Journal of Contemporary Urban Affairs

2024, Volume 8, Number 1, pages 102–119

Original scientific paper

The Relationship Between Sense of Place and Nature-Based Architectural Beauty: A Comparative Case Study

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ARTICLE INFO:

Article History:
Received: 20 February 2024
Revised: 18 June 2024
Accepted: 25 June 2024
Available online: 30 June 2024

Keywords:
Biophilic Design,
Sense of Place,
Naturalistic Architecture,
Socio-economic Impact,
Urban Planning.

ABSTRACT

Biophilic design, which integrates nature into the built environment, has shown positive impacts on human well-being. However, the benefits of indirect experiences of nature remain less explored, particularly in relation to the sense of place (SoP). This study investigates the relationship between nature-based architectural beauty and SoP through a comparative case study of two educational buildings with different aesthetic qualities: one classical and naturalistic, the other modernist and mechanistic. Using a quasi-experimental design, the study employs a survey-based quantitative analysis, measuring 1) SoP among users, 2) perceptions of naturalness through image-based judgments, and 3) objective measures of naturalistic beauty using image analysis. Findings indicate that users of the naturalistic building report a significantly higher sense of place, supported by perceptions of naturalness and objective measures. This suggests that environments embodying naturalistic beauty foster positive connections and place attachment. The study contributes to architectural and urban design strategies by highlighting the socio-economic benefits of nature-inspired aesthetics. By enhancing emotional and psychological well-being, such designs can lead to increased productivity, reduced stress, and stronger community ties, ultimately contributing to socio-economic development through improved quality of life and sustainable urban planning.

JOURNAL OF CONTEMPORARY URBAN AFFAIRS (2024), *8*(1), 102-119.
https://doi.org/10.25034/ijcua.2024.v8n1-6

www.ijcua.com

Highlights:	**Contribution to the field statement:**
- Biophilic design principles, when applied to architectural aesthetics, can lead to improved well-being and socio-economic benefits. - Architectural environments with naturalistic properties can be objectively measured and subjectively perceived to assess their aesthetic and psychological impact. - Naturalistic buildings foster a higher sense of place by enhancing place identity, attachment, and dependence. - The study employs a novel combination of survey-based data with low-level image analysis to evaluate naturalistic qualities in architecture.	This study enriches place theories by demonstrating the critical role of naturalistic visual properties in fostering a sense of place, and advances biophilic design by empirically validating the psychological impact of indirect nature interpretations. By linking architectural beauty with place attachment, the research offers novel insights into design strategies that enhance well-being and socio-economic development.

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How to cite this article:
Al-azzawi, S., İnalhan, G., & Al-azzawi, N. (2024). The Relationship Between Sense of Place and Nature-based Architectural Beauty: A Comparative Case Study. *Journal of Contemporary Urban Affairs*, 8(1), 102-119. https://doi.org/10.25034/ijcua.2024.v8n1-6

1. Introduction

In recent years, there has been an increasing focus on integrating the built environment with nature, spurring the development of the biophilic design movement. Biophilia, a term coined by Wilson (1986), describes an inherent human tendency to seek connections with nature and the living world. The biophilic design movement aims to enhance this connection by emphasizing design strategies that promote human emotional and physical well-being (Almusaed, 2010; Kellert, 1993; Kellert et al., 2011). Although the core objectives of biophilic design are clear and intuitive, the concept encompasses a broad range of interpretations and methodologies related to how 'nature' is understood and experienced in the built environment. Ryan et al. (2014) categorizes biophilic patterns into three groups: (1) 'nature in space,' which focuses on incorporating visual and climatic elements of nature; (2) 'nature of space,' which involves spatial properties such as refuge, prospect, mystery, and peril; and (3) 'natural analogues,' which include biomorphic forms, materiality, and the complexity and order of natural patterns.

Similarly, Kellert (2018) identifies three categories of nature experiences: (1) direct experiences, which involve physical contact with natural elements like vegetation, water, and climatic conditions; (2) indirect experiences, where the built environment simulates natural elements through imagery, materials, and geometries; and (3) spatial experiences, focusing on organizational aspects of space that evoke natural qualities, such as prospect, refuge, and integrated complexity.

Recent developments in the biophilic design literature, particularly around natural analogues and space/place experiences, have extended the theory by incorporating elements of form and spatial design, which are central to the architectural and urban disciplines. This newer interpretation frames nature as a dynamic process that generates harmonious, integrated structures through geometric transformation and place-making.

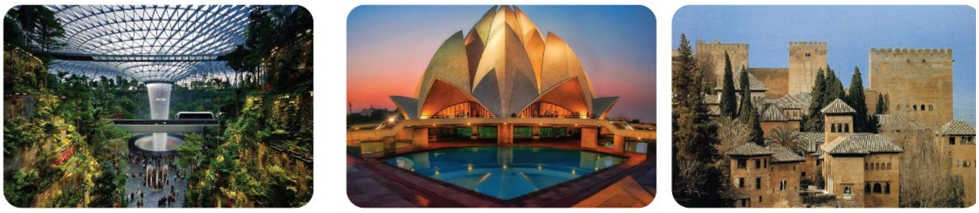
Evidence suggests that implementing biophilic design principles can significantly enhance human well-being (Gillis & Gatersleben, 2015; Hung & Chang, 2021; Soderlund & Newman, 2015; Zhong et al., 2022). Research has shown that direct experiences of nature in built environments positively influence various health outcomes, including improved workplace conditions (Nieuwenhuis et al., 2014), enhanced attention and memory (Lee et al., 2015; Berman et al., 2012), faster stress recovery (Ratcliffe et al., 2013), and increased physical activity and healing (Sari et al., 2023).

Indirect nature experiences, such as simulated natural environments and nature imagery, have also been linked to psychological benefits. For example, exposure to simulated office settings with natural views has been associated with reduced anxiety (Chang & Chen, 2005), while viewing natural scenes accelerates recovery from acute stress compared to urban scenes (Brown et al., 2013). Additionally, interior environments featuring fractal light patterns are shown to enhance visual preference and mood (Abboushi et al., 2019). Spatial configurations that resemble natural environments, like prospect-refuge spaces and organic visual patterns, are also found to support psychological restoration and preference (Akcelik et al., 2024; Coburn et al., 2019; Herzog & Bryce, 2007).

While aspects of space, place, and natural analogues have been extensively explored in aesthetic and landscape studies (Kaplan & Kaplan, 1989; Kuper, 2017; Liu et al., 2021; Ode et al., 2009), their connections to psychosocial theories of place are still inadequately defined (Zhong et al., 2022). The concept of 'place experience' is a central theme in theories of sense of place (SoP) or place attachment, which focus on the meanings, emotions, and behaviors that shape human interactions with their environment (Altman & Low, 1992; Lewicka, 2011a; Manzo & Devine-Wright, 2013). According to Lewicka (2011), research on SoP has predominantly highlighted social factors over physical ones, even though natural elements are frequently cited as key contributors to place attachment (Han et al., 2023; Ojalammi & Koskinen-Koivisto, 2023). The impact of the natural complexity, spatial configuration, and geometry of the physical environment on SoP, however, remains underexplored.

Addressing this gap can help evolve biophilic design from a superficial application of natural features to a more profound interpretation of nature as a dynamic, generative process that creates organic qualities with significant psychological impacts (Figure 1). This study seeks to establish a link between biophilia and place theory by exploring whether the modeled naturalness of built environments influences our sense of place.

Definitions of Natural (Biophilic) Architecture



	Explicit nature	Nature as image	Nature as process
Definitions of nature	Nature as an addition to the built environment	Nature as formalistic inspiration	Nature as a generative process (order and complexity)
Experience of nature	Direct experience of nature	Indirect experience of nature	Indirect experience of nature
Design strategies	Vegetation, natural lighting, Water, landscape Natural building materials	Use of organic shapes and forms, imitation of natural imagery	Form evolution, adaptation, naturalistic geometric properties
Examples	Changi Airport, Singapore	Lotus Temple, Delhi	Alhambra Palace, Granada

Figure 1. The different approaches and interpretations of biophilic design (Developed by the Authors).

1.2 Naturalness and Living Structures

The built environment can be naturalized by modelling generative processes typically found in nature and characteristic of timeless architecture and city planning. Architect and mathematician Christopher Alexander proposed a theory describing how this process creates 'living' or nature-like structures. In the "*Nature of Order*" (2002), he argued that we experience buildings and cities as 'living' due to a pervasive structure of interrelated parts forming integrated wholes. Here, 'life' is defined through complex orders rather than the typical biological sense. This deep structure endows any region of space with coherence, order, and beauty. *Living structure*s in nature and the built environment are hypothesized to be the underlying forces inseparable from our experience of beauty, sense of well-being, relatedness, and belonging. (Alexander, 2002).

Alexander identified *15 geometric properties* of living structures found in almost all natural and biological systems, as well as in timeless works of art and architecture. These properties outline how parts of a whole are organized to support each other, resulting in higher degrees of life, coherence, beauty, and naturalness. For example, the most fundamental property pertains to the organization of structures in proportionally related and organized *levels of scale*, favouring *local symmetries* over general symmetry and creating *contrast* between sub-structures through colour, shape, and other characteristics. These properties emerge from a generative process of step-by-step adaptation to the existing structure, where each step follows naturally from the previous one.

Such generative processes are evident in nature, from the growth of embryos to the crack patterns that form on dry land. When applied to architectural and urban design, they reflect an organic worldview that emphasizes orders of connecting and interdependent relationships, as opposed to the assembly of objects in space, which characterizes the mechanistic design approach of the modernist era.

Subsequent attempts have been made to quantify the concept of living structures. For example, Nikos Salingaros developed a method of quantification based on an analogy to thermodynamics (Salingaros, 1997). The latest mathematical model of living structures was introduced by Bin Jiang, which relies on two fundamental laws: *the scaling law,* which states that a living structure has far more small components than large ones across all scales, and *Tobler's law,* which posits that everything is related to everything else, but near things are more related than distant things (Jiang, 2015). Structural beauty or 'livingness' is determined by the number of substructures and the hierarchy of these substructures based on the head-tail/breaks, a method of iterative division according to their scale. Degree of life is formally defined by the formula L = S xH, where S is the number of substructures, and H is the number of hierarchical levels of these substructures calculated by the head/tail breaks. This method was tested on architectural and city plans with units of analysis similar to the space syntax method, such as convex spaces and axial lines. It was also applied to pixels in image-processing algorithms (Jiang & de Rijke, 2023).

Another study by Coburn et al., (2019) experimented with low-level image features as proxy measures for two of the 15 fundamental properties: *Levels of scale* and *contrast*. The *Levels of scale* property is operationalized by 1) *edge density,* measuring the number of straight and curved edges in an image; 2) *fractal dimensions* capturing the visual complexity and scaling differentiation of the edge maps of architectural images; and 3) *entropy,* a statistical measure of randomness in a scene, calculated using the scene's intensity histogram. The *contrast* property is operationalized by calculating an image's standard hue, saturation, and brightness values along with their standard deviations. In their experimental work, low-level features calculated for a sample of exterior and interior architectural images significantly predicted participants' perception of naturalness and other psychological outcomes, such as comfort, which have implications for well-being studies.

The nature of order includes several hypotheses that have not been empirically tested. Measurement methods such as those described can facilitate this testing. The ongoing research focuses on the relationship between living structures and human experiences within a given place. According to *the nature of order*, environments that exhibit the properties of living structures contribute to experiences of beauty, support human life and well-being, provide emotional nourishment, and foster a sense of belonging.

1.3 Sense of Place

Seamon (2019) argued that the properties of living structures must be inherently related to the experience of place. Alexander's description of experiencing life and wholeness in architecture resonates with the concept of SoP, particularly in its phenomenological and philosophical formulations. In recent decades, there has been increased interest in place research across social sciences, psychology, environmental design, and geography. At its core, place is understood to be more than just physical space because of its meaningfulness to the individual and groups (Tuan, 1979). Edward Relph (1976), the pioneering humanistic geographer famously stated, *"Places are sensed in a chiaroscuro of setting, landscape, ritual, routine, other people, personal experience, care and concern for home and the context of other places."* The meanings attributed to certain places tend to be multi-layered, complex, and depending on various factors. According to the phenomenological and psychological perspective, (Canter, 1997; Relph, 1976) SoP constitutes the following dimensions: 1) The physical characteristics of the environment, 2) The meanings and emotions attached to the place, and 3) The activities the place provides.

Due to the complexity of place processes and the multidisciplinary nature of the theory, place literature encompasses numerous concepts. One key term in environmental psychology is *place attachment*, which describes affective bonds to places. Place attachment is often defined through two concepts: *place dependence* and *place identity*. *Place identity*, a component of the self-system, refers to how individuals view themselves in relation to their environment (Proshansky, 1978). *Place dependence* relates to actions in place and refers to the degree of fit between what an environment offers in terms of usability and an individual's intended uses and competencies (Stokols & Shumaker, 1982).

Jorgensen and Stedman (2001) proposed an attitude-based interpretation of SoP, incorporating cognitive, affective, and conative (behavioural) components. They validated the measurement with data from a questionnaire survey of over 200 rural homeowners. The attitudinal components of the sense of place are defined as follows: 1) beliefs about the relationship between self and place (the cognitive component), 2) feelings towards the place (the affective component), and 3) the behavioural exclusivity of the place compared to alternatives (the conative component). This formulation serves as the basis of the most widely used psychometric measures of SoP (Boley et al., 2021; Jorgensen & Stedman, 2001; Williams & Vaske, 2003).

SoP is defined through people, place, and process (Scannell & Gifford, 2010). It varies depending on factors related to the place itself (its physical characteristics, such as scale, land use, and building density) or factors related to the individual (such as duration of stay, ethnicity, age, economic status, and value system). Due to the social constructivist nature of the concept, social and personal factors have been more prominent in place studies (Lewicka, 2011). However, ecological psychology has emphasized the importance of considering both physical and social factors in place of attachment studies. Recent research has attempted to link restorative environments with SoP, finding that nature and aesthetic appeal positively predict attachment and identity (Ariannia et al., 2024; G. Brown & Raymond, 2007; Hur et al., 2010; Jayakody et al., 2024; Li et al., 2023; Olla et al., 2023). SoP is also linked to pro-environmental behaviour and influences perceptions of human/nature relationships (Feng et al., 2022; Schroeder, 2007). Most studies focus on the perception of physical environmental quality and values, often lacking a theoretical basis from design theories that apply objectively measurable variables.

Advances in biophilic design theories with reference to complexity science, objective beauty, and living structures open new avenues for addressing this knowledge gap. By investigating the attractive power of living structures and sustaining emotional engagement through repeated interaction, we can better understand the connection between biophilic patterns and SoP. Naturalistic environments, both in their explicit nature content and underlying order, can attract people based on their biological inclinations and aesthetic drives. Experiencing these places can support environmental awareness and conceptualization of identity through the lens of human/nature relationships (Schroeder, 2007). Additionally, naturalistic patterns offer affordances, such as mystery, which encourages exploration of the environment (Figure 2).

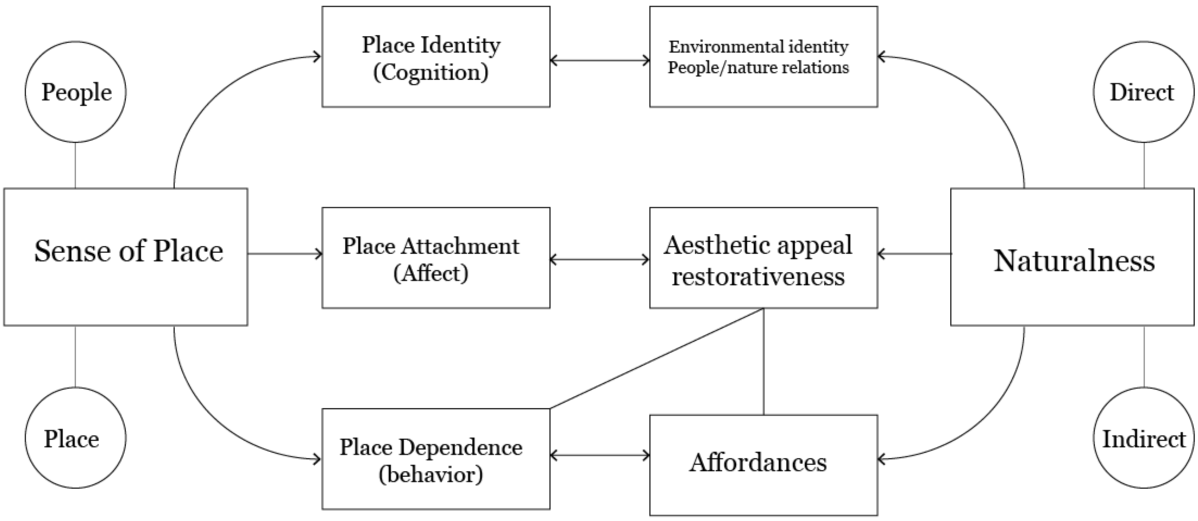


Figure 2. The different approaches and interpretations of biophilic design (Developed by the Authors).

Within this broader framework, this study explores one aspect of the relationship between naturalness and SoP by focusing on the properties of living structures and their impact on perceived naturalness and SoP. The findings could have significant implications for biophilic design, demonstrating how to reconnect people with nature beyond traditional greening schemes. They also encourage a revaluation of the fundamental spatial and morphological aspects that are critical to design disciplines.

2. Materials and Methods

A pilot study was designed to explore the research question using existing measures and manageable settings within this more prominent research topic. The study aims to test the hypothesis that occupants of buildings with higher degrees of modelled naturalness experience higher levels of SoP than those in less naturalistic buildings.

A comparative quasi-experimental case methodology was utilized to test this hypothesis by comparing two settings. Variables of the physical environment and user responses regarding SoP were analyzed and compared. Although the researcher could not manipulate the variables, potential influences on the outcome were neutralized by selecting cases with similar features. The study focused on two buildings with a hypothesized difference in degree of life (naturalness) as the basis of comparison. The objective was to compare the occupants' judgments of livingness and SoP using simple descriptive and t-test statistical analyses. Figure 3 outlines the methodological procedure.

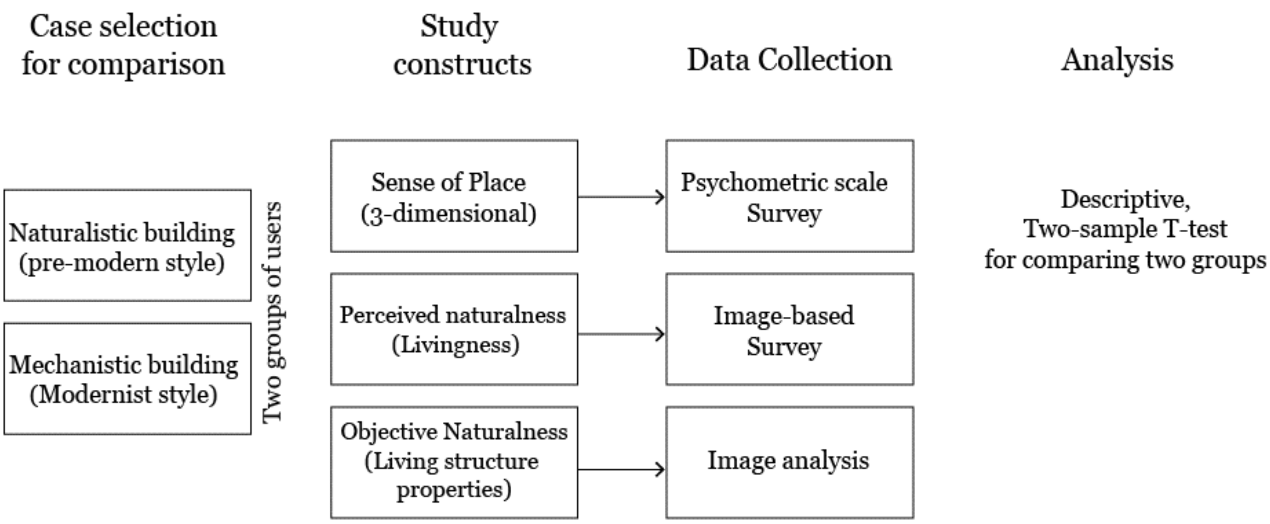


Figure 3. Research methodology and procedure (Developed by the Authors).

The selection criteria were developed to neutralize, as much as possible, the effect of common physical, social, and personal factors that can influence SoP. The criteria considered were:

- The two buildings must be similar in function and size.
- Users of the two buildings must have similar demographic backgrounds, such as age groups and occupations.
- The two buildings must have noticeable differences in their aesthetic character. One is expected to have naturalistic qualities, and the other is mechanistic.

The selected cases were two faculty buildings at Istanbul Technical University in Türkiye; the first building houses the Faculty of Architecture and is known as the *Taşkışla* building, located on a remote campus. The second building is the Electric-Electronic (EE) Engineering faculty on the main campus. Both buildings are similar in size, facilities, number of students, and typology; each features rectangular forms and internal courtyards. However, they are distinct in their form, language, and aesthetics, which form the basis of comparison.

Taşkışla is a restored and adapted neo-classical building, originally a military hospital and later a military barracks, constructed in the early 1850s. Its outstanding stylistic features include a detailed classical masonry façade, wide and spacious corridors, and hallways overlooking a central courtyard with a garden and fountain (Figure 4). An online search shows that the building is a cherished monument and historical architectural landmark in Istanbul, with many students sharing photographs of it on social media, especially its courtyard. The building has been used as a film location in many local productions.

In contrast, the EE building, built in the 1980s, is characterized by a mechanistic and utilitarian style, with a more recent addition featuring different materials and facade details while maintaining the overall structure (Figure 4). Classically designed buildings are more likely to have higher naturalistic quality. Based on this and the general response to the buildings, it was hypothesized that the Taşkışla building has a higher degree of life and that its students experience a higher SoP than students in the EE building.

Figure 4. The two faculty buildings that were used for the comparative method.

The variables in the study are SoP and naturalness (degree of life). These constructs are operationalized through three types of measurements as follows:

1) **Measurements of sense of place for the two groups of building users:** A highly reliable and widely used 5-point Likert-type instrument developed by Jorgensen and Stedman (2001) was used to measure SoP. This attitude-based construct includes three dimensions: *place identity*, referring to the role of places in the process of self-identity; *place attachment*, which revolves around the emotional bonds that people have towards significant places; and *place dependence*, or the ability of places to support the needs and activities of their occupants.

2) **Measurements of the users' subjective judgement of degrees of life**: Using image pairs, the degree of life test, originally developed by Alexander (2002), was employed to test perceived livingness as an approximation of perceived naturalness.

3) **Objective measurements of naturalness or 'life' of the building**: Image analysis of interior and exterior images of the two buildings was conducted using two methods outlined in the literature review. The first method involves measuring low-level image features, which have been shown to correlate with perceptions of an image's naturalness and predict aesthetic preference (Coburn et al., 2019). The second method is a recursive calculation of an image's structural beauty according to the scaling law. (Jiang & de Rijke, 2023).

Data collection began by photographing the two buildings to create a pool of image pairs showing equivalent features and spaces for image analysis and the degree-of-life test. All photos were taken during the day using an iPhone 13 camera. The images were generally taken at eye level, with a few exceptions where the camera was tilted to show distant façade details. None of the images included people to avoid influencing subjective judgement and image analysis calculations. Additionally, natural features such as trees and the sky were kept roughly similar in area across comparable image pairs. Next, a set of 30 image pairs was decided and analyzed using open-source Python codes for the specified image analysis measures. Following this, a survey was administered to the buildings' users. Survey participants were randomly assigned from two groups of students enrolled in the faculties housed by the two buildings. The students voluntarily participated in an online survey via the SurveyMonkey platform, with the link shared by faculty lecturers. The survey consisted of three sections:

1. The first five questions gathered personal information about the students, such as age, gender, level of education (bachelor's/ postgraduate), and the number of years spent studying in their faculty building.
2. The second section featured the SoP measuring instrument, containing 12 items grouped into three sets of four. Each set measured one of the three dimensions of SoP. Some items were modified from the original residential property scale to suit the study context.
3. The third section measured subjective judgments of an image's 'livingness'. It contained 30 questions, each featuring an image pair. Each pair displayed two equivalent spaces from the two buildings side by side, and the participants were asked to select the one that felt more alive. The images included both interior and exterior views, and their order was randomized in the survey.

3. Results

In total, 23 responses were received from Taşkışla students and 29 from EE students. Table 1 presents the frequency of demographic information for the two surveyed groups.

Table 1: Demographic information for the two groups of surveyed students.

Demographic		**Taşkışla students**	**EE students**	
Age	20 and below	13.0	10.3	
	20-23	47.8	41.4	
	24-26	21.7	24.1	
	27-29	4.3	6.9	
	30 and above	13.0	17.2	
Gender	Male	70	37.9	
	Female	30	62.1	
Educational Level	Bachelor's Degree	61	51.7	
	Post-Graduate	39	48.3	
Period of study	1 year or less	56.5	20.7	
	2 years	30.4	10.3	
	3 years 4 years	4.3 0	17.2	
	5 years and above	8.7	13.8	
			37.9	
Major	Architecture	69.6	86.2	Computer engineering
	Landscape architecture	4.3	3.4	Electrical engineering
	urban planning	26.1	10.3	Other

The internal reliability of the SoP scale was calculated using Cronbach's alpha, resulting in a score of .916 for the Taşkışla student survey and .896 for the EE students survey. Table 2 shows the mean score for each item of the Likert-type SoP scale. Additionally, the mean scores of place identity, place attachment, and place dependence were calculated for each group of students.

Table 2: Demographic information for the two groups of surveyed students.

	Taşkışla Students		**EE Students**	
Likert Scale Items	Mean	Std.Deviation	Mean	Std. Deviation
IDN 1 (I feel that X* is a reflection of me)	3.83	.984	2.00	.964
IDN 2 (Studying in X says much about who I am.)	3.87	1.100	1.97	.906
IDN 3 (I feel that I can be myself at X)	4.00	.853	2.34	1.078
IDN 4 (Studying at the X reflects the type of person I am.)	3.78	1.043	2.03	.823
ATTCH 1 (I feel relaxed when I am at X)	4.26	.964	3.31	1.072
ATTCH 2 (I feel happiest when I am at X)	3.35	1.229	1.97	1.085
ATTCH 3 (X is one of my favorite places to be.)	3.91	1.041	1.97	.823
ATTCH 4 (I will miss X when I graduate)	4.22	.795	2.34	1.233
DEP 1 (X is the best place for me to enjoy doing my studies)	3.74	1.214	2.03	1.052
DEP 2 (As a university facility, no other place can compare to X)	3.83	1.302	1.52	.738
DEP 3 (I wouldn't substitute any other place for studying and things I do at X.)	3.17	.984	1.72	.922
DEP 4 (I wish I were studying at some other place than Taşkışla)	4.00	.905	2.48	1.153
	A total of 23 responses		A total of 29 responses	

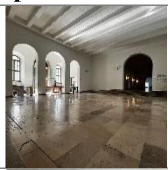
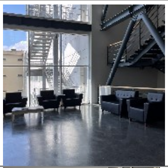
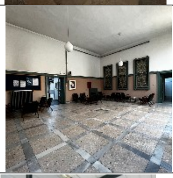
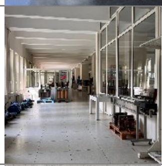
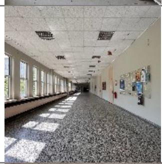
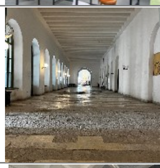
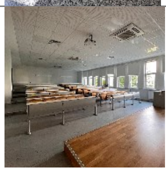
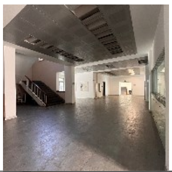
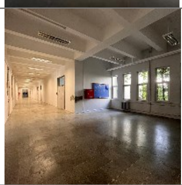
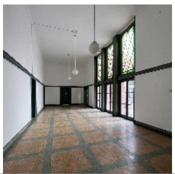
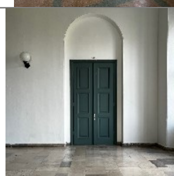
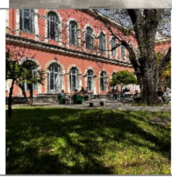
Comparing the two groups, students at Taşkışla reported a higher level of place identity, attachment, and dependence than those at the EE building. A 2-sample T-test was conducted to determine if the differences in these reported measures were statistically significant. Table 3 shows that Taşkışla students scored significantly higher on all three dimensions. Notably, students at Taşkışla reported a high SoP despite most having studied there for only one to two years. Additional statistical analyses revealed no significant correlation between the number of study years and any SoP constructs. Furthermore, there was no significant difference in the reported SoP between bachelor's and postgraduate students for both groups.

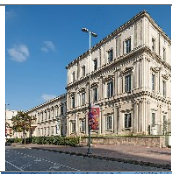
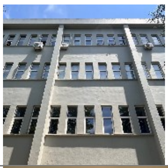
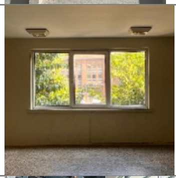
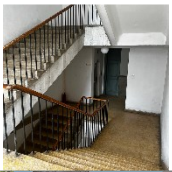
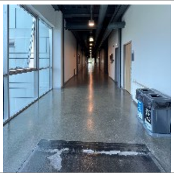
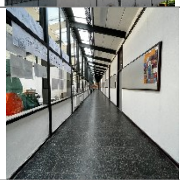
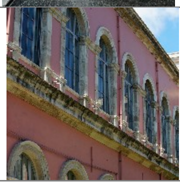
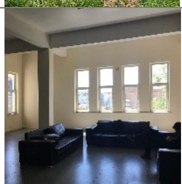
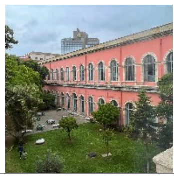
Table 3: Demographic information for the two groups of surveyed students.

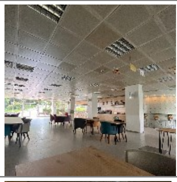
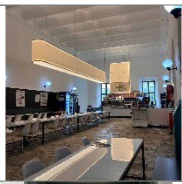
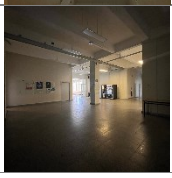
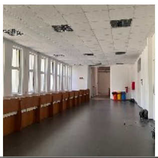
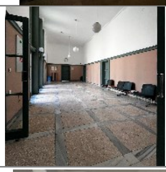
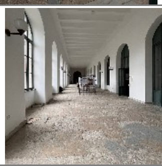
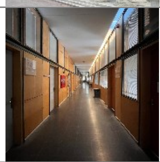
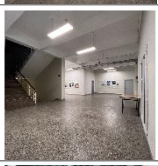
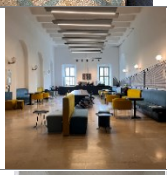
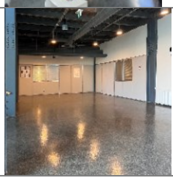
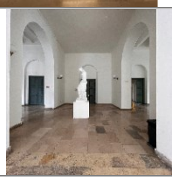
	Mean (Taşkışla)	**Mean (EE)**	**t**	**Two-Sided p**
IDN	3.8696	2.0862	7.860	<.001
ATTCH	3.9348	2.3966	6.877	<.001
DEP	3.6848	1.9397	7.769	<.001

The degree-of-life test showed a strong consensus between the two groups of students. Both Taşkışla and EE students rated images of the Taşkışla building as having more life than those of the EE building. Only out of the 30 image pairs had a majority preference for the EE images, which were of sitting areas and staircases. Table 4 presents the selection percentage for each image for both groups of students.

Table 4: The results of the degree-of-life test.

item	Responses					
	Taşkışla students		**Image pairs**		**EE students**	
1 Entrance Hall	14%	86%			31%	69%
2 Sitting Area	67%	33%			93%	7%
3 Lab/Studio	5%	95%			21%	79%
4 Corridor	5%	95%			14%	86%
5 Classroom	14%	86%			17%	82%
6 Hallway	5%	95%			10%	90%
7 Corridor	0%	100%			4%	96%
8 Hallway	24%	76%			24%	76%
9 Door	5%	95%			7%	93%
10 Courtyard	5%	95%			0%	100%

11 Facade	10%	90%			0%	100%
12 Façade Detail	0%	100%			0%	100%
13 Window	5%	95%			11%	90%
14 Stairway	62%	35%			93%	7%
15 Facade	0%	100%			21%	79%
16 Corridor	0%	100%			14%	86%
17 Façade Detail	5%	95%			21%	79%
18 Courtyard	10%	90%			18%	82%
19 Sitting Area	5%	95%			0%	100%
20 Courtyard	0%	100%			0%	100%

21 Cafeteria	45%	55%			15%	85%
22 Corridor	0%	100%			4%	96%
23 Hallway	10%	90%			15%	85%
24 Sitting Area	10%	90%			37%	63%
25 Corridor	0%	100%			11%	89%
26 Entrance	5%	95%			4%	96%
27 Corridor	10%	90%			11%	89%
28 Hallway	10%	90%			7%	93%
29 Sitting Area	20%	80%			11%	89%
30 Hallway	5%	95%			22%	78%

The third part of the analysis aimed to test the objective measures recently developed for the concept of living structures. Image analysis was conducted using the low-level image features method on the same set of images, approximating the effects of the two patterns of living structures: *level of scale* and *contrast*. Five measures were tested: *entropy* and *fractal dimension* to represent levels of scale, and the standard deviation of the image's *hue*, *saturation*, and *brightness* to describe the property of *contrast* (Coburn et al., 2019). A sixth measure applied is the scaling law method, which approximates the degree of life based on structural hierarchies and the number of substructures (Jiang & de Rijke, 2023).

The analysis utilized open-source Python codes and built-in Python image analysis features. Most images from the Taskisla building scored higher on five of the six measures (Entropy 53%, Hue 63%, Saturation 63%, brightness 70%, scaling 60%). Conversely, 60% of EE images scored higher for the fractal dimension. Higher scores on all dimensions generally correspond with images containing more vegetation, fine textures, and architectural detail. In contrast, images of monotone and minimalist interior spaces score the lowest, aligning with the theoretical concepts of living structures. Figure 5 summarizes the result of the image analysis.

Fractal dimension*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean	
Taşkışla	1.50	1.68	0.38	1.63	1.53	1.41	1.22	1.54	1.38	1.89	1.70	1.62	1.64	1.72	1.65	1.54	Taşkışla
EE	1.57	1.57	1.63	1.82	1.55	1.45	1.27	1.51	1.62	1.82	1.69	1.54	1.62	1.63	1.79	1.59	EE
image no.	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	percentage	
Taşkışla	1.66	1.47	1.74	1.60	1.74	1.60	1.57	1.37	1.62	1.72	1.42	1.52	1.71	1.54	1.44	40%	Taşkışla
EE	1.49	1.70	1.88	1.44	1.77	1.60	1.36	1.24	1.51	1.15	1.59	1.61	1.72	1.71	1.70	60%	EE

*a measure of visual complexity, detecting repeated pat erns across scales. Calculated using the Minkowski-Bouligand method (Coburn et.al, 2019).

Entropy*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean	
Taşkışla	7.53	7.72	7.77	7.32	7.77	7.64	7.75	7.61	7.75	7.67	7.67	7.15	7.44	7.87	7.31	7.52	Taşkışla
EE	7.47	7.75	7.65	7.43	7.40	7.60	6.89	7.55	6.72	7.80	7.83	7.66	7.39	7.89	7.70	7.57	EE
image no.	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	percentage	
Taşkışla	7.84	7.14	7.51	7.47	7.66	7.39	7.70	7.56	7.89	7.50	7.35	7.66	7.56	7.53	7.43	53%	Taşkışla
EE	7.68	7.65	7.71	7.51	7.71	7.42	7.15	7.33	7.63	7.45	7.32	7.18	7.48	7.88	7.77	47%	EE

*statist cal measure of randomness in a scene that is calculated using the scenes intensity histogram (Coburn et.al, 2019)

Hue St. deviation*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean	
Taşkışla	15.73	34.90	45.65	20.90	33.43	17.94	45.79	44.40	28.34	27.69	45.74	48.74	26.74	27.85	37.00	35.23	Taşkışla
EE	39.65	35.64	41.32	38.53	32.84	36.05	17.11	22.85	33.64	26.74	34.40	37.53	22.74	44.09	12.88	32.00	EE
image no.	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	percentage	
Taşkışla	30.83	57.95	64.67	58.13	35.39	40.46	23.08	13.33	34.31	25.70	27.43	36.10	30.72	40.26	37.82	63%	Taşkışla
EE	29.79	39.69	32.93	43.18	43.40	35.90	24.65	16.33	29.53	6.88	34.11	46.04	33.27	33.23	35.18	37%	EE

*a measure of color hue variation in an image, caluclated standard Python image HSV analysis (Coburn et.al, 2019)

Saturation St. deviat on*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean	
Taşkışla	48.57	51.49	31.07	39.30	51.90	61.69	37.98	41.40	31.52	84.76	61.46	51.77	34.77	71.46	54.79	49.23	Taşkışla
EE	27.90	53.75	44.51	25.69	50.78	27.26	22.96	44.29	26.41	87.89	60.93	39.52	58.19	48.44	66.42	43.15	EE
image no.	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	percentage	
Taşkışla	45.00	51.37	64.00	62.42	58.88	48.19	38.38	59.24	45.32	23.58	27.90	71.43	36.61	59.17	30.79	63%	Taşkışla
EE	42.53	48.62	69.53	39.02	50.49	36.79	39.76	26.67	58.31	28.49	25.64	21.74	27.90	37.42	41.54	37%	EE

*a measure of color saturation variat on in an image, caluclated standard Python image HSV analysis (Coburn et.al, 2019)

Brightness St. deviation*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean	
Taşkışla	48.47	62.12	65.13	41.72	58.65	48.78	54.46	53.56	56.21	76.8	57.51	45.3	59.37	68.45	48.68	56.62	Taşkışla
EE	46.66	70.17	53.05	49.18	42.49	53.95	37.28	53.49	40.17	71.51	79.17	65.74	54.03	68.14	67.08	58.96	EE
image no.	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	percentage	
Taşkışla	68.85	43.51	80.38	66.65	70.73	55.62	73.3	52.41	68.12	50.37	67.08	63.58	54.82	52.27	45.41	70%	Taşkışla
EE	65.45	65.51	64.74	66.28	66.07	47.61	42.04	51.46	52.18	50.51	47.59	38.98	48.36	67.89	61.74	30%	EE

*a measure of brightness variation in an BW image, caluclated standard Python image HSV analysis (Coburn et.al, 2019)

scaling*

image no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean	
Taşkışla	13219	27357	3819	29395	13642	12866	13828	21999	5016	61312	30422	27312	3515	22259	25294	19692.16	Taşkışla
EE	8059	7333	9322	59228	11423	13819	12251	7153	27377	43935	21394	13041	12591	Error	18243	19044.54	EE
image no.	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	percentage	
Taşkışla	19955	26382	50749	Error	34654	15428	7122	5292	16295	31168	16118	Error	13243	Error	17651	60%	Taşkışla
EE	Error	15032	Error	5313	23553	37470	18915	12161	5985	6607	31007	30711	30698	18714	10472	40%	EE

*a function of levels of structure heirarchy (pixels) and number of substructures (Jiang & de Rijke, 2023)

Figure 5. Results of the image analysis measuring objective naturalness.

4. Discussion

4.1 Naturalness/life in Architecture

Alexander (2002) argued that a consensus can often be reached by asking people to reflect on which scene feels more alive, attributing this to certain universal properties of living structures that resonate with our experience of the world. He also suggested that pre-modern buildings were more likely to possess those properties. Similarly, Kaplan's preference theory has demonstrated the impact of natural complexity and coherence on aesthetic appraisal through naturalistic patterns such as mystery,

prospect, and refuge (Kaplan & Kaplan, 1989). The cases in this study were chosen for their demonstrable differences in aesthetic quality and style, with one hypothesized to be more naturalistic. As predicted, participants assessing the livingness of these buildings showed a clear consensus in favour of the classical building, which was hypothesized to be more naturalistic in its visual quality.
Objective measures of naturalness demonstrated close results when comparing the number of images scoring higher for the six measures and their mean score. Ranking the images according to these measures was generally consistent with their theoretical implications. For example, hallways with minimal geometry and little colour variation scored the lowest, while images with rich façade details or natural features scored the highest. Images with low L-score tended to feature less detail and overall blandness, such as the images of the EE building corridors. As expected, the detailed and aesthetically rich façade of the Taşkışla building scored higher than that of the EE building. Overall, some of these measures predicted perceived naturalness and preference in previous research. In this study, they were applied to real settings with building users, allowing for the examination of other psychological outcomes, such as the sense of place.

4.2 Naturalness and sense of place

The results from combining naturalness measures and SoP suggest that naturalistic buildings may foster a more positive place experience than mechanistic and utilitarian ones. The significantly higher level of SoP in naturalistic buildings confirms the research hypothesis. The demonstrable difference in perceptions of life indicates that variations in a building's naturalness likely influence the occupants' SoP.
Cole et al. (2021) have suggested that green buildings can support SoP by aligning common green building strategies with SoP dimensions. Similarly, naturalistic buildings can enhance SoP through the emotional dimension of forming attachments via attractive, nature-like features, identification with places based on environmental awareness and valuing nature, and dependence on places to perform desired actions. Previous research has shown that people tend to form attachments and identify with places due to the presence of nature. The perceived beauty of places also contributes to forming SoP. These results highlight the connection between nature and SoP, demonstrating that naturalistic patterns of order enhance this relationship.

4.3 Implications for theory and practice

This study has highlighted a theoretical link between SoP and the naturalistic properties of the built environment. Place theories have often been criticized for their ironic underemphasis on places and their objective physical properties (Lewicka, 2011). Exploring this link broadens our understanding of people/place relations, which are formed by a multitude of factors, including extended and repeated interactions, personal experiences and memories, social ties, and the attractive force of living structures that can evoke interest, aesthetic enjoyment, and emotional engagement.
On the other hand, the biophilic design theory should move beyond its focus on greening buildings and cities in order to explore the full potential of its goals. More empirical evidence is needed to examine the effects of indirect nature in place, such as prospect/refuge and mystery, as well as other properties of living structures, such as local symmetries and simplicity.
Nature and biology play a significant role in contemporary urban and architectural design thinking, whether through taking inspiration from natural forms, evolutionary and generative processes, or even for branding purposes. Designers can use this biological moment to make their designs more human-friendly and considerate of their emotional impact. To increase the naturalness of the environment, buildings and cities should be allowed to 'grow' organically through sensitive adaptive processes that fit new forms rather than impose them. Based on these findings, designers are encouraged to follow adaptive design processes that create highly integrated and aesthetically pleasing living structures. The theory of living structure and other advancements in biophilic design are promising in describing these processes and guiding designers to adopt this approach.

5. Conclusion

This study has demonstrated that architectural environments embodying naturalistic beauty significantly enhance the sense of place (SoP) experienced by their users. By comparing two educational buildings with distinct aesthetic qualities, it was found that the building with naturalistic elements, the Taşkışla, provided a stronger sense of attachment, identity, and dependence than its mechanistic counterpart. These findings suggest that environments designed with biophilic principles, which integrate nature and its analogues into the built form, can foster more profound emotional connections and promote psychological well-being.

The results also highlight the importance of objective measures of naturalistic beauty in understanding how architectural design influences human experience. The study's novel combination of survey-based data and image analysis revealed that features such as complexity, coherence, and detail are crucial in determining the perceived naturalness of a building. These findings support the argument that design strategies focused on enhancing naturalistic qualities, such as through the use of local symmetries, fractal patterns, and organic forms, can positively impact users' perceptions and experiences of their environment.

Overall, this research provides valuable insights into the interplay between architecture and human psychology, suggesting that biophilic design not only has aesthetic appeal but also contributes to socio-economic benefits by fostering environments that support well-being and community ties. Future studies should further explore the specific elements of naturalistic architecture that most effectively enhance SoP, using both qualitative and quantitative methods to build a more comprehensive understanding of the relationship between built environments and human experience.

Acknowledgement

N/A.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The authors declare no conflicts of interest.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

CRediT author statement:

Conceptualization: S.A., G.I. Data Curation: S.A. Formal Analysis: S.A, N.A. Investigation: S.A. Methodology: S.A Project Administration: G.I Resources: S.A., N.A., G.I. Software: S.A, N.A. Supervision: G.I. Validation: S.A, G.I. Visualization: S.A. Writing – original draft: S.A. Writing – review & editing: S.A., G.I.

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How to cite this article:

Al-azzawi, S., İnalhan, G., & Al-azzawi, N. (2024). The Relationship Between Sense of Place and Nature-based Architectural Beauty: A Comparative Case Study. *Journal of Contemporary Urban Affairs*, *8*(1), 102-119. https://doi.org/10.25034/ijcua.2024.v8n1-6