Journal of Electronics and Information Science (2023)
Clausius Scientific Press, Canada
DOI: 10.23977/jeis.2023.080614
ISSN 2371-9524 Vol. 8 Num. 6

A Method for Evaluating the Age-friendly Level in Hospitals Based on the Importance and Satisfaction

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Keywords: Human Factors Engineering, Evaluation of Age-friendly, Ergonomics, Fuzzy Comprehensive Evaluation Method, BCG Martrix

Abstract: Hospital age-friendly design is an important part of the medical security system, and how to evaluate it specifically is of great significance. This paper establishes a complete set of age-friendly methods, and firstly formulates the hospital age-friendly indexes through ergonomics evaluation. Subsequently, the Likert fuzzy semantic scale is used to collect expert opinions, and the independence of the indicators is screened and updated by Pearson correlation test. After that, the updated indicators were assigned importance using the objective CRITIC weighting method. Taking Wuhan Union Hospital as an example, the questionnaire design was used to evaluate the satisfaction of the elderly with each aging indicator of the hospital by using the fuzzy comprehensive evaluation method. Finally, using the BCG Matrix, combined with the importance degree and satisfaction data, it summarizes the aspects of Wuhan Union Medical College that are in urgent need of ageing improvement and the advantages that need to be maintained. This method is universal and can provide important references and improvement suggestions for the aging-friendly design of the hospital, and provide practical care for the actions of the elderly in the hospital, which is of high value.

1. Introduction

In According to the results of China's seventh population census in 2021, by the end of 2020, the total number of people over 60 years of age in China was 264 million, accounting for 18.7% of the total population, and the total number of people over 65 years of age was 191 million, accounting for 13.5% of the total population, and this ratio is increasing year by year, which indicates that it has already entered into an aging society. And with the increase of age, the physical functions of the elderly continue to decline, flexibility is gradually reduced, limb strength weakens, walking instability, vision and hearing impairment, slow response to the outside world, poor emergency response ability. At the same time, with the improvement of health consciousness of the elderly and the improvement of the medical insurance system, the demand of the elderly for medical services is increasing. Therefore, this special and large patient group needs to be paid more attention to, and the aging-friendly design of hospitals is indispensable.

The focus of ageing-friendly design is to be "elderly-centered", and to design spaces and equipments that are suitable for the elderly from the perspective of their needs and to enhance their experience. Aging-friendly design requires the necessary environmental modifications and aging-friendly design according to the situation of the elderly, in order to facilitate the mobility of the elderly, and at the same time, it should also take into full consideration the needs of the elderly for psychological comfort. Especially in hospitals, which are frequented by the elderly, how to do a good job of ageing research and renovation is an extremely important issue. After the ageing-friendly design, it is even more urgent to conduct ageing-friendly evaluation and propose reasonable improvements and summaries of the current ageing-friendly facilities.

2. Establishment of Age-friendly Evaluation System

2.1. Selection of the Age-friendly Indicators

Based on human factors engineering and ergonomics, this paper will select indicators from five categories as shown in Figure 1.

a) Fluency Assessment: An assessment of pedestrian flow analysis and pathway planning can identify the presence of congestion points, narrow corridors, or areas of poor flow within a facility. The results of the assessment can include flow distribution maps, hot spot analysis, and congestion point identification, which can provide recommendations for improving the layout.

b) Time Efficiency Evaluation: Time measurement allows for an assessment of how long it takes older adults to complete specific tasks. The results of the assessment can point to the presence of inefficient task flow or improperly laid out areas to provide optimization recommendations and improvements.

c) Action Optimization Evaluation: Action analysis allows for the examination of older persons' movements and movement sequences within a facility to assess the presence of unnecessary repetitive movements or inconvenient postures. The results of the assessment can provide recommendations for improving the layout and facility design to minimize physical exertion and inconvenience for older adults.

d) Human-Computer Interaction Evaluation: Barriers to use or inconveniences can be identified by assessing the interaction between older adults and the equipment, control panels, tools, etc. in the facility. The results of the assessment can include usability tests, ease-of-use scores and user feedback to provide recommendations for improving the design and layout of the equipment.

e) Signage and Orientation Evaluation: Evaluate the visibility, clarity, and comprehensibility of signage and orientation systems to ensure that older adults can easily locate needed facilities and services. The results of the assessment may include signage ratings, evaluation of the effectiveness of orientation and user feedback to provide guidance for improving the signage system.

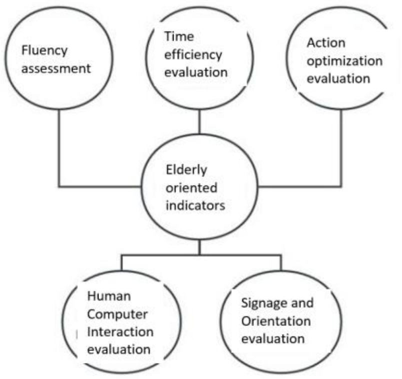

Figure 1: The Composition of age-friendly Indicators

Through reviewing the literature, it can be seen that Zhu Wenlong et al[1-2] divided the aging evaluation indicators of facilities in old neighborhoods into four categories: facility function, safety, appearance style, and compensatory design, under which there are 14 sub-items: practicability, ease of use, diversity, intelligence, structural solidity, stable performance, avoiding sharp corners, simplicity, aesthetics, easy recognition, appearance color scheme, material process, sensory compensation, and psychological compensation. However, it has the problems of fuzzy index selection ideology, easy to cause confusion of definition, and not comprehensive enough selection, which is not suitable for the selection of hospital aging indicators. Wang Tianfu and Wang Rui refined senior living facilities into 22 specific indicators from 105 indicators according to style satisfaction, use satisfaction, and experience satisfaction, which are easy to recognize, bright, simple, neat, beautiful, clean, convenient, applicable, sensitive, controllable, solid, safe, interactive, promptable, comfortable, affable, caring, and assistable, but it also has the problem of vague indicator selection, which may cause confusion in definition and is not comprehensive enough. However, there are problems such as duplication in the selection of indicators, which cannot be used as hospital aging indicators.

Therefore, based on the existing classification and the five directions delineated above, this paper selects brand-new indicators in a more detailed way and designs a way of filtering indicators in order to avoid the problem of duplication and insufficiently comprehensive selection of indicators. The specific indicators were selected as below.

a) Fluency Assessment: Fluency (1), Accessibility(2), Spatiality(3), Functionality(4).

b) Time Efficiency Evaluation: Simplicity (5), Sensitivity(6), Convenience(7).

c) Action Optimization Evaluation: Comfortableness(8), Safety(9), Labor-saving(10), Facilitative (11), Adjustability(12).

d) Human-Computer Interaction Evaluation: Compatibility (13), Practicality(14), Usability(15), Intelligence(16), Simplicity(17), Diversity(18).

e) Signage and Orientation Evaluation: Aesthetics (19), Easy Identification(20), Uniformity(21), Manufacturability(22), Interactivity(23), Lucidity(24), Colorability (25).

2.2. Expert Scoring and Improvement of the Indicators

Because the selected indicators may duplicate each other, leading to repeated evaluation, and some of the indicators may not be suitable for evaluating the hospital's age-friendly facilities. Therefore, in order to overcome these problems, this paper adopts the expert scoring method, which assigns weights to the relevance of the above indicators through the professional scores of different experts, and then filters the indicators through the Pearson correlation test, so as to obtain evaluation indicators that are more rigorous, independent, and responsive to the level of hospitals for the elderly[3-4].

2.1.1. Fuzzy Semantic Scale

The scale is based on fuzzy semantic scale, which not only takes into account the general ambiguity of human language, but also takes into account the subjective differences between different people when filling in the answers, so the questionnaire can also be designed to fill in the percentage of the cognitive state according to the degree of the filler's psychological feelings.

The scoring scale is based on 5, 4, 3, 2, and 1 for extremely important, relatively important, average, not so important, and very unimportant, respectively, and if a percentage is filled in by the filler, the score is calculated according to the percentage filled in. The final scores obtained (partially) are shown in Table 1 below.

Table 1: Rating Scale Score Calculation (Partial)

	Fluency	Accessibility	Spatiality	Sensitivity	Usability	Aesthetics	Uniformity	Interactivity
1	5	3	5	5	5	4.9	3	3
2	4	4	4	5	3	4	2	3
3	4.95	4.25	3.25	4.95	4.15	3.85	3.3	3.85
4	2.6	2.9	4.3	4.7	3.7	4.85	3.5	2.9

2.1.2. Indicator Correlation Studies and Indicator

By calculating the data from the resulting rating scale according to the above rules and analyzing the data in SPSS. The Pearson correlation standardized test table can be obtained, including the correlation coefficient and significance coefficient between the 25 proposed indicators, which is used to carry out correlation analysis. The steps of the analysis are as follows: first: first see if there is a significant relationship between Y and X; second: then analyze whether the correlation is positive or negative, and also the size of the correlation coefficient to indicate the degree of closeness of the relationship; third: summarize the analysis. Some of the data in the resulting table are displayed as shown in Table 2 below.

Table 2: Pearson Related Standards Data Sheet (Partial)

	$\bar{x}$	σ	1	2	3	4	5	...	25
(1)	4.645	0.486	1						
(2)	4.453	0.495	0.246	1					
(3)	4.210	0.614	-0.446*	0.048	1				
(4)	4.497	0.618	-0.083	0.055	-0.011	1			
(5)	3.337	0.980	0.145	0.210	-0.197	-0.027	1		
...	...	...	...	...	...	...	...	...	
(23)	3.995	0.713	0.297	0.044	-0.476*	-0.099	0.591**	...	
(24)	3.805	0.894	0.447*	0.219	-0.319	0.498*	-0.082	...	
(25)	3.955	0.945	0.191	0.028	-0.163	0.320	0.141	...	1
* p<0.05 ** p<0.01									

Statistics is based on the P-value obtained by the test of significance, generally with P < 0.05 for statistically significant differences, P < 0.01 for statistically significant differences, and P < 0.001 for extremely significant statistical differences. Significance answers the question of whether there is a relationship between them, indicating whether the results obtained are due to chance (statistically significant), and above that the correlation coefficient answers the question of the strength of the degree of correlation. When the absolute value of the correlation coefficient is between 0.1 and 0.3, it is generally considered that there is a weak correlation between the variables; when the absolute value of the correlation coefficient is between 0.3 and 0.5, it is generally considered that there is a moderate correlation between the variables; when the absolute value of the correlation coefficient is greater than 0.5, it is generally considered that there is a strong correlation between the variables[5-6].

Therefore, based on the test of significance, the correlation coefficient was examined to eliminate the indicators of Fluency (1), Labor-saving(10), Usability(15), Intelligence(16), Diversity(18), Manufacturability(22), Lucidity(24), and Colorability (25).

The updated Pearson correlation standardized test table was obtained, including the correlation coefficients and significance coefficients between the two of the remaining 17 proposed indicators for correlation analysis, and some of the data in the resulting table are presented in Table 3 below.

Table 3. Updated Pearson Related Standards Data Sheet (Partial)

	$\bar{x}$	σ	1	2	3	4	5	...	25
(2)	4.453	0.495	1						
(3)	4.210	0.614	0.048	1					
(4)	4.497	0.618	0.055	-0.011	1				
(5)	3.698	0.975	0.163	0.040	0.101	1			
(6)	4.188	0.822	0.416	0.039	-0.090	0.325	1		
...	...	...	...	...	...	...	...	...	
(20)	3.728	0.807	0.144	-0.177	0.032	0.244	0.036	...	
(21)	3.995	0.713	0.044	-0.476*	-0.099	0.247	0.437	...	
(23)	3.955	0.945	0.028	-0.163	0.320	0.275	-0.048	...	1
* p<0.05 ** p<0.01									

The same process as above, the analysis shows that none of the seventeen terms will show significance with correlation coefficient values of 0.048, 0.055, 0.163, 0.416, 0.275, 0.096, -0.218, -0.255, 0.101, -0.108, 0.139, 0.093, 0.254, 0.144, 0.044, 0.028, all of which are close to 0, and all of which have p-values greater than 0.05, implying that the screened indicators are no longer correlated.

The Pearson correlation visualization before and after filtering the indicators is shown in Figure 2 and 3 below, where the darker color represents the stronger correlation between the indicators.

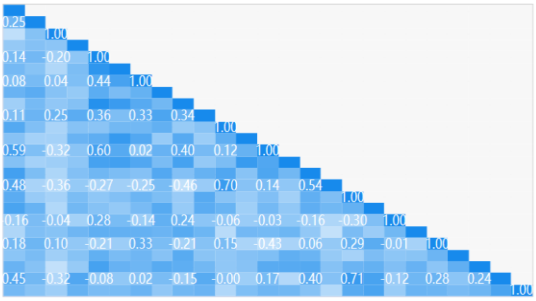

Figure 2: Pearson Correlation Visualization (before)

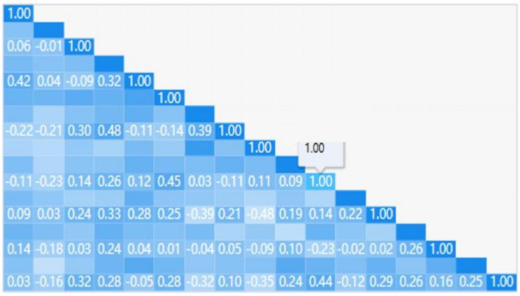

Figure 3: Pearson Correlation Visualization (after)

Through the correlation test, these 17 indicators were used as the final evaluation indicators for evaluating the hospital's age-friendly Level.

2.3. Calculation of CRITIC Indicator Weights

In order to try to objectively measure the difference in importance of different indicators for hospital facilities for the elderly, and at the same time balance the weak correlation between the indicators, it is necessary to find an objective weighting method to assign weights to the screened indicators. Through reviewing the information and related books, this paper finally decided to adopt the CRITIC weighting method, which utilizes expert scores to assign weights to the indicators.

CRITIC method is a better objective assignment method than entropy weight method and standard deviation method. It is a comprehensive measure of the objective weights of the indicators based on the comparative strength of the evaluation indicators and the conflict between the indicators. Considering the size of indicator variability while taking into account the correlation between indicators, it is not the case that the larger the number means the more important it is, but the objective attributes of the data itself are fully utilized for scientific evaluation.

The steps are shown below.

2.3.1. Dimensionless Processing

In order to eliminate the influence on the evaluation results due to the difference in the scale, it is necessary to process the indicators without a scale. CRITIC weighting method generally uses forward or reverse processing, and does not use standardized processing, the reason is that if you use standardized processing, the standard deviation of all become the number 1, that is, the standard deviation of all indicators is completely the same, which leads to the volatility indicator has no meaning. The formula (1) is as follows.

$$x_{ij}' = \frac{x_j - x_{min}}{x_{max} - x_{min}} \tag{1}$$

2.3.2. Indicator Variability

The standard deviation is used in the CRITIC method to indicate the fluctuation of the differences in the values taken within each indicator, the larger the standard deviation indicates that the greater the difference in the value of the indicator, the more information can be projected, and the stronger the evaluation strength of the indicator itself, the more weight should be assigned to the indicator. Variability is presented in the form of standard deviation, whose formula (2) is shown below.

$$\begin{cases} \bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij} \\ S_j = \sqrt{\frac{\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)^2}{n-1}} \end{cases} \tag{2}$$

2.3.3. Indicator Conflicting

The correlation coefficient is used to indicate the correlation between the indicators, the stronger the correlation with other indicators, the less the indicator is in conflict with other indicators, the more the same information is reflected, and the more repetitive the content of the evaluation is, which, to a certain extent, weakens the evaluation strength of the indicator, and the weight assigned to the indicator should be reduced. The formula (3) is shown below. rij denotes the correlation coefficient between evaluation indicators i and j.

$$R_j = \sum_{i=1}^{p}(1-r_{ij}) \tag{3}$$

2.3.4. Self-information

$$C_j = S_j \sum_{i=1}^{p}(1-r_{ij}) = S_j \times R_j \tag{4}$$

The larger Cj is, the greater the role of the jth evaluation indicator in the whole evaluation indicator system, the more weight should be assigned to it.

2.3.5. Self-information

So the objective weight Wj of the jth indicator is:

$$W_j = \frac{C_j}{\sum_{i=1}^{p} C_j} \tag{5}$$

In accordance with the above steps and formulas, the weight values of the screened indicators were calculated using the expert rating data, as shown in Table 4 below.

Table 4: CRITIC Indicators Weights Results

Indicators	Indicator Variability	Indicator Conflicting	Self-Information	Weights
Accessibility	0.495	14.726	7.291	3.63%
Spatiality	0.614	17.755	10.898	5.42%
Simplicity	0.618	14.905	9.215	4.58%
Sensitivity	0.822	12.747	10.479	5.21%
Easy Identification	0.919	15.02	13.807	6.87%
Interactivity	0.975	13.026	12.704	6.32%
Uniformity	0.935	13.001	12.161	6.05%
Convenience	0.852	16.583	14.128	7.02%
Functionality	1.083	15.271	16.54	8.22%
Aesthetics	0.76	14.557	11.07	5.50%
Simplicity	0.843	17.189	14.493	7.21%
Practicality	0.847	14.651	12.412	6.17%
Compatibility	0.746	14.508	10.817	5.38%
Comfortableness	0.945	14.362	13.573	6.75%
Adjustability	0.807	15.149	12.227	6.08%
Safety	0.616	15.259	9.397	4.67%
Facilitative	0.713	13.89	9.899	4.92%

2.4. Age-friendly Level Evaluation

After determining the indicators and their corresponding weights for evaluating the ageing and ergonomics of hospital facilities for the elderly, it is necessary to conduct a specific survey on the level of satisfaction of hospital facilities for the elderly, which has practical significance.

2.4.1. Elderly Satisfaction Survey

Based on the satisfaction evaluation index system, the Likert scale method was used to determine the evaluation set {very satisfied, satisfied, generally satisfied, dissatisfied, and very dissatisfied} of evaluation layer C to collect the satisfaction of the elderly.

Based on the satisfaction data collected, the fuzzy comprehensive evaluation method was used. Fuzzy comprehensive evaluation method is a comprehensive evaluation method based on fuzzy mathematics. This comprehensive evaluation method transforms qualitative evaluation into quantitative evaluation according to the affiliation degree theory of fuzzy mathematics, i.e., it uses fuzzy mathematics to make an overall evaluation of things or objects constrained by multiple factors. It is characterized by clear results and strong systematicity, and it can better solve the fuzzy and difficult to quantify problems, and it is suitable for a variety of non-deterministic problems. The steps are as follows:

1) The synthesized evaluation matrix R

Find the comprehensive evaluation matrix R, and use the fuzzy synthesis model to build the satisfaction evaluation matrix. Where the horizontal row indicates the percentage of each Likert scale indicator to the total number of people.

2) Based on the satisfaction evaluation matrix, the fuzzy comprehensive evaluation set B is obtained.

$$B_i = W_i * R_i \tag{6}$$

3) Based on E=B×H, the satisfaction rating values are calculated separately.

$$E_i = B_{ij} \times H \tag{7}$$

$$E_1 = 5B_{11} + 4B_{12} + 3B_{13} + 2B_{14} + 1B_{15} \tag{8}$$

2.4.2. BCG Matrix Analysis

The BCG Matrix method is a method for evaluating the attractiveness of a firm's business portfolio, which is used in this paper to evaluate the level of age-friendly in hospitals. This is because the evaluation of products and facilities for aging is similar, both consisting of importance and satisfaction as mentioned above. It can be divided into quadrant 1 (high concern): a quadrant of high importance and high satisfaction; quadrant 2 (priority improvement): a quadrant of high importance and low satisfaction; and quadrant 3 (irrelevant): a quadrant of low importance and low satisfaction. Quadrant IV (maintaining strengths): belongs to the quadrant of low importance and high satisfaction.

3. Practical Application--Wuhan Union Hospital

The Likert scale method was utilized to determine the evaluation set {very satisfied, satisfied, generally satisfied, dissatisfied, very dissatisfied} of evaluation stratum C to collect the satisfaction of the elderly. The survey was conducted in a combination of online and offline methods in order not to disturb the elderly's visiting time. Offline we used the questionnaire to consult with some older people who were waiting, and online we distributed QR codes in the Concordia Hospital in the hope that more older people or their families could take the time to fill out the survey.

A total of 86 online questionnaires and 37 offline questionnaires were collected.

Based on the satisfaction data collected, a composite evaluation matrix R was derived.

$$\begin{cases} C_1 : R_1 = (0.167, 0.333, 0.198, 0.202, 0.100) \\ C_2 : R_2 = (0.119, 0.358, 0.244, 0.093, 0.186) \\ C_3 : R_3 = (0.140, 0.279, 0.256, 0.130, 0.195) \\ C_{16} : R_{16} = (0.191, 0.286, 0.372, 0.050, 0.100) \\ C_{17} : R_{17} = (0.130, 0.173, 0.337, 0.171, 0.190) \end{cases} \tag{9}$$

Following the steps in D, the satisfaction rating values for each indicator are calculated separately. The Weight and Satisfacion level of each indicator are shown in the Table5 below.

Table 5: The Weight and Satisfacion level

Indicators	Weight	Satisfaction	Indicators	Weight	Satisfaction
Accessibility	3.63	3.24	Facilitative	4.92	3.2
Spatiality	5.42	3.3	Adjustability	6.08	3.06
Simplicity	4.58	3.17	Compatibility	5.38	3.24
Sensitivity	5.21	2.84	Practicality	6.17	3.3
Convenience	7.02	3.36	Aesthetics	5.50	2.58
Comfortableness	6.75	3.59	Functionality	8.22	3.08
Safety	4.67	3.29	Easy Identification	6.87	2.62
Simplicity	7.21	3.17	Uniformity	6.05	3.38
Interactivity	6.32	2.95			

Plotting the BCG Matrix shown in Figure 4 below. Where the horizontal axis represents Satisfaction and the vertical axis represents Weight.

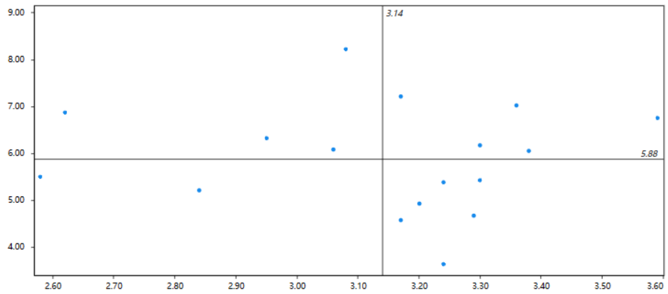

Figure 4: The BCG Matrix

As can be seen from this figure, the ease of identification, functionality, interactivity, and adjustability of the elderly-friendly facilities in the Wuhan Union Hospital are among the areas in need of urgent improvement. Advantages exist in the indicators of simplicity, utility, convenience, homogeneity, and comfort.

As a result, by identifying areas of urgent need for improvement in the institution, the hospital can target the improvement of age-friendly facilities in the institution. For example, in terms of functionality, hospitals can facilitate the provision of commonly used medicines for chronic diseases in the vicinity of the elderly through services such as drug delivery and medication counseling. Implement the construction of outpatient smart pharmacies and promote the docking of prescription systems with pharmacy delivery systems to reduce the waiting time for patients to pick up their medications.

4. Conclusions

This paper establishes a complete index evaluation system for hospital elderly-friendly facilities, from index selection, index relevance test, index screening to weight determination, satisfaction survey, and BCG matrix improvement. Based on ergonomics, a scientific and rigorous process method for solving the evaluation of hospital ageing facilities for the elderly is proposed. The method:

(1) can give evaluations for each specific aspect (performance) of the hospital. It can evaluate all five aspects of ergonomics mentioned before.

(2) It is possible to compare the advantages and disadvantages of each indicator.

(3) It is possible to determine the indicators that need to be improved urgently and those that need to be maintained. It can clarify the improvement route and direction for the hospital.

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