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Multifunctional Space Conversion and Environmental Design in Modern Interior Design

Siqi Wang[1,*]
[1]Department of Architectural Engineering, Hebei Vocational University of Industry and Technology, Shijiazhuang, Hebei, 050000, China
Corresponding authors: (e-mail: 13131160928@163.com).

Abstract In order to solve the contradictory nature of the limitations of small house space and multiple functional needs, this paper actively explores the variable space planning strategy in interior design. The environmental design scheme is proposed to realize the indoor ecological functional needs by utilizing space design with minimum energy consumption. The analysis of the functional needs of residential users reveals that it is feasible to meet the functional needs of different groups and different stages of residential use by dividing and combining indoor functional spaces. According to the results of a survey in a first-tier city, the average expectation of bedroom and living room area for 30-70m² houses is 20.7m² and 15.8m² respectively, which means that when small houses are designed, the important functional spaces such as bedrooms and living rooms under the limiting dimensions are prioritized to be combined. The results of the case study of four local houses of different sizes verify the effectiveness of the proposed strategy. 92.28% and 94.54% of space utilization is achieved in house 1 and house 2 respectively, while the energy efficiency of house 4 reaches 61.42%.

Index Terms variable space, functional conversion, environmental design, interior design

I. Introduction

In modern society, people pay more and more attention to the interior design to bring people's sensory experience, but also more and more understanding of a space designed for good use or not. Throughout the history of interior design development of various factors cohesion and confusion, only to find out the essential relationship to analyze, in order to organize the development of the law of interior design, the establishment of scientific design concept [1]–[4]. The value of space is not only embodied in the use to meet the needs of people's living and living, but also on the production of human life has a psychological implication, good design not only to meet the functional needs of the space embodied in the form of beautiful management and embodiment [5]–[8]. Since the establishment of the discipline of interior design, it has been accompanied by function and space, especially in modern times, the functional requirements are more and more. It is undeniable that in interior design, the connection between function and space is very close, and the embodiment of function in space also provides us with more thinking [9]–[12].

Interior design cannot be separated from environmental design, and it can even be understood that interior design and environmental design complement each other. Environmental design includes the natural environment around the space and the human environment design of the project area. The influence of the natural environment on the form of space is mainly reflected in the architectural form and the use of spatial materials [13]–[16]. Taking the hotel as an example, the hotel building is a part of nature and will never rob the beauty of nature, it is integrated with the surrounding natural environment. The human environment is the embodiment of the geographical environment around the space, including lifestyle, customs, language, and psychological quality. Each nation possesses its own spirit, temperament, character and aesthetic habits, etc. [17]–[20].

This study proposes the concept of variable space based on functional transformation, and explores and solves the problem between the limited space and the multi-functional needs of small apartments. Furthermore, combined with the needs of indoor ecological functions, the strategy of using design to improve the indoor environment in terms of "sound", "light" and "heat" is proposed. Combined with the time dimension, the functional needs of residential users are analyzed, and it is shown that the multi-functional space conversion strategy can meet the functional needs of different groups in different stages. Based on this, the variable space planning strategy and environmental design strategy in interior design are proposed. The effectiveness of the proposed strategy was verified by field investigation and questionnaire survey results.

II. Relevant concepts

II. A. Interior design

Interior design is based on the nature of the use of the building, the environment and the corresponding standards, the use of material and technical means and architectural aesthetics, to create a reasonable function, comfortable and beautiful, to meet the needs of people's material and spiritual life of the indoor environment. This spatial environment not only has the value of use, to meet the corresponding functional requirements, but also reflects the cultural lineage, architectural style, environmental atmosphere and other spiritual factors.

Interior design is no longer a part of architectural design, but an extension of architectural design. Architectural design is a synthesis of many factors. Whether it is equipment, materials, appearance and other aspects, or the environment, cost and other aspects, are all factors that need to be considered in architectural design. And many design factors of interior design and architectural design are the same, interior design needs to echo the building design to some extent, highlighting the building design embodied in a variety of atmospheres and connotations, the need to focus on the visual environment, the psychological environment, and at the same time, the need to pursue the sensibility and cultural connotations, is a comprehensive discipline.

II. B. Residential variable space

Residential variable space refers to the design of space for the occupants, the design focuses on maximizing the functionality and flexibility of the space, not only to adapt to changes in the needs of the occupants over a period of 10 years or more, but also to adapt to changes in the space from the point of view of the occupants with regard to differences in their ages, occupations, personalities, lifestyles, and so on. The design focuses on the variability, flexibility and regeneration of the living space, which is in line with the principle of sustainable development advocated by today's society.

Along with the development of the times and the improvement of people's living standards, the users' demand for the quality of space is also gradually increasing. Users pursue a higher quality of life, diversified aesthetics, personalized design, and reject the uniformity of indoor space, and are more inclined to pursue the diversity and changeability of residential space. At present and in the future, the demand for indoor variable space design is also increasing, and small and medium-sized interior spaces will become more and more popular. Although the area of the space used has become smaller, people's lifestyles are increasing, and people are emphasizing their spiritual needs, so there is also the possibility of adding functional space due to the constant changes in lifestyles.

II. C. Functional conversion design

In this paper, the design of functional conversion is divided into two modes: short-term and long-term [21]. For example, in an elderly family, the bedroom can be converted into a study space when the children are not at home in general, and when the children are at home it can be converted into the original bedroom space. It can be converted into several different functional attributes within the same functional space according to the time difference. This way can be achieved through the intervention of variable furniture, so as to achieve the composite and conversion of functional space.

II. D. Environmental design

In the past interior design, the design of space composition form, functional zoning, the organization of the dynamic line and other aspects of the design is relatively perfect, which is correct. However, other aspects such as orientation, ventilation, lighting, indoor air quality, indoor acoustic environment, indoor thermal comfort are all components of indoor ecological function, and should be given equal attention. Modern interior design should uphold the concept of energy conservation and protection of the natural environment, so the design of the interior environment should pay more attention to the care of human nature and the relationship with the environment.

III. Research on users' needs

III. A. Analysis of short-term residential space activities

The short-term period is the change in daily life, and the length of use of a conventional house type is categorized into three groups of users, namely, the elderly, parents and children. The functions of short-term housing need to focus on meeting the needs of living, entertainment, food, hygiene, and office study. The statistical results of the activity space and activity time of the residential user groups in a day are shown in Figure 1. It can be seen that the three groups rest in the bedroom during the six hours from 0:00 a.m. to 6:00 a.m., and eat together in the dining room at around 18:00 p.m. In addition to the bedroom, the living room functions as a living room. In addition to the bedroom, the functional space of the living room was the most used, with the elderly, parents and children using it for 6 hours, 2 hours and 0.5 hours respectively in a day. Use of the study function space was also high, with 1 hour, 2.5 hours and 2.5 hours of use in a day, respectively. The use of the bedroom and dining room by the three groups was concurrent at specific times, while the use of the living room, study, and bathroom was at different times. Since the kitchen and the bathroom have independent configurations and require users to use them in a fixed space, it is not appropriate to design spatial function conversion for these two functional spaces. While the living room, study

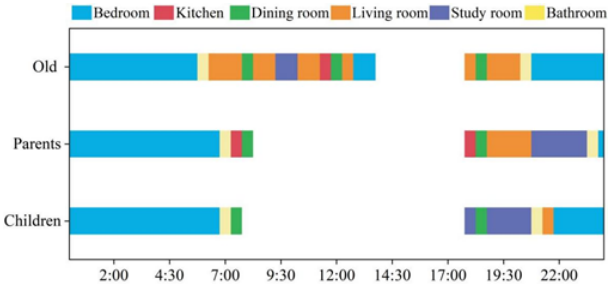

Figure 1: The analysis of household activities in 1 day

Stage	Minimum type	Duration (years)
Form	One bedroom+one kitchen+one bathroom	1-5
Extend	Two bedroom+one kitchen+one bathroom	22
Stabilization	Three bedroom+one kitchen+two bathroom	
Contraction	Three bedroom+one kitchen+two bathroom	18
Empty nest	Two bedroom+one kitchen+one bathroom	15
Disintegration	One bedroom+one kitchen+one bathroom	5-10

Table 1: The relationship between family cycle and family

and spare time period of the dining room can be adjusted according to the user's use of the time difference, and combined with the interior furniture to increase the functionality of the space, to achieve the purpose of multi-functional space conversion.

III. B. Analysis of long-term residential demand

The long period of change is measured in years and is mainly generated by demographic changes that require housing to adapt to population growth or sudden changes. Using the nuclear family as the subject of the study, the functional space needs of the dwelling over the life cycle cycle are shown in Table 1. It can be seen that in the formation and expansion phases, the functional space needs are low, and variable furniture as well as flexible partition solutions can be used to enhance the variability of spatial partitioning. In the stabilization and contraction phases, however, the number of functional spaces required by the nuclear family is at its maximum, and therefore the replacement of functions needs to be maximized while the spatial status remains unchanged. In the empty nest and disintegration phases, the re-planning of the house type through space merging and space reorganization becomes the new demand, and the function-oriented space design for aging needs to be considered.

III. C. Analysis of area requirements for various functional rooms

According to the notice issued by China's General Administration of Taxation (GAT) in 2013, the current floor area range of medium living level is 30-140m², which is further divided into three types of residential units: 30-70m², 70-100m² and 100-140m². In a first-tier city, 500 home buyers were randomly selected as research subjects, and their expectations of the functional space of medium living level homes were investigated by questionnaire. Based on the results of the questionnaire survey, the average expected area of the six types of residential functional space is shown in Figure 2. It can be seen that users of the three types of residential units have the highest demand for the bedroom and living room, and the average expectation of the bedroom and living room of 30-70m² residential units is 20.7m² and 15.8m² respectively. Compared to other house types, 70-100m² homes have the highest average bedroom space requirement at 27.6m², while 100-140m² homes have an average space requirement of more than 15m² for each functional space. The area demand data can divide the house type into more detailed combinations of house distribution and functional zones. Considering that the actual area of small houses is small, only just-demanded functions under the limit size can be selected for combination, while large houses with larger actual area can appropriately increase the room size and increase the number of functional spaces.

IV. Interior design strategy

IV. A. Variable space planning strategy

At present, most of the residential interior space design is relatively fixed, once the spatial layout adjustment must pay a big price, if the initial design stage takes into account the flexible use of space, taking into account the possible changes in the needs of the main body of the residence, then in the limited space of the residence can expand the multi functionality of the space, to achieve the purpose of maximizing the use of space [22].

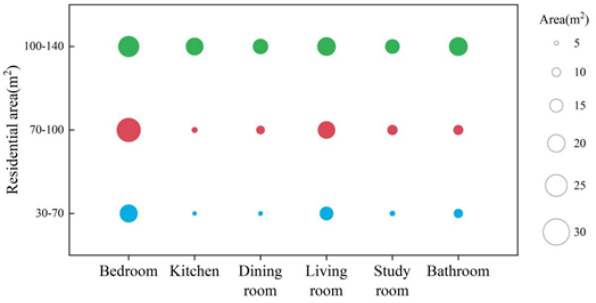

Figure 2: Average area of expectation of residential function space

IV. A. 1) Spatial overlap

Space overlap can also be called space sharing, that is, in the same space in accordance with the needs of the arrangement and appropriate trade-offs, through the interior design, intelligent technology, variable furniture and other elements of the living room, study, dining room, bedroom, etc. to realize the overlap of the design, in the absence of changes in the original space division and the size of the space, so that the same space to meet the needs of different functions at different times to achieve the performance of the transformation.

This design approach is characterized by its original space layout and size of the basic unchanged, only through other means such as changes in the increase or decrease of furniture to achieve functional conversion, so that a particular space in different time periods to play a different purpose. For example, the living room can be designed as a multi-performance space model, as a living room in the meeting time period, in the dining time period by changing the seats or adjusting the placement of furniture and other methods to change to the dining mode, in the sleeping time period, the sofa can be changed into a bed will be adjusted to the space to sleep mode.

IV. A. 2) Space transfers

The separate functional spaces of a traditional house are usually divided by walls or fixed partitions, so the form of each space is relatively fixed. Re-dividing the space by smashing the wall would require a relatively high renovation cost, and after the renovation, the relationship between each space would be fixed again.

In fact, each functional space has its own unused spare space when it is not being used, for example, when we use the living room, the space in the bedroom where no objects are placed is the spare space, which is temporarily left unused. For example, when we use the bedroom, the space in the living room without objects becomes a spare space, which is also unused during the sleeping phase. In fact, there is a certain amount of spare space in every space, if we can collect these spare spaces and turn them into transfer spaces, then we can realize the expansion and scaling of specific functional spaces in a limited snail house to meet more functional needs.

IV. B. Design strategies to improve the spatial environment

Under the natural geographic conditions of different regions, the morphology and spatial layout of buildings are different, i.e., the design standards of regional technologies adapted to the climate are different. Therefore, in the process of interior space design, the close integration of the indoor environment and the natural environment is realized by adapting to the environmental characteristics of the surrounding site [23]. The design combines local climatic characteristics and geographical conditions to maximize the use of sustainable natural resources such as light, wind and heat, thus reducing a large amount of energy consumption and pollution.

IV. B. 1) Design of the acoustic environment

Indoor acoustic environment mainly consists of internal sound formed by repeated reflections from indoor walls, ceilings, floors, furniture and people and other media, as well as traffic noise, construction noise and other external sound, of which indoor sound sources include the sound of people's activities and equipment, electrical appliances, piping and other sounds.

To build a good indoor acoustic environment, we should start noise reduction from the wall of residential enclosure, choose the light steel keel with good sound insulation effect, environmental protection acoustic cotton, gypsum board and other materials to build the residential wall roof, while matching the vacuum laminated glass windows and composite structure of the sound insulation door, so as to reduce the frequency of the noise into the room.

From the point of view of the sound capacity density in the indoor field, in order to make the indoor sound environment, adjust the layout shape of the indoor room and the arrangement of interior materials can reduce the indoor echo, "reverberation" and other phenomena. Setting up buffer areas such as entry spaces and noise-reducing balconies can make outdoor noise diminish

	House 1	House 2	House 3	House 4
Total area	34m²	72m²	105m²	143m²
Space utilization	55.31%	54.15%	59.66%	61.42%

Table 2: Comparison of efficiency efficiency of indoor buildings

continuously in the space layer. According to the design method of "separation of motion and static", the layout of indoor space can be adjusted to form green zoning. For example, public areas such as bathrooms, kitchens, and dining rooms can be placed on the side adjacent to the road, while bedrooms and study rooms with high noise limit requirements can be placed on the other side to ensure the comfort of each functional area.

IV. B. 2) Light environment design

Indoor light environment is divided into natural lighting and artificial lighting. The layout of indoor lighting is divided into four types: basic lighting, local lighting, accent lighting and decorative lighting, and the combination of different illuminance, brightness and color temperature constitutes the light environment. Residential light environment design should focus on reducing building energy consumption, scientific and reasonable use of natural lighting, the use of transmittance, shading, light filtering, light control and light mixing and other processing techniques, to meet the indoor lighting at the same time to create a variety of spatial environment atmosphere, thus saving the resources consumed by artificial lighting.

With the improvement of light technology there are many new technologies to enrich the indoor light environment, such as intelligent skylight adaptive system, infrared sensors, remote control and other technologies to control the light, through the photosensitive control technology to automatically adjust the indoor lighting status, easy and fast operation; intelligent light soft start function can avoid the visual stimulation caused by the sudden change of light, but also effectively protect the bulb, prolonging the service life and saving electricity. Combined with the intelligent control system with the selection of efficient operation, installation and maintenance process is simple energy-saving lamps and lanterns, to achieve good illumination effect at the same time also has considerable energy saving effect, can show a higher level and comfortable light environment.

IV. B. 3) Thermal environment design

The indoor thermal environment consists of indoor temperature, humidity, airflow rate and average radiation temperature of each surface. At the stage of interior design, the layout is flexible according to the actual spatial needs of the residents, and natural ventilation is formed by combining the principles of "through-the-room air" and "heat pressure ventilation" when organizing the space, so as to achieve the corresponding hot and cold cycles while realizing the purification of indoor air, which is also conducive to energy saving and consumption reduction, and when the active method cannot meet the quality of the indoor environment, the air conditioning and heating systems are used to make up for it. When the active method fails to meet the quality of the indoor environment, air conditioning and heating systems are used to make up for it.

In terms of heat transfer in interior design, improving the heat preservation and insulation performance of the building envelope is an important way to realize energy saving in buildings. In addition, the color, texture, style and other factors of interior decorative materials also subtly affect people's feelings about the indoor thermal environment. The use of warm and cold color contrast collocation, uniform distribution of the medium tone design can make the space in an optimal state of balance, not only in the psychological thermoregulation can also be relaxing, creating a warm space, but also to enhance the comfort of the indoor thermal environment is an effective way.

V. Case studies

The proposed interior design strategies based on multifunctional space conversion and improvement of the physical environment are applied to four residential units of different sizes. The effectiveness of the proposed modern interior design strategies is verified by testing the indoor space utilization and indoor building energy efficiency of the four housing types.

V. A. Testing of energy efficiency rates in indoor buildings

China's building energy efficiency standards are divided into three stages, based on the building energy consumption of 1980-1981, the first stage is to save 30% on the basis, the second stage is to save 50%, and the third stage is to save 60%.

The indoor building energy efficiency of the environmentally designed four dwellings is shown in Table 2. The data shows that the energy efficiency of dwelling #4 is maintained at stage 3 at 61.42%. And the energy efficiency of dwelling #3 is 59.66%, which remains around the third stage. In contrast, the energy efficiency of the smaller dwellings #1 and #2 is slightly lower, at 55.31% and 54.15%, respectively, and remains around the second stage. It can be seen that the design of the residential environment effectively improves the indoor building energy efficiency rate and has practicality.

	House 1	House 2	House 3	House 4
Total area	34m²	72m²	105m²	143m²
Family number	3	3	6	5
Space utilization	92.28%	94.54%	89.29%	84.25%

Table 3: Comparison of interior space utilization efficiency

V. B. Indoor space utilization test

The indoor space utilization rates of the four dwellings that have undergone variable space design are shown in Table 3. The data show that the space utilization rate of the 4-family houses after adopting the multifunctional space conversion strategy is maintained at a high level. The space utilization rate of small dwellings is better than that of large dwellings, and the space utilization rates of 34m² and 72m² are 92.28% and 94.54% respectively, both higher than 90%. Residence 3 has a space utilization rate of 89.29%, which is very close to 90%, also reaching a high level. The space utilization rate of Residence 4 with a residential area of 143m² is 84.25%, which is much lower than that of other residential areas. In summary, it can be seen that the multifunctional space conversion strategy can effectively improve the level of indoor space planning and utilization efficiency, and the optimization effect is more prominent for small-sized residences.

VI. Conclusion

This paper explores how to realize a multifunctional and coexisting space planning method within a limited residential area, and discusses the environmental design in relation to the indoor ecological functional requirements. An empirical study using a combination of questionnaires and field research was conducted to analyze the current needs of residential users on the one hand, and to verify the effectiveness of the proposed interior design strategies on the other.

The analysis of users' functional space needs shows that in short-term daily life, except for the bedroom and dining room, the three groups of elderly people, parents and children use the rest of the functional space at different times, so it is feasible to change the multifunctional space according to the time difference. Changes in demand for long-term housing can be accommodated by increasing the number of functional spaces through spatial division schemes, or by merging and reorganizing spaces to meet new demands. In addition, the questionnaire survey data of a first-tier city shows that the average expectation of bedroom and living room area for 30-70m² houses is 20.7m² and 15.8m² respectively. And as the size of the house type increases, the size and number of functional rooms increase together. Therefore, when designing the interior of a small house, only the important functional spaces such as the bedroom and living room under the limit size can be selected for combination.

Based on the analysis of the functional space requirements of residential users, this paper proposes two variable space planning strategies, i.e., space overlapping strategy and space transfer strategy. In view of the importance of indoor ecological functions, the indoor environmental design strategies of sound, light and heat are also proposed to maximize the use of the natural environment to enhance the living experience. Taking four local houses of different sizes as a case study, the analysis results effectively prove the optimization effect of the proposed strategies. The multifunctional space conversion strategy can effectively improve the level of indoor space planning and utilization efficiency, and the optimization effect is more prominent for the small-sized houses. 92.28% and 94.54% of the space utilization rate of House 1 and House 2 respectively, much higher than that of House 3 (89.29%) and House 4 (84.25%). In addition, the design of the residential environment effectively improves the rate of indoor building energy efficiency. the energy efficiency of Residence 4 is maintained at the third stage (61.42%), while the energy efficiency of Residence 1 (55.31%), Residence 2 (54.15%), and Residence 3 (59.66%) is maintained at the second stage.

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