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Applied Research Article

Theoretical Modeling of Effective Components on Biophilic Design of Spaces between Residential Complexes

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ABSTRACT: The construction of biophilic residential complexes is one of the new approaches to increasing the nature of the residents of residential complexes whose benefits will lead to better people's life. In recent years, in the field of architecture, biophilic residential architecture has been paid special attention and tries to consider the link between architecture and nature further. This study aims to investigate the theoretical modeling of the components affecting the biophilic design of the intervening spaces of residential complexes and the design of the relationships of these factors. The research method is descriptive-analytical in terms of applied results. A qualitative research approach was used through systematic review and purposive sampling to identify the studied components. In the section on interpretive structural modeling, expert academic opinions in architecture and Urbanism have been used through the Delphi method. Data collection tools are interviews and a two-way questionnaire, and a face validity criterion was used to assess the validity of the questionnaire. The relationships between the components affecting the biophilic design of the spaces between residential complexes have been determined using a new analytical methodology called interpretive structural modeling (ISM) and analyzed seamlessly. The findings showed that the relationship with natural systems with nine penetration power is the most effective and the strongest motivator of the biophilic design of the spaces between residential complexes and acts as the underlying stone of the model. Also, the order and complexity component with the penetration power of 4 has the least effect.

Keywords: *Intervening space, Biophilic residential complexes, Biophilic design, Structural-Interpretive Modeling.*

INTRODUCTION

Biophilic design is an approach to architecture that aims to bring the users of the building closer to nature. Biophilic buildings have features such as suitable natural light, air conditioning, natural landscape, and other things to create a healthy built environment for people. Since biophilic design connects natural elements with the built environment, it has received much attention in health-related topics. Recent studies show the positive effects of nature and its relationship with it on health, improvement of mental and physical conditions, and improvement of social conditions in the built environment. Although the details of the spaces between the residential complexes are also effective in improving the health of the residents, so far, no research has been done on the biophilic characteristics of the residential complexes. The concepts of biophilic and biophilic design have gone beyond the theories of Biophilia - which Eric Fromm first presented - and in 2014, by introducing 14 models of biophilic design, Broly has paid attention to and investigated areas such as the connection of human biological sciences or the human-made environment. Is. If we look at biophilic concepts from this angle, different branches of science can be discussed. All these efforts will lead to better human life and less destructive effects on the natural environment, and as a result, the built world will move towards sustainability.

Although biophilic concepts and their applications in design are expanding every day, until today, the research on the concepts of biophilic design in the spaces between residential complexes has been neglected. Researchers who have studied biophilic design have emphasized more on interior spaces, and the research on the exterior space of buildings is very limited. It has not been recorded in

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internal and external research sources in the space between residential complexes. Most studies related to biophilic cities (Beatley, 2011, 8 & 2016), biophilic buildings (Soderlund & Newman, 2015, 14), biophilic design (Kellert et al., 2011, 10), and biophilic and its effect on the treatment of people. Also, the review of written sources shows that green spaces and their quality, directly and indirectly, affect people's quality of life (Groenewegen et al., 2006, 7).

In this regard, considering the importance and position of biophilic design in the middle space of residential complexes, many studies have been conducted over the past years, but despite the high range of these studies, a comprehensive model of these factors and their relationship has not been presented. Accordingly, in this research, first by examining the literature on the subject studied, factors affecting its design in the spaces between residential complexes will be identified. Then, interpretive structural modeling (ISM) will determine and analyze the relationships between these factors seamlessly. Finally, the theoretical model of the factors affecting the design of the spaces between residential complexes will be drawn.

Therefore, this study aimed to identify the criteria affecting the design of the spaces between residential complexes, design an integrated theoretical model of these factors and identify the relationships of these components. In line with this goal, the main question of this paper is: What is the theoretical model of the components affecting the biophilic design of residential spaces with a structural-interpretive approach?

Identification of the Basis and Progression of Biophilic Emergence

Biophilia is a deep human need to connect with nature (Ryan & Browning, 2020, 21). Biophilic means loving life (Harel, 2022, 13), and biophilic design becomes objective by applying these principles in the human-made environment.

Based on this, a major part of the research related to this research has been done in the physiological sciences and anthropology and topics related to behavioral sciences (sociology, psychology.). Table 1 lists some of the research related to this article's topic.

Table 1: Identification of the interstitial space fields from theorists' point of view

Source	The title of the research	Topics
Buffon & Daubenton, 1766	Natural history	All living phenomena based on the general laws of nature/ bionics, biomimicry, biomimicry, Biophilia
Howard, 1946	Garden cities of tomorrow	Using walkability and access to garden cities
Fromm, 1964	Creators and destroyers	Biophilia means nature lover.
Register, 1987	Ecocity Berkeley: building cities for a healthy future	-Ecocities will bring gardens back to cities -Cities that are not against nature
Kellert & Wilson, 1993	the Biophilia Hypothesis	-Strengthening and refining the meaning of Biophilia - The innate desire to focus on life and establish an emotional connection - Human dependence on nature
Shelton, 1994	Hitting the green wall: Why corporate programs get stalled Corporate Environmental Strategy	Shared environmental activities, improving the quality of the built environment, and increasing green walls and roofs in cities.
Kellert & Wilson, 2008	Biophilia	-Nature inspires architecture -Design for all times
Beatley, 2011	Biophilic Cities: integrating nature into urban design and planning	Biophilic city, standards, indicators, design, and performance
Makes & Sense, 2012	the economics of Biophilia	Human's natural attraction towards nature, a kind of economic investment, health, and even physiological productivity

Continiue of Table 1: Identification of the interstitial space fields from theorists' point of view

Source	The title of the research	Topics
Ryan et al., 2014	Biophilic design patterns: Emerging nature-based parameters for health and well-being in the built environment	- Providing 14 patterns for biophilic design -Connecting human biological sciences and the built environment
Newman, 2014	Biophilic Urbanism: a case study on Singapore	-Creating natural systems in buildings and their facades -creating natural systems between buildings and urban spaces
Abdelaal & Soebarto, 2019	Biophilia and Salutogenesis as restorative design approaches in healthcare architecture	-The concrete role of biophilic design in the treatment of Patients -Analysis of the reasons for the failure of today's industrial hospitals -The potential of returning to nature by adopting the principles of environmental design
Salingaros, 2019	The biophilic healing index predicts the effects of the built environment on our well-being	The relationship between biophilic design and the general health of people
Brielmann et al., 2022	What Happens in Your Brain When You Walk Down the Street? Implications of Architectural Proportions, Biophilia, and Fractal Geometry for Urban Science	Investigating the effect of visual stimuli in the first few seconds of exposure, its positive or negative effects on people's attraction in the street environment
Zhong et al., 2022	Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review	-Theoretical framework for interpreting 'nature' in architecture. - Emergence and definition of a biophilic design concept - Biophilic design and sustainable architecture
Tekin et al., 2023	A Systematic Review and Conceptual Framework of Biophilic Design Parameters in Clinical Environments	-Biofill design parameters -Environmental features for designing clinical treatment environments
Čákyová et al., 2023	The Concept of Green Industrial Zones	Providing solutions to transform urban gray areas into biophilic green areas

As can be seen in the research related to the biophilic approach, human dependence on nature, the effect of nature on the human psyche, and the improvement of human living conditions can be proven. Participation and interaction with the natural environment is one of its characteristics, and nature defines the environment and gives it character and meaning. (Fig.1)

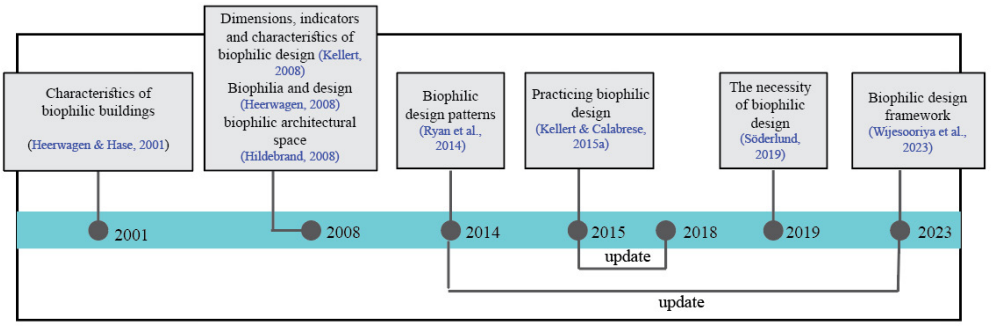

Fig. 1: Timeline of different approaches in biophilic design

As seen in Figure 1, research in recent years has been directed towards identifying biophilic design parameters in special specialized fields. Considering the gap in the biophilic design of interstitial spaces and related research, the effective factors of biophilic design in interstitial space and the effects of using biophilic design features in the interspace of residential complexes will be investigated. In this regard, the research on this topic is given in Table 2.

Table 2: A selection of research conducted in the field of interspace

Source	The title of the research	Topics
Zucker, 1960	Town and Square: From the Agora to the Village Green	Field of occasional mental stops in terms of the urban landscape, social interaction, social aspects, and current activities
Gehl, 1987	Soft edges in residential streets	Physical features of the street edges
Afrogh, 1998	space and social inequality, providing a model for spatial selective segregation and its consequences	Providing a model for spatial selective separation and its consequences
Bentley et al., 2003	Responsive environments	This book emphasizes the environmental quality of collective arenas and physical organization, physical permeability, Visual penetration, diversity, flexibility, possibility of personalization, and richness.
Lang, 2004	Creation of Architectural Theory, The Role of Behavioral Sciences in Environmental Design	Social interaction and built environment, sociable space and non-sociable space, the pattern of social interaction in regions
Madanipour, 2005	Urban space design (attitude on the social and spatial process)	Understanding the urban space, the structural frameworks of the urban space and people and the city, the process of urban design
Tibbalds, 2005	Making people-friendly towns improving the public environment in towns and cities	Models and successful examples of urban environments
Lynch, 2005	A Theory of Good City Form	The relationship between human values and the physical-spatial city
Jacobs, 2011	Death and life of large American cities	Objective and strong search and observation of the surrounding phenomena and people's daily life
Holten et al., 2015	Social life under cover: tree canopy and social capital in Baltimore, Maryland	Personal variables (age, education, income), local green space
Hady, 2021	Activating biophilic design patterns as a sustainable landscape approach	Examining biophilic design patterns in common with landscape design patterns
Abazari et al., 2022	A biophilic well-being framework for positive indoor-outdoor connections in energy-efficient Arctic buildings	Introduction of effective biophilic patterns in heating buildings and energy consumption efficiency

By examining the research conducted in the field of interstitial spaces, it can be concluded that some characteristics of interstitial spaces have more effects on the livability of these spaces and their quality. For example, the amount of local green space, the setback of the building from the crossing, the amount of green space encroaching on the privacy of residential blocks, and physical distances can be considered and improve the quality of interspaces.

Characteristics of Spaces Between Biophilic Residential Complexes

Biophilic and Re-connect with Nature

In 1984, Wilson introduced the hypothesis of Biophilia as "the need to communicate with other living species" (Simaika & Samways, 2010, 12). Wilson's biophilic hypothesis shows an instinctive link between humans and other living systems. Recently, in the United States of America, Browing et al. (2014) proposed 14 biophilic design models to link life sciences and nature with the built environment and improve the indicators of biophilic design. The use of these models leads to health improvement and the quality of individual and collective life. Also following the theory of Biophilia, the biophilic design developed by Kellert and Bitley seeks to re-connect people with the natural environment throughout the world (Figure 2) (Amat et al., 2020, 2).

In general, in the last decade, little research has been done in this field, and a complete understanding of the application of this theory, its principles, the processes that lead to the design of a biophilic environment, and how to use the biophilic theory to improve the environment of existing cities, does not exist. Also, specific methods for connecting with nature have not been systematically studied.

One of the reasons for this is that communication, feelings, meaning, and love, which are the spiritual consequences of connecting with the beauties of nature, are not science-based concepts yet. However, progressive research in this field shows that a positive and close relationship with nature will lead to pro-environmental attitudes and well-being benefits (Martin et al., 2020, 36).

The findings show that contact, feelings, meaning, compassion, and beauty are the ways to improve the relationship with nature (Fig.3) (Richardson & Butler, 2022, 4).

The mutual effects of humans and nature are more understandable when we fully understand the complex relationship between the mind, body, culture, and environment (Giusti, 2019, 14) (Figure 4).

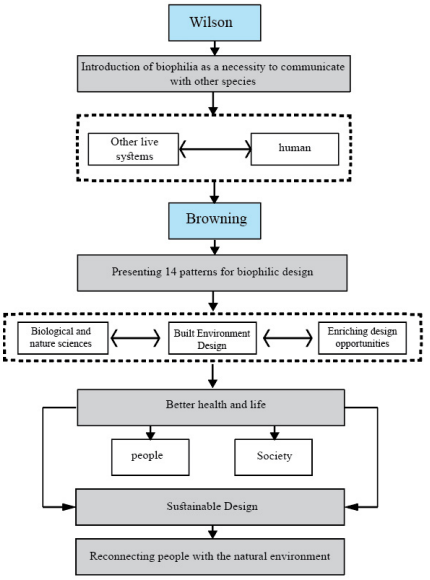

Fig. 2: Evolution of the basics of biophilic design and re-connecting with nature

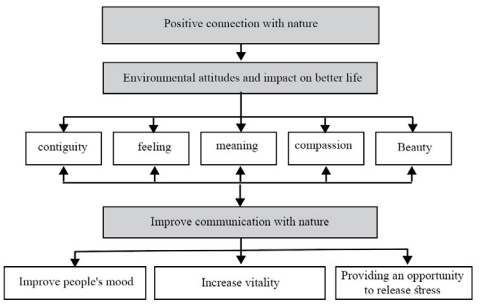

Fig. 3: Positive relationship with nature and its effects

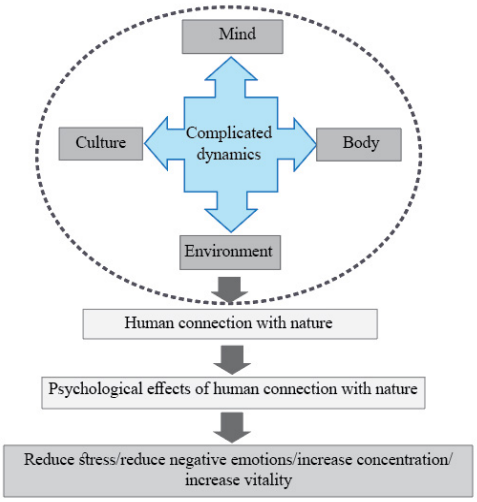

Fig. 4: Interactions between humans and nature

A positive relationship with nature is an important indicator of well-being, health, and happiness in a way that can be compared with important indicators such as income and education. (Capaldi et al., 2014, 11) Communication with nature is not only important and effective in the individual field but also the social field. It can cause the development of nature; Because personal connection with nature will lead to pro-environmental tendencies and will subsequently lead to positive behaviors in the direction of protecting and caring for the environment (Oliver et al., 2022, 3); While the relationship between connection with nature and well-being, quality of life, health, and environmental protection attitudes is a proven issue; But the connecting roots of this connection are not precisely known (Zylstra et al., 2014). A thorough investigation of the methods leading to this continuous communication is needed.

Every day, more and more evidence shows that the imperceptible connection with the natural environment can be effective in people's mental recovery. In general, research on healing environments shows that exposure to these environments, for example: walking in the forest, or looking at patches of green space from windows, can reduce stress (Parsons et al., 1998; Ulrich et al., 1991), reducing negative emotions (Cackowski & Nasar, 2003; Kweon et al., 2008), reducing visual fatigue (Berto, 2005; Hartig et al., 2003) and increasing vitality. (Ryan et al., 2010).

Necessity of Biophilic Design

As the urban population increases in the world, the importance of biophilic properties will also increase. The truth is that every year a large amount of money is spent on diseases caused by stress, and it is possible to use biophilic design to provide spaces with the least amount of stress and better health and quality (Scull, 2011; Pyle, 2003).

There is much convergence between the concepts and scales related to interaction with nature, which indicates a developed order in the common natural structures. (Tam, 2013) Also, the disconnection between humans and nature will cause environmental crises (Tam, 2013; Zylstra et al., 2014). From the mentioned cases, it can be concluded that the connection with nature is a stable state of consciousness, which includes: coexistence, influence, and experiential behaviors and creates a kind of intelligent resilience between people's individuality and nature. As a result, nature can be a place to escape from the existing situation to increase the quality of life. The biophilic design allows the use of nature, daylight, air, and life force as design elements to increase the quality of spaces and strengthen collective experiences in societies. (Gür & Kaprol, 2022)

Besides including green spaces and ecosystems, biophilic design can enrich the multi-sensory and multi-dimensional experiences in individual and social terms and enable the users to participate in this experience. In addition to looking for a healthy and safe life, this approach creates stable and resistant cities. (Gür & Kaprol, 2022) Due to the spread of urbanization and its widespread isolation, human life has inevitably faced long-term living and working in small spaces, which will negatively affect people's mental health and cognitive performance. Perhaps one of the solutions to these problems is to introduce design with a biophilic approach in which plants are often very important elements. (Li et al., 2022)

Identification of Biophilic Primary Criteria from the Viewpoints of Experts

From some experts' points of view, the biophilic criteria are presented in Tables 3 to 5.

Table 3. The six main elements of biophilic design and their indicators (Source: Kellert & Wilson, 2008)

Environmental features	Natural forms	Patterns and natural processes	light and space	Relationships based on place	Evolved human-nature relations
Color	Plant motifs	Sensory changeability	Natural light	Geographic connection to the place	Landscape and refuge
Water	Trees and strengthening of vertical movements	Abundance of information	Filtered and diffused light	Historical connection to the place	Order and complexity
Air	Animal motifs (mainly vertebrates)	Age, changes, and the passage of time	light and shadow	Ecological connection to the place	Curiosity and seduction
Sunlight	Shells and snails	Growth and Effectiveness	reflected light	Cultural connection to the place	Change and metamorphosis
Plants	oval and tubular shapes	The central point	Waterfronts	Native materials	Security and protection
Animals	Arches, vaults, domes	General patterns	Warm color lights	A central perspective	Dominance and control
Natural materials	Avoid geometric shapes, straight lines, and right angles	spaces with defined borders	Lights with different shapes	Landscape features that define the building form.	love and affection
Landscape and Views	Simulation of natural features	transitional spaces	The lights that define a special space	Landscape ecology	Attraction and beauty
Green facades	biomorphic	Series and related chains	Spatial changeability	Integration of culture and ecology	Recognition and discovery
Land morphology and landscape	geomorphology	Composition of components	Space as form	The soul of the place	Information and knowledge
Habitats and ecosystems	Biomimicry	Complementary differences	Spatial coordination factor	Avoid being out of place	fear and grandeur
		Dynamic tension and calm	Defining indoor and outdoor spaces		Spirituality and respect
		Complex geometry and fractals			
		Hierarchically organized			

Terrapin has studied three categories of relational values of nature and related patterns, which help biophilic design. The performance extracted from these models is mentioned in Table 4.

Kellert and Calabars have also investigated the biophilic criteria and their effects on users from another point of view. These criteria are presented in Table 5.

Table 4. Fourteen biophilic design patterns in terms of Terrapin (Source: Browning et al., 2014)

Values	Patterns	Function
Nature in architecture	A visual connection with nature	View of natural elements
	non-visual connection with nature	The feeling of referring to nature
	Non-rhythmic sensory stimuli	The subconscious relationship with nature
	Thermal changes and airflow	Small changes in the weather with a natural routine
	presence of water	Increasing the effectiveness of nature by using water
	dynamic and diffuse light	different intensity of light at different times
	Relationship with natural systems	Dominate nature
Natural similarity	Shapes and patterns similar to nature and biomorphic	A shape that evokes nature in mind
	Physical connection with nature	Use of local materials
	Complexity and regularity	sensory richness
Architecture in nature	landscape	Free view for viewing and planning
	refuge	An independent area that is protected from the surrounding
	Mystery	Promoting a deeper journey to discover more scenes
	Risk and danger	The detectable risk with reliable security

Table 5: The effects of biophilic criteria on the skills and performance of environmental users (The author obtained from Kellert & Calabrese, 2015b)

Values	Pattern	Function
usefulness	Natural performance benefits (such as using natural materials and resources.)	Improving mental, emotional, and intangible capacities
Territorialism	The desire to consider nature as a territory (such as belonging to a mountain's glory or a river's roar.)	A sense of security, freedom, integrity, self-respect, and problem-solving ability
naturalism	The origin of revitalization, promotion, and diversity increases nature awareness.	Developing and increasing the feeling of clarity, strength, and peace
scientific	A source of experimental science and cognitive literacy	Promoting critical thinking, problem-solving, and mental skills
symbolic	Source of imagination, connection, and intellect.	Increasing imagination, innovation, connection, and subtle mental maturity
beauty	Inspiring a sense of beauty and attraction	Developer of curiosity, discovery, imagination
humanistic	A source of affection and emotion	Forming friendships, cooperation, sociability, and trust
avoidant	Avoiding fear of natural dangers	Positive feelings towards awe, value, and return to nature
moralistic	The source of spiritual and moral inspiration	Promoting a sense of importance, spiritual belonging, self-confidence, dependence on nature, and unity with the whole being

By summarizing these tables, it is possible to reach the general criteria of biophilic design and to be able to combine these criteria with the criteria of the desired interstitial space. Each of these classifications can inspire biophilic design patterns in residential complexes' interspaces.

Interstitial Space

The Effect of Connecting with Nature on the Interstitial Space

One of the solutions is to expand the space and connect to the surroundings of the building and create spatial connections between buildings, increase green spaces, expand them, and provide biophilic interface spaces. Therefore, understanding the characteristics of biophilic intermediate spaces can be helpful in this field; (Van Nes & Yamu, 2021a). An attraction that causes the presence of the residents of the houses next to the windows or encourages people to bring light views. Into the buildings (Day, 2017). In Table 6, the principles of biophilic design related to the interstitial natural space are given from Klert's point of view. (Table 6)

Intervening Spaces in Residential Complexes

What are the interspaces and spatial distances from the body of the building? And what are their characteristics? It has always attracted opinions and has been discussed from different points of view. These Interstitial spaces are semi-public and public spaces and semi-private spaces of urban spaces.

Green space plays an important role in improving the livability of cities, which has always been under much pressure due to the high speed of city development and increasing urbanization. The importance of urban green spaces is not a new issue, but in recent decades, comprehensive information has become available about a wide range of social, economic, and environmental benefits that make cities more livable and attractive (DE, 2017). Several studies have shown that urban green spaces provide benefits related to individual health and well-being, such as calm (Chiesura, 2004), recreation (Koohsari et al., 2015), and connection with nature (Schiebel et al., 2022). Other studies have confirmed that green spaces are necessary to improve air quality and provide habitats for wildlife (Vidal et al., 2022; Ma & You, 2022).

In addition, studies have revealed important advantages related to the cultural benefits of urban green spaces, such as landscape aesthetics, outdoor recreation, and cultural values (Gehl, 1987; McCann & Mahieus, 2021; Van Nes & Yamu, 2021b). Table 7 shows the characteristics of desirable urban open spaces.

Table 6: Principles of biophilic design related to interstitial natural space according to Kellert (Source: Kellert & Calabrese, 2015b)

Biophilic design requires frequent and sustainable interaction with nature.
The biophilic design focuses on human adaptations to the natural world and improves people's health, fitness, and well-being over time.
The biophilic design causes emotional attachment to special places.
Biofill design promotes positive interactions between people and nature and will increase people's feelings and responsibility in human and natural societies.
Biophilic design increases synergy, connection, and integration in architectural design.

Table 7: Desirable urban open space indicators based on the RIBA report

	features	Created quality
1	A suitable place for a suitable housing	Qualifying sense of belonging
2	A place to start and a place to stay	
3	A place to cultivate a sense of belonging	A sense of loyalty and belonging
4	A place for living in nature	Merging with nature and comfort
5	A place for enjoyment and pride	the pleasure
6	A place with the possibility of becoming a home	Sense of belonging and comfort
7	A place where people feel at home	
8	A place with a unique and, at the same time, lasting feeling	distinction
9	A sustainable place for future generations	sustainability
10	A place where people grow	Sociability

MATERIALS AND METHODS

This study aimed to investigate the theoretical modeling of the effective components of the biophilic design of the spaces between residential complexes and the design of the relationships of these factors. The research method in this article is descriptive-analytical and applied in terms of results. The content analysis method was used to determine the theoretical modeling of the components affecting the biophilic design of the residential complex intervening spaces.

In the section on interpretive structural modeling, expert academic opinions in architecture and Urbanism have been used through the Delphi method. In this research, data collection tools after applying a qualitative research approach through systematic review were interviews and binary questionnaires, and the face validity criterion was used to assess the validity of the questionnaire or any measurement instrument.

Interpretive-structural modeling is a systematic and structured method of establishing relationships and understanding the relationships between complex system elements, introduced by Warfield in 1974. Interpretive Structural Modelling (ISM) is a process of interaction in which a set of different and interrelated elements is structured into a comprehensive systematic model.

The method investigates the complex relationships between system elements, in other words, a tool by which the group can overcome the complexity between elements (Ali Akbari & Akbari, 2017, 10). This methodological framework helps create and orient complex relationships among system elements.

The main idea of interpretive structural modeling is to break down a complex system into several subsystems, using experts' practical experience and knowledge to build a multilevel structural model (Azar et al., 2013, 286-257).

Sampling method: Delphi and interpretive structural modeling methods require that information be received and analyzed from experts and experts. Since the goal is not to generalize the results, a purposeful sampling method has been used to select the Delphi and ISM teams.

The criteria for selecting experts are theoretical fluency, practical experience, willingness and ability to participate in research, and accessibility. A significant point in determining the number of experts is to ensure the comprehensiveness of different viewpoints in research. The number of experts participating in ISM of reviewed articles is usually between 14 and 20 (Akbari et al., 2020, 289).

According to the above criteria, 20 experts and specialists from universities and research centers have been selected to participate and cooperate in the research process.

Content Validity: Using the content analysis method, factors affecting the biophilic design of the intervening spaces of residential complexes have been identified, and to interpret the relationships between those dimensions and indices, interpretive structural modeling (ISM) has been performed.

Because this model is a desirable method for identifying and analyzing the relationships between dimensions and indicators, the content validity of the questionnaire in this study refers to the extent to which a tool reflects the specific content of the study.

According to Lavsheh's method, to create content validity in the questionnaire, first, by reviewing the literature in the field of study, the scope of content and items of the questionnaire is developed. The members of the content panel are asked to respond to the appropriateness of each item by selecting one of three options: "Essential," "Useful but not Necessary," or "Unnecessary" (Jafari Mehrabadi et al., 2017, 686).

Accordingly, with the help of relationship number one, the content validity ratio is calculated, and according to the required level of statistical significance ($p>0.05$), at least CVR=0.75 for each stage is obtained for acceptance of that stage. For example, the content validity ratio for the biophilic design of the spaces between residential complexes is 0.8 and is calculated as follows. In other words, it means more clearly:

$$CVR == \frac{N_{e-\frac{N}{2}}}{\frac{N}{2}} = \frac{19-\frac{20}{2}}{\frac{20}{2}} = 0/8$$

(Equation 1)

N_e =The number of members who responded to the need,

N =Total number of panel members

Reliability: A test-retest method has been used to measure the reliability of the ISM questionnaire. Accordingly, the questionnaire was sent again to 3 experts and experts who could be re-accessed. Finally, the total correlation of the responses announced by experts for both stages was calculated at 0.785. This indicator confirms that the questionnaire has acceptable reliability.

Interpretive structural modeling process:

Step 1: Identify the variables related to the problem. This step is done by reviewing past studies and receiving expert opinions.

Step 2: Form a structural self-interaction matrix. In this step, variables are checked in bilaterals, and the respondent determines the relationships of the variables using the following symbols:

The symbol V: i leads to J.

The symbol A: That is the j that leads to i.

Symbol X: Two-way communication from i to j and vice versa

Symbol O: There is no relationship between i and j.

Step 3: Create an initial access matrix. At this stage, the structural self-interaction matrix becomes a binary matrix, and the initial access matrix is obtained. The structural self-interaction matrix is transformed into a binary matrix called the primary access matrix by converting symbols A and O to 0, X, and V into one.

Step 4: Create the final access matrix. After the initial access matrix is obtained, the final access matrix is obtained by entering transferability in the relationships of variables.

Step 5: Warfield's surface segmentation states two main rules for leveling.

Rule 1: Determine the total frequency of elements based on the total output column and the common set, from the smallest to the largest abundance, respectively.

Rule 2: According to this rule, known as the rule of repetition, the first table is leveled according to the smallest total of frequencies in the column, the sum of output, and the common sum, the element or elements. The surface elements are removed from the table, and the rule is re-executed. The process of elimination and indirect relations is generalized.

Identification of Effective Components on Biophilic Design of Spaces between Residential Complexes

This paper investigates recent research in the intermediary spaces of biophilic residential complexes considering the proposed methods for systematic review. This method consists of four steps:

1) search by online database, 2) screening process, 3) access to selected articles, 4) summing up related articles. In the first step, to obtain related articles, four comprehensive databases of Google Scholar, Science Direct, Web of Science, and Scopus were used as the main sources of receiving articles. Biophilic principles, interstitial space efficiency, residential sets, and the theoretical model were searched in scientific databases.

Google search engine was also used to define other terms related to this subject and organizations related to this research. On the other hand, gray resources related to the subject were used as information sources, including conference papers, conferences and congresses, websites, and other studies.

In this context, the terms biophilic principles, interstitial space efficiency, biophilic residential complexes, biophilic design, biophilic landscape, and theoretical model were used as search keywords which resulted in finding 1024 articles.

Although this paper aims to discuss biophilic interstitial spaces in residential complexes, there are few studies in this regard. Therefore, studies in landscape and biophilic green space (if they align with this study) were added to this study.

In the second and screening stage of the articles, 510 articles and their derivatives were selected from the results of the most relevant articles containing the term biophilic principles, the space between biophilic residential complexes, biophilic landscape, and its derivatives. There are several sources in this area that the characteristics of the inter-space spaces of biophilic residential complexes should be identified to achieve an accurate definition of biophilic residential spaces as a new concept in architectural knowledge and architectural design. Therefore, by reviewing the related terminology, a wide range of identification sources and features of the inter-space spaces of biophilic residential complexes will be identified.

In addition, resources classified in subject areas other than the ones studied are excluded. In the next step, after obtaining the full file of the articles, the process continued by reading each article's keywords, summaries, and conclusions and scanning its content to determine the relevance of the articles to the proposed study.

Of these, 114 articles were not congruent in content and were excluded from the list of resources. This process led to finally 396 articles on the intermediary spaces of biophilic residential complexes as case studies of this study by meta-analysis method.

Finally, to categorize the contents of each article, the following items were examined: 1) What are biophilic spaces in the paper? 2) Has the biophilic outer spaces been studied in the paper? 3) Is the article in biophilic interstitial spaces in residential complexes? Finally, 84 sources were cited in this study.

Finally, by expanding the patterns of Trapine and Kellert mentioned in separate tables and also theorists in this area, table 8 is extracted in which the categories of nature and architecture, the studied criteria, and the created qualities are extracted from these components, goals, and examples.

Then, the dimensions and factors obtained by 20 experts in architecture and Urbanism were evaluated and finalized using the Delphi method. (Table 8)

Table 8: Primary Components Identification Effective on Biophilic Design of Spaces between Residential Complexes

Artificial Examples	Natural examples.	Goals	Qualities created.	Components	Categories
Simulation of Nature sounds	Runoff water	Interaction to reduce Stress	Recognizable and Relaxing	Non-visual connection with nature	Presence of Nature in Architecture
Green walls.	Animals	Decentralization in the direction of relaxation.	Stimulating and Sedative	Visual connection with nature	
Waterfront surface	breeze	Vitality and vitality of the mind	Attractive and energetic.	Non-rhythmic sensory stimulus	
Artificial Ventilation	Shade and Sunshine	The feeling of airflow and Thermal changes	Alive and refreshing	Thermal and airflow variation	
Aquarium	Visual access to rain	Increased thinking and experience.	Stimulating and relaxing	The presence of water	
Artificial light	Sunlight.	Increased attention and circadian rhythm of the bio	Feeling calm and romantic	Dynamic & Comprehensive Light	
Use of water in infrastructure	Geology	To increase awareness and Ecosystem Management	Memorable Relaxing Thinker	Contact with natural systems.	
Form/Function	Furniture	Connection to nature	Attractive, comfortable, intermediary.	Forms and patterns derived from nature	Natural similarity.
Inspirational Shape Furniture	Natural shapes as furniture decorations				
Skyline Building	Planting design, diversity, and plant habitat	To create an environment with visual nutrition	Information richness and fun.	Order and complexity.	
Pedestrian bridges with natural materials	Nature's color tonnage (especially green)	Finding Optimum Natural Ingredients	Perfect, warm, authentic.	Use of natural materials	
Spaces for reflection and meditation.	Numerous small shelters.	Assists in access and protection of the area	Reflective, protective, surrounding.	Refuge	Architectural Presence in Nature
Common Characteristics	Spatial Properties	Allows visual examination of the perimeter.	Open, Secure and Controlled	Outlook	
Possibility to see from above.	Space distance is more than 6 meters.				
Visual Clarity of the Shields and even Floor Floors	Attraction	To stimulate attention, Curiosity, memory and Problem-Solving Skills	Excitement with imperceptible risk.	Risk and danger.	

Structural Self-Interactive Matrix (SSIM)

After identifying the factors affecting the biophilic design of the interspace between residential complexes, these factors were entered into the structural self-interaction matrix (SSIM). To this end, a questionnaire was designed, the same as Table 9, so that thirteen factors were selected in the first row and column of the table were mentioned, and the respondents were asked to specify the type of double-correlation between the factors.

Interpretive structural modeling suggests expert opinions based on different management techniques, such as brainstorming and nominal group. It should be used in developing content relationships between variables.

Therefore, this matrix was formed using four modes of conceptual relationships and has been completed by 20 experts and experts in architecture and urban planning. The data is aggregated based on the interpretive structural modeling method, and the final structural interaction-self-interaction matrix is formed. The symptoms and moods used in this conceptual relationship are:

The symbol V: i leads to J.

The symbol A: That is the j that leads to i.

Symbol X: The two-way relationship from I to J and vice versa; symbol O: There is no relationship between i and j. (Table 9)

Primary Access Matrix

The initial access matrix is derived from transforming the structural self-interaction matrix into a two-value matrix (0-1). To extract the access matrix, one must replace the V symbols in each row; X and zero replace the symbols; A and O, and in the primary access matrix, the resulting result is called the primary access matrix after transforming all rows. Secondary relationships between dimensions/indicators are then controlled. The secondary relationship is such that if the dimension J leads to the I dimension and the dimension K leads to the other, then the J dimension leads to the K dimension. The matrix can be obtained by converting the symbols of SSIM matrix relations to zero and one number according to the following rules. These rules are as follows: If the cell (i,j) in the SSIM matrix takes the symbol V, the corresponding house in the access matrix gets one, and its symmetry house, house (j, i), gets zero. If the house (i,j) in the SSIM matrix has the symbol A, the corresponding house in the access matrix gets zero, and its symmetry house (j, i) gets 1. If the cell (i,j) in the SSIM matrix takes an X symbol, the corresponding house in the access matrix gets 1, and its symmetry house (j, i) gets 1. If the cell (i,j) in the O matrix assumes the symbol SSIM, the corresponding house in the access matrix gets zero, and its symmetry house (j, i) gets zer) . According to the rules of the ISM technique, the initial access matrix is converted according to Table 10.

Table 9: Structural Self-Interaction Matrix of Effective Biophilic Components in Efficiency of Residential Complexes Between Spaces

J / I	Components	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13
c1	Non-visual connection with nature	_	X	A	A	v	A	X	A	A	V	X	A	A
c2	Visual connection with nature		_	X	V	A	V	A	X	V	X	O	X	O
c3	Non-rhythmic sensory stimulus			_	A	O	X	X	A	A	A	O	V	O
c4	Thermal and airflow variation				_	A	X	A	V	V	V	X	V	O
c5	The presence of water					_	V	X	V	A	A	O	X	O
c6	Dynamic & Comprehensive Light						_	A	X	V	V	A	X	V
c7	Contact with natural systems.							_	X	X	A	O	V	A
c8	Forms and patterns derived from nature								_	V	X	X	A	O
c9	Order and complexity.									_	V	O	A	A
c10	Use of natural materials										_	X	A	X
c11	Refuge											_	O	X
c12	Outlook												_	O
c13	Risk and danger													_

Final Access Matrix

After forming the primary access matrix of the components affecting the biophilic design of the interspace between residential complexes by involving transferability in the relationships of variables, the final access matrix is formed to adapt the initial access matrix. If (i,j) are related and (j,k) are related, then (i,k) are related. The transferability of conceptual relationships between variables in interpretive structural modeling is a basic assumption and indicates that if variable A affects variable B and variable B affects variable C, A affects C. All secondary relationships between variables are checked in this step, and the final access matrix is obtained according to Table 11. In this matrix, the influence strength and dependence of each variable are described. The influence power of each variable is the final number of variables (including itself) that can contribute to their creation. Dependency is the final number of variables that cause the said variable.

In Table 11, the influence of each factor on other factors is shown in 13 factors affecting the biophilic design of the spaces between residential complexes.

The results indicate that the communication component with natural systems with a penetration power of 9 has the highest effect and encourages development, promotion, order, and complexity with the lowest penetration power of 4

Table 10: Primary Access Matrix

J / I	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13
c1	1	1	0	0	1	0	1	0	0	1	1	0	0
c2	1	1	1	1	0	1	0	1	1	1	0	1	0
c3	1	1	1	0	0	1	1	0	0	0	0	1	0
c4	1	0	1	1	0	1	0	1	1	1	1	1	0
c5	0	1	0	1	1	1	1	1	0	0	0	1	0
c6	1	0	1	1	0	1	0	1	1	1	0	1	1
c7	1	1	1	1	1	1	1	1	1	0	0	1	0
c8	1	1	1	0	0	1	1	1	1	1	1	0	0
c9	1	0	1	0	1	0	1	0	1	1	0	0	0
c10	0	1	1	0	1	0	1	1	0	1	1	0	1
c11	1	0	0	1	1	1	0	1	0	1	1	0	1
c12	1	1	0	0	1	1	0	1	1	1	0	1	1
c13	1	0	0	0	0	0	1	0	1	1	1	0	1

Table 11: Final Access Matrix

J / I	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	Leverage
c1	1	1	0	0	1	0	1	0	0	1	1	0	0	5
c2	1	1	1	1	0	1	0	1	1	1	0	1	0	8
c3	1	1	1	0	0	1	1	0	0	0	0	1	0	5
c4	1	0	1	1	0	1	0	1	1	1	1	1	0	8
c5	0	1	0	1	1	1	1	1	0	0	0	1	0	6
c6	1	0	1	1	0	1	0	1	1	1	0	1	1	8
c7	1	1	1	1	1	1	1	1	1	0	0	1	0	9
c8	1	1	1	0	0	1	1	1	1	1	1	0	0	8
c9	1	0	1	0	1	0	1	0	1	1	0	0	0	4
c10	0	1	1	0	1	0	1	1	0	1	1	0	1	7
c11	1	0	0	1	1	1	0	1	0	1	1	0	1	7
c12	1	1	0	0	1	1	0	1	1	1	0	1	1	8
c13	1	0	0	0	0	0	1	0	1	1	1	0	1	5
Dependency Rate	10	7	6	5	6	8	7	8	7	9	5	6	4	-

Leveling of Effective Components on Biophilic Design of Residential Spaces

After the final access matrix, different levels are sorted at this research stage. To determine the level of components in the final model, three sets of output, input and joint are formed for each of them. In the first table, the components that share the output set and the input are the same in the hierarchy process, so these variables are ineffective in creating any other component.

After identifying the highest level, those components are excluded from the list of other variables. These repetitions continue until the surface of all components is determined. In this paper, thirteen tables of six levels of components have been obtained, the final result of which is stated in Table 12. Effective biophilic components in the efficiency of inter-space spaces of residential complexes whose common and output sets are identical are at the highest level of the interpretive structural model hierarchy.

As seen in Table 12, the components affecting the biophilic design of residential spaces have been classified into six levels. The ISM graph shows the interrelationships and influence between components and their relation to different levels, leading to a better understanding of the decision-making space.

In this section, the component of the relationship with natural systems with a penetration power of 9 is located at the lowest level, which acts as the underlying stone of the model, and the biophilic design of the intervening spaces of residential complexes should start from this component and spread to other components.

It should be noted that all of these components are among the most important factors in biophilic components effective in the efficiency of the intervening spaces of residential complexes. However, the factors located in the high level of interpretive structural modeling are more effective. (Figure 5).

Table 12: Leveling of Effective Components on Biophilic Design of Residential Spaces

Code	Components	Output set	Input set	Shared Collection	Level
c1	Non-visual connection with nature	2,5,7,10,11	2,3,4,6,7,8,9,11,12,13	11,2,7	Second
c2	Visual connection with nature	1,3,4,6,8,9,10,12	1,3,5,7,8,10,12	1,3,8,10,12	fifth
c3	Non-rhythmic sensory stimulus	1,2,6,7,12	2,4,6,7,8,9,10	2,6,7	Second
c4	Thermal and airflow variation	1,3,6,8,9,10,11,12	2,5,6,7,11	6,11,13	fifth
c5	The presence of water	2,4,6,7,8,12	1,7,9,10,11,12	7,11	Third
c6	Dynamic & Comprehensive Light	1,3,4,8,9,10,12,13	2,3,4,5,7,8,11,12	3,4,8	fifth
c7	Contact with natural systems.	1,2,3,4,5,6,8,9,12	1,3,5,8,9,10,13	1,3,5,8,9	Sixth
c8	Forms and patterns derived from nature	1,2,3,6,7,9,10,11	2,4,5,6,7,10,11,12	2,6,7,10,11	fifth
c9	Order and complexity.	1,3,5,7,10	2,4,5,6,7,8,12,13	5,7	First
c10	Use of natural materials	2,3,5,7,8,11,13	1,2,4,8,9,11,12,13	2,8,11,13	Fourth
c11	Refuge	1,4,5,6,8,10,13	1,4,8,10,13	1,4,8,10,13	Fourth
c12	Outlook	1,2,5,6,8,9,10,13	2,3,4,5,6,7	2,5	fifth
c13	Risk and danger	6,10,11,12	1,7,9,10,11	10,11	Second

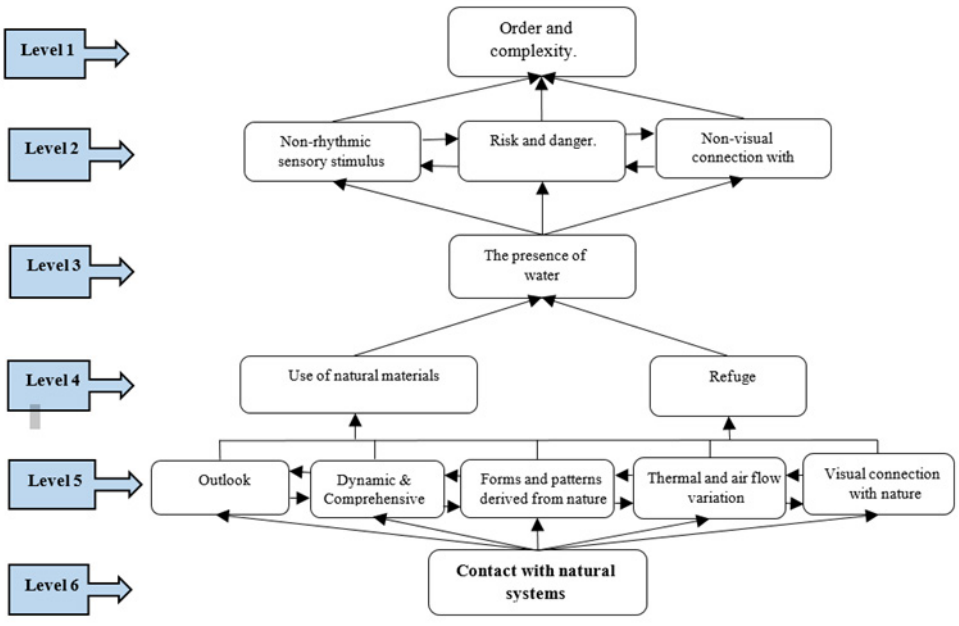

Fig. 5: Theoretical Model of Biophilic Components Effective in the Efficiency of Residential Complexes between Spaces

Source: Research findings.

RESULTS AND DISCUSSIONS

By expanding the models of Terrapin and Kellert, which have been mentioned in separate tables, as well as summarizing the theories of the experts in this field in table 8, the categories of nature and architecture, the studied models, the qualities created from these models, the goals and examples have been extracted.

Presentation of the Theoretical Model

The purpose of this research is to present a theoretical model. The authors prepared this theoretical model as a result of the research after examining the ideas of previous researchers, each of whom gradually completed the results of the previous researcher. Researchers have already stated many indicators of this theoretical model, but the authors identified the overlap of these indicators by examining the characteristics of biophilic design and the characteristics of desirable interstitial spaces. According to the article's purpose, the variables in the previous tables are presented in the form of the theoretical model of Figure 6.

Table 8: Biophilic patterns in the efficiency of interstitial spaces (source: authors)

Categorization	Patterns	Quality Created	Goals	Natural examples	Artifact examples
Nature's presence in architecture	Visual connection with nature	Stimulating and soothing	Decentralization to relax	animals	Green walls
	Non-visual connection with nature	Recognizable and comforting	Interaction to reduce stress	flowing water	Simulating the sounds of nature
	non-rhythmic sensory stimulus	Attractive and energetic	mental vitality	breeze	The water of a fountain
	Variety of thermal and airflow	Lively and refreshing	The feeling of airflow and thermal changes	Shadow and sun	artificial ventilation
	presence of water	Stimulating and soothing	Increase thinking and experience	Visual access to rain	aquarium
	Dynamic and comprehensive light	A feeling of peace and romantic	Increasing attention and daily life rhythm	sunlight	Artificial light
	Relationship with natural systems	Memorable thinker soothing	To increase awareness and management of ecosystems	Geology	The use of water in infrastructure
Natural similarity	Forms and patterns are taken from nature	Attractive, comfortable, inductor	Connection with nature	Furniture	Form/Function
				Natural forms as furniture decoration	Inspiration for the form of furniture
	Use of nature-oriented materials	Perfect, warm, credible	Finding optimal natural materials	Color tones of nature (especially green)	Bridges and walking side paths with natural materials
	Order and complexity	Rich information and entertainment	To create an environment with the possibility of visual feeding	Planting design, variety, and determining the place of plants	The skyline of the building
Architectural presence in nature	landscape	Open, safe, and controlled	Allows visual inspection of the surroundings	Spatial features	Common features
				Space distance of more than six meters	The possibility of seeing from above
	refuge	Contemplative, protective, and enveloping	Help to access and protect the area	Numerous small shelters	Spaces for thinking and meditation
	Mystery	Prediction	Encouraging space exploration	Stimulation of the senses from an invisible source	the scent
	Risk and danger	Excitement with imperceptible risk	For stimulating attention, curiosity, memory, and problem-solving skills	gravity	The visual transparency of the guards and even the floors

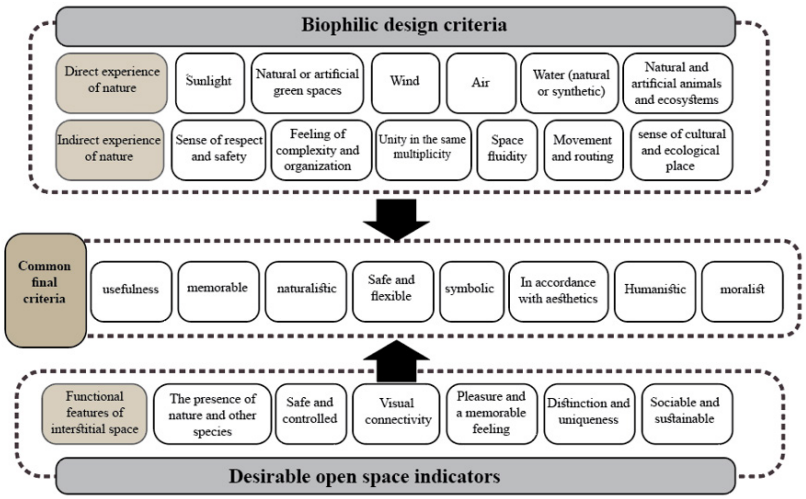

Fig. 6: a theoretical model

CONCLUSION

The most important public open space in residential areas are the intermediate spaces that provide access for the users of the residential space to the surrounding uses. Providing access from private space to semi-private and public space is perhaps the most important function of intermediate spaces in residential complexes, and for this reason, its quality and function are important. Interstitial spaces are a complement to the private residential space and an extension of it. Therefore, it should be able to support and improve people's private lives. Due to the connecting and moving role of interspaces, there is a threat that these spaces will have a one-dimensional function, and with the construction of residential complexes, it will be difficult to make changes in the interspaces. On the other hand, with the characteristics that biophilic design has shown at the global level, biophilic design patterns can be used in the Interstitial space of residential complexes and provide more connection areas between space and nature to promote human well-being.

The conducted studies show that biophilic design patterns in Interstitial spaces affect the person's relationship with the environment. Individual connection with the environment will also cause positive social effects on nature; Because as much as a better relationship can be established between the person and the surrounding natural environment, efforts will be made to expand it, and it will promote nature. These criteria are in the form of direct experience of nature, including sunlight, green space, wind, air, water, animals, or natural ecosystems, or indirect experience of nature, including respect and security, order and diversity, and unity in diversity. , becoming one with the environment and considering oneself a part of the whole, the fluidity and flexibility of the environment, movement, and navigation, in such a way that the environment is permeable and legible, will include the feeling of being in a natural place.

These criteria are in the form of direct experience of nature, including sunlight, green space, wind, air, water, animals, or natural ecosystems, or indirect experience of nature, including respect and security, order and diversity, and unity in diversity. , becoming one with the environment and considering oneself a part of the whole, the fluidity and flexibility of the environment, movement, and navigation, in such a way that the environment is permeable and legible, will include the feeling of being in a natural place. The more these patterns are used, the efficiency of the interstitial space increases.

This research has provided new insight and understanding of how to increase the efficiency of the spaces using biophilic design patterns and integration of these patterns in residential intervening spaces, which identify priorities of action in the decision-making space. Accordingly, in this study, the effective components of the biophilic design of the spaces between residential complexes (13 components) were extracted using a qualitative research approach during a systematic review and relying on expert academic experts in architecture and Urbanism. Then, by designing a two-way questionnaire, expert opinions were collected to determine the relationship between factors, and finally, a theoretical model was designed using interpretive structural modeling. The results of this study show that the relationship with natural systems with a penetration power of 9 is the most effective and the strongest motivator of biophilic design of the intervening spaces between residential complexes and acts as the underlying stone of the model. On the other hand, the component of order and complexity with the penetration power of 4 has the least impact.

Since this article seeks to achieve how to increase the efficiency of interstitial spaces by using biophilic design patterns and integrating these patterns in residential interstitial space, Studies and classifications show what spatial qualities biophilic design patterns can provide in the interspaces of residential complexes and which of these qualities can be effective in the direction of which of the design goals. These patterns generally affect people's cognitive function, mood, relaxation, and stress reduction.

The connecting point of biophilic design and the design of the interstitial space is their essential commonality, which increases their sustainability. The direct and indirect use of natural elements in the design of intermediate spaces adds spatial qualities to these spaces, which various researchers have mentioned many times as the

characteristics of an efficient interspace. This intersection leads to creating useful spaces that can be used and beneficial to the users and interactively memorable spaces with activity-creating and memory-making factors. Spaces that are nature-oriented and play a role in preserving and developing nature; Spaces that have security and can accept other biological species for their sense of belonging and memories. Creating spaces that are the result of the said features will be able to create value and become symbolic. Spaces that will be considered as a measure of beauty in individual and collective memories and standards. The creation of spaces whose centrality is human and the shadow of modern development does not take it away from its humanistic scale, and with the values it creates in the interspace, it will grow human morality, which will be the sublime state of the design of interspaces.

For a better and more sustainable interaction in the interspace of residential complexes, paying attention to these features and trying to include patterns in biophilic design can be considered. Also, it seems that the naturalist spirit of humans will consciously and unconsciously include the features of friendly biophilic nature in their choice to create a desirable intermediate space.

AUTHOR CONTRIBUTIONS

F. Yazdanirotam performed the literature review, and experimental design, analyzed and interpreted the data, and prepared the manuscript text and edition Z. Saeideh Zarabadi helped in the literature review and manuscript preparation. F. Habib performed some of the remained experiments.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication or falsification, double publication and, or submission, and redundancy, have been completely witnessed by the authors.

REFERENCES

Abazari, T., Potvin, A., Demers, C. M., & Gosselin, L. (2022). A biophilic well-being framework for positive indoor-outdoor connections in energy-efficient Arctic buildings. Building and Environment, 226, 109773.

Abdelaal, M. S., & Soebarto, V. (2019). Biophilia and Salutogenesis as restorative design approaches in healthcare architecture.

Afrogh, E. (1998), space and social inequality, providing a model for spatial selective segregation and its consequences, Tehran: ¬¬Agah publication.

Akbari, M., Taherpour, F., Boostan Ahmadi, V., Fouladi, A. (2020). Structural-Interpretive Modeling of Factors Affecting the Development of Religious Tourism in Iran with Future Studies Approach. Tourism and Development, 9(4), 296-285.

Ali Akbari, E., Akbari M. (2017), Interpretive structural modeling of factors affecting the viability of Tehran metropolis. Journal of Space Planning and Planning, 21(1), 1-31.

Amat, R. C., Ismail, S., Wahab, M. H., Ahmad, N. H., & Rani, W. N. M. W. M. (2020). A Dimension of Biophilia in Urban Design. In IOP Conference Series: Earth and Environmental Science (Vol. 409, No. 1, p. 012016). IOP Publishing.

Azar, A., Khosravani, F. & Jalali, R. (2013). Soft Operation Research Problem Structured Approaches. First edition, Industrial Management Organization.

Beatley, T. (2011). Biophilic cities: integrating nature into urban design and planning. Island Press.

Beatley, T. (2016). Handbook of biophilic city planning & design. Island Press.

Bentley, I., McGlynn, S., Smith, G., Alcock, A., & Murrain, P. (2003). Responsive environments. Routledge.

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. Journal of Environmental Psychology, 25(3), 249-259.

Brielmann, A. A., Buras, N. H., Salingaros, N. A., & Taylor, R. P. (2022). What Happens in Your Brain When You Walk Down the Street? Implications of Architectural Proportions, Biophilia, and Fractal Geometry for Urban Science. Urban Science, 6(1), 3.

Browning, W. D., Ryan, C. O., & Clancy, J. O. (2014). Patterns of biophilic design. New York: Terrapin Bright Green, LLC, 3-4.

Buffon, G. L. L., & Daubenton, L. J. M. (1766). Histoire naturelle, générale et particulière, avec la description du Cabinet du Roi (Vol. 1). Chez JH Schneider.

Cackowski, J. M., & Nasar, J. L. (2003). The restorative effects of roadside vegetation: Implications for automobile driver anger and frustration. Environment and behavior, 35(6), 736-751.

Čákyová, K., Vertaľ, M., Vargová, A., & Vranayová, Z. (2023). The Concept of Green Industrial Zones. International Scientific Conference EcoComfort and Current Issues of Civil Engineering,

Capaldi, C. A., Dopko, R. L., & Zelenski, J. M. (2014). The relationship between nature connectedness and happiness: A meta-analysis. Frontiers in Psychology, 5, 976.

Chiesura, A. (2004). The role of urban parks for the sustainable city. Landscape and urban planning, 68(1), 129-138.

Day, C. (2017). Places of the soul: Architecture and environmental design as a healing art. Routledge.

DE, N. C. G. T. (2017). Ecosystem Services in the City—Protecting Health and Enhancing Quality of Life. Summary for Deci-Sion-Makers.

Fromm, E. (1964). Creators and destroyers. The Saturday Review, New York (4.1. 1964).

Gehl, J. (1987). Life between buildings (Vol. 23). New York: Van Nostrand Reinhold.

Giusti, M. (2019). Human-nature relationships in context. Experiential, psychological, and contextual dimensions that shape children's desire

to protect nature. PloS one, 14(12), e0225951.

Groenewegen, P. P., Van den Berg, A. E., De Vries, S., & Verheij, R. A. (2006). Vitamin G: effects of green space on health, well-being, and social safety. BMC public health, 6(1), 1-9.

Gür, M., & Kaprol, T. (2022). The Participation of Biophilic Design in the Design of the Post-Pandemic Living Space. In Emerging Approaches in Design and New Connections With Nature (pp. 75-106). IGI Global.

Hady, S. I. M. A. (2021). Activating biophilic design patterns as a sustainable landscape approach. Journal of Engineering and Applied Science, 68(1), 1-16.

Harel, K. L. (2022). Darwin's Love of Life: A Singular Case of Biophilia. Columbia University Press.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T.) 2003). Tracking restoration in natural and urban field settings. Journal of Environmental Psychology, 23(2), 109-123.

Heerwagen, J. (2008). Biophilia and design. Handout for Portland lectures.

Heerwagen, J., & Hase, B. (2001). Building biophilia: Connecting people to nature in building design. Environmental Design and Construction, 3, 30-36.

Hildebrand, G. (2008). Biophilic architectural space. Biophilic design: the theory, science, and practice of bringing buildings to life Hoboken, New Jersey: John Wiley & Sons.

Holtan, M. T., Dieterlen, S. L., & Sullivan, W. C. (2015). Social life under cover: tree canopy and social capital in Baltimore, Maryland. Environment and behavior, 47(5), 502-525.

Howard, E. (1946). Garden cities of tomorrow. Faber London.

Jacobs, D. (2011). Death and life of large American cities. Russ. ed.: Dzhekobs D.(2011)Smert'izhizn'bol'shikh Amerikanskikh Gorodov. Moscow: Novoe Publ.

Jafari Mehrabadi, M., Akbari, M., Ataei, F., Razeghi Chamazkati, F. (2017). Interpretive Structural Modeling of Factors Affecting the Development of Food Tourism (Case Study: Rasht). Human settlements planning studies, 12(3), 681-698.

Kellert, S. R. (2008). Dimensions, elements, and attributes of biophilic design. Biophilic design: the theory, science, and practice of bringing buildings to life, 3-19.

Kellert, S. R., & Wilson, E. O. (1993). The biophilia hypothesis.

Kellert, S. R., & Wilson, E. O. (2008). Biophilia. Human Ecology, 2008, 462-466.

Kellert, S. R., Heerwagen, J., & Mador, M . (2010) Biophilic design: the theory, science, and practice of bringing buildings to life. John Wiley & Sons.

Kellert, S., & Calabrese, E. (2015a). The practice of biophilic design. London: Terrapin Bright LLC, 3, 21-46.

Kellert, S., & Calabrese, E. (2015b). The practice of biophilic design. London: Terrapin Bright LLC, 3, 21.

Koohsari, M. J., Mavoa, S., Villanueva, K., Sugiyama, T., Badland, H., Kaczynski, A. T., Owen, N., & Giles-Corti, B. (2015). Public open space, physical activity, urban design, and public health: Concepts, methods, and research agenda. Health & Place, 33, 75-82.

Kweon, B.-S., Ulrich, R. S., Walker, V. D., & Tassinary, L. G. (2008). Anger and stress: The role of landscape posters in an office setting. Environment and behavior, 40(3), 355-381.

Lang, J. (2004). Creating Architectural Theory: The Role of the Behavioral Sciences in Environmental Design. (A. Einifar, Trans.). Tehran: Institute of Publishing and Printing of Tehran University.

Li, Z., Zhang, W., Wang, L., Liu, H., & Liu, H. (2022). Regulating effects of the biophilic environment with strawberry plants on psychophysiological health and cognitive performance in small spaces. Building and Environment, 108801.

Lynch, K. (2005). A Theory of Good City Form (Q. Bahrain, Translator) Tehran.

Ma, Y., & You, X.-y. (2022). A sustainable conservation strategy of wildlife in urban ecosystems: Case of Gallinula chloropus in Beijing-Tianjin-Hebei region. Ecological Informatics, 101571.

Madanipour, A. (2005). Urban Space Design: An Attitude Toward a Social-Spatial Process. Translated by Farhad Mortezaei, Urban Planning and Processing Company Publications: Tehran.

Makes, N. I. M., & Sense, F. (2012). The Economics of Biophilia. In: New York: Terrapin Bright Green, LLC.

Martin, L., White, M. P., Hunt, A., Richardson, M., Pahl, S., & Burt, J. (2020). Nature contact, nature connectedness, and associations with health, well-being, and pro-environmental behaviours. Journal of Environmental Psychology, 68, 101389.

McCann, E., & Mahieus, L. (2021). Everywhere from Copenhagen: Method, Storytelling, and Comparison in the Globalization of Public Space Design. In Professional Service Firms and Politics in a Global Era (pp. 115-134). Springer.

Newman, P. (2014). Biophilic Urbanism: a case study on Singapore. Australian Planner, 51(1), 47-65.

Oliver, T. H., Doherty, B., Dornelles, A., Gilbert, N., Greenwell, M. P., Harrison, L. J., Jones, I. M., Lewis, A. C., Moller, S. J., & Pilley, V. J. (2022). A safe and just operating space for human identity: a systems perspective. The Lancet Planetary Health, 6(11), 919-927.

Parsons, R., Tassinary, L. G., Ulrich, R. S., Hebl, M. R., & Grossman-Alexander, M. (1998). The view from the road: Implications for stress recovery and immunization. Journal of Environmental Psychology2(18)-113-140.

Pyle, R. M. (2003). Nature matrix: re-connecting people and nature. Oryx, 37(2), 206-214.

Register, R. (1987). Ecocity Berkeley: building cities for a healthy future. North Atlantic Books.

Richardson, M., & Butler, C. W. (2022). Nature connectedness and biophilic design. Building Research & Information, 50(1-2), 36-42.

Ryan, C. O., & Browning, W. D. (2020). Biophilic design. Sustainable Built Environments, 43-85.

Ryan, C. O., Browning, W. D., Clancy, J. O., Andrews, S. L., & Kallianpurkar, N. B. (2014). Biophilic design patterns: emerging nature-based parameters for health and well-being in the built environment. ArchNet-IJAR: International Journal of Architectural Research, 8(2), 62.

Ryan, R. M., Weinstein, N., Bernstein, J., Brown, K. W., Mistretta, L., & Gagne, M. (2010). Vitalizing effects of being outdoors and in nature. Journal of Environmental Psychology, 30(2), 159-168.

Salingaros, N. A. (2019). The biophilic healing index predicts effects of the built environment on our well-being.

Schiebel, T., Gallinat, J., & Kühn, S. (2022). Testing the Biophilia theory: Automatic approach tendencies towards nature. Journal of Environmental Psychology, 79, 101725.

Scull, J. (2011). The separation from more-than-human nature. In: Retrieved.

Shelton, R. D. (1994). Hitting the green wall: why corporate programs get stalled. Corporate Environmental Strategy, 2(2), 5-11.

Simaika, J. P., & Samways, M. J. (2010). Biophilia as a universal ethic for conserving biodiversity. Conservation Biology, 24(3), 903-906.

Söderlund, J. (2019). The emergence of Biophilic design.

Soderlund, J., & Newman, P. (2015). Biophilic architecture: a review of the rationale and outcomes. AIMS environmental science, 2(4), 950-969.

Tam, K.-P. (2013). Concepts and measures related to connection to nature: Similarities and differences. Journal of Environmental Psychology, 34, 64-78.

Tekin, B. H., Corcoran, R., & Gutiérrez, R. U. (2023). A Systematic Review and Conceptual Framework of Biophilic Design Parameters in Clinical Environments. HERD: Health Environments Research & Design Journal, 16(1), 233-250.

Tibbalds, F. (Ed.). (2005). Making people-friendly towns: Improving the public environment in towns and cities. Taylor & Francis.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology, 11(3), 201-230.

Van Nes, A., & Yamu, C. (2021a). Introduction to space syntax in urban studies. Springer Nature.

Van Nes, A., & Yamu, C. (2021b). Private and Public Space: Analysing Spatial Relationships Between Buildings and Streets. In Introduction to Space Syntax in Urban Studies (pp. 113-131). Springer.

Vidal, D. G., Fernandes, C. O., Teixeira, C. P., Dias, R. C., Seixas, P. C., Barros, N., Vilaça, H., & Maia, R. L. (2022). Behavioural Mapping of Urban Green Spaces Users: Methodological Procedures Applied to Corujeira Garden (Porto, Portugal). In Sustainable Policies and Practices in Energy, Environment and Health Research (pp. 147-166). Springer.

Wijesooriya, N., Brambilla, A., & Markauskaite, L. (2023). Biophilic design frameworks: A review of structure, development techniques and their compatibility with LEED sustainable design criteria. Cleaner Production Letters, 100033.

Zhong, W., Schröder, T., & Bekkering, J. (2022). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. Frontiers of Architectural Research, 11(1), 114-141.

Zucker, P. (1960). Town and square: From the agora to the village green.

Zylstra, M. J., Knight, A. T., Esler, K. J., & Le Grange, L. L. (2014). Connectedness as a core conservation concern: An interdisciplinary review of theory and a call for practice. Springer Science Reviews, 2(1), 119-143.