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Biophilic Renewal Design Study of Outdoor Space In Old Residential Areas: Evaluation scale and toolkit generation

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Abstract

Purpose: This study aims to attempt to apply biophilic design concepts to the renewal design research of outdoor spaces in old residential areas, summarizing strategies suitable for the renovation of outdoor spaces in these areas. **Research design, data and methodology:** Based on the existing theoretical framework of biophilic design and the actual conditions of outdoor spaces in residential areas, a biophilic quality evaluation scale and a biophilic design "toolkit" for residential outdoor spaces were summarized. The current situation of residential outdoor spaces was investigated and analyzed using the scale, and biophilic renovation strategies were proposed for old residential areas. **Results:** Specific biophilic quality evaluation scales and biophilic design "toolkits" for residential outdoor spaces were generated, and biophilic renovation strategies were proposed for old residential areas. **Conclusions:** According to existing theories and research analysis, diversified biophilic design can enhance the overall biophilic quality of residential areas. To achieve this, the biophilic quality evaluation scale can be used to analyze the biophilic quality of outdoor spaces in old residential areas, and appropriate biophilic renovation strategies can be proposed through the biophilic design "toolkit". This study will provide valuable references for the renovation of outdoor spaces in old residential areas.

Keywords: Biophilic Design, Old Residential Areas, Renewal Design Studies, Biophilic Quality Evaluation Of Outdoor Space, Toolkit

JEL Classification Code: R21, R30, Q56, Q57

1. Introduction

In 2016, the Central Committee of the Communist Party of China and The State Council issued the Outline of Healthy China 2030 Plan, which clearly states that building a healthy city is an important starting point for developing a healthy China. As the most basic element of a city, the overall quality of a community has a direct impact on people's quality of life, and the living environment also has a direct impact on people's physical and mental health. However, with the continuous

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advancement of urbanization, many old residential areas have gradually revealed the problems of dilapidated outdoor space, functional insufficiency and lack of attractive space, which is difficult to meet the growing needs of residents for visual aesthetic and ecological experience. In recent years, the application of biophilic design in the field of residential renewal has been gradually developed, and has received more and more attention. Biophilic design aims to extract and transform the elements that are beneficial to people in nature, and design a space that conforms to the characteristics of modern life and is full of natural elements. Studies have proved that biophilic design has many benefits for human health at the physiological and psychological levels, and can provide residents with a more comfortable living environment. The purpose of this paper is to discuss how to apply the biophilic design method to the renewal design of outdoor space in old residential areas, so as to improve the living quality of residential areas.

2. Literature review

2.1 The development of biophilic design theory

In 1964, the term biophilic was coined by the German philosopher Erik Fromm to describe the psychological orientation that attracts all living things. In 1993, Edward Wilson et al. introduced the term "biophilia" into the field of design and jointly proposed the "biophilia hypothesis", believing that biophilia does exist and is an innate emotional connection between human beings and nature or other organisms, which means that this emotional connection is hereditary and a part of human nature. In 2008, Stephen Kellett officially named biophilic design, and gave a specific definition: it refers to learning from the experience of nature, through the reproduction, utilization, simulation and extraction of nature and other means to create an artificial environment that can support and revive human biophilic nature. Kellett developed a preliminary framework for biophilic design, with a total of 72 attributes. In 2018, the original framework was simplified, and the original three levels were simplified into two levels and 25 attributes, as shown in Table 1.

Table 1: 2018 Kellert classification of biophilic design methods

Design category	Design method
Direct experience of nature	Light; Air; Water; Plants; Animals; Landscape; Weather; Views; Fire
The indirect experience of nature	Images; Materials; Texture; Color; Shapes and forms; Information richness; Change, age, and the patina of time; Natural geometries; Simulated natural light and air; Biomimicry
Space and place experience	Prospect and refuge; Organized complexity; Mobility; Transitional spaces; Place; Integrating parts to create wholes

Note: The table is redrawn based on the biophilic design approach classification by Kellert.

In 2014, William Browning also proposed the classification of 14 design methods for biophilic design, as shown in Table 2. Compared with the classification method proposed by Kellert in 2018, the two are classified from three aspects: the direct organization and application of natural elements; abstract extraction and application of natural elements; the relationship between man and nature.

Table 2: William Browning taxonomy of biophilic design methods (modified by the author)

Design category	Design method
Natural elements in the space	A visual connection with nature; Non-visual connection with nature; Irregular induction stimulation; Changes in thermal environment and air flow; Water features; Dynamic and astigmatic environment; Links to natural systems
Simulated natural elements	Biomorphic simulation; The connection between material selection and nature; Complexity and regularity
Property of space itself	Vision design; Shelter design; Mysterious design; Adventure element design

Note: The table is redrawn based on the biophilic design approach classification by William Browning.

2.2 Study on biophilic theory in outdoor space of residential area

There are relatively few researches on the biophilic theory in residential areas. Lee from South Korea proposed specific means of residential regeneration from the perspective of biophilia. In his research, space is divided into three levels, namely residential interior space, building monomer and residential area, and the biophilic design method is introduced from these three levels. However, at present, there are few studies on the evaluation of biophilic quality of outdoor space in residential areas. This paper takes this as a starting point, constructs an evaluation scale on the basis of previous studies, and then proposes a "toolkit" for biophilic design.

3. Construction of biophilic quality evaluation scale for outdoor space in residential areas

In order to carry out the biophilic transformation of old residential areas, the biophilic quality of residential areas should be evaluated first. Biophilic quality refers to the overall quality of elements with biophilic attributes that can be perceived in the environment, and is a measure of the natural characteristics of the built environment and the natural experience of users. The scale is designed to clearly show several elements that affect the biophilic quality of outdoor space in residential areas, so as to carry out corresponding renovation according to the evaluation results.

The construction of the biophilic quality assessment scale for outdoor space in residential areas is based on the perceptive biophilic Design scale constructed by Hung and Chang. The scale screened 72 attributes proposed by Kellert and finally obtained a perceptive biophilic design scale composed of 28 indicators, as shown in Table 3. The biophilic quality of built environment can be evaluated with good reliability and validity. This paper further sorted out the biophilic quality evaluation scale for outdoor space in residential areas.

3.1 Determination of classification methods for biophilic design

In 2008, Kellett first designed the framework of the biophilic design method and proposed a series of design attributes. The perceptual biophilic design scale constructed by Hung and Chang screened 72 attributes into five categories through conceptual discrimination and statistical data analysis. In order to facilitate understanding and use, this paper reclassified them according to the three main aspects of current biophilic design methods mentioned above, namely: direct experience of nature; experience nature indirectly; the relationship between man and nature.

Table 3: Perceptual biophilic design scale (modified by the author)

28 biological quality evaluation indicators	
Environmental attribute	index
Environmental features	Views and vistas; Geology and landscape; Habitats and ecosystems
Natural shapes and forms	Egg, oval, and tubular forms; Geomorphology; Biomimicry
Natural patterns and processes	Growth and efflorescence; Change and metamorphosis; Landscape ecology; Landscape ecology; Patterned wholes; Complementary contrasts; Light and shadow
Place-based relationships	Historic connection to Place; Cultural connection to place; Indigenous materials; Landscape orientation; Integration of culture and ecology; Spirit of place
Evolved human-nature relationships	Information richness; Exploration and Discovery; Curiosity and enticement; Security and Protection; Information and Cognition; Attraction and beauty; Affection and Attachment; Reverence and spirituality

Note: The table is redrawn based on the Biophilic Design Scale by Hung and Chang.

3.2 Setting of biophilic quality evaluation elements and indexes

Since the perceptual biophilic design scale constructed by Hung and Chang is only for the outdoor built environment, but not for the outdoor space of residential areas, it needs to be adjusted according to the actual outdoor space of residential areas.

"Geology and landscape" mainly consider the integration of architectural forms with local topography and natural landscapes. However, considering that most residential areas are man-made landscapes, which are not integrated with large areas of natural landscape, and landscape has been comprehensively considered in "landscape view", "landscape ecology" and "landscape integration", it is no longer repeatedly included in the scale. The ecosystem in "habitat and ecosystem" refers to wetland, forest, grassland and river basin, but urban settlements are difficult to relate to these ecosystems, so this part is included in "landscape ecology" and "integration of culture and ecology" for comprehensive consideration. "Topography" mainly refers to the combination of building structure and terrain, but residential buildings, due to their own characteristics, will not make much change to its structure and will not be included in the final scale. "Change and change process" emphasizes a series of changes of the built environment over time. The changes of outdoor space in residential areas are mainly the four seasons of vegetation, so this element is not included in the scale. "Local spirit" and "feeling and attachment" require various aspects of design, such as cultural activities, landscape design, and characteristic node design, which are involved in other elements, so they are not repeated. "Curiosity and temptation," "attraction and beauty," and "exploration and discovery" essentially stimulate people's curiosity and desire for exploration through environmental design, and will be uniformly classified as "exploration and discovery" in this scale design. Although the "information and cognition" element is divided into two indicators in the perceptual biophilic design scale - satisfaction and cognitive enhancement - it is still essentially a complex design of natural shape and form, so it is no longer subdivided.

In order to make the scale more clear and easy to understand, it is necessary to further subdivide the scale according to the specific design perspective of outdoor space in residential areas on the basis of secondary indicators. On the one hand, it is convenient to accurately evaluate the biophilic quality of outdoor space in residential areas; on the other hand, it provides a theoretical basis for the generation of the "toolkit" for biophilic design in the next step.

The complete scale is shown in Table 4.

Table 4: Biophilic quality evaluation scale of residential outdoor space (Author drawing)

Classification of biophilic design methods	Scale element	Scale detail classification
Direct experience of nature	Light and shadow	Structure
		Vegetation
		Building facade
	Views and vistas	Density of artificial landscape in residential area
	Landscape ecology	Diversified ways of greening
	Landscape orientation	Lighting and ventilation Utilization of terrain
Experience nature indirectly	Indigenous materials	Utilization of natural materials
	Information richness	Auditory perception
		Olfactory stimulation
		Tactile stimulation
	Information and cognition	Architectural sketch art treatment
	Growth and efflorescence	Seasonal plant
	Egg, oval, and tubular forms	Arcuate element
Central focal point	Centrality	

	Patterned wholes	Harmony and unity
	Complementary contrasts	Spatial contrast
The relationship between man and nature	Biomimicry	Bionic design of outdoor facilities
	Security and protection	Perfect facilities
	Historic connection to place	Historical connection
	Cultural connection to place	Cultural connection
	Integration of culture and ecology	The relationship between residents' activities and ecology
	Reverence and spirituality	A place that forgets time and space
	Exploration and discovery	Attraction of space

Note: self-drawn by the author.

4. Generation of biophilic design tools for outdoor space in residential areas

4.1 The principle and function of generating toolkit

The biophilic quality evaluation scale of outdoor space in residential areas can evaluate the biophilic quality of outdoor space in residential areas to a certain extent, and its enhancement commence with the indicators in the corresponding scale. In order to facilitate the enhancement of outdoor space in residential areas, this paper proposes a biophilic design "toolkit" based on outdoor space in residential areas, which is divided into two parts: (1) The overall strategy of biophilic modification; (2) Modular node design for biophilic enhancement. After evaluating the biophilic quality of the outdoor space of the target residential area, the designer can formulate a specific renovation plan suitable for the target residential area by referring to the modular design and the overall strategy in the "toolkit" in combination with the specific situation of the residential area.

4.2 Biophilic design "toolkit"

This section will give a literal interpretation of the "Toolkit". The corresponding relationship between the overall strategy and modular node design in the "Toolkit" and the scale is shown in Table 5.

Table 5: The corresponding relationship between the "Toolkit" and the biophilic quality assessment scale

Scale index	Overall strategy	Modular design
Structure	The structure is combined with the green plant design to form a natural rich light and shadow change	The roof of the pavilion is hollowed out and treated with green plants
Vegetation	Provide opportunities for people to get up close and personal with vegetation	The combination of vegetation and seating creates a rich light and shadow in the sunlight
Building facade	The facade of the building is kept uniform and clean	/
Density of artificial landscape in residential area	In the vegetation design, choose as many kinds of vegetation as possible to enrich the greening	/
Diversified ways of greening	Planting multiple types of landscape plants to provide a variety of types of greening methods	Wall greening, roof greening, pot greening, flower pond greening, rainwater collection, etc
Lighting and ventilation	The key activity place of the community should be combined with the layout of the residential building, and should be set in the place with good ventilation and lighting as far as possible	/
Utilization of terrain	Based on the terrain design to meet the psychological needs of the scene	The landscape ladder is designed in combination with the slope to meet the viewing Angle and take into account the aesthetics
Utilization of natural	Seats, structures and other natural materials, such as stone, wood, etc	/

Scale index	Overall strategy	Modular design
materials		
Auditory perception	Consider natural sounds like water, wind blowing leaves, birds singing, etc	Dynamic water feature design such as small fountain, small waterfall or floating pool
Olfactory stimulation	The design of a variety of flowers and green plants, emitting aromas to stimulate people's sense of smell	/
Tactile stimulation	The facilities accessible to people use a variety of materials to enrich the touch	Through the design of different materials of the pavement to enrich people's walking touch, such as cobblestone road, wooden trestle road, rubber runway, SLATE road, sand pit
Building structures art treatment	Carry out artistic processing of architectural pieces and outdoor facilities	The artistic treatment of the seat
Seasonal plant	More plants with seasonal changes can be planted, and plants with different flowering times can be selected	/
Arcuate element	As far as possible, avoid linear design in the design of outdoor facilities	Streamlined landscape seat design
Centrality	In the overall design, it is necessary to consider the focus of the whole site, such as activity venues, symbolic sculptures, etc., to facilitate the unification of the pattern of the entire site	/
Harmony and unity	Outdoor space design to meet the diversity of the same time, to ensure that there are unified elements, so that the overall harmony and unity	/
Spatial contrast	Design a space with a strong sense of contrast, while satisfying the sense of openness and privacy	The addition of lounge space on the flyover provides an adventurous design while satisfying a sense of security
		An open corridor is designed on one side of the wall, and a water feature is designed on the other side of the corridor
		The roof is designed in the outdoor open space to create spatial contrast
Bionic design of outdoor facilities	Bionic treatment of outdoor facilities, such as tree-like pillars, trash cans with tree roots, plant signs, etc	/
Perfect facilities	The road in the community needs to have a clear road network system, entrance and exit and road guidance system, improve the infrastructure, and ensure the free walking of residents in the community	/
Historical connection	The historical elements of residential area are extracted and reproduced	Design decorations that depict patterns with historical or regional associations
		Post or paint historical photos on the facade walls
Cultural connection	The neighborhood committee organizes various cultural activities	/
	Design structures, sculptures, etc. with reference to specific forms and concepts	/
The relationship between Residents' activities and ecology	Promote the active participation of residents in ecological aspects	Residents participate in planting gardens, vegetable gardens, etc., to foster common interests and enhance residents' participation
A place that forgets time and space	The meditation space is designed to allow residents to empty themselves in a quiet place	Meditation corner design for quiet area
Attraction of space	The main consideration is to create a sense of mystery in the space	Create a sense of mystery through the tortuous design of the flyover and the shading of plants, or partially design the glass flyover
		Through the winding path design, create a sense of mystery

Note: self-drawn by the author.

5. Investigation and analysis of outdoor space status of some residential areas in Dalian City

Six residential areas in Dalian were selected for this research, which were divided into two age groups of "2010 and beyond" and "1990-2000". The biophilic quality level of old residential areas was assessed through research, and the biophilic design elements of residential areas built in a later age were analyzed. Finally, combining the "toolkit" and the actual situation, the author puts forward the strategy of biophilic transformation of outdoor space in old residential areas.

5.1 Period group "2010 and beyond"

In the "2010 and beyond" period, there are three residential areas, namely Dongfang Shengkla Residential area, Yuyuan Residential area and Yihe Xinghai Residential Area, which are located in Shahekou District of Dalian City, and the residential scale is between 1000 and 4000 households. Through the analysis of biophilic elements in the outdoor space of residential areas, it is found that there are generally more biophilic elements that can be extracted in the residential areas of the "2010 and beyond" age group, and residents give them a high evaluation. The summary analysis is as follows.

5.1.1 Experience nature directly

The above three communities are all designed in terms of direct experience of nature. A typical example is the central activity square area of the Yuyuan Community as shown in Figure 1, which consists of a children's activity square and a corridor space on one side. This space is located in the core area of the residential community, which is convenient for residents to use for activities and has a relatively good lighting and ventilation environment. Residents have a good view of the landscape in the space, giving full play to the role of natural elements in promoting human health.

5.1.2 Experience nature indirectly

As shown in Figure 2, in the outdoor space design of Yihe Xinghai Community, there is a core activity space composed of a pool as the main landscape, where more residents, including children, gather to chat and engage in activities. On one side of the waterscape, a corridor surrounded by greenery has been designed, while on the other side, a viewing walk has been created, forming a contrast between semi-open and open spaces. Additionally, its abundant vegetation and flowers offer residents a rich sensory experience. In terms of material selection, wood is used as both decorative and structural material in the design of seats and corridors.



Figure 1. Experiencing nature directly



Figure 2. Experience nature indirectly

5.1.3 The relationship between man and nature

As shown in Figure 3, Yihe Xinghai Community has an overpass space, and a landscape pavilion is designed at the corner of the stairs of the overpass to create a small enclosed space. This small enclosed space can provide residents with a sense of security, and at the same time, it is open on all sides and provides an open prospect space for residents, offering them a unique viewing experience.

Through questionnaire interviews with residents and actual observation, a preliminary conclusion can be drawn that diverse biophilic design of outdoor space in residential areas improves the overall biophilic quality of residential areas, enriches residents' recreational lives, and encourages more residents to leave their homes for outdoor activities, contributing to their physical and mental health, while also enhancing the overall living atmosphere of the residential areas.



Figure 3. The relationship between man and nature

5.2 Period group "1990-2000"

Three typical old residential areas built in Dalian between 1990 and 2000 were selected for field investigation, namely Zhenhua Community (see Figure 4a), Linmao Community (see Figure 4b), and Cangshan Road District (see Figure 4c), located in Shahekou District, Xigang District, and Ganjingzi District of Dalian, respectively. The residential scale generally ranges from 2,000 to 3,000 households.

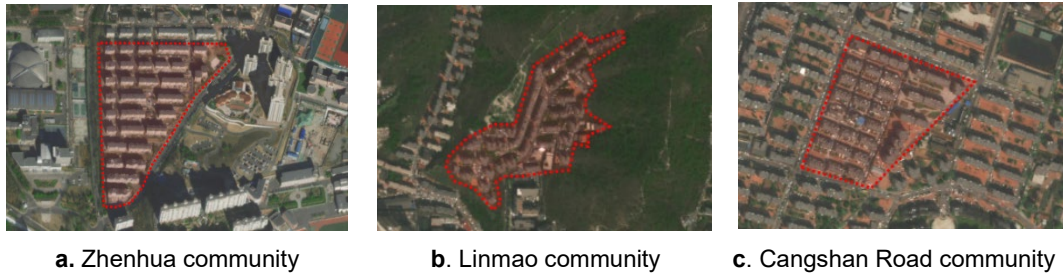


Figure 4. Satellite images of three typical old residential areas

This research employs field investigation and interview methods to understand the type, distribution, environmental status, and usage of outdoor space in residential areas. The author distributed the pro-biological quality survey questionnaire based on the aforementioned scale on-site. Through questionnaire interviews, the author surveyed three levels: direct experience of nature, indirect experience of nature, and the relationship between humans and nature, collecting the questionnaires on-site. A total of 120 questionnaires were distributed (40 for each residential area), with 113 valid responses collected. The data were then analyzed.

As shown in the questionnaire results (Figure 6), with the dotted line representing the average value, the old residential areas generally receive low evaluations for the elements of "building facade," "diversified greening methods," "artistic treatment of small building pieces," "bionic design," and "historical connection." The following transformation strategies are proposed in conjunction with the aforementioned "toolkit."

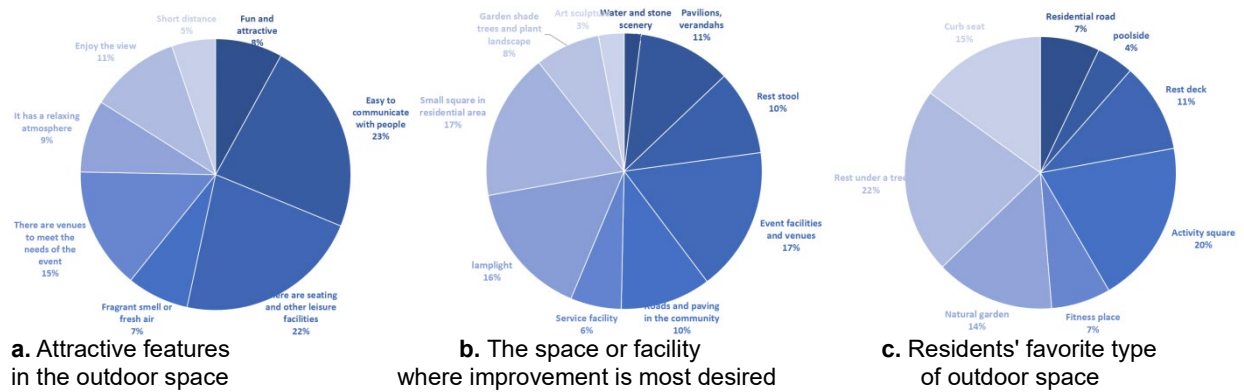


Figure 5: Survey on renovation needs of public space in three typical old residential areas

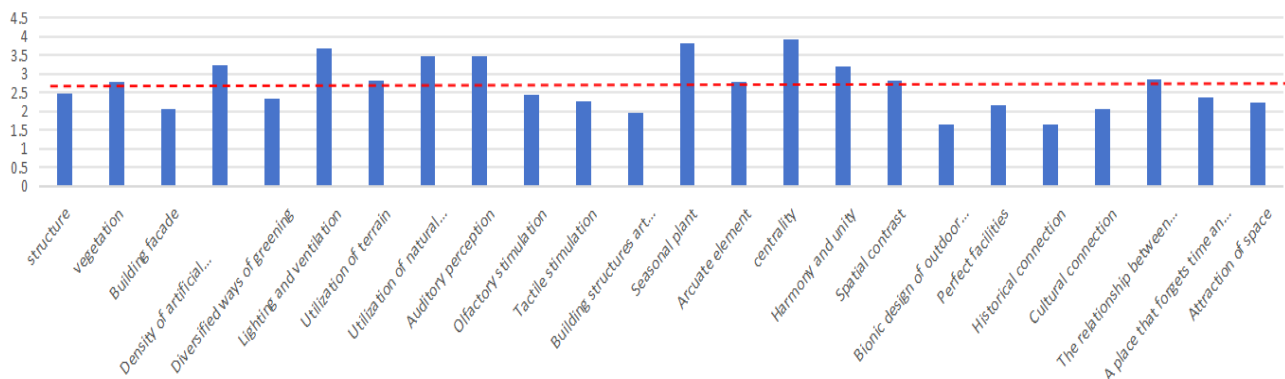


Figure 6: Survey and statistics of biophilic quality of outdoor space in three typical old residential areas

5.2.1. Experience Natural Elements Directly

Increase the presence of direct natural elements in the outdoor spaces of residential areas, utilizing vegetation and terrain effectively. The three residential areas surveyed in this study all feature slopes with varying gradients, which can be employed to design landscape stairs (see Figure 7a) to enhance residents' visual experiences. As illustrated in Figure 7b, pavilions designed with climbing vines can create an engaging interplay of light and shadow, sparking residents' curiosity. When selecting green plants and flowers, it is advisable to consider a diversity of species and to increase vegetation density appropriately within the residential areas. Additionally, vegetation planning should integrate the design of paths and squares.

5.2.2. Experience Natural Perspectives Indirectly

The outdoor space should evoke feelings of being in nature. In the internal roads and squares of residential areas, pavilions, seating, and other architectural features should be incorporated to beautify the environment and facilitate social interaction among residents. The design should harmonize with the overall landscape of trees, considering bionic design elements to enhance the cohesion between structures and their surroundings, as shown in Figure 7c. Moreover, the activity square can be divided into distinct activity and rest areas (see Figures 7c and 7d) to enrich the square's functionality and accommodate various needs. Activities in this space can provide not only psychological security but also an open perspective, contributing to a sense of enjoyment.

5.2.3. The Relationship Between Man and Nature

Create ecological gardens for residents, as depicted in Figure 7e, which provide planting spaces that cater to their viewing and recreational needs. Residents can "claim" these planting areas, thereby boosting their sense of happiness and enhancing the residential landscape. Given the limited activity space in old residential areas, the integration of pedestrian overpasses is recommended. As shown in Figure 7f, these overpasses can facilitate pedestrian traffic while also expanding visual perspectives. A zigzag design combined with greenery can stimulate residents' desire to explore and enhance their sense of pleasure.

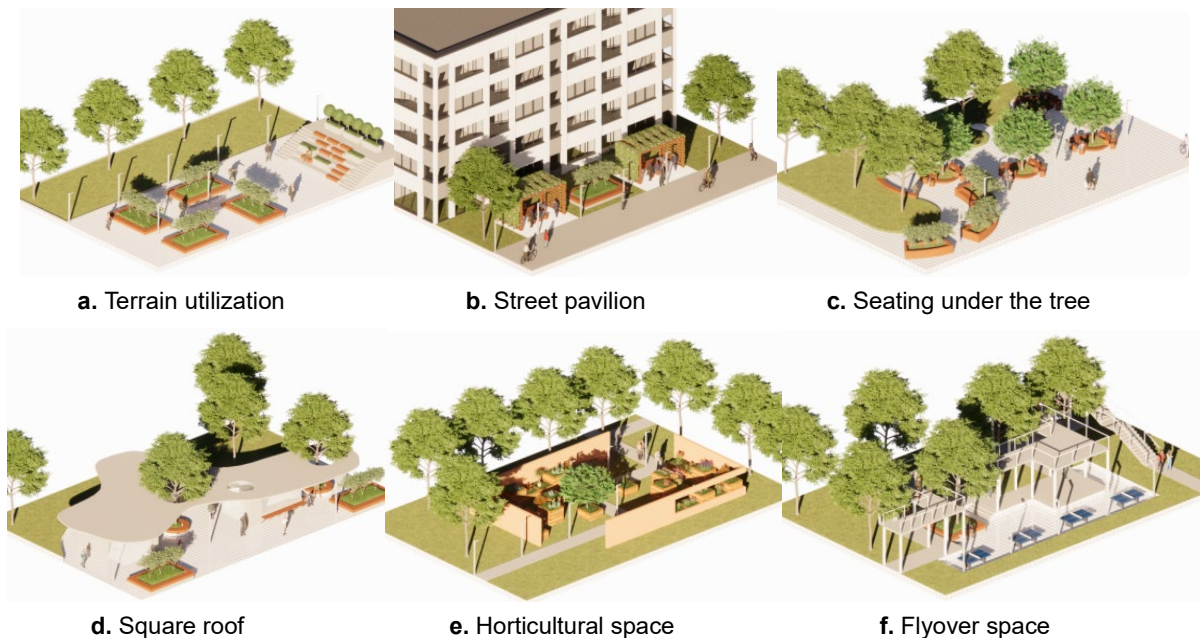


Figure 7: Schematic diagram of transformation strategy

6. Conclusion

Embracing nature is a natural instinct for humans as living beings. In today's ever-developing urbanization, residential areas should not be barriers that isolate people from nature but should serve as a link to bring people closer to nature within urban life. Biophilic design offers a new perspective for the renovation of outdoor spaces in aging residential areas. Building upon existing research, this article proposes a biophilic quality assessment scale and a design "toolkit" for the renovation of residential outdoor spaces. It conducts research on new and old residential areas in Dalian and proposes renovation strategies for the old ones, aiming to provide some references for the renewal of aging residential areas.

When renovating the outdoor spaces of old residential areas, designers can use the scale to gain a general understanding of the biophilic quality of the outdoor spaces and draw on the biophilic design "toolkit" for renovation. In the design process, they should focus on aspects with lower assessment scores. Biophilic design theory should be combined with theories such as barrier-free design and child-friendly design to improve residential facilities, enhance the charm of the residential areas, better promote the quality of living in the areas, and contribute to the strategy of a healthy China.

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