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Study on Evaluation of Indoor Material Aging Based on Analytic Hierarchy Process

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Abstract: In order to improve the living environment of the elderly, the physiological and psychological influence of indoor materials on the elderly's living was investigated. The evaluation index system of indoor material aging was composed of 4 first-level indicators and 11 second-level indicators. The analytic hierarchy process (AHP) was used to analyze the weight of each index in the evaluation system. The result provided a reference for the selection of the appropriate materials in the interior space design for the elderly to promote customized construction in an age-friendly society.

Keywords: Analytic hierarchy process; Suitable for aging; Interior materials; evaluation

1. Introduction

Aging is an issue to which all countries pay great attention. According to the latest census data, there were 260 million people aged 60 or above in 2020, accounting for 18.70% of the population in China. Among them, 190 million were aged 65 or above, accounting for 13.50 % of the total population. Compared with the sixth national census in 2010, this index increased by 5.44 and 4.63% respectively [1], indicating an aging Chinese population. As the elderly's physiological function declines and their living habits change, the elderly demand indoor materials with special requirements. Materials are the carrier of the age-appropriate design and often have a profound impact on the design [2]. Appropriate materials improve the comfort of the living environment for the elderly. Although there are many materials on the market, there are few indoor materials that meet the requirements of the elderly. Every year, accidents occur for the elderly due to improper selection of indoor materials. Therefore, we constructed the evaluation index system of indoor materials for the elderly using the analytic hierarchy process (AHP) to improve the elderly service system and build an age-friendly society.

2. Physiological and Psychological Characteristics of the Elderly

With the aging of the body, the physiological and psychological characteristics of the elderly change. The analysis and summary of the characteristics are a foundation for the selection of the evaluation indicators for indoor materials and the safe, reasonable, and humanized design for the elderly [3].

2.1. Physical characteristics

The elderly's physical functions are greatly reduced by age. Motor function degrades with reduced joint mobility and controllability, especially in the legs. As bones become brittle and lose regenerative ability, the elderly are prone to bone fractures with slow recovery, which sometimes is life-threatening. The degradation of the sensory system is also manifested especially in vision and hearing. Blurred vision, weak color discrimination, and hearing loss especially in the high-frequency area are the most obvious phenomena for the elderly. The third is the weakening of the adjustment ability. The aging of the elderly's internal organs leads to slow metabolism and poor adjustment ability to environmental factors such as temperature, humidity, light, and others, especially with a large temperature difference [4].

2.2. Psychological characteristics

The psychological characteristics of the elderly change due to the changes in social environment and physiological characteristics [5]. One of the main psychological characteristics is feeling lonely. After retirement, the activity of the elderly occurs mainly at home not at work, narrowing social interaction and increasing free time. When other family members are busy with work and do not have enough time to communicate with the elderly at home, the estrangement between the family and the elderly deepens, which make them elderly feel lonely. The second is depression. Due to the gradual degradation of physical functions, the elderly

are unable to move, resulting in a lack of self-worth, prone to inferiority. This causes depression and other negative emotions. The third is nostalgia. Most of them used to meet people and experience many things having enjoyed a rich life experience. Thus, the elderly are eager to express themselves and be recognized as a respectful person by others.

3. Method

3.1. Literature Review

A literature review was conducted for a systematic investigation and social research to understand the state of research in a related field to this study [6].

3.2. AHP

AHP is a simple, flexible, and practical multi-criteria decision-making method for quantitative analysis of qualitative problems. In the AHP process, elements are grouped into levels according to decisions such as objectives, criteria, and schemes, on which qualitative and quantitative analyses are based [7]. The first step of AHP is to establish a hierarchical model composed of a target, criterion, and index layer. Then, a judgment matrix is created. Table 1 shows the meaning of importance scales and their definitions. In the judgment matrix in an empirical scale, the evaluation criteria (Hs) and the evaluation factor (Si) are defined. The third step, is to calculate the weight and test consistency.

Table 1. Meaning of scale

Importance scale	Definition
1	Relative to H_s, S_i and S_j are equally important
3	S_i and S_j are slightly more important than H_s
5	Relative to H_s, S_i and S_j are important
7	S_i and S_j are much more important than H_s
9	Relative to H_s, S_i and S_j are absolutely important
2，4，6，8	It is in the middle of the two adjacent scales above

There are many methods to calculate index weight, including THE summation method, root method, summation method, iteration method, and so on. Among them, the root method is widely used in AHP. In the root method, the pairwise comparison matrix A= (a_{ij}) is created to find the weight of hierarchical elements as follows.

- Finding the product of each row of elements of A:$M_i=\prod_{j=1}^{n} aij$,i=1，2，...，n
- Taking the NTH root of M_i:$\overline{M_i}=\sqrt[n]{Mi}$
- Standardizing $\overline{M_i}$：$w_i=\frac{\overline{Mi}}{\sum\overline{Mi}}$，i=1，2，...n

Then, the weight vector of the hierarchical element W=（w_1，w_2，...，w_n）T is obtained.

Due to the complexity of objective things and the fuzziness and diversity of people's understanding, the judgment matrix cannot be completely consistent, so it is necessary to teest consistency. The consistency test is carried out as follows.

The largest Eigenroot of matrix A (λmax) is calculated using the following equation.

$$\lambda max=\frac{1}{n}\sum\frac{(Aw)}{w_i}，w_i（1，2，...，n） \quad (1)$$

The consistency indicator (C.I.) is calculated as follows.

$$C.I.=\frac{\lambda max-n}{n-1} \quad (2)$$

Then, the average random consistency index (R.I.) is tested. R.I. is the average of consistency indexes calculated according to a random occurrence judgment matrix. The R.I. values of 1 to 10 in an order matrix are shown in Table 2.

Table 2 . Values of average random consistency indicator (R.I).

Order of matrix	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.58	0.90	1.12	1.24	1.32	1.4	1.45	1.49

Finally, the consistency ratio (C.R.) is calculated as

$$C.R.=\frac{C.I.}{R.I.} \quad (3)$$

When C.R.<0.1, the consistency of judgment matrix A is considered satisfactory.

4. Results and discussion

4.1. Indicator System

Through the collection and collation of previous research results related to the aging evaluation of indoor materials, the evaluation was carried out from the four aspects of safety, comfort, usability, and environmental protection by considering the physiological and psychological characteristics of the elderly. Experts were invited to combine, modify, and sort out the influencing factors and screen the evaluation indexes of indoor materials' senility. Based on these four principles, 11 indicators were determined and categorized. The basic framework of the evaluation index system of indoor materials based on AHP is shown in Figure 1.

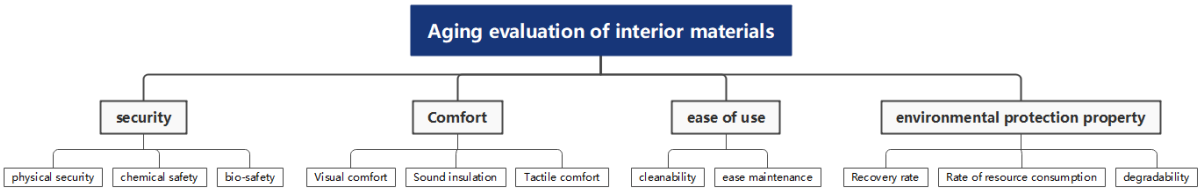

Fig. 1. Evaluation index system of indoor materials based on AHP.

4.2. Evaluation Indicators

4.2.1 Safety

The elderly's motor system deteriorates, and muscle degeneration leads to slow behavior, reduced balance ability, and easy bumping and toppling. Therefore, it is necessary to ensure the safety of using indoor materials [9]. Indoor material safety mainly is related to physical, chemical, and biological safety.

- Physical safety refers to the hardness, smoothness, waterproof and anti-slip, wear resistance, and elasticity of the material to meet the needs of the elderly's living. The elderly's legs and feet are not flexible. As they are easily fallen, the waterproof and non-slip properties of the materials must be chosen. Secondary injuries must be avoided from falls of the elderly. When wheelchairs, crutches or other tools are used, the wear resistance of indoor materials must be strengthened. At the same time, for the elderly to move conveniently, handrails need to be installed, and nails for hanging objects on the wall must be easily and firmly attached to the wall. These must be considered for the strength of the material.
- Chemical safety refers to whether harmful chemical substances are contained in the material.
- Biological safety refers to whether the material contains harmful microorganisms. A clean environment and high air quality are particularly important for the physical health of the elderly due to their weakened immunity.

4.2.2 Comfort

After safety is secured, comfort needs to be considered. Materials support for creating a comfortable physical environment. Therefore, comfort is a key to the test of the design's suitability. Comfort refers to visual comfort, tactile comfort, and sound insulation.

- Visual comfort: Due to the visual degradation of the elderly, building materials must facilitate visual comfort and accurate recognition of the elderly [10]. The visual comfort of the material can be offered with the colors, patterns, and gloss of the material. Different colors of materials give different feelings to the elderly. Warm colors provide a sense of safety and comfort. Due to the decline of the visual ability of the elderly, they cannot see fine patterns, especially patterns that are similar to the wall, ceiling, and bottom causing visual confusion. The ciliary muscle and the pupil regulation ability of the elderly is weakened, and the eye's tolerance to light intensity is decreased. The high gloss of the material causes the

phenomenon of glare. If the material produces strong visual contrast, it triggers anxiety or other negative emotions in the elderly.

- Tactile comfort is mainly reflected in the hardness, temperature, and texture of the material. Thermotactile sensation refers to the feeling of temperature obtained when a person touches a material. The tactile comfort of the material makes people feel warm. When the tactile temperature of the material is the same as that of the human body, the human feels it most appropriate [11]. The softness or hardness of touching materials also affects the tactile experience. Different degrees of softness and hardness provide different feelings to people. Soft materials give people a kind, warm, and comfortable psychological feeling, while hard materials make people feel firm and stable. In the selection of materials for the elderly, The softness or hardness of the material must be considered to provide a positive experience for the elderly.
- Sound insulation: The elderly generally have worse sleep quality and require silence indoors. The elderly are prone to neurasthenia in noisy environments, and their quality of life is seriously affected [12]. Therefore, indoor materials with soundproofness and noise prevention must be selected to provide a more comfortable and humanized living environment for the elderly.

4.2.3 Ease of use

The weakened physical movement of the elderly produces a sense of inferiority and loss. Thus, indoor materials must be easy to clean, convenient, and simple to maintain. When materials require complex cleaning and maintenance, they make the elderly feel inferiority, psychological pressure, and frustration.

4.2.4 Environmental protection

The ventilation function of the elderly is reduced by 40−50% compared to that of the young. The respiratory function is weakened, which makes the elderly prone to respiratory system infection. Environmental protection for materials is important and no toxic substances are contained in the materials. Green environmental protection and no possible environmental pollution of the material must be certified. Environmental protection can be reflected in recycled materials with repeated consumption.

5. Result and Discussion

12 experts in related fields were surveyed by a created questionnaire in this study. 11 questionnaires were returned with an effective rate of 91.7%. Starting from the second layer, a pairwise comparison between an element of the upper and lower layers was conducted to find elements connected between layers. According to the level scale, the level according to its importance was evaluated to obtain the judgment matrix of the lower layer against the upper layer [13] (Tables 3−7).

Table 3. Judgment matrix of criterion layer to target layer A

Destination layer (A)	A1	A2	A3	A4
Security (A1)	1.000	2.818	2.636	2.091
Comfort (A2)	0.355	1.000	1.364	1.655
ease of use (A3)	0.379	0.733	1.000	1.533
Environmental protection property (A4)	0.478	0.604	0.652	1.000

Table 4. Judgment matrix of index layer to criterion layer A1

Security (A1)	B1	B2	B3
B1	1.000	1.533	1.364
B2	0.652	1.000	1.533
B3	0.733	0.652	1.000

Table 5. Judgment matrix of index layer to criterion layer A2

Comfort (A2)	B4	B5	B6
B4	1.000	2.152	2.758
B5	0.465	1.000	1.667
B6	0.363	0.600	1.000

Table 6. Judgment matrix of index layer to criterion layer A3

Ease of use (A3)	B7	B8
B7	1.000	1.667
B8	0.600	1.000

Table 7. Judgment matrix of index layer to criterion layer A4

Environmental protection property (A4)	B9	B10	B11
B9	1.000	2.030	1.364
B10	0.493	1.000	0.867
B11	0.733	1.154	1.000

5.1. Weight Calculation

The root method was used to calculate the weight of the elements of the evaluation criterion layer of the AHP model for the indoor material. In the criterion layer, the judgment matrix was calculated with the weights listed in Table 8.

Table 8. Weight of indoor material evaluation index

Destination layer	Criterion layer	Index level	Weight
Aging evaluation of interior materials	Security（0.451）	physical security	0.418
		chemical safety	0.327
		bio-safety	0.256
	Comfort（0.215）	Visual comfort	0.544
		Tactile comfort	0.276
		Sound insulation	0.181
	ease of use（0.184）	Cleanability	0.625
		ease maintenance	0.375
	Environmental protection property（0.150）	Recovery rate	0.453
		Rate of resource consumption	0.243
		degradability	0.305

5.2. Consistency

4 first-level indicators and 11 second-level indicators were selected to test the consistency of the judgment matrix after the index system was constructed and the weight value was calculated. When CR < 0.1, the consistency test was passed (Table 9).

Table 9. CI and CR of judgement matrix

	A	A1	A2	A3	A4
λmax	4.080	3.033	3.008	2.000	3.007
CI	0.027	0.017	0.004	0.000	0.004
CR	0.030	0.029	0.007	0.000	0.006

5.3. Analysis Result

The criterion level was as follows: safety (0.451) > comfort (0.215) > ease of use (0.184) > environmental protection (0.150). This indicated that the selection of indoor materials must be made to ensure the health and safety of the indoor environment considering the elderly's demand. The weight value of visual comfort was the highest (0.544), indicating that the elderly paid more attention to visual experience. Among the two indexes of usability, the weight of easy cleaning was higher (0.625), indicating that it was necessary to use convenient and clean indoor materials in the living space of the elderly. In environmental protection, the weight of recycling efficiency and degradation were high with little difference, indicating that people paid attention to the treatment of materials.

6. Conclusions

The acceleration of aging in Chinese society provides opportunities and challenges for the design and use of indoor materials for the elderly home. Thus, it is urgent to improve the design of such materials. Materials are important in indoor environment design. Considering the psychological and physiological needs of the elderly, we evaluate the suitability of indoor materials to be used for interior design. With the physiological and psychological characteristics of the elderly, an evaluation system of indoor material was proposed with 4 first-level indexes and 11 second-level indexes including safety, comfort, ease of use, environmental protection, safety and health, ease of use, and humanistic care. Paying attention to the needs according to the elderly's pursuit of beauty, desire, and self-realization, materials must be selected carefully.

References

1. Tong, Y. The latest trends and trends of China's population -- Based on the analysis of the seventh National Census Data . *Journal of China Institute of Industrial Relations*, **2021**, *35*(04), 15–25.
2. Zhang, H.; Wang, W. Analysis on the development trend of furniture design for the aged. *Furniture*, **2019**, *40*(04), 42–45.
3. Shi, C.; Chen, W.; Zhang, Q. et al. Design of aging seat based on multi-dimensional perception of materials. *Design*, **2023**, *36*(10), 110–113.
4. Zhu, H. Research on Landscape design of elderly care community based on relevant theories of environmental behavior. *Suzhou University*, **2020**. DOI:10.27351/d.cnki.gszhu.2020.002691.
5. Hou, M. Research on design of elderly products based on humanization concept. *Industrial Design*, **2020**, *164*(03), 67–68.
6. Hsu, W. et al. Smart city governance evaluation in the era of internet of things: An empirical analysis of Jiangsu, China. *Sustainability,* **2021**, *13*(24), 13606.
7. Shen, X. et al. Application of fuzzy analytic hierarchy process to evaluate resource environmental bear capacity. *International Journal of Environmental Sustainability and Protection* **2022**, *2*(1), 10–16. https://doi.org/10.35745/ijesp2022v02.01.0002
8. Saaty, L. Decision Making-The analytic hierarchy and network processes(AHP/ANP). *Journal of Systems Science and Systems Engineering*, **2004**, *1*, 1–35.
9. Wu, H.; Shi, C.; Han, S. et al. Research on aging seat design based on CMF multi-dimensional sensing feature fusion. *Design*, **2021**, *34*(23), 81–83.
10. Zhang, Y. New requirements on materials for aging buildings. *China Building Materials Journal*, **2021**,*3*, 10–28.
11. Wang, J. Tactile perception of materials influencing interior design. *Art Appreciation*, **2018**, *18*, 222–223.
12. Gu, Q.; Liu, B. Application of new materials in aging renovation of old houses. *Housing Industry*, **2021**, *241* (01), 38–40.
13. Zhang, L.; Jia, Y. Research and discussion on sensory properties of materials. *Art and Design (Theory)*, **2008**, *1*, 126–128.