Journal of Al-Azhar University Engineering Sector

Vol.18, No. 67, April 2023, 430- 442

WEIGHTING THE ASSESSMENT CATEGORIES OF EGYPT'S GREEN HOSPITALS RATING SYSTEM USING ANALYTICAL HIERARCHY PROCESS

Sarah Elariane*, Dina Salem

Architecture & Housing Institute, HBRC, Cairo

*Correspondence: saraelariane@gmail.com

Citation:

S. Elariane and D. Salem, "Weighting the Assessment Categories of Egypt's Green Hospitals Rating System Using Analytical Hierarchy Process", Journal of Al-Azhar University Engineering Sector, vol. 18, pp. 431-443, 2023.

Received: 21 September 2022

Accepted: 7 February 2023

ABSTRACT

Green building rating systems are important tools widely used to assess buildings' sustainability and certify a building as "green". Some of these tools are applied in different regions regardless of the weights or the priority of different indicators within a specific region. The Analytical Hierarchy Process method is used to weight sustainability assessment categories as part of the process of developing a green building rating system for healthcare facilities in Egypt. An expert survey has been conducted and Team Expert Choice software was used to calculate the relative weight of the weighting criteria and assessment categories based on the relative importance of the challenges and pressing environmental issues in Egypt. The results showed that resource efficiency and economic viability are the challenges with high relative importance and the final weights of assessment categories determined the highest weights for three categories: energy efficiency, indoor quality, and materials and resources.

KEYWORDS: Analytical Hierarchy Process, multicriteria decision-making process, green healthcare facilities, Egypt (Should not be more than 5 keywords)

تحديد الوزن النسبي لعناصر تقييم استدامة المستشفيات الخضراء في مصر باستخدام عملية التحليل الهرمي

سارة عبد المنعم العريان ، دينا سالم

مركز بحوث الاسكان والبناء ، القاهرة

*البريد الاليكتروني للباحث الرئيسى : saraelariane@gmail.com

الملخص

أصبح تقييم المباني الخضراء أمر ضروري لا سيما مباني الرعاية الصحية لما لها من تأثير على صحة الإنسان والبيئة. تعد أنظمة تقييم المباني الخضراء من الأدوات الهامة المستخدمة على نطاق واسع لتقييم استدامة المباني واعتمادها كمباني "خضراء". يتم تطبيق بعض هذه الأدوات في مناطق مختلفة بغض النظر عن أولوية المؤشرات المختلفة داخل منطقة معينة. يستخدم البحث عملية التحليل الهرمي لتحديد الوزن النسبي لعناصر تقييم استدامة المستشفيات كجزء من عملية تطوير نظام تقييم المباني الخضراء للمنشآت الصحية في مصر. تم تصميم استبيان للخبراء لتحديد العلاقة بين عناصر تقييم المستشفيات الخضراء والقضايا والتحديات الملحة في مصر. تم تحديد الوزن النسبي بناء على تقييم الخبراء للأهمية النسبية للتحديات، وتقييم تأثير كل عنصر من عناصر التقييم على تلك التحديات. أظهرت النتائج أن كفاءة استهلاك الموارد والجدوى الاقتصادية هي التحديات ذات الأهمية النسبية الأعلى، وجاءت الأوزان النسبية النهائية لعناصر التقييم الثلاث كفاءة الطاقة، وجودة البيئة الداخلية، والمواد والموارد في المرتبة الأولى بالنسبة لعناصر التقييم الأخرى.

الكلمات المفتاحية : عملية التحليل الهرمي، عملية صنع القرار متعددة المعايير، المنشآت الصحية الخضراء، مصر

1. INTRODUCTION

The construction, operation, and maintenance of buildings influence the environment and human health. The impacts of these processes include toxic pollution, resource depletion, biodiversity loss, and climate change. The built environment affects indoor air quality as well, the level of pollutants indoors is up to five times greater than outdoor levels.

Healthcare buildings have a significant effect on the environment and health. They become more resource-intensive, stressing both renewable and non-renewable building material stocks, and construction practices extend beyond their sustainable capacities. A large healthcare infrastructure means more energy, more materials, and more development, The environmental degradation will push the healthcare industry to build larger, more resource-intensive structures to respond to downstream health [1 - 4].

Recently, the green hospital design witnessed a great revolution by employing green technologies, energy-efficient systems, and renewable/ recyclable materials and resources.

This led to the need for rating systems that can assess the performance of such facilities in achieving energy efficiency, resource conservation, lower environmental impacts, and improving human health. In response to that need some assessment tools related to green healthcare buildings have emerged such as BREEAM healthcare, and LEED for healthcare.

There are many definitions for green healthcare facilities, Indian Green Building Council states that the objective of this type of building is to enhance patient well-being, and aid the curative process while utilizing natural resources in an efficient, environment-friendly manner. WHO has defined green healthcare facilities as a building that responds to local climate conditions with optimized energy use. According to Global Green and Healthy Hospitals, a green hospital and healthy hospital is one that promotes public health by continuously reducing its environmental impact and ultimately eliminating its contribution to the burden of disease. A green and healthy hospital recognizes the connection between human health and the environment and demonstrates that understanding through its governance, strategy, and operations. It connects local needs with environmental action and practices primary prevention by actively engaging in efforts to foster community environmental health, health equity and a green economy [2, 5, 6].

A green hospital needs to be health-supporting, and efficient in terms of resource consumption, operation, and management. Studies that discuss green and sustainable healthcare facilities are limited, especially within the Egyptian context. Recently, A green hospital rating system has been developed in Egypt, this research aims to allocate weights for the assessment categories of the Egyptian green hospitals rating system based on local priorities and challenges derived from Egypt's sustainability strategy for 2030.

The paper discusses the weighting process for the assessment categories of the green hospitals rating system (GHRS) in Egypt. These weightings criteria are selected based on the most challenging issues in the Egyptian context. The paper starts with a review of definitions of sustainability assessment and sustainable healthcare buildings, followed by the weighting methods for some of the widely used rating systems, and then demonstrates the weighting process applied to the Egyptian green hospitals rating system.

2. SUSTAINABILITY ASSESSMENT AS A MULTICRITERIA DECISION-MAKING PROCESS

The definition of assessment is "the act of judging or determining the quality, excellence." The sustainability assessment process, according to Mitchell, consists of systems that are in place to identify related goals and measures and evaluate progress towards achieving them. Mitchell emphasises the significance of this process in light of the widespread recognition that human development urgently needs to follow a more sustainable path [7]. sustainability assessment is defined as a formal process of identifying, predicting, and evaluating the potential impacts of a wide range of relevant initiatives (such as legislation regulations, policies, plans, programs, and specific projects) and their alternatives on the sustainable development of society, a process by which the implications of a wide range of relevant initiatives are identified, predicted and evaluated [8, 9]. The previous definitions of the sustainability assessment process indicate the purposes and necessity for this assessment, in a way that: ensures that existing plans, policies, and activities contribute to sustainable development; assists in setting criteria and goals for progress towards sustainability; guides design strategies and decision-making based on the performance measures and end goals; provides particular initiatives, metrics, and evaluation procedures to support sustainable decision-making and to assess sustainability progress [9, 10].

Sustainability is a multidimensional concept which makes sustainability assessment a complex process that depends on the assessment of multiple indicators that are linked to multiple criteria, the weights of indicators are to be recognized according to their contribution to certain criteria and the overall sustainability goals. Multi-Criteria Decision Analysis is one of the most helpful methods for determining the importance of assessment criteria in relation to various sustainability goals and challenges is decision analysis (MCDA), which can be used in conjunction with an appropriate weighting method to determine assessment priorities in the presence of conflicting criteria [11].

3. SUSTAINABLE HEALTHCARE BUILDINGS

The objective of green healthcare buildings is to reduce resource consumption, use sustainable and healthy building products as well as minimize the environmental impacts of new and existing healthcare buildings by taking specific actions. Redesigning the healthcare's-built environment reduces the ecological resource burdens within communities associated with an expanding healthcare sector.

The GGHC states that building design and construction practice can be shaped to protect health at three scales [12]. The first scale, protecting the immediate health of building occupants; the second scale, protecting the health of the surrounding community; and finally protecting the health of the global community and natural resources. Further steps for a green healthcare building are to be a carbon-neutral building; a zero-waste building; protect and restore natural habitat; minimize the combined footprint of the building, parking, roads and walks; use high reflectance roofing and paving, or "green roof" systems and pervious paving; manages stormwater and promote habitat; provides a design that respects local natural and social contexts; puts into consideration solar orientation and prevailing wind; employs passive systems; takes full advantage of daylighting and natural ventilation; uses of materials with fewer impacts on health in all phases of their life cycle; uses of local and regional materials; utilizes salvaged and recycled materials; provides indoor air quality, lighting and acoustical settings that support health and productivity [13, 14].

To encourage green and sustainable building design, many rating systems and assessment tools have been established few of them discuss the healthcare buildings such as LEED and BREEAM. Usually, those rating systems and assessment tools cover six main dimensions: energy efficiency, water efficiency, material efficiency and waste reduction, and indoor environmental quality, in addition to operations and maintenance optimization. Each dimension has its relative weight. Although the relative weight differs according to the context and building type, there is an agreement regarding the order of importance. Commonly, energy has the highest relative weight, followed by indoor environmental quality, then sustainable site, followed by material efficiency and end by water efficiency [15, 16].

The key issue of green healthcare buildings is the performance in terms of indoor air quality, energy consumption, acoustic comfort, visual comfort, and water consumption. The rating systems and environmental initiatives measure performance based on the actual local urgencies and opportunities of the country.

4. WEIGHTING METHODS AND TOOLS

There are several methods used for assigning the relative importance and the weights of the indicators. The weighting techniques are based either on statistical or mathematical procedures, such as principal components analysis (PCA), regression analysis (RA) or based on value judgments expressed by experts or decision-makers such as AHP, PA, budget allocation process (BAP). Each of those methods has its advantages and disadvantages [17, 20].

4.1 Statistic-based methods

4.1.1 Principal components analysis (PCA)

One of the most commonly used methods is the principal components analysis (PCA), which aims to reduce the dimensionality of the data without significant information loss using linear transformation techniques. this method is most valuable when a large number of indicators need to be considered. An advantage of PCA is that it reduces the risk of double weighting, but weighting based on correlations instead of real-world links among assessed indicators is considered one of the downsides. For example, PCA may assign lower weights to a crucial dimension simply because it is weakly correlated with other dimensions. This method works well if a sufficient number of indicators are used and if they present a certain degree of correlation.

4.1.2 Regression analysis (RA)

Regression analysis (RA) is also a widely used statistical method, where weights can be determined by discerning the relationship between a set of indicators and a single output measure (dependent variable). This method performs well when there is large number of independent variables or indicators. In this method, it is extremely important to choose an appropriate dependent variable that can reflect the target and be explained by the indicators. This method allows for using the results for updating or validating weights, but one of its disadvantages is that multi-collinearity among indicators or an improper dependent variable may lead to poor results.

4.2 Public/Expert opinion-based methods

4.2.1 Analytic hierarchy process (AHP)

This method decomposes the complex problem into a hierarchical structure consisting of an overall goal, several criteria contributing to this goal, and several attributes (indicators). Then the opinions of the experts are extracted using pairwise comparisons for each cluster pertaining to the same level in the hierarchy. The advantages of this method are: it can be used for quantitative and qualitative data; the weighting is based on expert opinion. A large number of pairwise comparisons is one of the disadvantages, as well as the results, depend on a set of selected evaluators and the experiment context.

4.2.2 Budget allocation process (BAP)

The experts are asked to allocate a budget of a number of points to a set of indicators, which describe a given theme, based on their previous experience and subjective judgment of the relative importance of the indicators. The weights, in this method, are estimated as average budgets. This process is characterized by transparency and short duration; besides weighting is based on expert opinion and not on technical manipulations. Although all those advantages, this method measures urgency instead of importance; weights reflect the local conditions; allocating a budget for a large number of indicators, higher than 10, may cause serious stress for the experts.

4.2.3 Public opinion

In this method, people are asked to set their degree of concern (great or small) about issues as measured by base indicators. Indicators with high concern are allocated relatively high weights and vice versa. Weights are based on public concern rather than importance. This method is suitable for issues related to the public agenda because of its transparency and participatory nature; it allows all participants to express their preferences and creates a consensus for policy action. A high number of indicators can produce inconsistencies in results.

This research chooses to determine the weights of indicators based on the opinion of experts on green hospitals. In particular, the research uses the AHP because it is the most commonly applied technique among the subjective weighting methods available.

5. WEIGHING AND ASSESSMENT CRITERIA FOR SOME OF THE AVAILABLE RATING SYSTEMS

From a methodological standpoint, indicator-based approaches are widely recognized as useful international tools to evaluate a situation in several dimensions and to test sustainability [21]. These approaches organize indicators and allow for selected indicators to be combined and weighted in a manner which reflects the dimensions or structure of the phenomenon being measured. Most of the available rating systems used multiple criteria to weight their assessment categories. The process of weighting the indicators is the core sustainability assessment and the basis for having quantitative relative importance of each component of a rating system [22]. The weight or importance assigned to any component or category in a rating system needs to reflect the goal of the assessment process, the impact of each category and to address the local needs along with global. The well-known rating systems: LEED, BREEAM and GSAS clearly show their weighting and point allocation criteria and methods.

BREEAM first established a clear weighting system in 1998 and was updated in 2007, then another update was needed to suit the expansion of the scope of BREEAM schemes. BREEAM for healthcare comprises eight assessment categories: Management, Health & well-being, Energy, Transport, Water, Materials, Waste, Land Use & Ecology, and Pollution. The weighting process begins by determining how each assessment category's goal relates to the sustainability dimensions. Next, it rates the significance of the social, environmental, and economic impacts for each category in terms of the "seriousness" of the goal to address the related social, environmental, and economic issues, as well as the "relevance" of those issues in the country where the BREEAM scheme will be used and the "potential" of doing so within that country. The three "seriousness, relevance, and potential" values for each sustainability dimension are multiplied to create category scores from stakeholder ratings, which are then summed and normalised for each category to provide the category weighting [23].

The sustainability objectives and local context criteria were intended to be integrated into the formulation of GSAS weighting. A direct impact on environmental sustainability and/or human well-being is linked to each of the eight main performance assessment categories in the GSAS: air pollution, land use and contamination, water depletion, water pollution, materials depletion, human discomfort and illness, and climate change. The life cycle approach is also the foundation of the assessment framework. The Analytic Hierarchy Process (AHP) is used to calculate category weights based on stakeholders' ratings of the relative relevance of several parameters using pairwise comparison and the relative impact of each criterion within a category [24].

Early iterations of LEED allocated points in accordance with the experts' opinions of the members of the Technical Advisory Committees. Using impact categories taken from Environmental Protection Agency categories used for life cycle assessment, LEED 2009 established a new weighting method that awards points based on the intention to reduce environmental consequences [25]. The categories were evaluated according to their relevance to the built environment and subsequently adjusted to include wider sustainability challenges and human health concerns. In LEED v4, a new set of criteria or system goals were added to the analytical framework created for 2009, and each approach was evaluated in relation to its capacity to achieve those goals. These goals/ impact categories are: Reverse Contribution to Global Climate Change, Enhance Individual Human Health and well-being, the protection and restoration of water resources, the preservation, enhancement, and restoration of biodiversity and ecosystem services, the promotion of sustainable and regenerative material resource cycles, the development of a greener economy, and the improvement of social equity, environmental justice, and the quality of life in communities are all important. Different weights are assigned to these system goals in relation to one another. The assessment categories, also known as credit categories, include location and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality. Based on how well it performs in each of the seven impact categories, each assessment credit is given a weight. Associations between assessment credits are also taken into consideration. A web-based tool is used to make it possible to statistically analyse the results of this multivariate relationship. By layering and normalizing the weights for each of the associations, the final 100-point scorecard is produced [26].

The three rating systems weighted their assessment categories with regard to their impact or association with sustainability goals which are translated to the rating system goals, but LEED's weighting included also weights derived from the association between credits to better address an understanding of the whole system's interrelations. BREEAM added a weighting criterion related to the region of application, GSAS goals are more focused on the local context, while LEED criteria are based on the applicability in the built environment in general. The available rating systems are a beneficial tool for assessment, especially for global sustainability challenges related to climate change and resource-saving but the weights of some assessment criteria should vary according to local context challenges, which is why the GHRS relied on previous rating systems in deriving the assessment categories while their weights and importance are related to the challenges of the local context along with the overall sustainability goals.

6. METHODS

6.1 Weighting criteria and green building assessment categories for GHRS

The present study aims to allocate weights to the rating system assessment categories based on the local challenges and pressing issues, assessment categories include the sets of measurable indicators proposed by the green hospitals and healthcare committee after screening most of the well-known rating systems that are currently in use worldwide LEED, BREEAM, CASBEE, GSAS, GPRS, & GBI [23, 27, 31]. The committee members relied on the well-known rating systems worldwide to identify the main categories of the GHRS after conducting multiple meetings and discussions about the most common criteria for sustainability assessment, how to be adapted to the local context and how to address issues related to healthcare buildings in Egypt. Finally, they selected the criteria related to resources efficiency and environmental issues which are energy, material and water efficiency; as well as criteria related to healthcare facilities and human health such as open spaces provision and in site sustainability, indoor quality and healing environments and finally added operation and management as it is an important aspect in healthcare sustainability, the measures for each of the selected criteria are adapted to the local conditions in Egypt and the weighting criteria for the categories are supposed to be allocated based on local challenges. The assessment categories of the rating system and the weighting criteria are shown in Table 1.

Table 1: Rating system categories and weighting criteria

Rating system categories	Weighting criteria
• sustainable site • Energy efficiency • Water efficiency • Materials and resources • Indoor quality and healing environment • Operation and management	• Economic viability • Climate change • Land use and ecology • Human health • Resources depletion • Pollution reduction • Inclusive design

The assessment categories of the green hospitals rating system to be weighted are briefly described below [32]:

Sustainable site: includes site selection, pollution reduction and site development criteria. It aims to promote site accessibility, mitigate pollution impact, preserve and restore site ecology, and reduce thermal loads on the hospital building to help reduce the energy demand and achieve comfort for users. In addition, it contributes to creating an appropriate healing environment by providing safe, secure, comfortable outdoor spaces.

Energy efficiency: Measures reduction in energy demand passively and mechanically and the related environmental impacts including ozone depletion and carbon dioxide emissions. It aims to reduce the energy demand by enhancing indoor thermal comfort according to the different climatic regions in Egypt, as well as achieving efficient use of energy for the mechanical and electrical systems in hospitals and healthcare facilities. In addition, it aims to protect the environment from polluting refrigerants and emissions and encourages maximizing renewable energy sources.

Water efficiency: Aims to reduce the use of potable water in healthcare facilities and to improve the quality of wastewater, which consequently reduces the operational cost of these buildings and mitigates the environmental impacts resulting from the extensive use of potable water and the quality of the water drained to sewer systems and water bodies. Water efficiency considers the optimal reuse of wastewater and non-potable water resources by the permissible limits to ensure the quality of the reused water for a healthcare facility.

Materials and resources: The efficient use of materials and resources used during the whole building lifecycle, besides reducing carbon emissions and negative impacts of materials and toxic chemicals on human health and the environment, also considers the use of rapidly renewable materials or materials that include recycled components to preserve natural and economic resources, and reduce the impact of extraction, transportation, and manufacturing processes.

Indoor quality and healing environment: it contributes to improving the quality of the indoor environment to maintain health and comfort for all building users, minimize risks and hazards and help speed the recovery of patients and increase the productivity of workers.

Operation and management: this category aims to maintain the sustainability of the healthcare facility during all stages of construction, operation and maintenance and to ensure compliance with quality requirements, waste management, infection control, health and safety standards as well as risk management.

The criteria used for weighting the rating system categories are selected based on the local pressing issues and challenges according to Egypt's sustainability strategy 2030. The weighting criteria are as follows:

Economic viability: achieving the greatest possible economic efficiency throughout the different phases of the project including construction, operation and maintenance.

Climate change: mitigating the effect of climate change through reducing emissions, as well as eliminating ozone-depleting substances.

Land use and ecology: preservation of biodiversity and land as well as alleviating pressure on the environment.

Human health: maintaining all users' health, safety, recovery and comfort.

Resources depletion: the challenge of waste reduction and efficient use of resources including energy, water and materials.

Pollution reduction: environmental hazards and pollution challenges including water, air and soil as well as noise and visual pollution

Inclusive design: equality between all categories of users of all ages and abilities in access to service and ease of use.

6.2 Using AHP for weighting indicators

Assigning weights enables the identification of the relative importance of the individual categories. This study suggests using the AHP decision making tool to determine the weight of green hospitals rating system categories. A hierarchical structure with three levels has been done. The first level represents the main objective to be achieved by sustainable healthcare facilities which is "Human health and the environment"; the second level represents the criteria used for weighting the rating system categories; the third level represents the categories that make healthcare facilities sustainable, in this case, there are six green hospitals rating system categories (sustainable site, energy efficiency, water efficiency, materials and resources, indoor quality and healing environment, operation and management) Fig. 1.

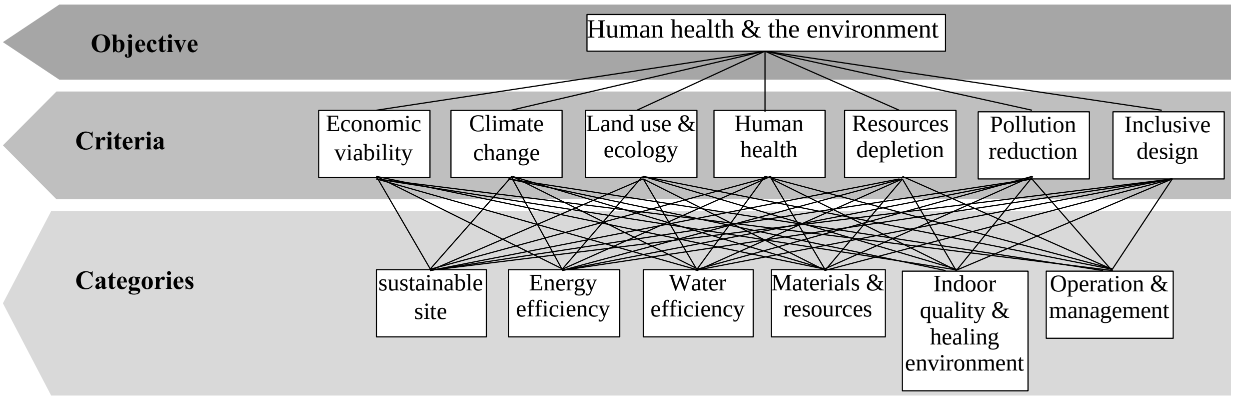
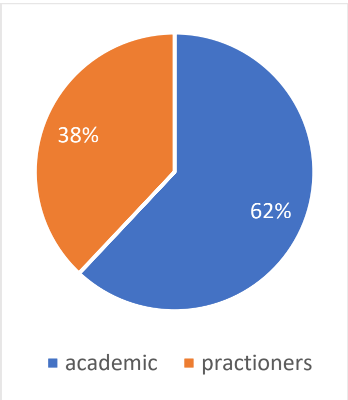


Fig. 1: Hierarchy Decision Model

6.3 Expert survey

A questionnaire was designed for using the AHP method to weight each of the assessment categories of the green hospitals rating system based on their association with each of the suggested weighting criteria. The survey was based on purposive sampling or expert judgement which relies on sampling informants with a specific type of knowledge or skill [33], The survey participants were a multidisciplinary group of 50 academic experts and practitioners with experience related to healthcare facilities and green buildings as shown in Fig. 2.



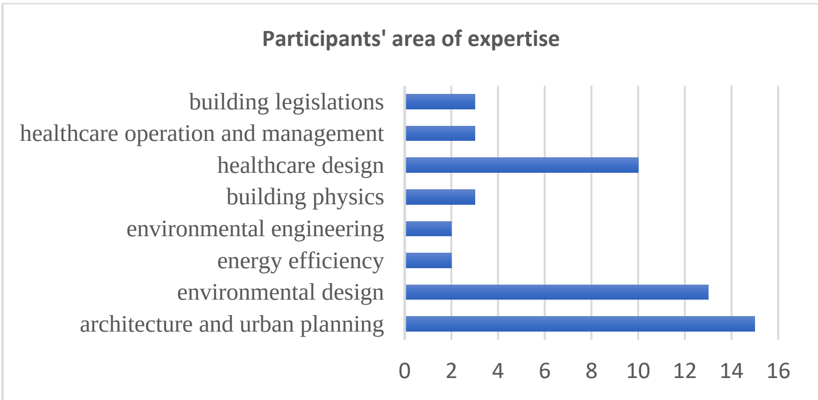


Fig. 2: Summary of the survey sample

The questionnaire is composed of three parts: the first part is an introduction that explains the objective of the study, the assessment methods and a brief description of the six assessment categories as well as the seven weighting criteria. The second part aims to measure the degree of importance of each of the seven criteria with regard to challenges of the Egyptian context, experts were asked to rate the importance of each of the seven challenges. The third part of the questionnaire aims to measure the impact of each of the assessment categories on the previously rated weighting criteria. The survey requires approximately 20–30 minutes to be fully answered.

6.4 Computing the relative weights

As mentioned above, the technique of the AHP is selected to calculate the relative weights of the six categories. This study uses the Team Expert Choice software to apply the AHP model and calculate the relative weight of criteria and categories based on Experts' responses. Two types of priorities have been obtained, the first one is the priorities of the weighting criteria with the respect to the main goal. The second is the priorities of the categories with respect to each criterion. The inconsistency ratio (CR) measure is useful for identifying possible errors in judgments as well as actual inconsistencies in the judgments themselves. The inconsistency ratio should be less than approximately 0.1 to be considered reasonably consistent. Thus, the judgments with an unacceptable CR value are omitted.

The weight of each category is then normalized by dividing the weight of each category by the sum of the weights of all categories.

The final result of the healthcare building evaluation is based on the environmental and urban local challenges as well as the importance of rating system categories in relation to those challenges as follows: the sum of the evaluation points for each rating system category is calculated and multiplied by final normalized weight of the rating system category it belongs to; finally, the points of design innovation are added to the sum of other rating categories Fig. 3.

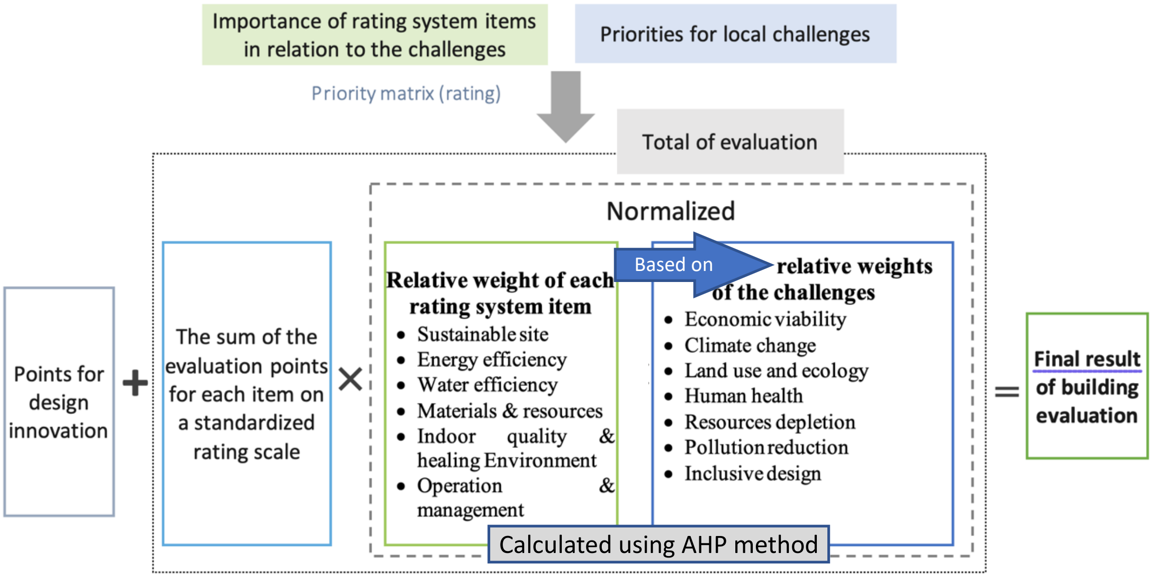


Fig. 3: Final result of healthcare building evaluation calculation

7. RESULTS AND DISCUSSION

In order to achieve the research objective and deduce the relative weight of rating system categories for Egyptian healthcare facilities with respect to environmental challenges in Egypt, the research uses the AHP method. The AHP is selected for the current study as it represents consistent means for explaining trade-offs among objectives in multi-objective analysis. The AHP process starts with drawing the hierarchy of the decision model to determine the relationship between the different criteria, then the questionnaire is designed based on this hierarchal mode. 50 experts are invited to answer the questionnaire in small focus groups of minimum 2 participants to better understand the objective of the questionnaire. This research uses the Team Expert Choice software to analyse and interpret the gathered data. The data entry is done into two levels based on the hierarchal model, the first level represents the impact of the seven criteria on the main objective "human health and the environment", and the second level represents the effect of the six categories with respect to each criterion. Based on the data entry, the relative weights are computed. It is important to mention that the inconsistency ratio (CR) is used to select any errors or inconsistencies in the judgment process. Consequently, the judgments with an unacceptable CR value, of more than 0.1, are omitted.

After computing the relative weights of local challenges based on the expert survey, it can be deduced that economic viability and resource depletion have the highest priority. From experts' point of view, the economic efficiency of a healthcare building in the construction, operation, and maintenance phases as well as the pressure caused by a healthcare building on the environment, are two important elements that should be considered during the whole healthcare building lifecycle. While climate change mitigation and land use and ecology scored the least weighting criteria as shown in Fig. 4.

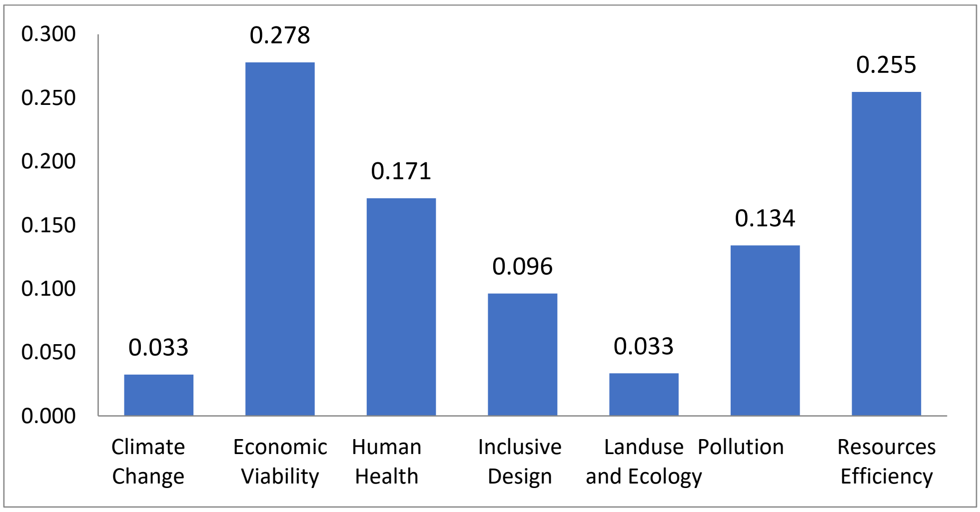


Fig. 4: Relative weights for weighting criteria

Fig. 5 shows the weight of each category after being normalized by dividing the weight of each category by the sum of the weights of all categories, and multiplied by hundred to show the percentage each category represents. There are slight differences between the relative weights of the rating system categories. This shows that the rating system categories contribute to the assessment criteria. The results show that energy efficiency and indoor quality scored the highest weight (18.2%), followed by materials and resources (17,3 %), water efficiency (16.9%), operation and management (15.9%) and finally sustainable site (13.6%) as shown in (figure 5). The weights of the categories agree with international rating systems in terms of resource efficiency which usually score the highest weights especially the energy efficiency category, while indoor environmental quality and healing environments scored higher than usual equally important to energy efficiency, which makes sense in healthcare buildings especially in Egypt as it requires more attention in design and operation. The operation and management category is not addressed as a separate category in LEED, while in BREEAM and GSAS they are separate categories but different in weight allocation, it has a relatively high weight in BREAM 12 % but is the least weight in GSAS only 5%. The sustainable site gained more importance regarding weight allocation in international rating systems with relatively higher weights.

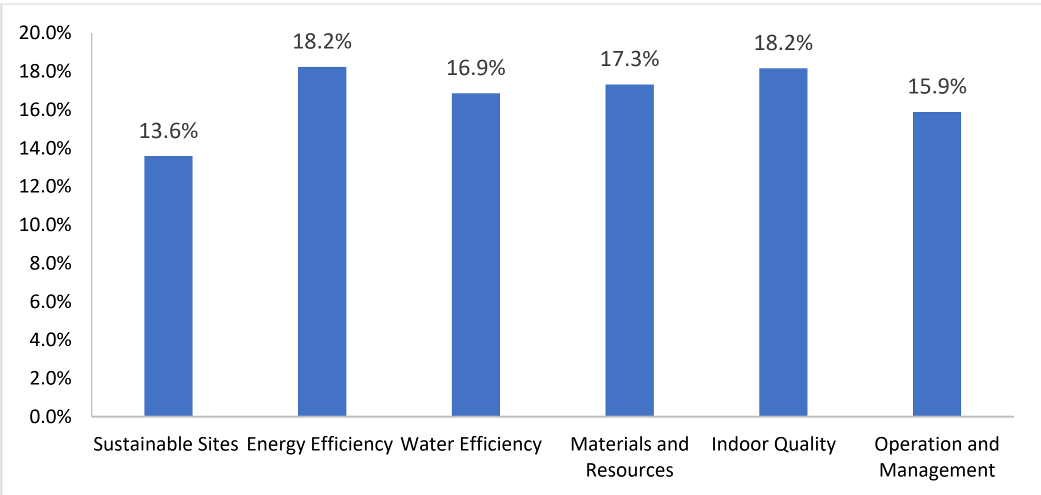


Fig. 5: Relative weights for green healthcare rating system categories after being normalized

8. CONCLUSIONS

The study highlights the importance of sustainability assessment and green buildings especially when it comes to the development of large consumer buildings such as healthcare facilities. The study discussed the importance of rating systems as assessment tools and their weighting methods and emphasized on the need to reflect local priorities. The assessment serves as a tool to improve public health and the environment by guiding and evaluating healthcare facilities' design and construction and encouraging sustainable construction practices. The assessment process is usually based on multiple criteria related to challenges and goals. Multiple criteria decision-making tools are widely applied in this process, with various methods for weighting indicators such as Analytic Hierarchy Process (AHP); Budget Allocation Process (BAP); Public Opinion, …etc.

The paper used the Analytic Hierarchy Process (AHP) to allocate weights for the different rating system categories of the green hospitals rating system (GHRS) in Egypt, based on the judgments expressed by experts or decision-makers and their academic experience or practices in both green buildings and healthcare facilities. The study results showed that the values of the inconsistency ratios for AHP did not exceed the permissible threshold levels, which confirms the reliability of sample selection and deduced results as well as the suitability of AHP for weight allocation.

The study provided the weights of each assessment category of the GHRS in relation to local priorities and challenges, results showed that energy efficiency and indoor quality & healing environment scored the highest weights followed by materials & resources; water efficiency; operation & management and the least was the sustainable site category. These deduced weights reflect the importance of the categories in green healthcare buildings in the Egyptian context and the environmental challenges facing Egypt, especially in the healthcare sector. The study demonstrates a method to adapt the assessment categories of the green hospitals rating system to the local context through weight allocation that is based on the local priorities and judgement of Egyptian experts in the field.

It is important to encourage and guide healthcare facilities towards more sustainable practices in general, it is recommended to prioritize energy efficiency and indoor quality during the design and operation of healthcare facilities in Egypt. Further research is recommended to respond to the rapidly changing requirements and needs of healthcare buildings and their ability to fulfil well-being and user satisfaction while maintaining resource efficiency.

LIST OF ACRONYMS

AHP	Analytical Hierarchy Process
BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
DGNB	Deutsche Gütesiegel Nachhaltiges Bauen
GBI	Green Building Index
GSAS	Global Sustainability Assessment System
GPRS	Green Pyramid Rating System
GGHC	Green Guide for Health Care
LEED	Leadership in Energy and Environmental Design

ACKNOWLEDGEMENTS

We would like to express our gratefulness to all the experts who gave their valuable input in the experts' survey, as well as the members of the committee of "Design guidelines for Green Hospitals and Healthcare Facilities" committee members for their support in the whole process.

CONFLICT OF INTEREST

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES:

[1] H. Sadatsafavi, M. Shepley, A. Kim, and H. Huynh, "How Do Green Healthcare Facilities Perform Financially When Compared to Non-Green Hospitals Overtime? Results from a National Database," in International Conference on Sustainable Infrastructure 2017, New York, New York, 2017, 145–160. doi: 10.1061/9780784481196.014.

[2] S. Kumari and R. Kumar, "Green hospital - A necessity and not option," Journal of Management Research and Analysis, 7(2), 46–51, 2020, doi: 10.18231/j.jmra.2020.010.

[3] D. S. Kamath, "ENGINEERING GREEN HOSPITALS: AN IMPERATIVE FOR A SUSTAINABLE FUTURE," International Journal of Civil Engineering and Technology, 10(2), 2019.

[4] K. Borges de Oliveira and O. J. de Oliveira, "Making Hospitals Sustainable: Towards Greener, Fairer and More Prosperous Services," Sustainability, 14(15) 9730, 2022, doi: 10.3390/su14159730.

[5] Joshua Karliner and Robin Guenther, "Global green and healthy hospitals agenda," Health Care without Harm, 2011, retrieved from: www.greenhospitals.net.

[6] World Health Organization, "Healthy Hospitals Healthy Planet Healthy People," Geneva, Switzerland, retrieved from: https://www.who.int/docs/default-source/climate-change/healthy-hospitals-healthy-planet-healthy-people.pdf?sfvrsn=8b337cee_1

[7] R. Therivel, E. Wilson, S. Thompson, and D. Heaney, Strategic environmental assessment (1st ed.). Routledge, 1999, retrieved from: https://doi.org/10.4324/9781315070339

[8] J. Pope, D. Annandale, and A. Morrison-Saunders, "Conceptualising sustainability assessment," Environmental Impact Assessment Review, 24(6), 595–616, 2004, doi: https://doi.org/10.1016/j.eiar.2004.03.001.

[9] D. Salem, "Sustainable Urban Landscapes, A System Based Approach for Developing A Sustainable Urban Green Space Network Heuristic Assessment Model," Cairo University, Egypt, 2016.

[10] United Nations, Ed., Indicators of sustainable development: guidelines and methodologies, (3rd ed.) New York, United Nations, 2007.

[11] A. Abrishamchi, A. Ebrahimian, M. Tajrishi, and M. A. Mariño, "Case Study: Application of Multicriteria Decision Making to Urban Water Supply," Journal of Water Resources Planning and Management, 131(4), 326–335, Jul. 2005, doi: 10.1061/(ASCE)0733 9496(2005)131:4(326).

[12] American Society for Healthcare Engineering, Green Guide for Healthcare - Best Practices for Creating High Performance Healing Environments, Version 2.2. American Society for Healthcare Engineering, 2007.

[13] GGHH, "Case studies buildings | Global Green and Healthy Hospitals." retrieved from: https//www.greenhospitals.net/case-studies-buildings/, 2021.

[14] Robin Guenther and Gail Vittori, Sustainable Healthcare Architecture, (2nd ed). Wiley, 2013.

[15] K. H. D. Tang, C. Y. H. Foo, and I. S. Tan, "A review of the green building rating systems," IOP Conf. Ser.: Mater. Sci. Eng., 943(1), 012060, 2020, doi: 10.1088/1757-899X/943/1/012060.

[16] H. M. Karmany, "Evaluation of green building rating systems for Egypt," American University in Cairo, 2015.

[17] S. S. Abdalla, S. A. Elariane, and S. H. El Defrawi, "Decision-Making Tool for Participatory Urban Planning and Development: Residents' Preferences of Their Built Environment," Journal of Urban Planning and Development, 142(1), 04015011, Mar. 2016, doi:10.1061/(ASCE)UP.1943-5444.0000289.

[18] J. Gómez-Limón, M. Arriaza, and M. Guerrero-Baena, "Building a Composite Indicator to Measure Environmental Sustainability Using Alternative Weighting Methods," Sustainability, 12(11), 4398, 2020, doi: 10.3390/su12114398.

[19] OECD, European Union, and Joint Research Centre - European Commission, Handbook on Constructing Composite Indicators: Methodology and User Guide. OECD, 2008. doi: 10.1787/9789264043466-en.

[20] X. Gan et al., "When to use what: Methods for weighting and aggregating sustainability indicators," Ecological Indicators, 81, 491–502, 2017, doi: 10.1016/j.ecolind.2017.05.068.

[21] K. S. Bawa and R. Seidler, Dimensions of Sustainable Development - Volume I. EOLSS Publishers/UNESCO, 2009, 2022, retrieved from: https://www.eolss.net/ebooklib/bookinfo/dimensions-sustainable-development.aspx

[22] K. S. Bawa and R. Seidler, Dimensions of Sustainable Development - Volume I. EOLSS Publications, 2009.

[23] T. Taylor and C. Ward, "New Methodology for Generating BREEAM Category Weightings,", BREEAM, 2016.

[24] Gulf Organization for Research & Development, "GSAS Technical Guide 2019",2, 2019, retrieved from: https://gsas.gord.qa/wp-content/uploads/2021/10/GSAS-Technical-Guide_2019.pdf

[25] USGBC, "LEED 2009 Vision and executive summary.", 2019, retrieved from: http://www.usgbc.org/Docs/Archive/General/Docs4121.pdf

[26] B. Owens, C. Macken, A. Rohloff, and H. Rosenberg, "LEED v4 Impact Category and Point Allocation Process Overview | U.S. Green Building Council.", 2022, https://www.usgbc.org/resources/leed-v4-impact-category-and-point-allocation-process-overview.

[27] USGBC, "LEED v4 for Building Design and Construction." 2019. retrieved from: https://www.usgbc.org/sites/default/files/LEED%20v4%20BDC_07.25.19_current.pdf
[28] BRE, "BREEAM_Healthcare," 2008. retrieved from: https://tools.breeam.com/filelibrary/Technical%20Manuals/SD5053_4_1_BREEAM_Healthcare_2008.pdf
[29] Institute for Building Environment and Energy Conservation (IBEC), "CASBEE for Building New construction, Technical Manual." Institute for Building Environment and Energy Conservation (IBEC), 2014, retrieved from: https://www.ibec.or.jp/CASBEE/english/download/CASBEE-BD(NC)e_2014manual.pdf
[30] Egyptian Green Building Council, "Green Pyramid Rating System." Housing and Building National Research Center, 2017.
[31] "GBI NREB Non-Residential Existing Building Tool V1.1 Final.pdf.", 2022, https://www.greenbuildingindex.org/Files/Resources/GBI%20Tools/GBI%20NREB%20Non-Residential%20Existing%20Building%20Tool%20V1.1%20Final.pdf
[32] Housing and Building National Research Center, "Design Guidelines for Hospitals and Healthcare Facilities, part 4: Design guidelines for green Hospital, Phase1: Green Hospitals Rating System." 2019.
[33] Ma. D. C. Tongco, "Purposive Sampling as a Tool for Informant Selection," Ethnobot. Res. App. 5, 147, 2007, doi: 10.17348/era.5.0.147-158.