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Original Research Article

Developing a Framework for Enhancing Livability in Contemporary Residential Complexes through the Application of the Biophilic Architecture Model

(Selected Complexes in the City of Qazvin)

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Abstract

Problem statement: Enhancing livability in residential complexes has become one of the major challenges of urban design due to increasing urban density and environmental changes. Biophilic architecture is a contemporary approach that, by creating a connection between humans and nature, contributes to improving the quality of life and the mental well-being of residents. Therefore, applying the biophilic architecture model can play a key role in improving the livability of contemporary residential complexes.

Research objective: This study employed a mixed quantitative–qualitative approach based on space syntax analysis and conducted a comparative evaluation of the design methods of contemporary residential complexes, emphasizing biophilic strategies for enhancing housing livability.

Research method: The research method is logical and deductive reasoning. By simulating selected case studies (six residential complexes in the city of Qazvin) in the Depthmap software, the study interprets the impact of mass/space composition methods on livability components based on biophilia. The comparative analysis includes six distinct spatial composition types of buildings and open spaces using the indicators of connectivity, integration, visual integration, and entropy, as well as the comparison of two typical floor plans using the indicators of connectivity, depth, and integration.

Conclusion: The analysis of results at both the typical floor plan and site plan levels demonstrates a positive correlation between these indicators and biophilic components such as access to nature, green views, and the quality of social interactions. The main achievement of this paper is the development of strategies for improving livability according to the status of indicators and design approaches in the studied cases, and the presentation of a practical framework for architects and urban planners in designing livable residential spaces.

Keywords: *Livability, Biophilic Housing, Space Syntax, Simulation, Depthmap.*

Introduction

With the expansion of urbanization and the increase in population density within urban environments, the quality of life of residents in residential complexes has become one of the main priorities of urban design and architecture. In recent decades, the design of residential complexes in Iran has mostly been based on engineering and purely physical principles, while human-centered approaches—such as biophilic design—have received little attention. Biophilic architecture seeks to restore the deep connection between humans and nature through the regeneration and integration of natural elements within built environments. In this context, the use of space syntax indicators provides a foundation for understanding the dynamics of movement, accessibility, and visual experience of users, leading to the design of spaces that better correspond to human needs in achieving the goals of livability and biophilia. Given the importance of the topic, the present study aims to develop a scientific framework based on spatial analysis indicators for enhancing livability in contemporary residential complexes, with an emphasis on applying the biophilic architecture

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model. To this end, it analyzes key spatial indicators—including connectivity, integration, entropy, and visual integration—in selected residential complexes in the city of Qazvin. The main objective of the research is to formulate a framework for enhancing livability in contemporary residential complexes in Qazvin, while the secondary objective is to evaluate the strengths and weaknesses of the selected complexes and to propose improvements based on the analysis of the aforementioned indicators. The innovation of this study lies in combining quantitative analytical methods (using Depthmap software) with qualitative analysis, as well as in establishing a direct connection between the subject and the fields of landscape architecture and contemporary issues in Iran, such as urban density and the quality of life in residential complexes.

Research Background

The body of research conducted on the livability approach has primarily focused on urban-scale issues, with less attention given to the housing scale and semi-open spaces within architectural environments. While the subject of urban livability and its components has been widely studied across various contexts, research within the architectural domain remains limited. In this regard, Radaei et al. (2022) examined ecological and livability approaches in vernacular houses within the historical fabric of Yazd, concluding that the revitalization of ecological rationality principles at multiple scales can promote the livability of contemporary urban fabrics. Padashi Amlashi et al. (2021) explored vernacular architecture to develop livability indicators in the city of Amlash, finding through statistical analysis that, from the perspective of Amlash residents, the environmental dimension holds the highest priority in fostering housing livability based on local architectural patterns. Amir et al. (2015) investigated residents' participation in achieving livable housing within rental complexes and concluded that participation can have a positive effect on large-scale environments, while livable places, in turn, positively influence residents' activity, productivity, and the creation of suitable living environments. Several other studies have examined the impact of biophilia on residential spaces, aiming to preserve environmental values while improving residents' quality of life. For instance, Lee & Park (2025) presented a strategic biophilic design framework focused on the well-being of elderly residents, showing that targeted use of visual connections to nature, natural light, and indoor greenery significantly enhances their quality of life. Zhong et al. (2022), through an extensive analysis of biophilic design, concluded that this design approach is not limited to plants or facades but encompasses a wide range of sensory and natural experiences linked to urban sustainability goals. Similarly, Al-Sayyed & Al-Azhari (2025) conducted an experience-based study on the physiological responses of humans to biophilic design in simulated residential spaces, revealing significant reductions in stress levels when exposed to biophilic environments. A 2023 study in China examined high-density residential complexes, analyzing site plans, green spaces, and outdoor furnishings to propose an appropriate design framework, demonstrating that the inclusion of biophilic components such as views of nature and public open spaces enhances residents' quality of life (Gong et al., 2023). Yue et al. (2024) developed an empirical framework on how biophilic components influence life experiences in high-rise buildings, introducing a questionnaire-based measurement tool. Lefosse et al. (2023) conducted a systematic review of urban environments and residential design from a biophilic perspective. Their article, through three criteria—extent of design models, environmental scale, and human–nature interactions—identified research gaps and future needs. Yaseen & Mustafa (2023) combined space syntax analysis with biophilic assessment in a case study of a school, showing that spatial analysis can be an effective tool for evaluating biophilia. The innovation of the present study, compared to the existing research gaps, lies in its simultaneous focus on livability and biophilic design approaches, the dual-scale analysis (both internal and external spaces of residential complexes), and the application of Depthmap software for spatial indicator analysis. Whereas most previous studies relied on questionnaire-based or qualitative methods, this research emphasizes quantitative spatial analysis using Depthmap across two scales (interior and exterior), linking the results with biophilic design components and livability concepts. Thus, the present study takes an innovative step toward establishing an indicator-based, independent framework for evaluating the quality of residential environments. It bridges the gap between biophilic qualitative assessment and spatial network analysis, offering practical applicability in real-world design processes.

Research Method

The research method combines descriptive–analytical, logical reasoning, and deductive approaches. In the first stage, data were collected from the research literature through a library-based study to explain and categorize the indicators and concepts of livability and biophilia, as well as related theories, and to examine the objectives and emphasized aspects of these two approaches. In the second stage, the identification of various layout patterns and the composition of open and enclosed spaces in the design of contemporary residential complexes, and the quantitative and qualitative analysis of data in two-dimensional maps and real spatial settings of the selected cases were conducted. This was done through the analysis of the relationship between the observer and natural views, the relationship between open and closed spaces, area and adjacency, and the study of social patterns in architectural plans using the Depthmap simulation software based on the research components. These analyses led to the development of redesign proposals for the selected cases and the formulation of a framework for enhancing livability. The criterion for case selection was to create a diverse range of spatial form patterns and geometric variety in the configuration of open and closed spaces (buildings and their surroundings). Accordingly, six patterns were selected: rectangular and symmetrical forms with linear layout (Aseman Complex); symmetrical courtyards and blocks with circular layout (Farhangian Complex); grouped box-shaped blocks with limited landscaping (Kasra Complex); linear extension of blocks with intermediate spacing and linear landscaping (Razhia Complex); circular layout of five blocks with semi-circular central courtyard (Sadra Complex); and row arrangement of individual cubic blocks (Venus Complex). These were evaluated using space syntax indicators related to biophilic-based livability.

Theoretical Foundations

- **Livability**

Livability, as a multidimensional concept, considers the overall quality of the living environment in terms of well-being, physical and mental health, safety, accessibility to services, and social interactions (Beatley, 2011). This concept, emphasizing the harmonious coexistence of humans and the natural environment, seeks the sustainable enhancement of residential settings in a way that ensures both the well-being of residents and the preservation of the natural environment.

- **Livability in residential environments**

The house is the most important place of living and a shelter of life, encompassing concepts such as identity, solidarity, safety, and protection (Varmaghani, 2022, 177). Livability is one of the key concepts in housing design, referring to the degree to which a space is suitable for human life. As a multidimensional criterion, it represents the quality of life in residential environments, including physical health, psychological well-being, access to services, social interaction, and connection with the natural environment. At the residential level, in addition to public spaces, the quality of interior design and internal circulation plays a crucial role in enhancing residents' comfort (Jayakody et al., 2024). Recent studies show that livable environments not only improve residents' health and satisfaction but also have a direct impact on environmental sustainability and reduce the pressures of urban development (Dempsey et al., 2011). Livability in residential complexes depends not only on the quality of individual housing units but also on the quality of public spaces, social connections, and spatial cohesion. In this regard, the biophilic architectural approach, based on the integration of natural elements and patterns in the design of built environments, is recognized as an effective strategy for enhancing livability (Kellert et al., 2008). Numerous studies have demonstrated that the presence of biophilic elements in residential environments can reduce stress, increase satisfaction, and improve the overall quality of residents' lives (Joye & Van den Berg, 2011).

- **Biophilia theory and biophilic design**

Biophilia expresses the innate human tendency toward natural processes and signifies a fascination with all living and life-giving things (Varmaghani, 2023, 4). This theory was first introduced by Wilson (1984), emphasizing humans' inherent need for connection with nature and the presence of biological elements in their living environments. Various models have been proposed for implementing biophilic architecture. Among them is Stephen Kellert's six-dimensional model, which includes direct elements of nature (light, plants, water), indirect elements (organic patterns, natural colors, materials), and spatial and place-based conditions (human scale, spatial legibility, sense of territory). Kellert (2018)'s framework systematically identifies 14 components of biophilic design, the most significant of which are visual connection with nature, refuge and quietness, sensory diversity, and natural patterns in space. Among these, privacy, silence, and refuge are key factors in livability, as they create boundaries that do not imply separation but rather influence all aspects of life and social relations, and consequently, architectural design (Varmaghani & Soltanzade, 2018, 131). Empirical studies have shown that designs based on this framework—through the provision of natural light, green views, and natural elements—can reduce stress, improve mental health, increase residents' satisfaction, and enhance productivity (Ulrich, 1984; Liu & Zhou, 2025). For instance, recent research identifies the use of large windows overlooking greenery, access to daylight, and natural materials as key factors in successful biophilic design (Turner-Skoff & Cavender, 2019). Biophilic architecture, as a contemporary design approach, emphasizes reconnecting humans with nature and integrating natural elements—such as daylight, vegetation, natural materials, landscapes, sounds, and even scents—into the built environment (Kellert et al., 2008). Accordingly, biophilic design, beyond its aesthetic dimension, also performs a functional role in enhancing quality of life (Table 1).

- **Space syntax theory**

The space syntax method, using three indicators—connectivity, depth, and integration—examines the physical and social characteristics of the samples (Karbasi, 2023, 6). The visual integration indicator specifically reflects the degree of views to nature and natural light (Farshidi et al., 2022), which aligns with biophilic principles such as visual connection with nature. Connectivity and integration of the spatial structure, in addition to facilitating smooth movement (Behmanesh et al., 2023), strengthen features such as place attachment and environmental coherence, both of which are key components in enhancing livability (Hillier & Hanson, 1984; Yu et al., 2025). Furthermore, relative depth, by defining spatial and locational hierarchies for residents and providing refuge–quiet scenarios, enhances the sense of safety and private retreat. Entropy, on the other hand, creates movement diversity and path choice opportunities, contributing to a more varied and engaging spatial experience (El-Khouly & Penn, 2012; Salingaros, 2015). Therefore, the biophilic approach can serve as an effective strategy for improving urban quality of life and designing human-centered residential environments, and its integration with spatial analysis enables objective evaluation of space quality and the development of efficient design solutions. Table 2 presents the relationship between spatial indicators, livability components, and biophilic objectives, based on the synthesis of theories presented in the research literature.

Study Samples

The Farhangian Residential Complex consists of two semi-circular towers, 120 meters in height, arranged symmetrically, and is one of the major urban residential projects. Each tower has 28 residential floors and 2 basement levels for parking, including 12 elevators, 4 staircases, and approximately 28 commercial units. The central space between the two towers forms a green courtyard. The Razhia Complex consists of three elongated 14-story blocks arranged linearly on a 9,000 m² site. Together, these blocks include 30 commercial units on the ground floor and 280 residential units on floors 1 to 13. Other ground-floor facilities include a meeting and reception hall, gym and fitness center, jacuzzi and sauna, private car

Table 1. Livability and biophilic design criteria based on experts' opinions. Source: Author.

Domain	Criteria/ Components	Description	Reference
Livability	Physical and mental health	Access to natural light, ventilation, stress reduction, and enhancement of psychological well-being	Beatley, 2011
	Safety and security	Sense of protection and comfort in residential spaces	Jayakody et al., 2024
	Social interaction	Opportunities for forming social bonds in public spaces	Dempsey et al., 2011
	Interior design quality	Efficient circulation and flexibility of interior spaces	Jayakody et al., 2024
	Connection with nature	Presence of green views and natural landscapes within the space	Beatley, 2011
Biophilic	Direct nature elements	Natural light, plants, water, and views/landscapes	Ulrich, 1984
	Indirect nature elements	Natural materials, organic colors, nature-inspired patterns	Kellert et al., 2008
	Spatial conditions	Human scale, spatial legibility, sense of territory, privacy, and refuge	Kellert, 2018
	Visual connection with nature	Direct view of green spaces or natural landscapes	Joye & Van den Berg, 2011
	Functional impact	Stress reduction, improved mental health, and increased productivity	Liu & Zhou, 2025

Table 2. Relationship of spatial indicators with livability components and biophilic objectives. Source: Author.

Spatial indicator	Scale of application	Biophilic component/ responsive element	Implication for livability
Connectivity	Internal and site plan	Smooth circulation, access to nature	Easy and fluid access to spaces
Integration	Both scales	Functional integration, sense of place	Integrated environmental experience
Mean depth	Interior	Shelter and privacy, tranquility	Psychological safety and well-being
Visual integration	Site plan	Visual connection with nature, natural light	Stress reduction, increased satisfaction
Entropy	Site plan	Path diversity, varied spatial experience	Cognitive stimulation and spatial attractiveness

wash, and a kindergarten. The Kasra Complex comprises six 17-story box-shaped blocks grouped into two independent courtyards (four-block and two-block arrangements) connected by narrow passages. Ground-floor spaces include commercial units, art classrooms, a sports club, and a meeting hall. The Aseman Complex includes two 14-story rectangular residential towers arranged symmetrically, with an irregularly shaped green landscape in front. Ground-floor facilities for residents include a swimming pool, meeting hall, and supermarket. The Sadra Complex consists of five quasi-rectangular 14-story blocks arranged in a semi-circular layout around a central green courtyard with a gazebo and children's play area. A covered ramp connects the central courtyard to the underground parking. Each block has two basement floors for parking, as well as a lobby and common areas on the ground floor (Table 3).

Findings

For the analysis of the study samples, two scales were considered: the architectural scale (typical floor plans, including residential units and circulation corridors) and the site scale (ground-floor plans in connection with the surrounding courtyard). The space syntax indicators were analyzed at each scale according to their purpose and application (Table 4).

Table 5 shows the morphological simulation and the values of the three indicators—visual integration, connectivity, and entropy—for the six studied residential complexes. Warm colors on each map indicate high indicator values, while cool colors represent low values.

Analysis of connectivity maps: Areas with high connectivity (warm colors) represent spaces with the greatest accessibility and path flow. These spaces act as movement and social hubs, serving as the living cores of the complexes. From a biophilic architectural perspective, such areas provide opportunities for human–nature interaction, as proximity to high-traffic paths allows optimal use of green spaces, natural light, and airflow. Areas with low connectivity (cool colors) indicate spaces with limited access, interpreted as quiet or private zones. Within the livability framework, these spaces offer restorative and calming functions for residents, while needing clear differentiation from isolated or unsafe areas. In the Aseman Complex, connectivity is relatively dense at the entrances and lobbies of both towers, especially the eastern block, due to the extensive landscaped courtyard in front. However, large garden beds in the courtyard reduce overall connectivity. In the Kasra Complex, the central area of the four-block courtyard has the highest access, highlighting the importance of the main entrances of each block. Nevertheless, the lack of natural elements (trees, fountains, gardens) in high-density areas and the compactness of the blocks reduce the effectiveness of connectivity, visual quality, and private spaces for residents. In Razhia, despite the linear elongation of blocks, the creation of intermediate open spaces between blocks and connections with north and south green courtyards increases overall connectivity (320.512, above average). However, the three-part division of the site (north courtyard – blocks – south courtyard) and the dominance of axial and parallel connection lines reduce the effectiveness of entrances and internal–external links from a biophilic perspective. In the Venus Complex, the very limited courtyard has low-density, mostly linear connection lines. The lack of natural elements and interactive central spaces means that connectivity does not enhance livability indicators; rather, it primarily connects the ground-floor commercial units to urban pathways. The Farhangian and Sadra complexes, despite having relatively similar layouts, show maximum and minimum connectivity values, respectively. The simulation colors indicate that this difference arises from courtyard patterns and the transparency or spatial hierarchy of the ground

Table 3. Introduction of the studied residential complexes. Source: Author.

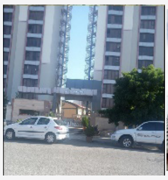
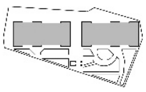
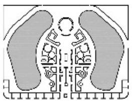
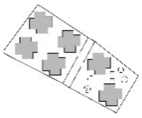
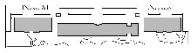
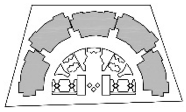
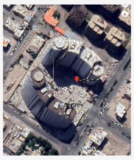
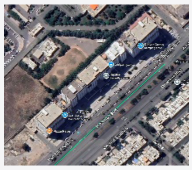
Feature	Aseman	Farhangian	Kasra	Razhia	Sadra	Venus
View						
Plan						
Map						
Date	2013	2024	2016	2016	2022	1395
Story	14	30	17	14	14	13
Built area	3098	5545	5310	3460	5765	6839
Area	8500	15600	15800	9000	17600	9600
Layout	Symmetrical linear	Opposite, circular	grouped	Linear	Semi-circular	Separated row

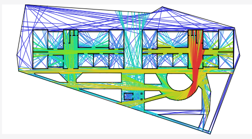
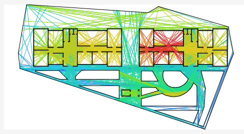
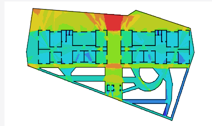
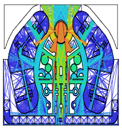
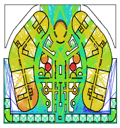
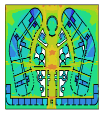
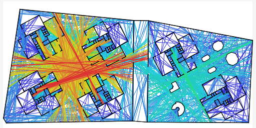
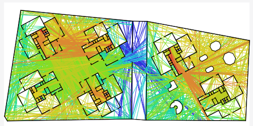
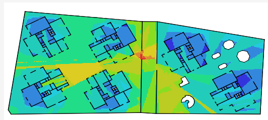
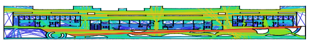
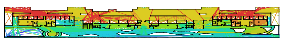
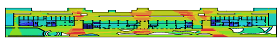
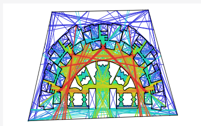
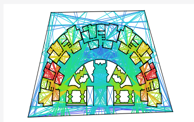
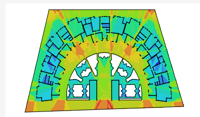
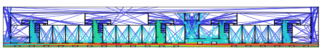
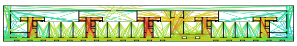
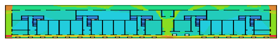
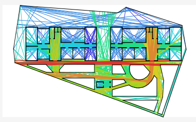
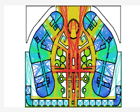
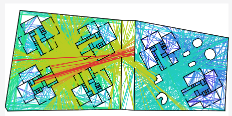
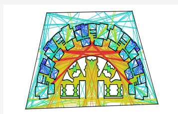
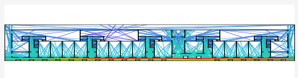
Table 4. Space syntax indicators and their applications in livability analysis. Source: Author.

Scale	Purpose	Indicator	Applicable	Link to biophilia
Micro (residential indoor spaces)	The relationship between interior design, ease of movement, spatial hierarchy, and psychological security	Connectivity	Rapid and direct accessibility between interior spaces	Appropriate spatial form, sequential experience, visual diversity, sense of refuge, and privacy
		Integration	Smooth circulation between spaces (e.g., from the kitchen to the living room)	
		Mean depth	Degree of spatial privacy (e.g., the bedroom relative to the entrance)	
Macro (site plan and surroundings)	Access to open spaces, natural light, green areas, and social spaces	Connectivity	The connectivity between pedestrian and vehicular pathways	Visual contact with nature, access to open spaces, movement and spatial diversity (spatial dynamism), perception of hierarchy, and spatial familiarity.
		Integration	The linkage of open spaces with entrances and overall building functions	
		visual integration	Visual connectivity to green spaces, pathways, and the surrounding environment	
		Entropy	Spatial variety and availability of route choices	

floor. The maximum connectivity in Farhangian (565.937) corresponds to smooth movement, wayfinding, and direct axes, while the minimum connectivity in Sadra (180.624) is due to the complex internal ground-floor hierarchy and low permeability of the central green space. Increasing connectivity facilitates social interactions and easier pedestrian movement within the courtyards.

Analysis of integration indicator: Livability is directly related to the integration indicator, as better spatial connections, easier access to green spaces, and the presence of natural elements along circulation paths enhance the quality of life. Complexes with higher integration in open and green spaces provide residents with better opportunities to enjoy nature, foster a sense of belonging, promote social interactions, and support psychological well-being. The Farhangian Complex shows the highest level of integration (red and orange areas) in the central parts and the green courtyard between the two towers. This indicates maximum accessibility and spatial connectivity within the landscape structure, which can improve livability and social

Table 5. Morphological simulation of the site plan. Source: Author.

Complex	Index value		Connectivity (C)	Entropy (E)	Visual integration (VI)
Aseman	C	232/559			
	E	1/96051			
	VI	9/69369			
Farhangian	C	565/937			
	E	2/1553			
	VI	6/18906			
Kasra	C	245/551			
	E	2/08658			
	VI	6/0797			
Razhia	C	320/512			
	E	2/06295			
	VI	6/69728			
Sadra	C	180/626			
	E	2/09665			
	VI	7/54406			
Venus	C	266/639			
	E	1/64944			
	VI	5/73536			
Integration indicator	A	5/24376			
	F	3/98631			
	K	4/29229			
	R	4/5931			
	S	4/22381			
	V	5/88134			

interactions in a natural setting. In the Razhia Complex (4.5931, below average), integration is divided into two distinct zones: the northern commercial courtyard has lower integration, while the southern residential courtyard has significantly higher integration. The color coding on the integration map highlights suitable locations for environmental elements and optimizes spatial usability for residents.

Analysis of entropy indicator: The entropy indicator in space syntax reflects the complexity, diversity, and unpredictability of spatial paths and relationships. High entropy indicates high complexity and lower order (more difficult spatial legibility), whereas low entropy suggests simplicity, higher order, and a predictable structure. The Farhangian Complex, with the highest entropy value (2.1553), exhibits lower legibility, with greater complexity in internal spaces and less in the green courtyard. High entropy in internal spaces (commercial and residential areas) may confuse new users. The Venus Complex, with minimal movement choices, has the lowest entropy (1.64944), reflecting uniformity and simplicity. The Aseman Complex shows a moderate entropy level (desirable condition). The integration map indicates that optimal entropy occurs along the central axis and the focal point of the western courtyard, which defines entrances and overall plan legibility. In the Kasra Complex, entropy distribution is uneven: the central courtyard of the four-block section reaches optimal values, while peripheral areas show maximum entropy. Sparse and scattered green spaces in high-entropy areas, combined with undefined circulation paths, reduce the effectiveness of the courtyard's green space. In the Razhia Complex, the linear block geometry separates the site into two distinct zones: the northern area exhibits high entropy (due to the broken northern site edge and multiple commercial unit entrances), and the southern residential area shows moderate entropy, resulting in two distinct design patterns.

The visual integration analysis identifies spaces with higher visibility and visual connections to other areas. Visual integration reflects the degree of visual connectivity between spaces, playing a key role in perceived safety, comfort, and connection with nature. In the Kasra Complex, the grouped and relatively compact block arrangement concentrates areas of high visual integration in the central sections, while most green spaces and seating areas in the peripheral zones show low values for this indicator. The Aseman Complex, with the highest visual integration value (9.69369) among the samples, facilitates social interaction and better wayfinding at intersections of transverse axes between blocks and longitudinal axes, due to enhanced visual connectivity. In the Sadra Complex, pathways around the central green space enhance visual quality. These continuous and visible paths strengthen the sense of connection with nature. The Farhangian Complex, with wide pedestrian routes weaving through expansive and diverse central green spaces, exhibits maximum visual integration (red and orange areas) across the plan. This enables high permeability of green patches, increasing visual appeal, reducing monotony, and enhancing overall livability.

Spatial legibility, analyzed in Depthmap through the integration–connectivity diagram (Fig. 1), is directly linked to comfort, accessibility, human–nature interactions, and consequently, the enhancement of livability from a biophilic architectural perspective. Highly legible spaces are typically high-traffic, active, and noticeable to residents. In biophilic design, high legibility supports better human–nature connection and increased social interactions.

Low dispersion of the diagram in Sadra has created a proper balance between accessibility and spatial concentration, and the central green spaces provide opportunities for greater interaction among residents. The steep slope and appropriate dispersion in Kasra create favorable conditions for interaction, accessibility, and the possibility of applying biophilic elements along high-traffic paths. With proper design of soft layers and courtyard furniture, this complex can provide a more desirable environment for enhancing livability, as users can easily access different spaces and have more opportunities to experience nature. The optimal level of legibility in Sadra and Kasra reflects a greater number of coherent and aligned paths in the plan structure, which increases the potential for biophilic design (easy and convenient access to green spaces and high potential for social interaction). High legibility in these two complexes provides a better foundation for implementing biophilic architecture and enhances livability. The very regular and ascending diagram in Venus provides a highly legible and predictable structure suitable for biophilic designs that require easy paths and direct access; however, the integration and connectivity maps show that this optimal condition is related to the ground-floor commercial

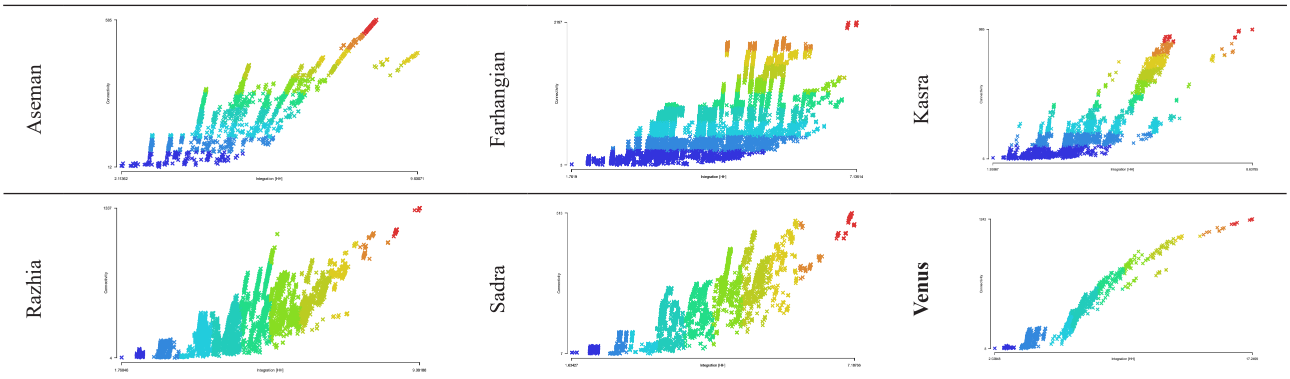


Fig. 1. Comparison of spatial legibility levels in the studied samples (site plan scale) using the integration-connectivity chart. Source: Author.

units and the direct internal circulation paths. Maximum integration with lower connectivity means clear key paths with limited diversity, which, if combined with sufficient open and enclosed areas, can offer a suitable opportunity for biophilic space design. Legible and connected paths provide more opportunities for a sense of calm, access to nature, and improvement of residents' quality of life, which constitutes a core principle of biophilic architecture. Farhangian and Razhia, with lower legibility, require redesigning paths and increasing spatial connections to allow more presence in nature and social interaction. The high dispersion of data in Aseman, Razhia, and Farhangian indicates spatial heterogeneity and insufficient integration of access, which, due to a reduced sense of cohesion and connection with nature, poses a challenge for livability and the application of the biophilic model. Fig. 2 compares the study samples based on normalized values and weighted indicator values. To rank the study samples according to the weighted index and normalized values, the importance of each indicator must be determined based on the research objective. Accordingly, a weight of 0. 3 is assigned to connectivity (high importance of easy and smooth access to open, green, and natural pathways), 0. 1 to entropy (medium importance of diversity in space and the possibility of choosing different paths for varied experiences), 0. 25 to integration (relatively high importance of merging spaces in the circulation system and overall access), and 0. 35 to visual integration (very high importance of visual connection with nature and the sense of openness).

Table 6 presents the values of three indices—Connectivity, Integration, and Mean Depth—in the typical floor plans of the Farhangian and Razhia residential complexes. These measurements aim to provide a more detailed analysis of permeability and biophilic qualities at the scale of the internal spaces of residential units.

In the Razhia Complex, the density of connectivity lines in the access corridors is very high and concentrated. Additionally, stairs and elevators are located at the most congested points. In the Farhangian Complex, the connectivity lines are more distributed and less concentrated; however, at the intersection of access corridors (central section), the density increases, improving the functionality of stairs and elevators in this area. The connectivity maps indicate that the internal layout of units in both complexes aligns with livability and spatial quality indicators; however, smoother circulation and more direct access in public areas and longer paths with finer connectivity in private unit areas are more evident in Farhangian than in Razhia. Conversely, Razhia exhibits greater spatial transparency with higher connectivity values even in private areas. In the integration analysis, the central corridors in Razhia create greater overall cohesion within the floor plan. In the average depth analysis, the numerous subspaces and hierarchical access in Farhangian units result in larger portions of the plan being at higher depth levels. Moreover, the location of some open balconies at higher depths reduces their effectiveness for interaction with outdoor air. In Razhia, overall, the units have less spatial connection with nature. Furthermore, lower depth may reduce the benefit of private spaces and the degree of enclosure from entrances. Security, refuge, and privacy indicators in the biophilic approach contribute to improving the quality of life, in which Farhangian performs more favorably. Razhia, due to high connectivity and integration and low depth (3.28179), benefits from a coherent spatial structure that facilitates movement and active social spaces. In contrast, Farhangian, with a less integrated structure and greater spatial depth (4.00556), provides fewer social areas and more private spaces, which supports residents' privacy and individual connection with nature rather than social interaction.

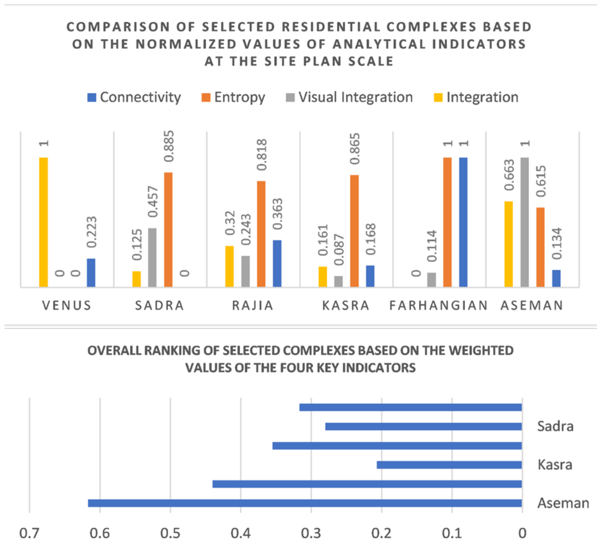
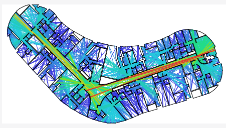
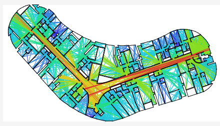
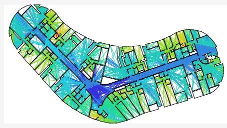
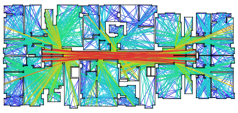
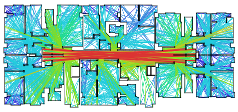
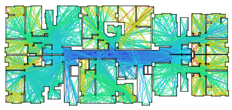


Fig. 2. Comparison and ranking of residential complexes based on research indicators. Source: Author.

Table 6. Morphological simulation of typical residential floor plans in Farhangian and Razhia complexes. Source: Author.

Complex	Index value		Connectivity (C)	Integration (I)	Mean depth (MD)
Farhangian	C	108/537			
	I	3/216			
	D	4/00556			
	R	0/25			
Razhia	C	129/323			
	I	3/97375			
	D	3/28179			
	R	0/75			

• Spatial correction strategy based on analysis results

Spatial correction through analyzing the samples according to the research indicators and improving the indicators in each case can enhance livability and residents' quality of life in residential complexes. It is necessary to determine the performance status of each complex and identify its strengths and weaknesses (Table 7). Spatial correction strategies aligned with biophilic architecture principles create a deeper connection between humans and nature.

Spatial correction in the Kasra complex can be achieved by focusing on high-visibility paths for planting greenery, natural shading, and biophilic elements along high-traffic routes, emphasizing the main paths as green corridors with diverse vegetation. The weakness of the Kasra complex lies in the lack of effective communal green spaces despite the favorable interaction between open and built spaces, resulting in disorder and movement chaos (high entropy), particularly in the area of the four-block section. In this regard, creating an interactive garden in the central area to enhance social and ecological performance and designing shaded seating areas in high-traffic points to encourage pause and interaction will effectively increase integration and moderate entropy. The problem in the Sadra complex is low integration and connectivity and relatively high entropy, especially in linking the peripheral green areas with the interior of the blocks. The proposed solution includes increasing connectivity between zones and reducing segregation and boundaries through proportional pathway widths in the green areas and adjacent spaces. Strengthening existing paths and widening green walkways around the existing park with varied vegetation is also suggested. The strength of the Farhangian complex is high connectivity and organic design, while its weakness is maximum entropy and low visual integration. In this complex, measures such as using natural markers like distinctive trees or color combinations along pathways to guide users and enhance legibility, as well as reinforcing the interior-exterior connection through transitional green spaces along openings and entrances, are recommended to improve visual and movement continuity between the site and interior areas. The issue in the Aseman complex is low connectivity. Therefore, creating a central green core or courtyard visible and accessible from all sides, with clearly defined walking paths and natural boundaries, can reduce this weakness. Additionally, increasing connectivity and integration through better-designed paths within the large enclosed green space and providing safe green areas in the northern site to enhance interaction, accessibility, cohesion, and continuity between the northern and southern zones are effective solutions. A summary of spatial correction strategies and related recommendations is presented in Table 8.

• Framework for enhancing livability in contemporary residential complexes

To develop a framework for enhancing livability, it is necessary to identify the conceptual and functional dimensions of each indicator and their relationship with livability and biophilic principles at both scales of study, and then adopt the related key strategies (Table 9). The proposed framework for improving livability in contemporary residential complexes based on the biophilic architecture model should rely on increasing spatial connectivity and integration to facilitate movement and social interactions; enhancing functional and spatial diversity to stimulate cognition and increase user satisfaction; improving visual

Table 7. The performance status of study samples and their strengths and weaknesses. Source: Author.

Complex	Rank	Relative to the average					Weakness	Strength	Spatial correction strategy
		Average values	E	C	I	VI			
Aseman	0/617		+	-	+	+	Connectivity	Visual integration	Creating secondary pathways
Farhangian	0/44	C= 295/303	+	+	-	-	Integration	Connectivity-entropy	Site geometry regularization
Kasra	0/207	E= 1/7269	+	-	-	-	Visual integration	Entropy	Attention to visual connections
Razhia	0/355	VI= 6/9898	+	+	-	-	Entropy	Connectivity	Cohesion and proportionality of pathways
Sadra	0/28	I= 4/703	+	-	-	+	Connectivity	Visual integration	Connecting separate zones
Venus	0/317		-	-	+	-	Visual integration	Integration	Expansion of landscaping

integration and views toward green and natural spaces to promote a sense of calm and psychological well-being; emphasizing the design and maintenance of gardens and green spaces as key biophilic elements; improving circulation paths and connectivity of spaces; increasing functional and spatial diversity; and revising visual connections with the natural environment.

Discussion

Among the case studies, the Farhangian complex exhibits the highest connectivity index, creating a legible and accessible structure that facilitates movement and social interactions. In contrast, the Sadra and Aseman complexes, due to lower connectivity, face challenges in circulation and accessibility. The Aseman and Razhia complexes, with optimal entropy, offer suitable spatial diversity, enhancing resident satisfaction, whereas Venus, with lower entropy, exhibits more uniformity. High integration in Aseman and Venus indicates spatial cohesion, although Farhangian and Sadra show greater weakness in this regard; however, the high connectivity in Farhangian compensates partly for this deficiency. Visual integration in Aseman and Sadra provides better conditions and improves the spatial experience, while Venus and Kasra require adjustments in landscape design and site planning. Overall analysis indicates that complexes with high connectivity, diverse pathways, smooth circulation, better links to nature, and enhanced livability are more successful. Conversely, low-access areas and blind spots lead to isolation and reduced use of green spaces. The findings emphasize that appropriate continuity between interior and exterior spaces and the application of biophilic design principles—such as green walkways, social spaces, and enhanced views to nature—are key factors in improving livability as well as residents' physical and psychological well-being. Among the studied complexes, Farhangian and Sadra show the greatest potential for enhancement using a biophilic approach, whereas Venus requires fundamental revisions in spatial and landscape design to achieve optimal livability conditions. The proposed framework for enhancing livability in contemporary residential complexes in Qazvin should focus on increasing spatial integration, strengthening visual connections with nature, and creating diverse, accessible pathways. Special attention to natural elements and green spaces as core biophilic components can play a crucial role in improving residents' quality of life.

Conclusion

The findings of this study are presented in terms of theoretical implications (for architectural and landscape knowledge) and practical implications (for designers and urban managers) aimed at enhancing livability. The theoretical implications include the development of a conceptual framework for residential livability, the linkage between biophilic architecture and space syntax theory, and the provision of an analytical model for assessing livability. The research demonstrated that spatial indices such as connectivity, entropy, and integration can be applied to analyze the quality of livability in residential complexes, and their relationships with biophilic architectural principles can be elucidated. The results emphasize the importance of spatial integration and connectivity as mediating factors in enhancing the biophilic experience; this indicates that

Table 8. Spatial correction strategies and practical recommendations for enhancing the livability of selected residential complexes. Source: Author.

Complex	Strategy	Suggestion
Aseman	Revision of circulation paths	Creating secondary and shorter pathways to facilitate connectivity between spaces. Utilizing semi-covered walkways to enhance movement variety.
	Enhancing green spaces	Increasing the number of garden beds and adding diverse vegetation to create more natural spaces and improve visual integration.
	Enhancing spatial diversity	Designing multifunctional spaces such as cafes, small gyms, or educational areas within the site to create functional diversity.
	Enhancement of visual quality and landscape	Improvement of building façades and elimination of superfluous visual barriers to strengthen visual integration with green areas and garden spaces.
Kasra	Managing pathway complexity	Incorporating directional signage and wayfinding cues along circulation routes to enhance spatial orientation and minimize user disorientation.
	Green space management	Utilization of biophilic landscape design principles to improve the quality of garden spaces and foster greater human-nature interaction, exemplified by pedestrian pathways embedded within green environments.
	Public space optimization	Establishing small-scale and semi-private gathering spaces at strategic points to promote increased social engagement among inhabitants.
Sadra	Activation of underutilized spaces	The redesign and conversion of underused spaces into functional, active environments, including playgrounds, pocket gardens, and outdoor seating areas.
	Enhancement of internal-external connectivity	Strengthening the visual and physical linkage between housing units and adjacent green areas, achieved by incorporating open balconies and larger window openings.
	Improvement of the access network	Refinement of movement pathways to enhance flow efficiency and minimize inaccessible zones.
Razhia	Creation of semi-public spaces	The design of areas, including verandas, seating terraces, and green corridors to promote increased social engagement.
	Enhancing connectivity routes	Enhancing the number of access pathways to green and open areas to improve spatial integration and connectivity.
	Increasing plant diversity	Incorporating a variety of plant species within garden beds and outdoor spaces to engage sensory perception and improve landscape aesthetics.
Venus	Design of multifunctional spaces	Designing adaptable spaces that support diverse functions and activities.
	Façade and landscape rehabilitation	Enhancement of visual integration through the expansion of openings and the provision of open sightlines toward green areas.
	Improvement of access routes	Planning and designing integrated pedestrian and cycling networks linked to public and green areas.
Farhangian	Modification of the circulation network	The redesign of the main and secondary circulation routes to improve connectivity and minimize movement dead zones.
	Increasing spatial diversity	Establishment of varied functional spaces, including playgrounds, interactive garden beds, and relaxation areas.
	Enhancement of green spaces	Extending garden areas and incorporating native plant species to promote biodiversity and deepen ecological engagement.
	Enhancement of visual quality	Incorporation of landscape design features to improve visual quality and foster an enjoyable spatial experience.

livability is not solely dependent on the presence of natural elements but also relies on spatial organization and the quality of spatial perception. These findings can serve as a foundation for developing new analytical models in architecture and landscape studies that simultaneously consider both spatial and natural-biotic dimensions. The practical implications include design strategies for architects and planners, as well as urban management approaches. Design strategies involve increasing spatial connectivity through diverse pedestrian pathways and an integrated circulation network, creating open views to green spaces, strengthening visual connections between interior and exterior spaces, and enhancing spatial diversity within floor plans to prevent monotony and improve environmental attractiveness. Attention to biophilic elements—including natural light, plants, water features, and natural materials—at all design levels is also emphasized. Management strategies encompass revising landscape regulations for residential complexes with an emphasis on accessibility and social spaces, prioritizing connected and continuous

Table 9. Summary of the livability enhancement framework based on the main research axes. Source: Author.

Scale	Dimension	Related indicators	Key strategy	Connection with biophilia and livability
Interior space scale	Accessibility and legibility	Connectivity	Creation of short secondary pathways connected to main routes, linkage to green and community-centered nodes, and design of intermediate green spaces serving as natural and social gathering points.	Facilitation of movement, stress reduction, enhancement of social interaction, and provision of direct, safe, and natural passages.
	Cohesion and connectivity of space	Integration	Integrated spaces, open patios within intermediate areas, and the creation of semi-open seating zones.	Fostering a sense of belonging, psychological well-being, mental connection with nature, interactive green spaces, and integration of green areas.
	Tranquility, solitude, refuge	Mean depth	Incorporation of natural elements in semi-open spaces, skylights and windows oriented toward nature, and a hierarchy of private spaces.	Enhancement of natural experience, promotion of physical and mental health, creation of calming and pleasant environments, centralization of key spaces, and reduction of fatigue.
Site and open space Scale	Accessibility and legibility	Connectivity	Expansion of accessible, well-distributed green areas with improved linkage of pedestrian networks and natural access routes.	Safety and comfort in open spaces, clear and continuous pathways, and green corridors.
	Spatial diversity and choice	Entropy	Diverse movement flows, scale variation, and creation of adaptable and flexible spaces.	Biophilia and aesthetics, flexible and human-centered spaces.
	Physical cohesion and connectivity	Integration	Green corridors, open views, clear, continuous, and visible pathways, and seating and interaction spaces within natural settings.	Flexible and organic geometric forms, wayfinding and social connectivity, encouragement of social and individual activities.
	Visual cohesion and continuity	Visual integration	Eliminating blind spots, creating open views toward green spaces, incorporating large windows and openings, and enhancing visual connectivity between interior and exterior.	Enhancing visual connection with nature, fostering a sense of cohesion and belonging, and providing open views and natural daylighting.

green spaces as a key infrastructure for improving quality of life, developing implementation guidelines to enhance spatial integration in new projects and the revitalization of older complexes, and encouraging the use of biophilic architectural criteria as a standard measure for evaluating residential designs.

Conflict of Interest

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