# Study of Green Building Certification for Healthcare Facilities in Korea

## - Improvement of the Evaluation of Indoor Environments -

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Abstract

The development of green building certification systems is moving towards specialization and customization to adapt to the needs of specific building types; such is the case for healthcare facilities, which having conditions to be taken into consideration. Particularly for healthcare facilities, the indoor environment is primordial as it is directly impacting the health and well-being of the occupants within the building. The Green Standard for Energy and Environmental Design (G-SEED) is the green building certification developed by the Korean government. While it has gone thorough major revisions in September 2016, the healthcare facilities building type remained as being evaluated as a 'General Building' without any consideration for its function and any modified evaluation criteria. International green building certification programs such as LEED and BREEAM already have in place a distinct evaluation system for healthcare facilities. In Korea, the population is rapidly aging, and the demand for the construction of healthcare facilities is on the rise. Healthcare facilities are generally complex in function and are large energy consumers, consideration for green building design, such as energy and water efficiency will be essential. In parallel, the design of healthcare facilities will need to be mindful of the use by a variety of occupants, including medical staff, visitors and patients. In other words, the healthcare facilities would need to improve its “indoor environment” in order to optimize the well-being, comfort and health of the occupants, which could be physical or mental. This paper studies the Korean G-SEED certification and its relevance to healthcare facilities and attempts to define the future needs to be addressed in its implementation. Research methodology consists of literature review, comparative analysis of G-SEED with international certification programs (LEED and BREEAM) by assessing the relevance of “indoor environment” for healthcare facilities. Preliminary results of the study suggest discrepancies between the performed evaluation and the actual needs, and improvement measures to the evaluation of “indoor environment” in these facilities are proposed.

Keywords : Green Building, Certification Programs, G-SEED, LEED, BREEAM, Healthcare Facilities, Indoor Environment

## 1. INTRODUCTION

### 1.1 Background

Green building certification programs establishes standards for environmental and sustainable design. Recent development of the programs has become more and more specialized and customized to respond to the needs of specific building types, such is the case for healthcare facilities. As a building type, healthcare facilities are complex and consumes a lot of resources including energy and water. Green building standards may greatly improve the ecological impact of buildings; however, the design of healthcare facilities must also answer to the particular needs of the occupants, particularly factors affecting health and well-being. Green building certifications such as the Leadership for Energy and Environmental Design (LEED) in the United States and Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom has already accommodated for healthcare facilities, whereas the Green Standard for Energy and Environmental Design (G-SEED), revised in September 2016, still evaluates healthcare facilities as "general buildings" without special consideration and distinct evaluation criteria.

Currently, the number of healthcare facilities in Korea is on the rise. Further with the aging population in the country, the trend is expected to continue and the need for more healthcare facilities will be in demand. There are currently 3484 hospitals in total (345 general hospitals, 1596 hospitals, 1523 nursing hospitals, 20 military hospitals). Among those, only ten healthcare facilities are certified under G-SEED and ten others are under preliminary evaluation for certification (as of March 2017).

### 1.2 Research Objectives

The paper aims to firstly understand the current state of the G-SEED program and its application in the design of healthcare facilities for the “indoor environment” category. Second, it aims to identify the items that need to be modified from the current certification program to be adapted to the healthcare facilities’ building type, with the objective to improve the indoor

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environment evaluation.

This paper analyzes items of the indoor environment category of green building certification systems for healthcare facilities. For the purpose of this paper, indoor environment is divided into the following sub-categories: 1) air environment, 2) thermal environment, 3) lighting environment, 4) sound environment, and 5) other indoor environment.

## 2. RESEARCH METHODOLOGY

The research methodology consisted firstly of a literature review. While several studies have been published on the topic of green building certification for healthcare facilities in Korea and abroad, the research on indoor environmental assessment items and its detailed evaluation criteria of healthcare facilities is scarce. Precedent research on the topic includes: Study on the Evaluation Methods of Healing Environments of Healthcare Architecture through the Application of Green Building Certification Criteria (Jo, 2008) and a Study on Green Building Certification Criteria for Healthcare Facilities (Yoon, 2016), Study on Green Building Certification for Healthcare Facilities (Park, 2016).

Secondly, through a comparison study between green building certification programs. The most recent versions of LEED v4, G-SEED 2016, and BREEAM 2018 were use as the base of comparison, and items related to indoor environment were compared and extracted.

Thirdly, a questionnaire survey was performed and consisted of an evaluation of items derived from the previous analysis. The survey was distributed to general hospital's healthcare facility workers (doctors, nurses, facility managers, researchers) and healthcare building specialists (building construction, design, supervision) to investigate the applicability and necessity of improvement of items in the indoor environment of healthcare facilities in Korea.

### 2.1 Definition of Indoor Environments

According to the Korean G-SEED program, indoor environments are divided into the following four categories: air environment, thermal environment, lighting environment and sound environment. For the purpose of this study, evaluation items that are not applicable are classified under the title of "other indoor environments".

Within G-SEED, healthcare facilities are categorized as a 'general building'. According to its definition, 'General buildings' refers to any non-residential buildings, excluding commercial buildings, school facilities, sales facilities and accommodation facilities in accordance, defined under Article 3 of the Green Building Certification criteria. These evaluation items consequently refer to the minimum evaluation items in comparison to evaluation items of other certified buildings.

In LEED v4, "Indoor Environmental Quality" is the category of items that focus on the evaluation of indoor environments. The purpose of this category of evaluation is to create an indoor environment that guarantees the comfort of indoor air quality, thermal comfort, views and acoustic performance, and assures the health and convenience of the users.

Table 1. Items of Comparison for Indoor Environments in LEED v4, G-SEED 2016 and BREEAM 2018

| Evaluation Categories | LEED v4 | Points | | G-SEED 2016 | Points | | BREEAM 2018 | Points | |
|---|---|---|---|---|---|---|---|---|---|
| Air Environment | Minimum IAQ Performance | Prereq | 8 | Application of Indoor Air Pollutant Low Emission Products | Prereq 3 | 9 | Indoor Air Quality (IAQ) Plan | Prereq | 5 |
| | Environmental Tobacco Smoke Control | Prereq | | Confirm Natural Ventilation Performance | 2 | | Ventilation | 1 | |
| | Enhanced IAQ Strategies | 2 | | Design of Outside Air Supply and Exhaust Vent | 2 | | User Control | 1 | |
| | Low Emitting Materials | 3 | | Operation of $CO_2$ Monitoring System and Evaluation of Ventilation Rate | 2 | | Emissions from Building Products | 2 | |
| | Construction IAQ Management Plan | 1 | | | | | Post-construction Indoor Air Quality Measurement | 1 | |
| | IAQ assessment | 2 | | | | | | | |
| Thermal Environment | Thermal comfort | 1 | 1 | Thermostat Installation Level | 2 | 4 | Thermal Modelling | 1 | 3 |
| | | | | | | | Design for Future Thermal Comfort | 1 | |
| | | | | Comfortable Indoor Environment Control System Adopted | 2 | | Thermal Zoning and Controls | 1 | |
| Light Environment | Interior lighting | 2 | 5 | Direct Sunlight Adjustment and Awning Installation for Glare Reduction | 2 | 2 | Control of Glare from Sunlight | 1 | 4 |
| | Daylight | 3 | | | | | Daylighting | 2 | |
| | | | | | | | Internal and External Lighting Levels | 1 | |
| Sound Environment | Acoustic Performance | 1 | 1 | Noise in the Room from Traffic Noise (Road, Railway) | 2 | 4 | Acoustic Performance | 3 | 3 |
| | | | | Sound Insulation Performance of Partition Wall between Rooms | 2 | | | | |
| Other Indoor Environment | Quality Views | 1 | 1 | Creation of exclusive rest space | 1 | 1 | Laboratory Containment Devices and Containment Areas | 2 | 7 |
| | | | | | | | Security of Site and Building | 1 | |
| | | | | | | | Safe Access | 2 | |
| | | | | | | | View Out | 2 | |

In BREEAM 2018, the category that corresponds to indoor environmental assessment is “Health and Wellbeing”. The purpose of this evaluation is to encourage the health, well-being and safety of building users and to create a safe and comfortable interior and exterior environment. The items of comparison for indoor environments in LEED v4, G-SEED 2016 and BREEAM are shown in Table 1.

## 3. COMPARATIVE STUDY OF GREEN BUILDING CERTIFICATIONS

### 3.1 Study Overview

The comparative study of green building certifications was conducted and analyzed in four methods: 1) Comparison of Points by Weight, 2) Comparison of Similar Evaluation Items, 3) Comparison of Contents of Evaluation Items, 4) Items with Separate Criteria for Healthcare Facilities

1) Comparison of Points by Weight

The first method compared the number of points allocated to each indoor environment evaluation category. The proportion of points assigned to each evaluation item in each indoor environment category was compiled for each certification program. Table 2 and Figure 1 show the weight comparison of indoor environment evaluation items.

Table 2. Comparison of Indoor Environment Points Evaluation by Weight (%) between LEED v4, G-SEED 2016, BREEAM 2018

| Green Building Certification Systems | Indoor Environment Points Evaluation Weights (%) | | | | |
|---|---|---|---|---|---|
| | Air | Thermal | Light | Sound | Other |
| LEED v4 | 50.0 | 6.3 | 31.3 | 6.3 | 6.3 |
| G-SEED 2016 | 45.3 | 20.0 | 10.0 | 20.0 | 5.0 |
| BREEAM 2018 | 22.7 | 13.6 | 18.2 | 13.6 | 31.8 |

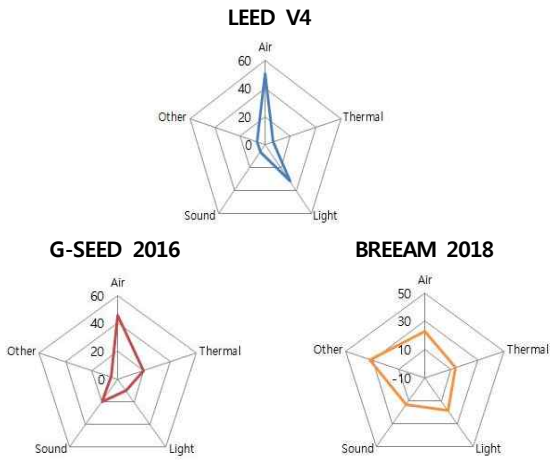


Figure 1. Comparison of Weight on Indoor Environmental Assessment of LEED v4, G-SEED 2016, BREEAM 2018

In the case of G-SEED and LEED, the evaluation criteria for air environment were similar. In LEED, the weight of points was most important for air environment, followed by light environment, thermal environment, sound environment, and finally other indoor environment. In BREEAM, other indoor environment, air environment, light environment, followed by thermal environment and sound environment were similar. The reason why BREEAM is different from other certification systems is that the evaluation of "other indoor environment" is high because it includes the evaluation of the sealing safety of laboratories and the security of the building and adjacent land, the safe access to the facility. This is because many evaluation items are included in other indoor environments, as compared to the other certification systems.

2) Comparison of Similar Evaluation Items

The second method is to compare similar items within the evaluation items of indoor environments in each certification system. Items with similar evaluation items were linked among indoor environment evaluation items from each certification system. In similar evaluation items, the differences between the evaluation methods and detailed evaluation criteria were juxtaposed. Table 3 indicates the items in which each of the evaluation items were similar or comparable.

Table 3. Similar Items for Indoor Environment between LEED v4, G-SEED 2016, BREEAM 2018

| | LEED v4 | | G-SEED 2016 | BREEAM 2018 | |
|---|---|---|---|---|---|
| Air Environment | Low emitting materials | | Application of indoor air pollutant low emission products | Emissions from building products | |
| | Minimum IAQ performance | Ventilation | Confirm natural ventilation performance | Ventilation | |
| | | | Design of outside air supply and exhaust vent | | |
| | | Monitoring of ventilation | Operation of $CO_2$ monitoring system and evaluation of ventilation rate | | |
| Thermal environment | Thermal comfort - Providing thermal environment control device | | Thermostat installation level | Thermal comfort – Column preferences and controls | |
| | | | Comfortable indoor environment control system adopted | | |
| Light environment | Daylight | | Direct sunlight adjustment and awning installation for glare reduction | Anti-glare with natural light control | |
| Sound environment | Acoustic Performance | HVAC background noise level | Noise in the room for traffic noise (road, railway) | Acoustic Performance | Deafening |
| | | Sound absorption, soundproofing, noise environment design | Sound insulation performance of partition wall between rooms | | Indoor ambient noise level |
| | | | | | Reverberation time |

3) Comparison of Contents of Evaluation Items

The third method is to extract the evaluation items by comparing the contents of indoor environment evaluation items from each certification system that are not in G-SEED, but apparent in LEED and BREEAM. The contents of the extracted items are used in the survey for experts and considered as potential evaluation items to be added to G-SEED for the evaluation of green healthcare facilities in the future.

Table 4 shows the evaluation items of the certification system for green buildings, by extracting the items which are not included as evaluation items of the indoor environments in G-SEED. The items include items.

Table 4. Extracted Contents of Evaluation Items from LEED v4 and BREEAM 2018

| | LEED v4 | BREEAM 2018 |
|---|---|---|
| Air Environment | Secondhand smoke control and smoking policy | Establish indoor air quality plan |
| | Indoor air quality management plan during construction | User control |
| | Evaluation of indoor air quality after construction | Indoor air quality measurement after construction |
| Thermal Environment | Thermal comfort - comfortable Thermal environment design | Thermal modeling |
| | | Designed for a comfortable thermal environment |
| Light Environment | Indoor lighting - Provides lighting control unit | Natural light |
| | | Internal and external lighting |
| Other Indoor Environment | Quality Views Provide external view Outdoor space connection diagram | Safe sealing of laboratories |
| | | Security of buildings and adjacent land |
| | | Secure accessibility and external Space connectivity |
| | | View out |

4) Items as Separate Evaluation Criteria for Healthcare Facilities

The fourth method is to compare items that are separate evaluation criteria for healthcare facilities in each certification program. When assessing the certification of green healthcare facilities, it is possible to identify the evaluation items that are differentiated from the buildings types and the need of each evaluation items.

Table 5 shows items that have separate evaluation criteria for healthcare facilities among evaluation items for the indoor environments in LEED and BREEAM. With the extraction of this information, items were interpolated as items more heavily in evaluation of healthcare facilities. According to the points allocated to these items, the shaded areas in the table represent items that with high points allocation in the evaluation for healthcare facilities as compared with the certification program for general buildings.

Table 5. Items with Separate Evaluation Criteria for Healthcare facilities for Indoor Environment for LEED v4 and BREEAM 2018

| | LEED v4 | BREEAM 2018 |
|---|---|---|
| Air Environment | Minimum IAQ performance | Ventilation - Natural ventilation |
| | Enhanced IAQ strategies | |
| | Low emitting materials | |
| | Indoor air quality management plan during construction | |
| | Evaluation of indoor air quality after construction | |
| Thermal Environment | Thermal comfort | Thermal comfort |
| Light Environment | Indoor lighting | Natural light |
| Sound Environment | Acoustic Performance | Acoustic Performance |
| Other Indoor Environment | Quality Views | View out |

## 3.2 Determination of Potential Evaluation Items to be Added to G-SEED

The evaluation items identified in the indoor environment of green healthcare facilities were extracted from the items not included in the evaluation items of the indoor environment evaluation in the G-SEED. Table 6 shows the evaluation items that are organized by each indoor environment influence factor.

# 4. SURVEY OF EXPERTS STUDY

## 4.1 Study Overview

Based on the previous comparative analysis, information was extracted to develop a survey designated for experts and professionals. Professionals were in two categories: healthcare facility experts and healthcare building specialists. The survey consisted of content related to indoor environment evaluation items for green healthcare facilities. The purpose of the questionnaire was to survey about the recognition of the green building certification system and the actual condition of the indoor environment in current healthcare facilities in Korea.

Table 7 shows the details of the survey of experts and its contents. The questionnaire survey was developed in the following sections: personal information, facility survey, cognitive survey, need survey and opinion survey. Each survey was designed to extrapolate information related to the current status of healthcare facilities related to indoor environment, and identify the needs, and determine the weight of its importance. Two sets of questions were prepared customized towards the two target survey subjects of healthcare facility experts and healthcare building specialists. The format was mainly Likert 5-point scale, multiple choice or free opinion.

Table 6. Configuration of Evaluation Items

| | | Evaluation Items |
|---|---|---|
| Items from Comparison of Green Building Certifications Programs | Air Environment | Installation of ventilation monitoring system - Measurement of outdoor air inflow |
| | | Establishment of CO2 concentration control and monitoring system in air |
| | | Secondhand smoke control and smoking policy |
| | | Indoor air quality management plan through material management during construction |
| | | Indoor air cleanliness measurement and evaluation for a certain period after construction |
| | Thermal Environment | Analysis system for thermal environment in buildings through room temperature modeling |
| | | Keeping warm environment comfort by predicting room temperature change |
| | | Provide individual control environment for users |
| | Light Environment | Direct sunlight adjustment and awning installation for glare reduction |
| | | Providing individual lighting control for user's living space |
| | | Indoor natural light coverage area and minimum natural light factor standard |
| | | Indoor lighting standards |
| | Sound Environment | Sound insulation performance criterion of boundary wall between rooms |
| | | Room acoustic performance standard (indoor environment noise, soundproofing, soundproofing, sound absorption, reverberation time compliance evaluation) |
| | Other Indoor Environment | Safe sealing of laboratories (management of pollutant emissions and minimization of pollutants) |
| | | Maintain security inside and outside the building and evaluate safety accessibility |
| | | Level of outdoor view (standard for installing outdoor view) |
| Items from Comparison of Certification Items for Healthcare Facilities | Air Environment | Maintain indoor air cleanliness (ventilation and ventilation monitoring system) |
| | | Hazardous air inflow blocking performance (harmful gas, fine dust, infection control) |
| | | Indoor air pollutants use of low emission materials |
| | Thermal Environment | Creation of pleasant temperature environment - Compliance with temperature range of comfortable heat environment level |
| | | Provides room temperature, humidity and ventilation control in a certain area of the living space other than the room and the room |
| | Light Environment | Provide individual lighting controls for staff-only spaces |
| | | Providing available light control devices in the patient's bed space |
| | | Mandatory area for natural light |
| | Sound Environment | Providing pleasant sound environment considering sound insulation (user privacy guarantee) |
| | Other Indoor Environment | Provide outdoor view |
| | | Connection of indoor and outdoor space and provision of external facilities (providing resting space and green space) |

Table 7. Survey of Experts Contents

| | Survey of Experts Contents |
|---|---|
| Facility Survey | Satisfaction with indoor environment of healthcare facilities |
| Recognition Survey | Survey of the recognition of the necessity for green healthcare facilities |
| | Survey of the recognition of weight per evaluation item by indoor environment |
| Need Survey | Survey of the need for indoor environment evaluation items for green healthcare facilities in indoor environment category |
| Opinion Survey | Survey of free response of items that could be added to indoor environment |

The first part is the facility's survey and it consisted of a satisfaction survey of the indoor environment, divided into air, thermal, sound, light and other indoor environment. Then, the recognition survey consisted of questions related to the recognition of the current state of the need for green building certification in healthcare facilities, and the weight of items by indoor environment item. The need survey consisted of question addressing the needs that should be included if it is not already. An opinion survey also allowed subjects to provide their free opinion of factors that should be considered in the indoor environment of green healthcare facilities.

Prior to the survey, a preliminary survey was conducted. The preliminary survey of three healthcare building specialist and three healthcare facility workers was conducted after the survey and the insufficient information of the survey was corrected and supplemented. The survey was conducted for 40 days from October 23 to November 28, 2017.

### 4.2 Determination of Survey Subjects

The survey subjects are categorized as healthcare facility experts and healthcare building specialists. As shown in Table 8, a survey was conducted on healthcare facility workers in general hospitals, and healthcare building experts, such as architects with experience in designing or constructing healthcare facilities.

The total number of respondents was 88, consisting of 56 (63.6%) healthcare facility workers and 32 (36.4%) healthcare building specialists. The first group of professionals consisted of doctors, nurses, facility managers, researchers working in healthcare facilities, and others. The second expert group consisted of healthcare building specialists, consisted of architectural design and supervision, environmental certification consulting expert, construction, and others.

Table 8. List of Survey Subjects

| | Experts | Number of Responses | Total |
|---|---|---|---|
| Healthcare Facility Workers | Doctors | 11 | 56 |
| | Nurses | 28 | |
| | Facility Managers | 8 | |
| | Researchers | 7 | |
| | Others | 2 | |
| Healthcare Building Specialists | Architectural Design and Supervision | 8 | 32 |
| | Green Building Certification Consultant | 5 | |
| | Building Construction | 16 | |
| | Others | 3 | |
| Total | | | 88 |

## 5. RESULTS AND ANALYSIS

### 5.1 Reliability Analysis

Based on the survey results, we conducted a reliability

analysis using the 'Cronbach α' method, which is the most commonly used reliability measure, to measure the internal consistency of the survey items. The higher the value of the coefficient, the higher is the internal consistency. As a result of the reliability analysis of the 28 questions of this questionnaire, the reliability of the survey group was determined to be 0.885 for healthcare facility workers and 0.877 for healthcare building specialist. A reliability coefficient of over 0.7 is considered acceptable.

### 5.2 Results from Satisfaction Surveys

The following are the results of the survey on indoor environment and indoor environment feeling satisfaction of Korea healthcare facility indoor environment.

Table 9. Satisfaction of Indoor Environment of Healthcare facilities by Healthcare Facility Workers

| | Very satisfied | Satisfied | Neither | Dissatisfied | Very dissatisfied | No answer | Total |
|---|---|---|---|---|---|---|---|
| Persons (%) | 1 (1.79) | 11 (19.64) | 21 (37.50) | 20 (35.70) | 3 (5.36) | 0 (0) | 56 (100) |

Table 9 is the result of a questionnaire survey for healthcare facility workers (n=56). The overall satisfaction with the indoor environment of the healthcare facility was measured using the Likert 5-point scale. The overall average obtained from the Likert 5-point survey was 2.76 points, indicating a relatively low satisfaction with the indoor environment.19.64% of healthcare facility workers responded that they are satisfied with the indoor environment of current healthcare facilities and 1.79% are very satisfied.

Table 10 shows the items of evaluation in indoor environment with most dissatisfaction by healthcare facility workers. The dissatisfaction with the air environment was the highest with 18(36%), followed by other indoor environmental factors 12(24%), with significant frequency of responses in thermal environment, light environment, and sound environment.

Table 10. Items of Evaluation in Indoor Environment Dissatisfaction by Healthcare Facility Workers

| | Air Environment | Thermal Environment | Light Environment | Sound Environment | Other Indoor Environment |
|---|---|---|---|---|---|
| Frequency (%) | 18 (36) | 7 (14) | 7 (14) | 6 (12) | 12 (24) |

Table 11 is the result of the questionnaire survey responded by healthcare building specialists(n=32). The overall satisfaction with the indoor environment of the healthcare facility was measured using the Likert 5-point scale. The overall average point obtained from the 5-point survey was 2.18 points, suggesting a low satisfaction with the current indoor environment of healthcare facilities. 56.25% of healthcare building specialists responded that they felt dissatisfied with the indoor environment of the current healthcare facility, and 15.63% answered that they felt very dissatisfied.

Table 11. Satisfaction of Indoor Environment of Healthcare facilities by Healthcare Building Specialists

| | Very Satisfied | Satisfied | Neither | Dissatisfied | Very dissatisfied | No answer | Total |
|---|---|---|---|---|---|---|---|
| Persons (%) | 0 (0) | 2 (6.25) | 7 (21.88) | 18 (56.25) | 5 (15.63) | 0 (0) | 32 (100) |

Table 12 shows the items of evaluation in indoor environment with the most dissatisfaction by healthcare building specialists. The highest level of dissatisfaction is suggested to be principally air environment 24(57%), followed by sound environment, thermal environment, other indoor environment, and light environment.

Table 12. Items of Evaluation in Indoor Environment Dissatisfaction by Healthcare Building Specialists

| | Air Environment | Thermal Environment | Light Environment | Sound Environment | Other Indoor Environment |
|---|---|---|---|---|---|
| Frequency (%) | 24 (57) | 5 (12) | 3 (7) | 6 (14) | 4 (10) |

### 5.3 Results from Needs Survey

The following is the result of the questionnaire about the need of green building certification for healthcare facilities in Korea. Table 13 shows the results of surveys by healthcare facility workers. It shows that healthcare facility workers generally feel there is a need to have certification systems for green healthcare facilities. 13(23%) answered that it was very necessary and 31(55%) answered that it was necessary, totaling 78%.

Table 13. Need for Standard Certification Criteria for the Evaluation of Green Healthcare facilities (Healthcare Facility Workers)

| | Absolutely unnecessary | Unnecessary | Neither | Needed | Very Needed |
|---|---|---|---|---|---|
| Persons (%) | 0 (0) | 4 (7.14) | 8 (14.29) | 31 (55.36) | 13 (23.21) |

Table 14 shows the results from questionnaire survey responded by healthcare building specialists. The results for the need of a certification for green healthcare facilities indicate that 28.13% consider it to be very needed, and 53.13% considered it to be needed, totaling 81%.

Table 14. Need for Standard Certification Criteria for the Evaluation of Green Healthcare facilities (Healthcare Building Experts)

| | Absolutely unnecessary | Unnecessary | Neither | Needed | Very Needed |
|---|---|---|---|---|---|
| Persons (%) | 0 (0) | 1 (3.13) | 5 (15.63) | 17 (53.13) | 9 (28.13) |

### 5.4 Analysis of the Importance of the Indoor Environment Evaluation Items

The following are responses to the ranking in importance of the evaluation items that should be weighted more heavily for the indoor environment of green healthcare facilities. Table 15 shows the results from the questionnaire survey for healthcare facility workers. On a 5-point scale, results indicate that air environment was the highest at 4.46, followed by light environment (3.73), sound environment (3.08), thermal environment (2.91) and other indoor environment (2.23).

Table 15. Importance of Evaluation Items in Indoor Environment by Healthcare Facility Workers

| | Air Environment | Thermal Environment | Light Environment | Sound Environment | Other Indoor Environment |
|---|---|---|---|---|---|
| Average | 4.46 | 2.91 | 3.73 | 3.08 | 2.23 |
| Standard Deviation | 1.23 | 1.31 | 1.13 | 1.21 | 1.48 |

Table 16. Importance of Evaluation Items in Indoor Environment by Healthcare Facility Workers

| | Air Environment | Thermal Environment | Light Environment | Sound Environment | Other Indoor Environment |
|---|---|---|---|---|---|
| Average | 4.89 | 3.63 | 3.63 | 2.90 | 2.20 |
| Standard Deviation | .315 | .830 | .760 | 1.350 | 1.520 |

Table 16 shows the results from the questionnaire survey responded by healthcare building specialists. Results indicate that air environment was the highest at 4.89, followed by light environment, thermal environment (3.63), sound environment (2.90), and other indoor environment (2.20).

### 5.5 Analysis of Additional Items Needed

The following section analyses the additional items needed in the evaluation of the indoor environments of green healthcare facilities. Items in this list represent evaluation items that are standard in LEED and BREEAM programs, but not available on G-SEED. 17 evaluation items were identified, and on a 5-point scale, the overall average value of these items is 3.78. Table 17 shows the list of items in ranking, based on its deviation from the standard value of the average. A total of 5 items showed an average of 3.78 or more.

The results indicate that the need of evaluation items for air environment was high. Items for the evaluation of air environment includes second-hand smoke control and smoking policy, the indoor air cleanliness measurement and the installation of a ventilation monitoring system for a period after the construction, Also, evaluation for safe accessibility, and provision of a user-individual control environment were also significant.

Table 17. Ranking List of Additional Items Needed for Indoor Environment of Green Building Certification for Healthcare Facilities

| Order | Question | Indoor Environment Evaluation Items | Average | Standard Deviation |
|---|---|---|---|---|
| 1 | A3 | Secondhand smoke control and smoking policy | 4.35 | .845 |
| 2 | A5 | Indoor air cleanliness measurement and evaluation for a certain period after construction | 4.22 | .837 |
| 3 | O2 | Maintain security inside and outside the building and evaluate safety accessibility | 4.03 | .702 |
| 4 | A1 | Installation of ventilation monitoring system - Measurement of outdoor air inflow | 3.85 | .878 |
| 5 | H3 | Provide individual control environment for users | 3.81 | .800 |
| 6 | O1 | Safe sealing of laboratories (management of pollutant emissions and minimization of pollutants) | 3.78 | .823 |
| 7 | L4 | Indoor lighting standards | 3.77 | .854 |
| 8 | H2 | Keeping warm environment comfort by predicting room temperature change | 3.75 | .848 |
| 9 | S1 | Sound insulation performance criterion of boundary wall between rooms | 3.74 | .837 |
| 10 | L3 | Indoor natural light coverage area and minimum natural light factor standard | 3.72 | .843 |
| 11 | A2 | Establishment of CO 2 concentration control and monitoring system in air | 3.70 | .961 |
| 12 | A4 | Indoor air quality management plan through material management during construction | 3.70 | .805 |
| 13 | L2 | Providing individual lighting control for user's living space | 3.69 | .889 |
| 14 | S2 | Room acoustic performance standard (indoor environment noise, soundproofing, soundproofing, sound absorption, reverberation time compliance evaluation) | 3.68 | .766 |
| 15 | L1 | Direct sunlight adjustment and awning installation for glare reduction | 3.75 | .785 |
| 16 | H1 | Analysis system for thermal environment in buildings through room temperature modeling | 3.55 | .741 |
| 17 | O3 | Level of outdoor view (standard for installing outdoor view) | 3.47 | .870 |
| Overall Average | | | 3.78 | .460 |

Table 18 shows the importance in need of evaluation items requiring separate evaluation criteria for indoor environment of green healthcare facilities. Items in this list represent evaluation items that are standard in LEED and BREEAM's healthcare facility certification program, but not available on G-SEED. The average of all 11 items identified was 3.93, and the item with highest deviation from the standard average was shaded.

The total number of items that are above the total average is 7, among which 3 items from air environment, followed by 2 items in thermal environment and 2 items in light environment evaluation. The evaluation items for air environment include evaluation items include harmful air inflow blocking performance, indoor air cleanliness maintenance, and the use of low-emission materials for indoor air pollutants. The thermal

environment evaluation items include the creation of a pleasant temperature environment - compliance with temperature range of comfortable heat environment level and provision of room temperature, humidity and ventilation control in a certain area of the living space other than the room and the room. Light environmental assessment items include provision for individual lighting control units in the staff space, and provision of lighting control units available in the patient's bed space.

Table 18. Ranking List of Additional Items Requiring Separate Assessment Criteria Needed for Indoor Environment of Green Building Certification in Korea

| Order | Question | Indoor Environment Evaluation Items | Average | Standard Deviation |
|---|---|---|---|---|
| 1 | A7 | Hazardous air inflow blocking performance (harmful gas, fine dust, infection control) | 4.40 | .796 |
| 2 | A6 | Maintain indoor air cleanliness (ventilation and ventilation monitoring system) | 4.26 | .750 |
| 3 | L5 | Provide individual lighting controls for staff-only spaces | 4.14 | .761 |
| 4 | A8 | Indoor air pollutants use of low emission materials | 4.03 | .809 |
| 5 | H4 | Creation of pleasant temperature environment - Compliance with temperature range of comfortable heat environment level | 3.97 | .780 |
| 6 | H5 | Provides room temperature, humidity and ventilation control in a certain area of the living space other than the room and the room | 3.95 | .815 |
| 7 | L6 | Providing available light control devices in the patient's bed space | 3.94 | .733 |
| 8 | S3 | Providing pleasant sound environment considering sound insulation (user privacy guarantee) | 3.81 | .800 |
| 9 | O5 | Connection of indoor and outdoor space and provision of external facilities (providing resting space and green space) | 3.69 | .717 |
| 10 | O4 | Provide outdoor view | 3.61 | .928 |
| 11 | L7 | Mandatory area for natural light | 3.51 | .897 |
| Overall Average | | | 3.938 | .405 |

## 5.6 T-Test Analysis

A t-test was conducted to find out the difference of significance level between the healthcare facility worker and the healthcare building specialist group in assessing evaluation items for the indoor environment of green healthcare facilities. An independent sample t-test method was used to analyze the two expert groups. The significance level of the two groups was determined according to the P value (significance probability) at a value of 0.05 or above. Generally, an alpha of 0.05 or 0.01 for p-value of a sample statistic is set as the cutoff for significance level. As a result, the evaluation items for each type of environment showed significant differences.

For air environment, results of the t-test for healthcare facility workers and healthcare building specialists are shown in Table 19. The needs indicated by healthcare building experts show higher scores than that of healthcare facility workers as a whole. The difference between the two groups of experts was most significant for A2 and A6 (shaded areas). A2 is the establishment of $CO_2$ concentration control and monitoring system in air, and A6 is to maintain indoor air cleanliness (ventilation and ventilation monitoring system).

Table 19. Significance Levels for Air Environment

| Division | Average | | Standard Deviation | | t value | p value |
|---|---|---|---|---|---|---|
| | Healthcare facility worker (n=56) | Healthcare building specialist (n=32) | Healthcare facility worker | Healthcare building specialist | | |
| A1 | 3.73 | 4.06 | 0.904 | 0.801 | -1.717 | .090 |
| A2 | 3.50 | 4.06 | 0.991 | 0.801 | -2.739 | .007** |
| A3 | 4.38 | 4.31 | 0.843 | 0.859 | 0.332 | .741 |
| A4 | 3.64 | 3.81 | 0.841 | 0.738 | -0.951 | .344 |
| A5 | 4.16 | 4.31 | 0.826 | 0.859 | -0.817 | .416 |
| A6 | 4.14 | 4.47 | 0.749 | 0.718 | -1.993 | .049* |
| A7 | 4.32 | 4.53 | 0.855 | 0.671 | -1.193 | .236 |
| A8 | 4.00 | 4.09 | 0.853 | 0.734 | -0.521 | .604 |

*P<.05, **P<.01, ***P<.001

For thermal environment, results of the t-test for healthcare facility workers and healthcare building specialists are shown in Table 20. The needs indicated by healthcare building experts show higher scores than that of healthcare facility workers as a whole. The difference between the two groups of experts was most significant for H2 and H4 (shaded areas). H2 is keeping warm environment comfort by predicting room temperature change, H4 is creation of pleasant temperature environment - compliance with temperature range of comfortable heat environment level.

Table 20. Significance Levels for Thermal Environment

| Division | Average | | Standard Deviation | | t value | P value |
|---|---|---|---|---|---|---|
| | Healthcare facility worker (n=56) | Healthcare building specialist (n=32) | Healthcare facility worker | Healthcare building specialist | | |
| H1 | 3.43 | 3.75 | .735 | .718 | -1.989 | .050 |
| H2 | 3.52 | 4.16 | .853 | .677 | -3.863 | .000*** |
| H3 | 3.73 | 3.94 | .774 | .840 | -1.160 | .249 |
| H4 | 3.77 | 4.31 | .713 | .780 | -3.330 | .001** |
| H5 | 3.96 | 3.94 | .785 | .878 | 0.147 | .883 |

*P<.05, **P<.01, ***P<.001

For light environment, results of the t-test for healthcare facility workers and healthcare building specialists are shown in Table 21. The needs indicated by healthcare building experts show higher scores than that of healthcare facility workers as a whole. The difference between the two groups of experts was most significant for L2, L4, and L7 (shaded areas). L2 is providing individual lighting control for user's living space, L4 is indoor lighting standards and L7 is mandatory area for

natural light.

Table 21. Significance Levels for Light Environment

| Division | Average | | Standard Deviation | | t value | P value |
|---|---|---|---|---|---|---|
| | Healthcare facility worker (n=56) | Healthcare building specialist (n=32) | Healthcare facility worker | Healthcare building specialist | | |
| L1 | 3.39 | 3.88 | .731 | .140 | -2.887 | .005 |
| L2 | 3.43 | 4.16 | .892 | .120 | -4.308 | .000*** |
| L3 | 3.57 | 3.97 | .828 | .145 | -2.171 | .033 |
| L4 | 3.59 | 4.09 | .890 | .122 | -2.963 | .004** |
| L5 | 4.02 | 4.34 | .774 | .124 | -7.964 | .053 |
| L6 | 3.88 | 4.06 | .788 | .109 | -1.235 | .221 |
| L7 | 3.27 | 3.94 | .904 | .127 | -3.592 | .001** |

*P<.05, **P<.01, ***P<.001

### 5.7 Discussion of Results

Firstly, 23 out of 56 respondents (40.06% of total) dissatisfied and very dissatisfied. Most of the opinions were that the indoor environment items that were dissatisfied were categorized in air environment. Air environment is particularly important for healthcare facilities, presumably from a health point of view has the most significance.

Second, the recognition of the need of an evaluation of indoor environments for green healthcare facilities showed a positive result. 78% of healthcare facility workers indicated there is need and 81% of healthcare building specialists indicated the same. This suggests that the industry is demanding a major reform and improvement of the standard evaluation systems implemented to assess the indoor environment of green healthcare facilities.

Third, the importance of indoor environment evaluation items for indoor environments in green healthcare facilities indicate the following: the perception of the proportion of indoor environmental impact factor evaluation of healthcare facility workers was in order of air environment (4.46), light environment (3.73), sound environment (3.08), thermal environment (2.91) and other indoor environment (2.23). The perception of the proportion of the indoor environmental impact factor of the healthcare architects was in order of air environment (4.89), thermal environment and light environment (3.63), sound environment (2.90) and other indoor environment (2.20). In both groups, it was suggested that the proportion of evaluation of air environment to be most important.

Fourth, the survey items of the additional items needed for evaluation of indoor environments in green healthcare facilities according to healthcare facility workers and healthcare building specialists are as follows. The items that were the most important were A3 (secondhand smoke control and smoking cessation policy), A5 (indoor air cleanliness measurement evaluation for a certain period after construction), O2 (safety accessibility evaluation), A1 (installation of ventilation monitoring system - measurement of outdoor air inflow), and H3 (providing individual control environment for users).

Fifth, the need of items that require separate evaluation criteria in evaluation of indoor environments in green healthcare facilities according to healthcare facility workers and healthcare building specialists are as follows. Items that were found to be higher than the average include A7 (harmful air inflow blocking performance), A6 (maintenance of room air cleanliness), L5 (providing individual lighting control unit for staff space), A8 (use of indoor air pollutant low emission material), H4 (pleasant temperature environment creation), H5 Humidity and ventilation control device in a certain area of the living space of the living room) and L6 (the lighting control device available in the patient's bed space).

Sixth, t-test analysis for significance levels indicate whether there is are differences in responses between the surveyed groups. As a result of the t-test for air environment evaluation items, there was a significant difference between the two expert groups in the evaluation item of the ventilation monitoring system installation ($p < .01$) and the air carbon dioxide concentration control and monitoring system installation evaluation item ($p < .05$). As a result of the t-test for thermal environment evaluation items, the two expert groups showed that the indoor thermal modeling was used for the analysis of the thermal environment in buildings ($p < .001$) and the pleasant temperature environment composition evaluation item ($p < .01$) There is one difference. As a result of the t-test for light environment evaluation items, the two expert groups showed that the evaluation items ($p < .001$), indoor lighting standard evaluation items ($p < .01$) There was a significant difference in the evaluation items ($p < .01$). In all environment categories, healthcare building specialists indicated a stronger need for improvement in the indoor environments of healthcare facilities.

## 6. CONCLUSION

The purpose of this study is to investigate green building certification programs in Korea and to propose a direction to improve the evaluation items for indoor environment for healthcare facilities for the Korean G-SEED program. The conclusions drawn from this study are described below.

First, as a result of the comparison between indoor environment evaluation items from Korean and overseas' green building certification systems, it was found that the G-SEED program does not contain evaluation criteria particular to healthcare facilities and evaluation items of general indoor

environment were lacking. Indoor environments divided by air, thermal, light, sound and other was analyzed. For air environment, it was found it lacks policy on smoking and tobacco control, management of the indoor air quality during and after the construction, and provision of user control of the environment related to the indoor air environment. In thermal environment, there lacks a thermal environment analysis system through room temperature modeling and estimation of indoor temperature change, creation of a comfortable thermal environment and user individual control environment. In light environment, there was lacking evaluation of indoor lighting control device and induction of natural light. In other indoor environments, the degree of provision of visibility, connection with external space, safe laboratory management and security of external space adjacent to the building were not available. The above-mentioned criteria should be firstly considered in being included in an evaluation of indoor environments in green healthcare facilities in Korea. These discrepancies also show that consideration for indoor environment in healthcare facilities in Korea is insufficient as green building certifications overseas' have already integrated these standards.

Second, as a result of the questionnaire survey, the average degree of need for an evaluation for air environment was the highest. Among the five items most needed of additional items for indoor environment of green healthcare facilities, 3 items belonged to air environment. The evaluation items showing the highest need was smoking control, followed by the need of indoor air cleanliness measurement and evaluation for a certain period after construction, and the maintenance of security inside and outside the building and the evaluation of safe access, the installation of the fourth ventilation monitoring system. Given the building type of healthcare facilities, it can be argued that the indoor environment category that is most important is air environment. The quality of the air affects directly the health, comfort and well-being of the users of the healthcare facility. Poor quality in buildings is known to induce sicknesses and may raise issued related to infection control within a healthcare facility. Also, these findings suggest that healthcare facilities in Korea still lacks strong policy for tobacco control and that this is a main cause of the poor air quality.

Similarly, in the study of evaluation items requiring separate evaluation criteria, items in air environment evaluation were highest, such as the item for harmful air inflow blocking performance to manage harmful gas, fine dust and air infecting elements were the most needed and indoor air cleanliness maintenance using the ventilation and ventilation monitoring system. Eminent fine dust in Korea as well as old and poor ventilation systems may be the cause of these findings.

Third, according to the t-test results, there were clear discrepancies between the two groups of experts. While both healthcare facility workers and healthcare specialist experts expressed a clear need for improvement in indoor environment for green healthcare facilities. There were differences in which items that need to be improved. The strongest differences were expressed in air environment for the establishment of CO2concentrationcontrolandmonitoringsysteminair,andtomaintain indoor air cleanliness (ventilation and ventilation monitoring system). In thermal environment, keeping warm environment comfort by predicting room temperature change, and creation of pleasant temperature environment - compliance with temperature range of comfortable heat environment level. In lighting environment, the providing individual lighting control for user's living space, indoor lighting standards and mandatory area for natural light. The priority of the items express the background and knowledge of the experts, and indicates the preference of healthcare building specialists towards improving the indoor environment at a whole building scale, while the healthcare facility workers' focus was more localized.

The findings in this paper are intended to determine the current state of the G-SEED certification program in Korea with regards to the certification of healthcare facilities, focusing on indoor environments. As indoor environments play an important role in the comfort, health and well-being of users in buildings, it is particularly significant for healthcare facilities. This research paper solely focused on the evaluation items of the indoor environment according to the G-SEED program for healthcare facilities, thus further research on this topic should expand to include evaluation items for other green building certification categories, such as to include evaluation of energy, water, waste, and so on.

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