Research of a Green Hospital Evaluation Index System based on Analytic Hierarchy Process

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Abstract:

With an increasing trend of the number of hospital buildings in China, hospital buildings are facing an urgent problem with a lot of demands for energy, and high quality requirements. Focusing on the problem, China has issued the evaluation of green hospital buildings, which provides more accurate quantitative evaluating indicators. According to the recent researches and concepts of green hospital at home and abroad, in order to solve the present problems better in the estimation of green hospital, the lack of an effective evaluation index system for guiding the construction and evaluation of effects in green hospital estimation should be focused on as the main issue. In the investigation of some hospitals on the basis of the expertise consultation, analytic hierarchy process (AHP) is employed to confirm the weight of grade Level-1 and Level-2 indexes of green hospital estimation, and calculate the weights of the combination coefficients for the construction of a green hospital evaluation index system in green healthcare. This paper takes Shanghai East Hospital as a research case, and based on AHP, a set of actual measurement indicators are figured out for evaluating the assessment of the hospital buildings. The evaluation indexes system of green hospital is established with the approach of AHP. Finally, 4 Level-1 indicators, 30 Level-2 indicators and the corresponding index weight coefficients are finally determined. And through the selection of the related evaluation indicators, we can positively make progress for the evaluation systems in green hospital estimation, which will provide useful reference for decision-making of hospital management.

Keywords: *Green Hospital estimation, Analytic Hierarchy Process, Green Building, Green Health Treatment*

I. INTRODUCTION

With the severe energy crisis and environmental problems, the concept of green environment has been widely accepted by international communities, and it has been widely extended to the issues of political, economic, cultural, social and other fields [1-3]. In 1989, the concept of green economy was first put forward by Britain, its core idea focuses on realizing the harmonious unity of environmental protection and economic development by calculating and evaluating resources and environment related products and services. In 2012, at the World Conference on Sustainable Development held in Rio de Janeiro, the participant countries focused on the promotion and significance of green economy to a sustainable development, and recognized that green economy is an important tool to achieve sustainable development and reach a goal of adhering to the management of natural resources for a sustainable development, so as to achieve a sustainable economic growth and improve the utilization efficiency of resource knowledge. As an important premise for promoting the development of green economy, health care industry becomes a necessary condition and an important factor to achieve a green sustainable development [4-5]. In domestics, China is also facing the problems of lacks of resources and energy and deterioration of ecological environment. Aiming at the problems of environmental pollution and energy crisis brought by economic development, the green concept of development has been put forward in the beginning decade of the 21st century, which has been developed into the issues of nature, ecology, environmental protection, low consumption of carbon and energy. As we know, the constructions and daily operations of hospitals will have a certain degree of impact on the health of citizens, environmental health and social health, so Medical treatment and activities have higher and more stringent requirements on the environment. As intensive units of equipment and assets [6], hospitals have caused environmental pollution due to inevitable medical wastes in the operation process. Environmental pollution increase the medical and residential risks faced by patients and surrounding population, and it occurs a negative impact on the role of hospitals in healthcare in some extent.

During the history of hospital development in China, many hospitals have one-side emphasis on medical usage, building area, number of beds, large-scale and top medical equipment configuration, and so on. Through these construction measures, whether the number of hospitals, the construction area and number of beds are expanded, it is beneficial to satisfy the demands of ordinary people in diagnosis and treatment, ease the difficulties and high costs for seeing a doctor. However, the expansion of scales, the increase of hardware equipment configuration, and the rapid increase of hospital operating costs lead to the significant increases of hospital energy consumptions. In response to the new problems in the developing process,

WHO has also carried out activities with the issue of "Health in the green economy" to reduce the impact of hospital enlargements in the world. In recent years, the concept of "green hospital" has been proposed, which makes hospitals to combine the development of units with the development of ecological environment. At the same time, government official departments have also issued a series of documents to guide the construction of green hospitals and improve the sustainable development of hospitals. Based on the advanced experiences at home and abroad, this paper attempts to establish a set of green hospital evaluation index system by studying the theoretical knowledge and management methods of green hospitals, hoping to provide new ideas for management and evaluation of hospitals.

1.1 Background

With the attention of public people to environmental protection and understandings of the impacts of climate changes on human life, it is proposed that the corresponding environmental governance and green development also should be achieved in hospitals [2]. The hospital medical activities make the differences of the green construction and evaluation methods with those of the other fields. It is inevitable for modern hospitals to practice the idea of green hospital management based on the concept of green development, which is conducive to a sustainable hospital development, and can improve the patients' experience and clinical satisfaction.

1.2 Overview of Green Hospital

The current definition of green hospital is mainly proposed by the European countries or the US [7-9]. It includes: environmental acceptance is firstly required in the site selection of hospital buildings, the sustainability and universities of buildings are also considered in the design processes, and green materials and products should be selected in the construction process, the green concept is penetrated in the process of renovation and construction, and considered in the follow-up operation. Combined with the basic national conditions of China hospitals, the issues of green hospital mainly includes: environmental protection and sustainable development of hospital construction engineering, energy saving and water saving and less pollution in daily operation, green health and patient satisfaction in healthcare service, and related hospital green management measures. The research work of this paper will also follow the above aspects.

1.3 The Research Status at Abroad

Since the 1960s and 1970s, due to increasingly serious problems of energy and

environment, the United Nations Environment Program (UNEP) started to discuss sustainable development ideas, around the world, promote the green concept, and it gradually become the prevalent concept of the international communities [10]. Developed countries have issued some "green development" policies continually, especially after the world climate conference held in Copenhagen in 2009, the concept of green and low-carbon development has been widely accepted and promoted in various countries. For example, WHO began to list the promotion of green concept as a key project in healthcare management as early as 2010[10]. Under the promotion of the green concept, developed countries have carried out the construction of green hospitals, which ranks in the forefront of the world. Hospital buildings focus on the combination of information technologies, which can fully accomplish the concept of environmental protection and sustainable development. United States have put forward an evaluation system of green buildings which can be used to estimate the energy consumption and environmental pollution caused by buildings, in order to realize the evaluation standard of green buildings. At present, the prevalent evaluation systems of green buildings in the world mainly includes LEED and GGHC standards. The former, LEED [2], as a high-performance design and operation standard of green buildings, has been widely applied in the evaluation of site selections in building construction, energy and water consumption, calculations of material resources and indoor environment quality, and its certification includes: building strategy, design and construction. The latter one, GGHC is based on the standards and evaluation indicators of LEED, which can be applied to the evaluation of green buildings in health care industry. In spite of green hospital has made some progresses in foreign developed countries, due to the lacks of mature and effective rules and evaluation systems, it has encountered various problems in promotion, so it is necessary to improve the relevant evaluation inevitably.

1.4 The Research Status in Domestics

At the beginning of the 21st century, the Ministry of health in China responded to the requirements of the national green environmental protection policy and established the green hospital. In 2000, No. 302 Hospital of PLA started to try the construction of green hospital. In 2003, China Hospital Association carried out the related activities of green hospital in large hospitals. In 2009, China Hospital Association established a leading group of green hospitals, and prepared a five-year plan for it; in 2011, the technical rules for green hospital building evaluation (Draft) was prepared and issued; and the evaluation standard for green hospital buildings was also promulgated and implemented, which mainly evaluates hospitals from the aspects of building planning, equipment, environmental assessment and environmental protection, as well as the operation management. According to the evaluation results, green hospital buildings are divided into three levels estimated by the flexible selection of evaluation indexes, and the relevant evaluation indexes can be selected flexibly according to the actual

development of different regions. In general, the current evaluation methods of green buildings in China refer to LEED or some green building standards issued by China. The implementation of these measures has continuously promoted the popularization of green buildings and project constructions in hospitals. Although many achievements have been made in the promotion, some problems about the application of various evaluation standards have also been found, which need to improve the corresponding evaluation index system.

II. RESEARCH PURPOSE AND METHOD

2.1 Research Purpose

Based on the advanced experience at home and abroad, this paper attempts to propose a set of green hospital evaluation indexes by studying the theoretical knowledge and management methods of green hospitals, trying to provide new ideas for hospital management and evaluation. The main purposes of this study are list as follows:

1) Analyzing and studying the current evaluation index system: According to the current analysis and queries, it is found that there is are lacks of scientific and effective evaluation index systems and methods in the promotion process of green hospitals. Through detailed demonstrations and continuous attempts, a set of system is constructed to promote its development.

2) Construction of evaluation index and calculation model and assignment: On the basis of researches and expert discussions, determine the first and second level indexes and assignments of the related weights, through statistical methods verification, figure out the final weight coefficients, in order to provide the basis for the construction and evaluation of green hospitals.

2.2 Research Method

The research methods used in this paper include:

1) Research method of literature reviews: Through the queries of domestic and foreign journals, dissertations and website resources of understanding the research status of green hospitals; according to the published standards and specifications, sort out the existing evaluation index structure, and analyze the feasibility of relevant indicators.

2) Experts group discussion: Through the experts team composed of medical administrative departments, research institutions, industry associations, or hospital managers, forums or

multiple interviews are used to build an outline for the evaluation principles, index elements, weights, and calculation models of green hospitals, and group discussions were conducted;

3) Investigation and analysis: Through questionnaires, seminars, face-to-face interviews or the other ways, we can obtain first-hand information about green hospital buildings, environment, energy consumption and medical business, and constantly optimize the relevant evaluation index systems based on the obtained information.

III. RESEARCH EXPERIMENT AND RESULTS

3.1 Evaluation Principles of Green Hospitals

As a process of continuous development and improvement, the construction of green hospitals needs a set of good evaluation systems for guiding the application. Through continuous improvements and rectifications, we can more objectively reflect situations which are beneficial to actual works. This paper adheres to the scientific principles, systematic guidance, comprehensive integrity, and focuses on the hierarchy, independence, sequencing and industry characteristics while constructing the evaluation index system, so as to set the indexes and weights more reasonable, for demonstrating the effective levels, promote the construction of green hospitals, and guide the follow-up developing direction.

It is difficult to select index systems for green hospitals evaluation. According to the above evaluation principles, the full-play elements of green hospitals are extracted by the brainstorming method of experts group as the evaluation indexes. And the core elements and grading index of green hospital are usually listed combined with the actual construction and management of hospitals, and considering the particularity of medical institutions.

3.2 Elements for Evaluation Indexes

In the process of determining the evaluation indexes, this paper mainly carries out preliminary screening through literature reviews, comparisons and inductions, combines the needs of hospital management departments with superior policies, and forms written opinions in the form of discussions by expert groups. And it forms the scheme can directly reflect the relationship between core elements and various factors. The technical route implementation process is shown in Figure 1 below:
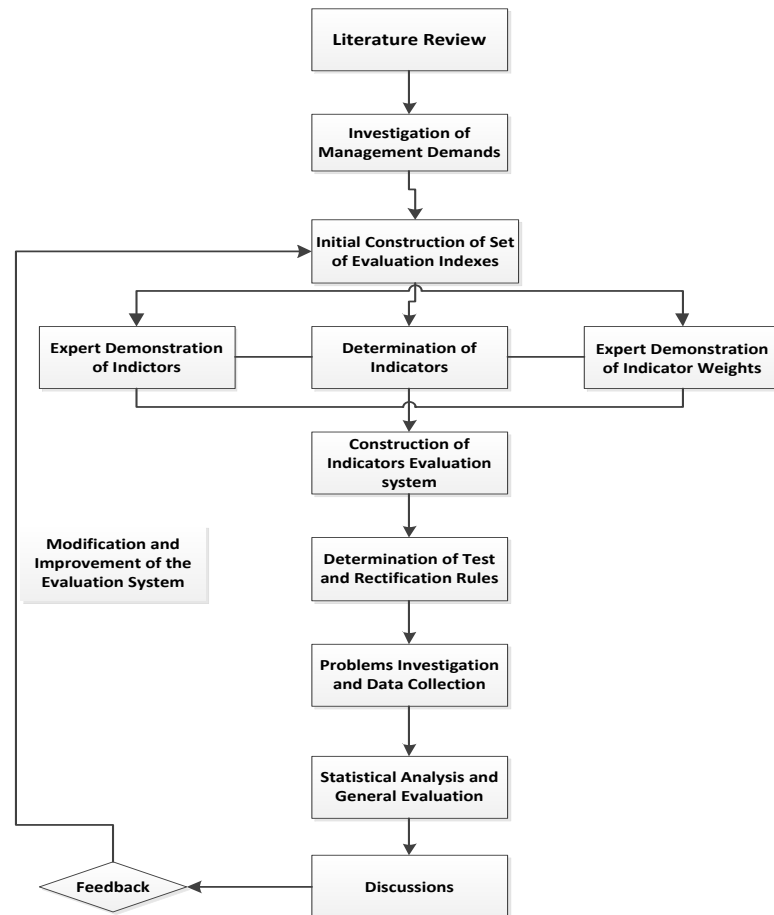
Fig 1: The technical implementation process of determining evaluation indexes

3.3 The Weights of Evaluation Indexes

After the rounds of argumentation of the experts group, combined with the principle of analytic hierarchy process (AHP) [11-12], this paper first builds a hierarchical structure that can reflect the independent objectives and needs, and then compares the importance of different factors at the same layer according to the evaluation and standardization of the experts. It forms a judgment matrix through the numerical assignments, and then calculates and standardizes the characteristics vectors and weights. The hierarchical structure model is demonstrated in Figure 2.
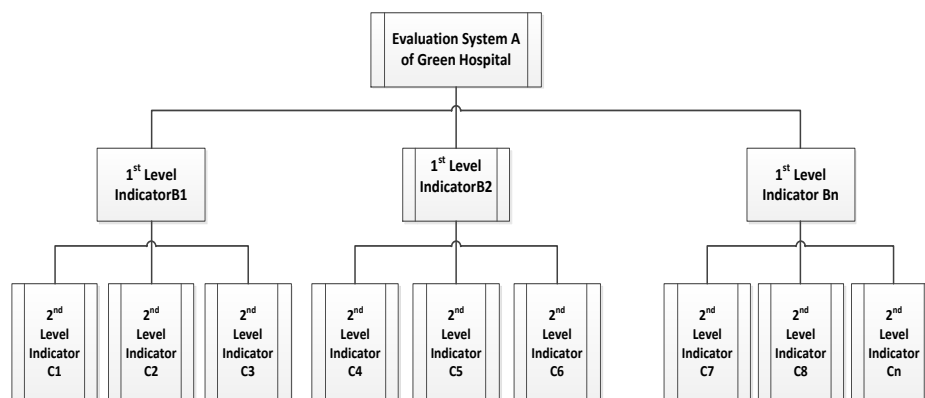
Fig 2: The AHP module of the hierarchical evaluation indexes

3.4 The Calculation Process of Index Weights

According to the principle of AHP, the calculation process of evaluation index weights of green hospital includes the following four steps:

a. A preliminary hierarchical structure model is established, which includes multiple factors decomposed into several levels. Each factor is used to evaluate the application effect of its level and reflects the correlation between them;

b. The judgment matrix A is established by comparing and assigning some factors in the above hierarchical structure model;

c. When the judgment matrix A is constructed, it needs to be processed mainly for single ranking and the consistency test between levels, and calculate the maximum eigenvalue λ and the corresponding eigenvector W; if it can pass the consistency test, the eigenvector value is determined as the index weight;

d. After obtaining the index weights in the above steps, the algorithm continues to rank the judgment matrix A and check its consistency. This step is used to calculate the combined weight vector of the application effect at the lowest level. If the calculation results can pass the consistency test, it proves that the combination weight vector is reasonable and can be used as the final evaluation index coefficient.

3.5 Evaluation Indexes and the related Weight Assignment

According to the above calculation steps, the judgment matrix A is established in turn, the

eigenvalue λ and the eigenvector W are calculated, and the consistency test and timely correction are carried out for the weight coefficient W_i of each index. The value of the combined weight coefficient is the product of the corresponding W_i value of the first level index B_i and the second level index C_i. Finally, it obtains the correlation between the primary and secondary indicators of green hospital, and calculates the weight results, as shown in TABLE I-III.

TABLE I. Composition of primary evaluation indexes and corresponding secondary index items of green hospital

1ST LEVEL INDEXES	2ND LEVEL INDEXES
GREEN MANAGEMENT B1	Hospital department setting C1, Hospital management long-term planning C2, Hospital rules and regulations C3, Hospital publicity and education C4, Hospital standard implementation C5, Professional management personnel composition C6, Annual plan and summary C7
GREEN BUILDING B2	Building planning C8, Greening rate C9, Energy saving management C10, Water saving management C11, Special facilities C12
GREEN ENVIRONMENT B3	Operating room environmental management C13, Intensive care unit Environmental management C14, Air quality monitoring system C15, Natural ventilation design C16, Mechanical ventilation / air conditioning management C17, Temperature management C18, Noise management C19, Sewage management C20, Medical waste management C21
GREEN MEDICAL B4	Medical personnel qualification management C22, Medical service price publicity C23, Open bed utilization C24, Rational drug use management C25, Average length of stay C26, Average hospitalization expenses C27, Pathogenic

	microorganism management C28, Nosocomial infection rate control C29, Patient satisfaction C30

Table II. Weight assignment of primary evaluation index of green hospital

1ST LEVEL INDEXES	W_i
B1	0.177
B2	0.208
B3	0.241
B4	0.374

Table III. Weight assignment and weight coefficients of secondary evaluation indexes of green hospital

Weight coefficients of 2nd Level Indexes	Wi	Combination weight coefficients
C1	0.067	0.012
C2	0.086	0.015
C3	0.162	0.029
C4	0.141	0.025
C5	0.177	0.031
C6	0.158	0.028
C7	0.209	0.037
C8	0.177	0.037
C9	0.131	0.027
C10	0.208	0.043
C11	0.241	0.050
C12	0.243	0.051
C13	0.083	0.020
C14	0.087	0.021

C15	0.150	0.036
C16	0.076	0.018
C17	0.103	0.025
C18	0.125	0.030
C19	0.134	0.032
C20	0.096	0.023
C21	0.146	0.035
C22	0.113	0.042
C23	0.087	0.033
C24	0.079	0.030
C25	0.125	0.047
C26	0.097	0.036
C27	0.135	0.050
C28	0.103	0.039
C29	0.117	0.044
C30	0.144	0.054

The calculation of Ci is shown in formula (1):

$$Ci = \frac{\lambda_{max} - n}{n - 1} \tag{1}$$

λ_{max} is the maximum eigenvalue of the judgment matrix K:

$$Aw = \lambda w \tag{2}$$

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(A^{\sim}W)_i}{W_i} \tag{3}$$

Through matrix calculation, we know that: λ_{max} =4.243；Ci =(4.243-4)/(4-1)=0.081；according to the above calculation results, if n = 4, the average random consistency index RI is 0.89. According to the formula CR = CI / RI, Cr = 0.081/0.89 = 0.091. Because the CR value is less than 0.1, it shows that there is no logical mistake in this index, and the consistency test of judgment matrix can be passed. By analogy, the calculation process and consistency test of judgment matrix established by comparison between other levels are the same, which will not be repeated again.

IV. CONCLUSION

Based on the investigation of the actual needs of hospitals, this paper analyzes the research

progress of green hospitals, and elaborates the related concepts and methods. Although the green hospital construction standards and related specifications have been issued at home and abroad, there is lack of a set of effective evaluation indexes, which is not conducive to the development and the evaluation of constructions of green hospitals. Therefore, according to the multiple rounds argumentation of the expert groups, this paper constructs the green hospital evaluation index system based on AHP, and finally it determines 4 first level indicators, 30 second level indicators and the corresponding index weight coefficients. In view of the limited research level, project deadline time, funds and other reasons, this paper only determines the weight coefficients of the evaluation indexes, its effects still need to be under evaluation and assessment with the actual construction of a number of hospitals, and he follow-up research process will need to be in promotion in future.

ACKNOWLEDGEMENTS

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