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A study of additional items for health and wellbeing based on Green Standard for Energy and Environmental Design (G-SEED) in Korea - Comparisons of IEQ field of G-SEED, BREEAM, LEED, and WELL certification -

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Abstract

Background/Objectives: Although social demands for health and acquisitions of G-SEED (Green Standard for Energy and Environmental Design) are increasing in Korea, health improvement cannot be secured by acquiring G-SEED that is based on specifications, not performances.

Methods/Statistical analysis: G-SEED as representative green building certification criteria domestically used was compared to internationally authorized BREEAM and LEED in this study. First, indoor environmental quality (IEQ) known to be very close to health was compared between domestic and international green building certifications. Second, individual certifications were analyzed by comparing BREEAM, LEED, and G-SEED with WELL for evaluating health-friendly buildings. The most necessary health element for G-SEED was then obtained.

Findings: As a result of comparisons between IEQ field of G-SEED and the level of BREEAM and LEED for improving health and wellbeing, it was found that expanding the evaluation range to include other facilities classified by building uses of G-SEED was important. This suggests that G-SEED should be followed by benchmarking the evaluation standard (i.e., evaluation levels of LEED) which is universally covered by the IEQ field of BREEAM and LEED. By comparing BREEAM and LEED based on WELL, the field with the lowest contribution to G-SEED was Lights, followed by Sound. This could propose G-SEED after benchmarking relative elements of BREEAM and LEED.

Improvements/Applications: Results of this study present a direction to recognize and improve health levels of G-SEED. They could be applied as basic information for follow-up studies or development of next versions in Korea.

Keywords: G-SEED, Health performance, WELL certification, LEED, BREEAM

1. Introduction

With increasing severity of global climate change, domestic and international government organizations have implemented policies to restrain greenhouse gases and resource consumptions across industries. National organizations have enacted and reinforced policies for greenhouse gas and recycling from not only industries, but also buildings [1]. Some countries have developed certification systems such as BREEAM of UK, LEED of USA, and CASBEE of Japan to evaluate eco-friendly buildings and grant grades. In Korea, G-SEED is a system of green building certification. It was introduced in 2002. Since then, it has been implemented. It has been revised constantly by reinforcing detailed regulations, scaling up certification objects, and reflecting characteristics of the construction market. This system is used for granting the grade after quantitatively evaluating performances of green buildings. However, it is managed at different levels according to situations by nations, climate environments, and evaluation methods based on social features and structures.

The frequently used fields in green building evaluation tools are Site, Energy, Water, Indoor Environment Quality (IEQ), Material, Waste and Pollution, and Management [2]. In addition to evaluate how this grade system for green buildings affects the environment, most plans manage human health and wellbeing in buildings somehow [3]. Especially, main items of IEQ estimate quite many topics related

to the health and wellbeing of residents. However, the broad range of other items to evaluate the sustainability of buildings excludes specific topics about the health and wellbeing [4].

In contrast to the above, the special plan focuses on this aspect and topics are developed according to increasing interests about health problems related to buildings. Some examples include WELL developed by International Well Building Institute in 2014 [5], Living Building Challenge proposed by International Living Future Institute in 2006 [6], Health, Well-being and Productivity in Offices published by World Green Building Council [7], and FitWell launched by Centre for Active Design [8]. They were developed not to substitute green building certification systems to evaluate the sustainability of buildings, but to emphasize special attentions for securing the health and wellbeing of residents in buildings. Of these plans, WELL is the most recognized plan globally. It is a leading certification system to estimate the health and the sustainability of buildings [4].

The number and medical expenses of domestic hospitals are increasing every year [9]. Health awareness and its importance are gradually growing due to recent pandemic of COVID-19 and micro dusts. Therefore, Green New Deal proposed by the Korean government is expected to reduce greenhouse gases and improve resident health through Green Remodeling [10]. Green Remodeling means that old buildings that consume a lot of energy can be transferred to green buildings to increase energy efficiency and performance.

According to this trend, some studies for reducing building energy and improving health after Green Remodeling have been conducted to have actual health improvements recently [11-12]. G-SEED in Korea had certified a total of 16,221 buildings by 2020 [13]. Although various studies have been performed in this field, there are not enough studies available to evaluate the health and its related effect in accordance with certification acquisitions.

Except for 'indoor and outdoor noise levels for 7.8 traffic noise (road, railroad)' of nonresident buildings in IEQ evaluations of G-SEED which is closely related to the health, only by adopting the standard of individual items for designs and constructions to obtain points of G-SEED cannot secure the improvement of IEQ unless there are quantitative performance data.

Therefore, the objective of this study was to compare and analyze main items of IEQ by evaluating topics related to resident health and wellbeing in the system of green building certification. Using WELL as a system for evaluating health-friendly buildings in USA, additional items are suggested for enhancing G-SEED based on results estimated for health and wellbeing levels.

2. Materials and Methods

2.1. *Analysis of previous studies*

2.1.1. Examples of domestic studies

Since its implementation in 2020, G-SEED in Korea has continuously revised to improve existing problems and reinforce the standard. Various studies have been conducted on G-SEED [14-16]. To reflect the current operating system, this study investigated examples from previous studies related to G-SEED that was revised in September 2016. Major keywords of this study were international green building certification system including G-SEED, health and wellbeing. Results are as follows.

In relation to green building certification systems domestically and globally, one study has suggested a global certification standard of G-SEED to apply in many countries after analyzing the international version of BREEAM and LEED [17]. This study also confirmed that the development mode of LEED and BIM could be applied to G-SEED and BIM by analyzing integrated literatures on BIM and LEED studied during several decades and by drawing similarities between LEED and G-SEED [18]. Another study has compared G-SEED and BREEAM of UK and analyzed the status of certification standards [19]. It provided basic data to establish improvements in the future [19]. As these studies compared and analyzed G-SEED and BREEAM/LEED as representative global systems for green building certification, the comparison between domestic/global certifications as the first step in this study was referred to previous studies. However, the analysis was carried out in perspective of health.

In relation to health and wellbeing, one study has derived priority items through AHP analysis using

WELL to complement G-SEED and pointed out the item to introduce first into domestic certification systems [20]. Another study has also figured out characteristics and critical point of G-SEED by comparing BREEAM, LEED, and WELL for management of indoor air quality and suggested four items to enhance this issue [21]. These studies are related to the health and wellbeing including G-SEED. They used WELL certification as in the present study.

2.1.2. Examples of international studies

Many studies about green building certification system, health, and wellbeing have been accomplished by mutually connecting more items globally. The following shows some samples.

For the purpose of reviewing green and non-green buildings for health and satisfaction of residents, one study has selected 40 previous studies that have evaluated IEQ elements and resident health. As a result, improvement of health index was shown in 38% of studies. However, it could not support the hypothesis that residents in green buildings may enjoy higher IEQ, satisfaction, and health [22]. Another study using WELL certification has analyzed the difference in aspects of health and wellbeing by comparing the evaluation field of existing buildings with LEED (USA), BREEAM (UK), and DGNB (Germany) which are international certification systems. That study provided a comprehensive overview to enhance the result. IWBI provides information of evaluated items as equivalent and aligned levels after comparing detailed items between WELL and LEED or WELL and BREEAM [23-24]. These previous studies suggest that the green building certification system cannot secure health improvements as shown in Korea. However, using WELL developed to guarantee health and wellbeing of residents can provide reliable information for mutual applications between green building certification system and WELL.

2.1.3. Differentiation from previous studies

This study is different from previous studies as shown below:

First, case studies using current global green building certification system are related to the globalization of G-SEED, BIM connection, and their improvements. However, this study tried to suggest additional items of G-SEED for the health and wellbeing. Secondly, a previous study [21] has figured out the feature and critical point of G-SEED by comparing BREEAM, LEED, and WELL for evaluations related to distributions and indoor air quality in an indoor environment. This study analyzed differences through comparison between detailed items in the indoor environment field (IEQ) of BREEAM, LEED, and G-SEED and indicated differences from current studies by performing quantitative comparison and analysis of health and wellbeing using WELL certification and introducing additional items of G-SEED.

2.2. *Overview of certification system*

2.2.1. Green building certification system used domestically and globally

BREEAM was developed in BRE, UK. It was firstly accomplished in 1990. It is a global certification system that has granted certifications for more than 594,011 cases in 89 countries. LEED (USA) had its original model in 1998. It is the most widely used system. It has granted about 87,900 cases in 160 countries since 2000. Thus, BREEAM and LEED are used by many nations as international certification systems. Five cases have been granted by BREEAM and 198 cases have been granted by LEED in Korea [25-26]. Domestic G-SEED has granted about 16,221 cases since 2002. Most buildings were granted in Korea except for 2 cases overseas [13]. More than 50% of G-SEED items were managed by the system based on domestic standard and climates. It has difficulties to be used as a global certification as it is. However, if it reflects regional standard and legislation by nations or regional characteristics (climates or vegetations), G-SEED could be applied as a global certification as well [17].

BREEAM, LEED, and G-SEED all evaluate eco-friendliness of buildings with similar features in evaluations. Because they are differently managed with different evaluation methods and structures according to situations by nations, climate environments, and social properties, their compositions and contents in detailed items are different from each other. Figure 1 presents the connection of similar evaluation fields among these three systems. Rates by each evaluation were calculated on the basis of

100% except for additional points of Innovation Design of three certifications and Regional Priority of LEED.

Both fields of energy and environmental pollution were the most highly evaluated, with rates of 30 ~ 33%. External environments such as land use, transportation, and ecological environment had high rates of 14 ~ 26%. The field of indoor environment also had a high rate of 16 ~ 19%. Especially, BREEAM manages a comprehensive item by expressing 'Indoor Environment' field to 'Health and Wellbeing'. Thus, it is highly focused on users' comfort and convenience, even in indoor environmental evaluations.

2.2.2. WELL Certification

WELL of USA was begun in October 2014 as a certification system. It encourages and evaluates health-friendly buildings for enhancing human health and wellbeing. WELL was developed during 7 years involving doctors, scientists, and construction experts. It includes 7 concepts, including Air, Water, Nourishment, Light, Fitness, Comfort, and Mind. It consists of detailed features. It was developed as a performance-based system to evaluate, certify, and monitor the influence of construction environments on human health. The effect of WELL includes many aspects such as resident health, welfare, increase of happiness, increase of worker productivity and performance, increase of building's asset and value, enhancement of company image, and so on [5]. After launching WELL v2 Pilot in 2018, WELL v2 which was improved by feedbacks from related workers and strict processes was launched in September 2019. It was subdivided into 10 concepts based on principles of Equitable, Evidence-based, Technically robust, Customer-focused, Resilient, and so on [27].

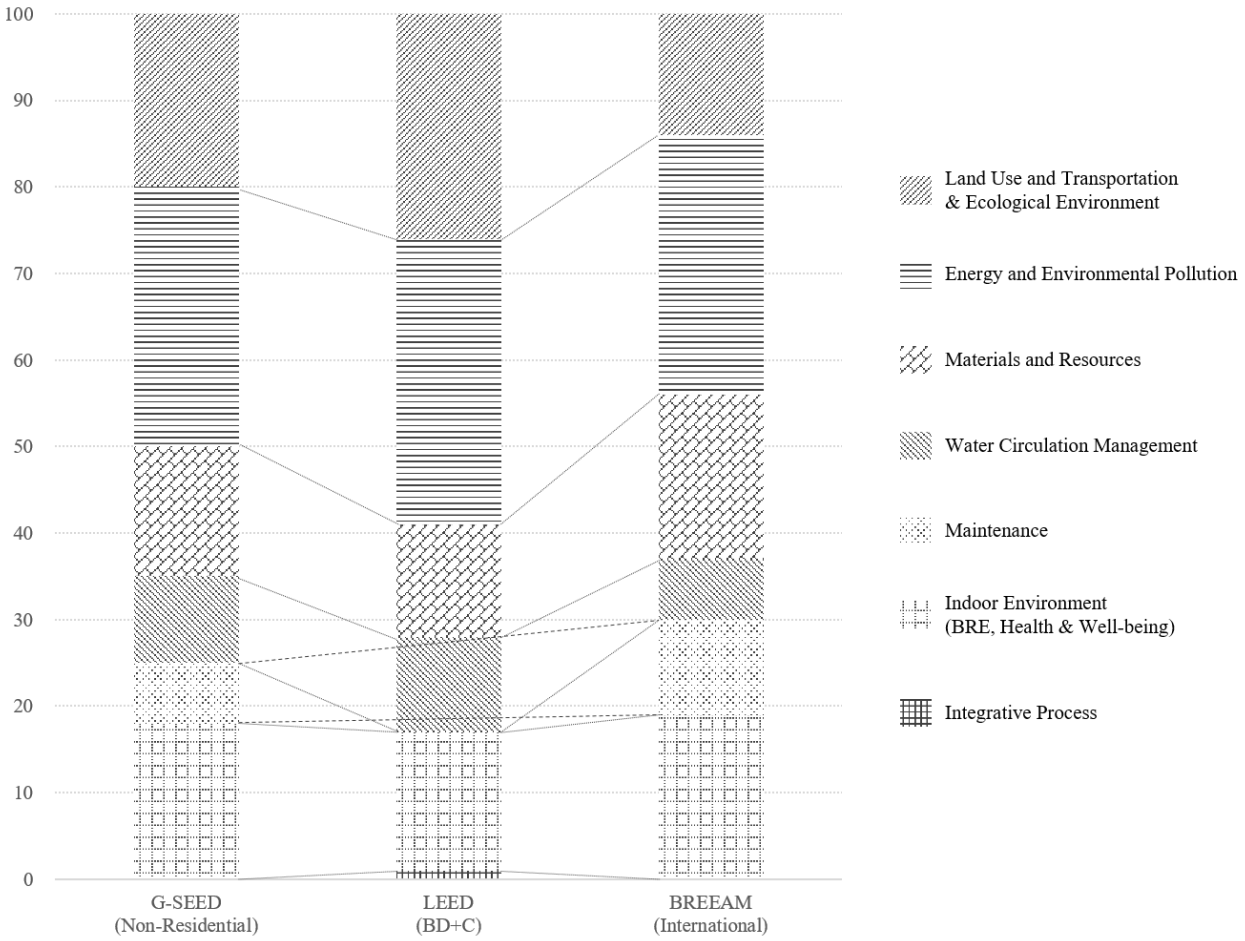

Figure 1. Score distribution by similar fields for domestic and overseas green building certifications

While the purpose of WELL is to focus on the health and wellbeing, the green building certification system evaluates the influence on the environment for sustainable buildings and includes items having human health and wellbeing in buildings. Many topics related to resident health and wellbeing in this certification system are directly independent on building designs. Topics in areas of air quality, water quality, nourishment and mind are more related to building managements and services provided within buildings [4]. Therefore, decisions of building owner and operator play an important role in reflecting this policy and system for enhancing health and wellbeing. This feature of WELL is the main difference from a green building certification system.

2.3. *Methods*

Methods used in this study are as follows.

First, BREEAM and LEED as representative global green building certification systems were analyzed to figure out mutual relationship by comparing them with G-SEED. The comparison and analysis included IEQ field of green building certification systems to evaluate topics related to health and wellbeing. Also, comprehensive items related to WELL were implemented individually.

Second, levels of health and wellbeing from G-SEED were estimated in IEQ fields for BREEAM and LEED.

Third, using WELL certification of USA as a health scale, levels of health and wellbeing from BREEAM and LEED were evaluated. Levels of health and wellbeing from G-SEED were evaluated by substituting results of BREEAM and LEED compared to G-SEED and WELL of USA.

Lastly, additional items were suggested to enhance G-SEED based on compared results of health and wellbeing from BREEAM, LEED, and G-SEED.

Figure 2 indicates detailed flow for completing this study.

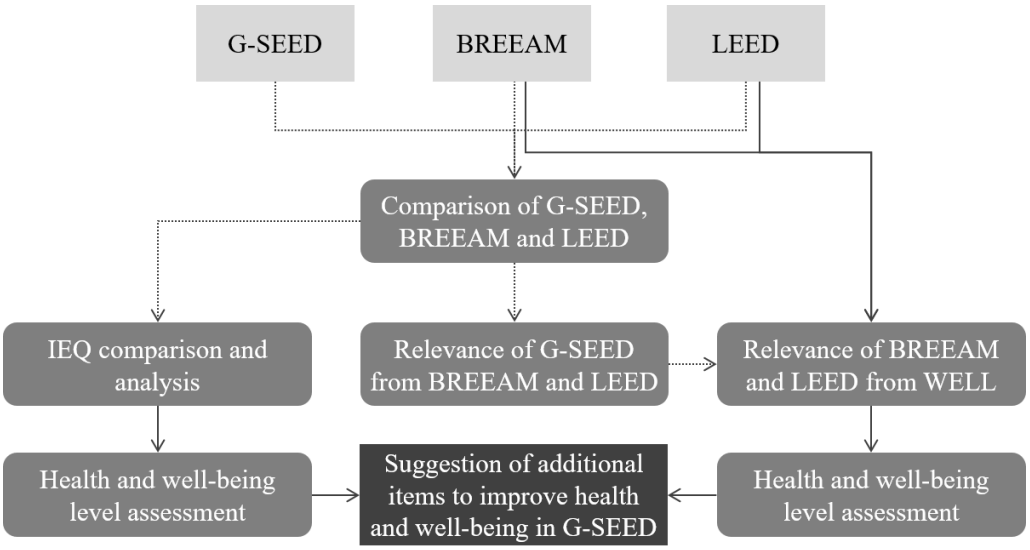

Figure 2. Research Methodology Process

In this study, green building certifications were progressed to mutually compare technical manuals [28-30] provided by organizations in BREEAM International New Construction 2016, LEED BD+C New Construction v4, and G-SEED 2016-5 New Construction for non-residential buildings. Each certification was categorized by detailed standard of related items according to building uses or required by additional applications. This study had limited certification standard of business facility for BREEAM and LEED. This is because business facility is the most general one suitable for other certifications. Thus, BREEAM and LEED were proceeded to establish certification standards of facility first. Domestic G-SEED was first developed for business facility standard to represent non-residential building. However, it is

very limited for the number of similar items to compare BREEAM and LEED with only G-SEED facility. Thus, this study considered all non-residential building standards without selecting building uses in G-SEED. In addition, because it was included in additional score field (Innovation Design) besides evaluation fields shown in Figure 1, option items with low importance were excluded.

3. Results and Discussion

3.1. *Analysis of G-SEED health level*

3.1.1. Comparison and analysis of IEQ field between green building certification systems

Based on IEQ fields that evaluate a related topic for health and wellbeing of green building certification systems used domestically and globally, results of comparison and analysis are shown in Table 1. Score distributions of IEQ fields in three certifications were similar at 16 ~ 19%. BREEAM had the highest rate. Detailed standard in BREEAM includes the most evaluation items and a comprehensive evaluation range higher than other two certifications for most standards except for 'Environmental tobacco smoke control' of LEED and '7.10 Creating rest areas' of G-SEED.

BREEAM arranged detailed standards having individual score to the concept of sub-item within certification items of 9 IEQ fields. It is an evaluation method to reflect weighed values after adding these items. Thus, it is different from the other two certifications. The score of IEQ fields is high at 19%. Its detailed items are 23, meaning two times more than the other two certifications. This indicated that BREEAM reflected more elements even though similar scores were obtained for the three certifications in the same IEQ fields. The difference of overall certified grade in BREEAM was about 1 grade higher than that in LEED based on results from a study that analyzed the correlation for the certification project using BREEAM and LEED [31].

In LEED, the weight of IEQ fields compared to the overall score is lower than that in G-SEED. However, it suggests broader evaluation ranges including views and lighting related to visual comfort such as 'Quality views', 'Daylight', 'Construction indoor air quality management plan', 'Indoor air quality assessment', 'Reverberation time', enhancing indoor air quality of construction and usage, and reverberation time in sound environment (here, 'Environmental tobacco smoke control' is excluded from comparisons due to obligatory standards in domestic laws). These standards of LEED are also included in BREEAM. On the other hand, G-SEED indicates evaluation standards in all uses for indoor air quality, indoor temp control, and external noise effect. However, other standards (awing installation for reducing appearance, CO2 monitoring, illumination from indoor environment controls) are regulated to apply only its related facility after categorized by building uses.

Table 1. IEQ evaluation field comparison of BREEAM, LEED, and G-SEED

BREEAM (19%*)			**LEED (16%*)**		**G-SEED (18%*)**		
BREEAM IEQ field certified items	**Score**	**No. of detailed items**	**LEED IEQ field certified items**	**Score**	**G-SEED IEQ field certified items**	**Score**	**Uses *****
Hea 01 Visual comfort	P**	5	-	-	-	-	
Glare control	1		-	-	7.9 Direct light control and installation of awning to reduce appearance	2	S
Daylighting	1		Daylight	3	-	-	
View out	1		Quality views	1	-	-	
Internal and external lighting levels, zoning and	1		-	-	-	-	

control							
-	-	-	Interior lighting	2	7.6 Adoption of control method for comfort indoor environment	2	O
Hea 02 Indoor air quality	P**	6	-	-	-	-	
Indoor air quality (IAQ) plan	1		Construction indoor air quality management plan	1	-	-	
Adaptability - Potential for natural ventilation	1		Minimum indoor air quality performance Enhanced indoor air quality strategies	P** 2	7.2 Obtaining natural ventilation performance	2	G
Ventilation	1				7.3 Design for intake and discharge port of outside air	2	G
					7.4 Operation of CO2 monitoring system and evaluation of ventilation volume	2	F
					7.6 Adoption of control method for comfort indoor environment	2	O
			Environmental tobacco smoke control	P**	(Complying domestic laws and regulations)	-	
Post-construction indoor air quality measurement	1		Indoor air quality assessment	2	-	-	
Emissions from building products	1		Low-emitting materials	3	7.1 Application of products emitting low pollutants for indoor air quality (P**)	3	G
Hea 03 Safe containment in laboratories	-	2	-	-	-	-	
Laboratory containment devices and containment areas	1						
Buildings with containment level 2 and 3 laboratory facilities	1						
Hea 04 Thermal	-	3	-	-	-	-	

comfort							
Adaptability - for a projected climate change scenario	1						
Thermal modelling	1				-	-	-
Thermal zoning and controls	1		Thermal comfort	1	7.5 Installation of automatic temp control unit 7.6 Adoption of control method for comfort indoor environment	2 2	G O
Hea 05 Acoustic performance	P**	3	-	1	-	-	
Indoor ambient noise and sound insulation	1		Acoustic performance (HVAC background noise, Sound Transmission, Reverberation time)		7.7 Sound insulation performance between rooms 7.8 Indoor/outdoor noise level for traffic noise (Road, Railroad)	2 2	H G
Reverberation times	1				-	-	
Hea 06 Accessibility	-	2	-	-	-	-	
Safe access	1						
Inclusive and accessible design	1						
Hea 07 Hazards	1	1	-	-	-	-	
Hea 09 Water quality	1	1	-	-	-	-	
-	-	-	-	-	7.10 Creating rest areas	1	G

* Indicating score weights by IEQ fields based on 100% of each certification according to Figure 1 results.

** Belongs to required items in IEQ evaluations by certifications.

*** Means items for its related uses in non-residential of G-SEED and indicating Office (O), School (S), Sales Facility (F),
Accommodation (A), and General (G) for applying equally for all uses.

Based on above results after comparing G-SEED IEQ fields and BREEAM and LEED levels for improving health and wellbeing, the expansion of evaluations is necessary to include other facilities for the standard categorized by building use of G-SEED. It is also suitable for G-SEED to benchmark the evaluation standard (i.e., evaluation levels of LEED) that equally covers IEQ fields of BREEAM and LEED.

3.1.2. Green building certification system and WELL certification comparison and analysis

This chapter compares and analyzes WELL that evaluates health-friendly buildings for the purpose of a green building certification system to enhance human health and wellbeing. WELL v2 launched in 2020 was utilized in this chapter. Comparisons between BREEAM and LEED were performed following the General Guidance of IWBI [23-24]. This Guidance evaluated the similarity with Equivalent (E) and Aligned (A) for the related standard of BREEAM, LEED, and WELL. 'E' means equivalent levels and 'A'

means that topic is identical but not completely overlapped. Thus, more works are required for outcomes [23-24].

Domestic G-SEED does not have direct comparison data for WELL. However, many studies have been conducted using BREEAM and LEED to suggest an enhancement of green building certifications. Like previous studies, this study matched similar items of two certifications and then analyzed levels of health and wellbeing through connection to the topic of WELL. From various studies that compared G-SEED and BREEAM or LEED, the matching between similar items was progressed by simply connecting items after researcher analyzed each technical manual or by the method classified to three steps in high, middle, and low after recognizing purpose, method, and range of evaluations [18-19]. This can drive different methods by its purposes. It may require background knowledge and enough project experiences.

In this study, the comparison between green building certifications is similar to previous works that link WELL, LEED, and BREEAM after matching the basis of evaluation purpose treated in each item of G-SEED. The evaluation purpose and the range of G-SEED related items are equivalent. The evaluation purpose of G-SEED related items is aligned, although its range belongs to partial levels for two steps. Detailed items of certification standards were referred to technical manuals [27-30] provided by each organization. This was done by experts who had experienced longer than 10 years. Table 2 shows results by comparing related items of G-SEED, BREEAM, and LEED and by crosswalk evaluation of health part based on WELL. Figure 3 shows a graph about the number of topics by individual certification after substituting results into 10 concepts for WELL certification. If the evaluation result (Table 2) for detailed items of G-SEED related to BREEAM and LEED is '◎' or 'ㅇ', it reflects a rate of 100% or 50%, respectively.

According to Figure 3, the following shows results of evaluating levels of health and wellbeing of BREEAM, LEED, and G-SEED based on WELL.

First, Air field had the highest rate in BREEAM, LEED, and G-SEED based on WELL. Distribution of its topics also had higher rate than other fields. This means that the most connected field with WELL topics in green building certifications is IEQ field and that the field of each certification has higher rate in indoor air quality as well (Table 1).

Second, three certifications have some relations with WELL certification in fields of Air, Lights, Movement, Thermal Comfort, Sound, Materials and Mind. This result also represents that the green building certification includes various elements of health and wellbeing for the evaluation. Especially, fields of Water and Community showed a difference with other certifications and covered a broader range of health and wellbeing in BREEAM. This indicates that BREEAM in IEQ field comparison of Table 1 includes items are not managed in LEED or G-SEED such as Hea 06 Accessibility, Hea 07 Hazards, and Hea 09 Water quality.

Third, when compared with BREEAM and LEED based on WELL, Lights had the lowest distribution in G-SEED, followed by Sound. While domestic G-SEED is focused on reducing illumination energy related to Lights, BREEAM and LEED manage both reduction of illumination energy and non-visual comfort. In the case of LEED, non-visual comfort is also considered in the evaluation for the purpose of reinforcing circadian rhythms by daylight. In Sound, while G-SEED simply evaluates sound insulation performances of indoor/outdoor sound effect and barrier walls from traffic sounds, BREEAM and LEED classify and evaluate more specific standard, objects, and its practicality. They also include a standard for reverberation time. Thus, they show a big difference from G-SEED. In summary, the most required fields for enhancing health and wellbeing of G-SEED are Lights and Sound in order. Thus, it is suitable for G-SEED to benchmark related elements of BREEAM and LEED.

Table 2. Comparison of related items among G-SEED, BREEAM, and LEED and crosswalk evaluation of health part based on WELL

G-SEED	BREEAM	LEED	Detailed items of

Detailed items of G-SEED related to BREEAM/LEED	BREEAM	LEED	Detailed items of BREEAM related to WELL and crosswalk evaluation		Detailed items of LEED related to WELL and crosswalk evaluation		WELL related to BREEAM/LEED
-	-	-	Man 01 Project delivery planning	A	-	-	C02.1 Facilitate Stakeholder Charette
-	-	-	***Man 04 Commissioning and handover***		-	-	-
2.2 Completing test, adjust, evaluate (TAB) and commissioning	◎	◎	Commissioning building services	E	EA Fundamental Commissioning and Verification	E	A03.2 Conduct System Balancing
	◎	◎	Testing and inspecting building fabric	E	EA Enhanced Commissioning EQc Enhanced Indoor Air Quality Strategies	E	A09.1 Part a) Design Healthy Envelope and Entryways
-	-	-	Handover	A	-	-	C01.1 Provide WELL Feature Guide
-	-	-	Man 05 Aftercare	A	-	-	C02.4 Facilitate Stakeholder Orientation
				A			C03.1 Select Project Survey
-	-	-	***Hea 01 Visual Comfort***		-	-	-
-	-	-	Daylighting	E	EQc Daylight	E	L01.1 Ensure Indoor Light Exposure
-	-	-	Internal and external lighting levels, zoning and controls	A		-	L02.1 Lighting Levels for Visual Acuity
2.8 Establishing daylight control plan to reduce cooling energy 7.9 Direct light control and owning installation to reduce appearance	◎	◎	Glare control	E		E	L04.1 Control Solar Glare
-	-	-	-	-		E	L05.2 Implement Enhanced Daylight Simulation
-	-	-	View out	E	EQc Quality Views	E	L05.3 Ensure Views

2.4 Saving illumination energy 7.6 Adoption of control method for comfort indoor environment	-	○	-	-	EQc Interior Lighting	A	L06.1 Manage Brightness
-	-	-	-	-		A	L07.1 Ensure Color Rendering Quality
-	-	-	***Hea 02 Indoor air quality***		-	-	-
-	-	-	-	-	EQc Indoor Air Quality Assessment	A	A01.1 Meet Thresholds for Particulate Matter
-	-	-	Post construction indoor air quality measurements	A		A	A01.2 Meet Thresholds for Organic Gases
-	-	-	-	-		A	A01.3 Meet Thresholds for Inorganic Gases
(Complying domestic laws and regulations)	◎	◎	Ventilation	E	EQp Environmental Tobacco Smoke Control	E	A02.1 Prohibit Indoor Smoking
	-	◎	-	-		A	A02.2 Prohibit Outdoor Smoking
7.2 Obtaining natural ventilation performance	○	○	Ventilation	E	EQp Minimum Indoor Air Quality Performance	E	A03.1 Ensure Adequate Ventilation
-	-	-	Indoor air quality plan	A	EQc Indoor Air Quality Assessment EQc Construction Indoor Air Quality Management Plan	E	A04.1 Mitigate Construction Pollution
7.4 Operation of CO2 monitoring system and evaluation of ventilation volume	◎	-	Ventilation	E	-	-	A06.2 Implement Demand-Controlled Ventilation
7.3 Design for intake and discharge port of outside air	-	◎	-	-	EQc Enhanced Indoor Air Quality Strategies	E	A06.1 Increase Outdoor Air Supply
-	-	-	-	-		A	A08.1 Implement Indoor Air Monitors
7.3 Design for intake and discharge port of outside air	○	○	Ventilation	E		E	A12.1 Implement Particle Filtration
7.1 Application of products emitting	-	◎	-	-	EQc Low Emitting Materials	E	X11.1 Manage Furniture and

low pollutants for indoor air quality							Furnishings Emissions
	◎	◎	Emission from building products	E		E	X11.2 Manage Flooring and Insulation Emissions
	◎	◎		E		E	X12.1 Manage Product Emissions: Adhesives, Sealants, Paints and Coatings
7.2 Obtaining natural ventilation performance	◎	-	Adaptability – Potential for natural ventilation	E	-	-	A07.1 Provide Operable Windows
-	-	-	***Hea 04 Thermal comfort***		-	-	-
-	-	-	Thermal modelling	A	EQc Thermal Comfort	A	T01.1 Support Thermal Environment
-	-	-	-	-		A	T02.1 Enhance Thermal Environment
7.5 Installation of automatic temp control unit	◎	-	Thermal zoning and control	E		-	T03.1 Ensure Thermostat Control
7.6 Adoption of comfort indoor environmental control	-	◎	-	-		E	T04.1 Ensure Personal Thermal Comfort
-	-	-	***Hea 05 Acoustic Performance***		-	-	-
7.8 Indoor/outdoor noise level for traffic noise (Road, Railroad)	○	○	Internal indoor ambient noise level	E	EQc Acoustic Performance	E	S01.1 Manage Background Noise Level
7.7 Sound insulation performance between rooms	◎	◎	Sound insulation	E		E	S01.2 Manage Acoustical Privacy
7.8 Indoor/outdoor noise level for traffic noise (Road, Railroad)	◎	-	Internal indoor ambient noise levels	A	-	-	S02.1 Limit Background Noise Levels
-	-	-	Indoor ambient noise and sound insulation	A	-	-	S03.1 Ensure Adequate Wall Construction
-	-	-		E	-	-	S03.2 Ensure Proper Door Specifications

-	-	-	Reverberation	E	EQc Acoustic Performance	A	S04.1 Meet Thresholds for Reverberation Time
-	-	-	-	-		A	S05.1 / 2 Points Implement Sound Masking
-	-	-	***Hea 06 Accessibility***		-	-	-
-	-	-	Safe access	A	-	-	V05.3 Select Sites with Pedestrian Friendly Streets
1.7 Installation of bike parking lot	◎	○		A	LTc Bicycle Facilities	E	V05.4 Select Sites with Bike Friendly Streets
-	-	-	Inclusive and accessible design	A	-	-	C13.1 Ensure Essential Accessibility
-	-	-	Hea 07 Hazards	A	-	-	C15.1 Develop Emergency Preparedness Plan
-	-	-	Hea 08 Private space	A	-	-	M07.2 Provide Restorative Outdoor Spaces
-	-	-	Hea 09 Water Quality	E	-	-	W03.1 Implement Legionella Management Plan
-	-	-		A	-	-	W06.1 Ensure Drinking Water Access
1.6 Proximity of public transportation	◎	◎	Tra 01 Public transport accessibility	E	LTc Access to Quality Transit	E	V05.2 Select Sites with Access to Mass Transit
-	-	-	Tra 02 Proximity to amenities	E	LTc Surrounding Density and Diverse Uses	A	V05.1 Select Sites with Diverse Uses
1.7 Installation of bike parking lot	◎	◎	Tra 03a or 3b (depending on project type) Alternative modes of transport	E	LTc Bicycle Facilities	E	V04.1 Provide Bicycle Storage
	◎	◎		A		A	V04.2 Provide Facilities for Active Occupants
-	-	-	Wat 03 Water leak detection	E	-	-	W07.3 Manage Interior Liquid Water
1.1 Ecological value of exiting lands	○	-	Le 01 Site selection	E	-	-	X06.1 Implement Site Assessment and Cleanup

6.1 Creation of linked green area 6.2 Ratio of natural green ground 6.3 Ratio of ecological area 6.4 Biotope composition 6.5 Creation of ecological learnings	◎	◎	Le 02 Ecological value of site and protection of ecological features Le 03 Minimizing impact on existing ecology Le 04 Enhancing site ecology Le 05 Long term impact on biodiversity	A	SS Open Space	A	M09 Provide Enhanced Access to Nature
-	-	-	Pol 02 NOx emissions	E	-	-	A10.1 Manage Combustion
3.1 Uses of environmental product declaration (EPD)	-	◎	-	-	MRc Building Product Disclosure and Optimization – Material Ingredients	E	X13.1 Select Optimized Materials
	-	◎				E	X14.1 Promote Ingredient Disclosure

◎ The purpose and the range of evaluation of G-SEED related items are equivalent
○ The purpose of evaluation of G-SEED relate items are identical but its range is partial

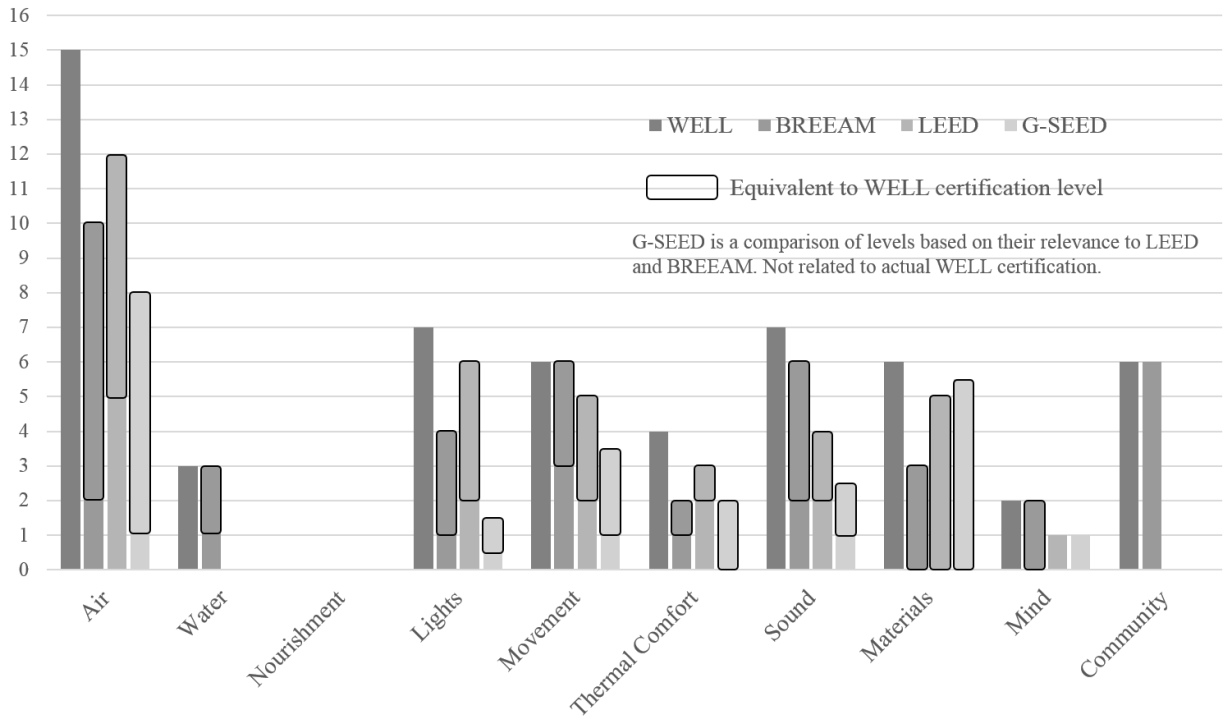

Figure 3. Numbers of topics by each certification after substituting Table 2 results into 10 concepts for WELL certification

3.2. *Discussion*

Domestic G-SEED attempts to improve the health and the comfort of residents through IEQ fields. However, the evaluation standard of G-SEED is not a performance-based method like BREEAM or LEED. It is a specification type that obtains scores only by applying given standards into designs and

constructions. Thus, it is difficult to prove the health enhancement effect against actual certified building without having related studies. Therefore, this study proposes additional performance for domestic G-SEED in terms of health using globally accredited certifications such as BREEAM, LEED, and WELL.

Due to few projects and studies available that could be mutually applied to each other, a direct comparison between G-SEED and WELL certification is very difficult. Thus, mutual comparison of G-SEED, BREEAM, and LEED was preceded by referring to previous studies for green building certification systems. In addition, results of comparison were used to recognize the health level of green building certification evaluation by applying to BREEAM and LEED based on WELL certification so that additional items of health and wellbeing for G-SEED could be derived.

According to results of this study, the most required field for health enhancement of G-SEED is Lights. The following attention is necessary to reflect this result. The purpose of green building certification is to decrease building energy and reduce greenhouse gases. However, more energy might be used to promote health and wellbeing (for example, to meet Equivalent melanopic lux in WELL requires the performance higher than standard illumination so the energy consumption can be increased). The health and wellbeing of residents who are subjects using buildings are very important elements as well. Thus, an appropriate balance between health and energy is eventually necessary. By solving the gap from both, we can achieve environmental responsibility and health advantage together. These aspects are already reflected in designs and constructions by considering mutual correlations to get certifications of BREEAM, LEED and WELL all together. According to this trend, this study could be used as basic information for developing the next version with post-studies on topics of health of G-SEED.

Regarding the field of Lights suggested in this study, a number of studies have focused on energy reduction and light environment enhancement [32-33]. The element of human health must be considered for suitable environment using current techniques. For doing this, it is necessary to consider visual and non-visual comfort of health element. A proper balance between energy reduction and health is needed while reflecting building properties. In addition, when considering the domestic effect of an apartment [34], a discussion on the residential part for the same topic of this study is also necessary.

4. Conclusion

To meet the increasing demand for health, this study reviewed evaluation levels by comparing domestic G-SEED used for a green building certification to global accredited BREEAM, LEED, and WELL in terms of health and analyzed additional items required. The study was approached in two directions. The first was accomplished mainly on IEQ fields closely related to health in green building certifications. The second was to compare and analyze three certifications based on WELL for evaluating health-friendly buildings. As a result, fields of Lights and Sound are equally necessary to enhance the health of G-SEED in both methods. Especially, the field of Lights was estimated at very low health level in comparison with BREEAM and LEED. Thus, it highly requires some extents of improvement. In other fields of health, BREEAM and LEED showed higher levels than G-SEED except for Materials. This result explains that global certification systems consider energy, eco-friendliness, and health all together.

The combination of an element of green building certifications and health performance are essential for logical approaches considered both social responsibility of reducing greenhouse gases and health enhancement of residents in buildings. BREEAM and LEED fully consider these elements. They could be used as good benchmarks for improving G-SEED. Results of this study could be used as basic information for post-studies for enhancing health of G-SEED and for developing the next version. Optimization analysis for the purpose of appropriate balance between energy reduction and health in fields of illumination is needed in the future to improve the health of domestic G-SEED.

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