional temporal framework. Methodologically, the study follows a descriptive-correlational design. The target population comprises adult residents of four historically

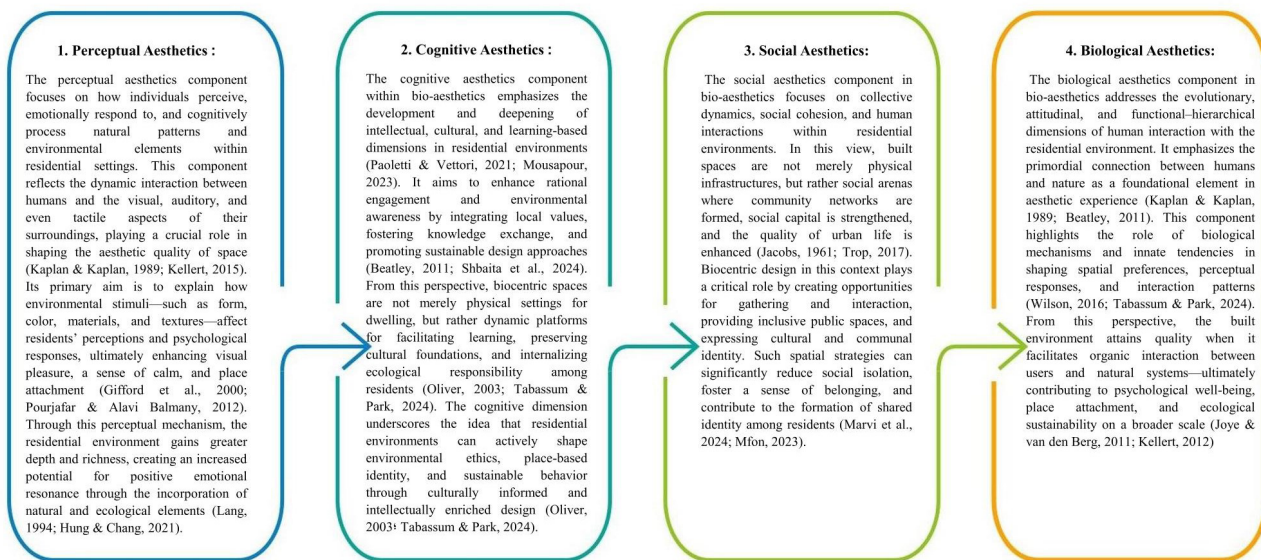


Fig. 2. Conceptual Scope and Components of Bio-Aesthetics. Source: Authors.

significant neighborhoods in the city of Sanandaj—namely, Khosrowabad, Agheh Zaman, Qatarchian, and Sartapuleh. A convenience sampling technique was employed due to the researchers' practical access to participants and the intent to maximize response rates. Out of 250 distributed questionnaires, 214 were accurately completed and returned, yielding a high response rate of 86%. The study utilized two researcher-constructed instruments for data collection. The first instrument—a 49-item scale—was designed to evaluate four key dimensions of bio-aesthetic experience: perceptual aesthetics, cognitive aesthetics, social aesthetics, and biological aesthetics. This instrument was originally developed as part of a meta-synthesis undertaken in the first author's doctoral dissertation. To measure residents' perception of residential environment quality, a separate four-item scale was administered. Both instruments employed a five-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (5). The content validity of the instruments was verified through expert evaluations. Internal consistency reliability was assessed via Cronbach's alpha, yielding coefficients of 0.86 for the bio-aesthetic scale and 0.72 for the environmental quality perception scale, both surpassing the commonly accepted threshold of 0.70 and thus confirming the reliability of the instruments. For data analysis, Pearson's correlation coefficient was used to examine associations between variables, while

simultaneous multiple regression analysis was conducted to determine the predictive capacity of the bio-aesthetic components. All statistical procedures were carried out using SPSS software, version 19. Table 1 presents an overview of the methodological specifications of the study.

Study Area

Sanandaj, the capital of Kurdistan Province, stands as a prominent urban center in western Iran. Its distinctive geographical setting, along with a rich historical and cultural legacy, has contributed to the formation of a unique pattern of residential development and spatial organization. The city's mountainous topography, the organic fabric of its traditional neighborhoods, and the continued influence of vernacular architectural and urban planning practices render Sanandaj a particularly suitable context for exploring issues of residential environment quality and bio-aesthetic integration. In recent decades, however, the city has undergone extensive physical expansion and socio-cultural shifts, which have markedly influenced the environmental conditions of its residential areas. These transformations have introduced a series of challenges, particularly concerning the preservation of livability and aesthetic coherence in historic neighborhoods. For the purpose of this study, four neighborhoods—Khosrowabad, Qatarchian, Agheh Zaman, and Sartapuleh—were

Table 1. Research Methodology. Source: Authors.

Methodological Dimensions of the Study	Overall Characteristics and Methodological Approaches	Elaboration of the Study’s Methodological Features
Type of Study	Approach: Quantitative Timeframe: Cross-sectional Objective: Applied Method: Descriptive - Correlational	The data in the present study are quantitative and were collected through a questionnaire. Data collection was conducted within a specific timeframe of less than six months. The findings of this research can contribute to improving decision-making in the field of residential environment quality. The researcher analyzed the relationships among variables without any manipulation or intervention.
Study Field Information	Statistical Population Sample Size Sampling Method	Adult residents of the Khosrowabad, Agheh Zaman, Qatarchian, and Sartapuleh neighborhoods in Sanandaj city 214 individuals Convenience sampling
Research Variables	Independent Variables Dependent Variable	Perceptual aesthetics, cognitive aesthetics, social aesthetics, and biological aesthetics Residential environment quality Meta-synthesis
Data Collection Method	Theoretical Phase Field Phase	Researcher-made questionnaire on bio-aesthetic components consisting of 49 items across four dimensions (perceptual, cognitive, social, biological) and a general questionnaire on residential environment quality, including 4 items
Instrument Validity and Reliability	Validity Reliability	Confirmed based on expert judgment Confirmed using Cronbach’s alpha coefficient
Data Analysis Method	Statistical Tests Statistical Software	Pearson correlation coefficient for assessing associations between variables; simultaneous multiple regression to determine predictive bio-aesthetic components SPSS version 19

selected as the case study sites (see Fig. 3). These areas were chosen based on the following defining attributes:

1. Historic Urban Fabric and Organic Settlement Patterns: The selected neighborhoods constitute some of the oldest segments of Sanandaj’s urban landscape. They exhibit organically evolved spatial configurations, defined by narrow, meandering alleys, an intricate interplay between private and semi-private spaces, and residential forms shaped through longstanding interactions among human settlement practices, natural features, and climatic conditions.
2. Environmental and Topographic Adaptation:

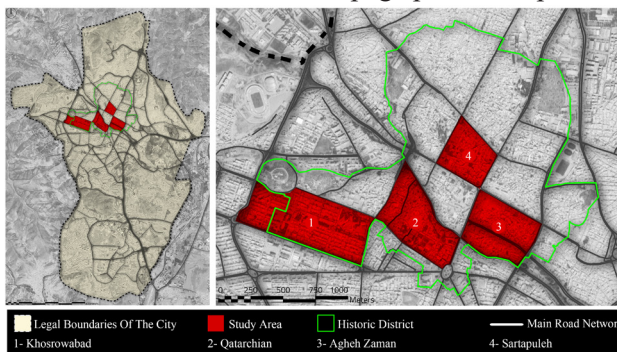


Fig. 3. The location of the selected study areas in Sanandaj City. Source: Authors.

These neighborhoods demonstrate a high degree of responsiveness to the ecological and geographical context of Sanandaj. Their architectural forms and spatial organization are attuned to the city’s hilly terrain and temperate climate, utilizing locally sourced materials and reflecting principles of traditional sustainable design rooted in vernacular architectural wisdom.

3. Contemporary Physical and Social Transformations: Over recent decades, forces of urban modernization, accelerated population growth, lifestyle shifts, and the reduction of green infrastructure have significantly altered the socio-physical landscape of these areas. Manifestations of these changes include the deterioration of historic structures, weakening of community ties, erosion of public space quality, and increased building density—each of which poses serious challenges to maintaining residential quality and aesthetic coherence.
4. Aesthetic Dimensions of the Residential Experience: Bio-aesthetic variables—such as visual perception, sense of place, integration of natural elements, and spatial legibility—play a pivotal role in shaping the lived experience of residents. Investigating these dimensions

offers critical insight into the perceptual foundations of residential satisfaction and serves as a guide for enhancing the ecological and aesthetic values of historic urban neighborhoods.

Fig. 4. Composite map of the four selected neighborhoods in Sanandaj—Khosrowabad, Qatarchian, Agheh Zaman, and Sartapuleh—each exhibiting unique spatial configurations, physical characteristics, and environmental attributes. These neighborhoods were purposefully selected as representative cases for analyzing bio-aesthetic perceptions of residential environment quality.

The selection of these four neighborhoods as the focal point of this study provides a unique opportunity to examine the influence of environmental and social dynamics on residential quality through the lens of bio-aesthetic principles. By centering the analysis on bio-aesthetic dimensions, the research aims to construct a comprehensive conceptual and practical framework for enhancing residential environments using nature-integrated design strategies. This focus not only deepens our understanding of how bio-aesthetic components shape residents’ perceptions of environmental quality but also offers actionable insights for improving livability and revitalizing the historical urban fabric in Iranian

cities with similar morphological and socio-cultural characteristics.

Results and Discussion

Table 2 summarizes the descriptive statistics and Pearson correlation coefficients among the study variables. Of the four bio-aesthetic dimensions, cognitive aesthetics yielded the highest average score ($M = 3.48$), followed by social, perceptual, and biological aesthetics. The mean score for residential environment quality perception was 3.68, with a standard deviation of 0.478. To investigate the associations between the bio-aesthetic components and perceived residential environment quality, Pearson correlation analysis was conducted. The results indicate that all four bio-aesthetic dimensions were positively and significantly correlated with residential environment perception at the 0.01 significance level ($p < 0.01$). Among these, perceptual aesthetics demonstrated the strongest relationship ($r = 0.53$), underscoring its critical role in shaping residents’ evaluations of their living environment. The biological, social, and cognitive dimensions followed in descending order of correlation strength, all maintaining statistical significance. These findings suggest that while each component contributes to environmental

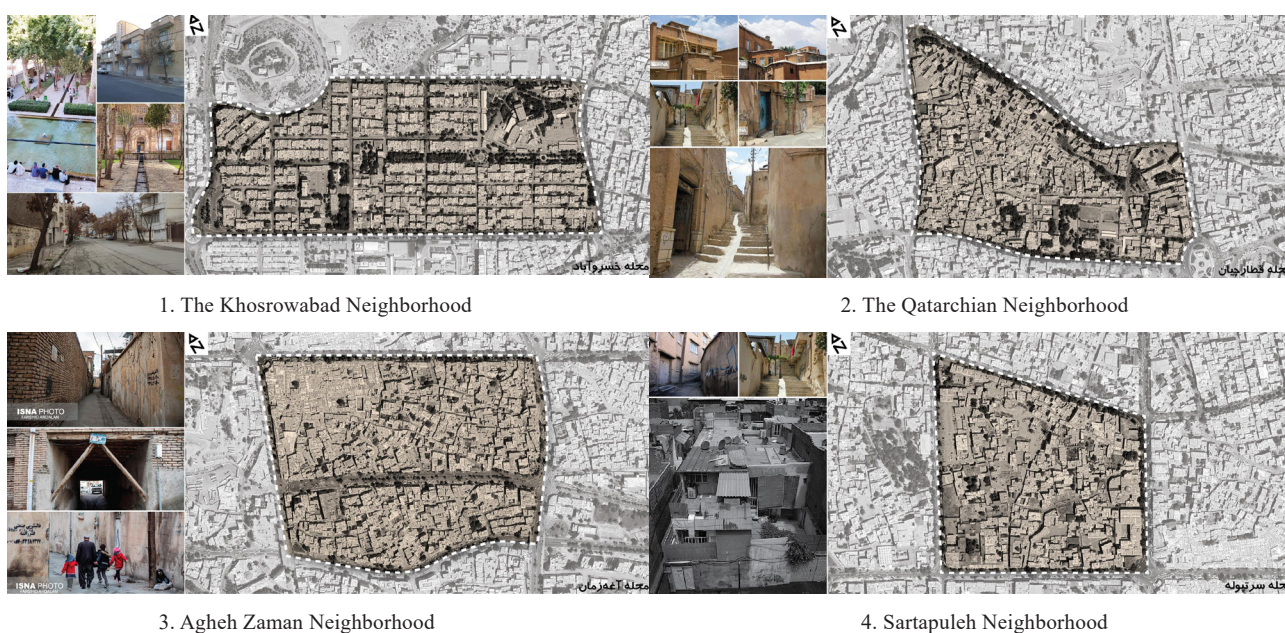


Fig. 4. A composite view of the four selected neighborhoods, serving as the physical and environmental context for analyzing bio-aesthetic components. Source: Authors.

Table 2. Descriptive Statistics and Pearson Correlation Coefficients among Research Variables. Source: Authors.

Variable	(1)	(2)	(3)	(4)	(5)	Mean	SD
1. Perceptual Aesthetics	1					3.39	0.446
2. Cognitive Aesthetics	0.55	1				3.48	0.312
3. Social Aesthetics	0.58	0.49	1			3.46	0.362
4. Biological Aesthetics	0.62	0.55	0.51	1		3.28	0.464
5. Perceived Residential Environment Quality	0.53	0.38	0.44	0.50	1	3.68	0.478

Bold values indicate statistically significant correlations at $p < 0.01$

perception, perceptual aesthetics holds the greatest predictive value, whereas cognitive aesthetics exhibits the weakest—yet still meaningful—correlation.

Following the establishment of statistically significant associations between the bio-aesthetic components and perceived residential environment quality, a multiple regression analysis employing the simultaneous (enter) method was conducted to determine the most effective combination of predictors. Before proceeding with the regression, it was essential to verify that the fundamental assumptions of the model were satisfied. A critical assumption involves the absence of multicollinearity among the independent variables. Multicollinearity arises when two or more predictors are highly correlated, leading to redundancy in the information they provide about the dependent variable. When multicollinearity is present, even models with high multiple correlation coefficients and coefficients of determination may suffer from compromised validity, ultimately reducing the interpretability and reliability of the results.

To evaluate whether the correlations among the predictor variables were excessively high—thus potentially violating the assumptions of multiple regression this study employed two widely recognized diagnostics: the Tolerance statistic and the Variance Inflation Factor (VIF), as recommended in previous research (Hanifiyeh, 2020; Karimi et al., 2019; Jafari et al., 2018). The Tolerance value reflects the proportion of variance

in a given independent variable that remains unexplained by the other predictors in the model. A Tolerance value approaching 1 signifies minimal multicollinearity, whereas lower values indicate redundancy. The VIF, calculated as the reciprocal of the Tolerance value, quantifies the extent to which multicollinearity inflates the variance of a regression coefficient. Conventionally, a VIF exceeding 5 is considered indicative of problematic multicollinearity. As shown in Table 3, the VIF scores for all four predictor variables fell well below the critical threshold of 5 and even below 3 demonstrating that multicollinearity did not pose a concern. Therefore, each bio-aesthetic component could be retained in the regression model without compromising its statistical validity. Another essential assumption in multiple regression is the independence of residuals—the differences between observed values and those predicted by the model. If residuals exhibit significant autocorrelation, the reliability of the regression findings may be undermined. To assess residual independence, the Durbin–Watson statistic was employed. This statistic ranges from 0 to 4, with values around 2 indicating no autocorrelation. Scores closer to 0 suggest positive autocorrelation, while values approaching 4 reflect negative autocorrelation. According to established benchmarks, values between 1.5 and 2.5 are generally regarded as acceptable. In this study, the Durbin–Watson value was calculated as 2.02, indicating that the

Table 3. Tolerance, Variance Inflation Factor (VIF), and Durbin-Watson Statistic. Source: Authors.

Predictor Variable	Tolerance Statistic	Variance Inflation Factor (VIF)	Durbin-Watson Statistic
Perceptual Aesthetics	0.490	2.04	2.02
Cognitive Aesthetics	0.534	1.87	
Social Aesthetics	0.580	1.72	
Biological Aesthetics	0.541	1.85	

assumption of residual independence was satisfied. As such, the conditions for conducting multiple regression analysis were adequately met, justifying the inclusion of all four bio-aesthetic components in modeling perceived residential environmental quality.

Table 4 summarizes the outcomes of the multiple regression analysis performed to assess the predictive power of the bio-aesthetic components with respect to residential environment quality. The analysis yielded an adjusted coefficient of determination (Adjusted R²) of 0.33, indicating that the combined influence of the four bio-aesthetic components accounts for approximately 33% of the total variance in residents' perceptions of residential environmental quality. This level of explanatory power is statistically meaningful yet moderate in magnitude. The corresponding F-statistic was calculated as 27.65, and the associated p-value was less than 0.01, confirming the overall statistical significance of the regression model. These results suggest that, taken together, the bio-aesthetic dimensions—perceptual, cognitive, social, and biological—offer a significant contribution to explaining how residents evaluate the quality of their living environment. However, it is important to interpret these findings with nuance. The R² value of 0.33 implies that 67% of the variance in residential environment perception remains unaccounted for by the current model. This observation highlights the complexity of residential quality as a multidimensional construct and suggests that additional psychological, socio-cultural, economic, or environmental factors

may also play a substantial role in shaping residents' subjective evaluations.

Following the confirmation that the bio-aesthetic components collectively offer a statistically significant model for predicting perceived residential environment quality, the analysis proceeded to evaluate the individual predictive strength of each component using standardized regression coefficients (β-values). As shown in Table 5, each component's contribution to the model was assessed independently to determine its unique effect on the dependent variable. Among the predictors, the perceptual aesthetic component exhibited the strongest individual influence, with a standardized beta coefficient (β) of 0.30. This suggests that for every one standard deviation increase in perceptual aesthetics, the perceived quality of the residential environment is expected to increase by 0.30 standard deviations, assuming all other variables remain constant. The associated t-value was 3.78, and the relationship reached a high level of statistical significance (p ≤ 0.001), reinforcing the robustness of this finding. Given these results, it can be inferred that the perceptual dimension not only contributes meaningfully to the overall regression model but also functions as a distinct and potent predictor of environmental quality perceptions. This underscores the critical role of perceptual aesthetics—including visual harmony, materiality, spatial coherence, and sensory engagement—in shaping residents' experiential evaluation of their living environments.

Following perceptual aesthetics, the biological aesthetics component emerged as the second most influential

Table 4. Summary of the Multiple Regression Model Predicting Residential Environment Quality Based on Bio-Aesthetic Components. Source: Authors.

Model Type	Multiple Correlation Coefficient (R)	Coefficient of Determination (R ²)	Adjusted R ²	F Statistic	Significance Level (p-value)
Simultaneous	0.588	0.346	0.334	27.65	0.001

Table 5. Regression Coefficients for Predictor Variables. Source: Authors.

Predictor Variable	Unstandardized Coefficient (B)	Standardized Coefficient (Beta)	t-value	Significance Level (p-value)
Constant	1.090	–	3.43	0.001
Perceptual Aesthetics	0.323	0.302	3.78	0.001
Cognitive Aesthetics	0.009	0.006	0.08	0.936
Social Aesthetics	0.192	0.146	1.99	0.048
Biological Aesthetics	0.242	0.235	3.09	0.002

predictor of perceived residential environmental quality, as evidenced by a standardized beta coefficient of 0.23. The corresponding t-value of 3.09, which is statistically significant at the $p < 0.01$ level, supports the conclusion that biological aesthetics functions as a distinct and significant independent predictor within the regression model. This finding underscores the relevance of biologically grounded design features—such as spatial hierarchy, ecological coherence, and natural morphological patterns—in shaping residents’ evaluations of their living environment. Following perceptual and biological aesthetics, the social aesthetics component was identified as the third most influential predictor of perceived residential environmental quality. This component yielded a standardized beta coefficient of 0.15, indicating that a one standard deviation increase in the social aesthetics

variable corresponds to a 0.15 standard deviation rise in residents’ perceived environmental quality. The associated t-value of 1.99 and p-value of 0.048 confirm its statistical significance at the 0.05 level, validating its role as an independent and meaningful predictor. In contrast, the cognitive aesthetics component demonstrated the lowest explanatory power, with a standardized beta coefficient of only 0.006, a t-value of 0.08, and a p-value of 0.936. Given that this p-value substantially exceeds the accepted threshold for significance, the null hypothesis—that this component has no predictive effect—cannot be rejected. Thus, unlike the other three dimensions, cognitive aesthetics does not significantly contribute as a standalone predictor of perceived residential environmental quality. These results, as synthesized in Fig. 5, delineate the final predictive model, highlighting the relative contributions

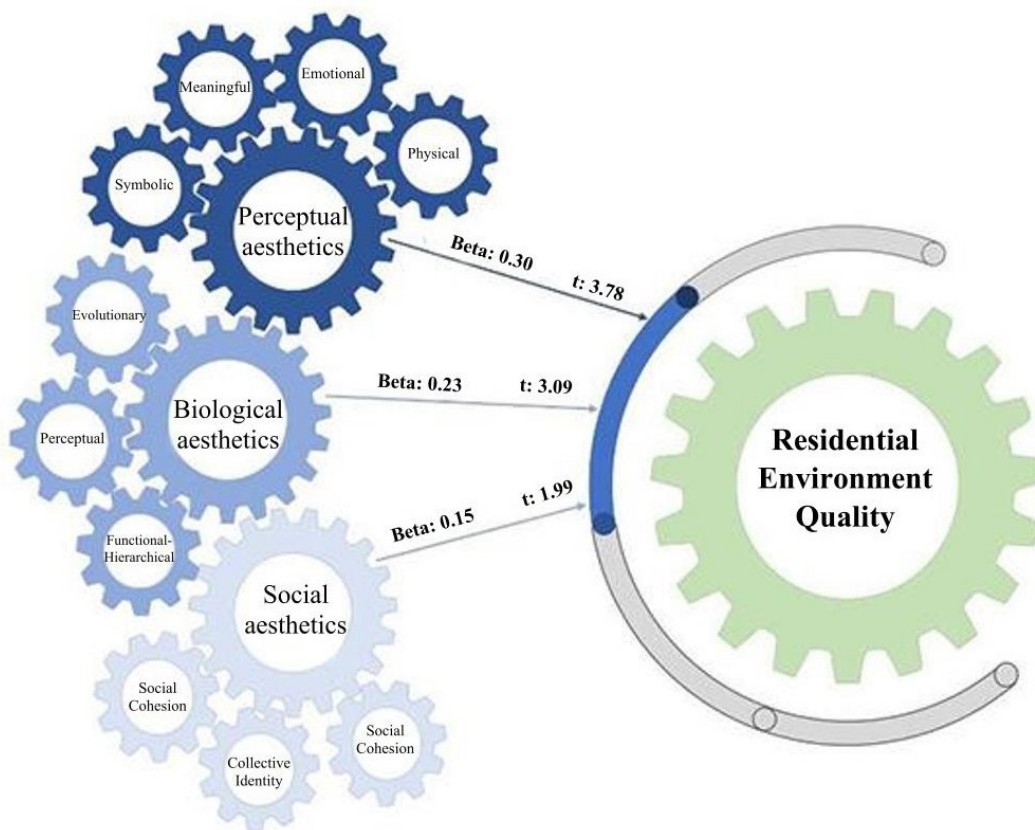


Fig. 5. Final Research Model: Predicting Perceived Residential Environmental Quality Based on Bio-Aesthetic Components. Source: Authors.

of the four bio-aesthetic components to residents' perception of environmental quality.

Conclusion

The conceptual evolution of bio-aesthetic approaches can be traced back to a period when human existence was deeply interwoven with natural environments. Although this intrinsic connection diminished during the rise of modernism and industrial urban development, it has witnessed a resurgence since the mid-twentieth century, particularly with the advent of environmental awareness movements and the articulation of the Biophilia Hypothesis. Since then, psychological and ecological considerations have become increasingly central in shaping contemporary architectural and environmental design philosophies. Within this context, bio-aesthetics has emerged as a forward-thinking paradigm, standing alongside biophilic design, biomimicry, and ecological architecture as a key contributor to sustainable urbanism and human-centered design. Unlike approaches that limit themselves to the visual mimicry of nature, bio-aesthetics embraces a more holistic perspective—one that acknowledges the perceptual, emotional, cognitive, social, and ecological dimensions of human-environment interaction. By fostering environments that are not only visually stimulating but also emotionally restorative, cognitively engaging, and ecologically responsive, bio-aesthetic principles serve as a foundation for enhancing the overall quality of residential environments. The present study aimed to explore the predictive relationship between various dimensions of bio-aesthetics and residents' perception of residential environment quality within four historically significant neighborhoods in Sanandaj (Khosrowabad, Agheh Zaman, Qatarchian, and Sartapuleh). The findings revealed that all four bio-aesthetic components—perceptual, biological, social, and cognitive—were positively correlated with perceived residential quality. Among them, perceptual aesthetics demonstrated the strongest association, suggesting its prominent role in shaping environmental perception. Biological and social aesthetics followed, while cognitive aesthetics, although conceptually significant, exhibited the weakest statistical relationship

in this particular context. These findings underscore the nuanced interplay between aesthetic dimensions and environmental perception, offering valuable insights for the integration of bio-aesthetic principles into residential design. In particular, they highlight the potential of perceptual and biological features to influence residents' sense of place, satisfaction, and overall well-being, especially in historically layered urban contexts such as Sanandaj:

1. Dominance of Sensory and Visual Qualities (Perceptual Aesthetics as the Strongest Predictor):

In the traditional neighborhoods of Sanandaj, the enduring presence of vernacular architecture, historical urban fabric, and rich visual details profoundly shapes residents' sensory experiences. These aesthetic cues, embedded in the built environment, foster emotional resonance and visual satisfaction, thereby enhancing the perceived beauty of the surroundings. Empirical evidence consistently supports the primacy of perceptual aesthetics, indicating that visual and sensory environmental attributes exert the strongest influence on residents' psychological well-being and subjective happiness within urban contexts.

2. Integration with Natural Elements (Biological Aesthetics as the Second Most Influential Factor):

The availability and integration of natural features—such as gardens, vegetation, and semi-natural open spaces—within these neighborhoods significantly contribute to the residents' sense of tranquility, relaxation, and attachment to place. Numerous studies have demonstrated that proximity to green spaces within residential settings can elevate life satisfaction and promote overall well-being. In this study, the salience of biological aesthetics underscores the vital role of nature in supporting emotional restoration and spatial affinity among urban dwellers.

3. Cultural Values and Social Cohesion (Social Aesthetics as the Third Predictor):

Beyond physical design, residential environments act as sociocultural arenas where interpersonal relationships, collective memory, and neighborhood identity are formed and maintained. Social aesthetics, which emphasizes shared spaces, interactional opportunities, and communal

ties, plays a pivotal role in fostering social integrity and enhancing quality of life. In the context of historic neighborhoods in Sanandaj, the persistence of traditional social patterns and dense neighborly networks reinforces a sense of security, belonging, and mutual trust. Prior research confirms that built environments with socially responsive design features enhance social interaction and community cohesion.

4. Subjective Interpretation and Personal Meaning (Cognitive Aesthetics with Minimal Predictive Power): Cognitive aesthetics is centered on individuals' interpretative engagement with space, shaped by personal knowledge, experiences, and cultural frameworks. Compared to more observable elements such as form, greenery, or public interaction, cognitive processes often remain implicit and individually variable. This may account for the component's relatively low statistical contribution to perceptions of residential quality. While conceptually significant, cognitive aesthetics tends to have a more nuanced and indirect influence on collective environmental appraisal, particularly when assessed at the neighborhood scale.

Additionally, the study's core findings concerning the predictive power of bio-aesthetic components on residential environment quality across the selected neighborhoods in Sanandaj reveal a clear pattern of significance among the variables. Specifically, perceptual aesthetics, biological aesthetics, and social aesthetics each emerged as statistically significant and independent predictors of perceived residential quality. These components demonstrated distinct and measurable contributions to how residents evaluate their living environments. In contrast, cognitive aesthetics did not exhibit a statistically significant standalone effect. This divergence may be explained by the inherently abstract and personalized nature of cognitive aesthetics, which is heavily influenced by individual interpretive frameworks, cultural conditioning, and prior lived experiences—factors that tend to manifest with greater variability across respondents and are thus less uniformly perceived at the collective level.

When considered collectively, the results of this study underscore the greater influence of perceptual,

biological, and social dimensions in shaping residents' perceptions of environmental quality in residential contexts. Accordingly, urban planners and designers seeking to enhance residential livability should prioritize strategies such as preserving and expanding green infrastructure, optimizing natural lighting, and mitigating both visual and auditory pollution—key elements within the perceptual aesthetics domain. Simultaneously, promoting closer human–nature interactions through biophilic integration and designing inclusive public spaces that facilitate social engagement represent essential pathways to elevate both the experiential and environmental quality of urban living. Although cognitive aesthetics remains a valuable interpretive dimension, it appears to function more as a reflective layer, shaped by previous sensory and social encounters. Therefore, designing environments that are visually and biologically expressive, as well as socially dynamic, may serve as an effective means of cultivating positive emotional responses and improving the overall residential environment quality in Sanandaj and comparable urban contexts.

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