Study on the Improvement of Korean Green Building Certification Criteria Focused on Certification Score and Specialist Survey Analysis

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Abstract

The purpose of the research is to suggest improvement directions of G-SEED certification criteria and standards. To verify the present condition and improvement points, the certification scores of 97 apartments were analyzed by category and criteria. Based on this, a certification specialist intensive interview was conducted, and specialist questionnaires were collected for multiple organizations. One hundred and thirty two questionnaires were analyzed by matrix analysis to establish synthetic improvement directions of criteria concerning similar tendencies. Based on this, the final improvement directions of G-SEED criteria were established.

Keywords: G-SEED; green building; certification; apartment; specialist survey

1. Introduction

Due to the global crisis concerning environmental pollution, the field of architecture has made various attempts to decrease environmental load. It has reported that the total amount of GHG emissions by commercial and residential buildings is 39% of total industry in the United States, while buildings represent 40% of energy consumption and 36% of GHG emissions in Europe[15]. As a result, the demands for green buildings have increased internationally, and since 2002, the Korean government has developed and operated Green Standard of Energy and Environment Design (G-SEED), formerly KGBCC, to lead and promote green building construction.

In the beginning, G-SEED certified only apartments, and the target has been expanded to every type of building today. There are four levels of certification in G-SEED, and 1,214 buildings received certification (Pre-Certification: 2,170) by March 2014. In addition, the numbers of certified buildings, certification types, and certification rate in total constructed apartment projects have increased steadily, and this verifies that G-SEED has been successfully established in the construction market in Korea[12].

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In spite of 12 years of certification, however, G-SEED has not been evaluated as a completed system, and it still requires improvement and development in various aspects[8]. There have been many studies to improve the criteria and standards of G-SEED. The studies related to the present conditions and improvement directions in systematical aspects have been conducted by many researchers ([1], [3], [5], [13]). Also, various studies on the improvement directions of criteria and standards in G-SEED were conducted based on case analysis: case analysis studies for improvement direction ([6], [7], [9], [14]), certification criteria improvement studies by certification score analysis[4], and studies on the importance analysis of certification criteria[2].

In addition, Seok and Hong[16] analyzed problems between pre-certification and certification, and demonstrated improvement directions. Lee and Yeom[11], [12] and Kwon *et al.*[10] conducted satisfaction surveys on the residents of certified and general apartments, and showed improvement directions focused on criteria that demonstrated low satisfaction. Also, Son *et al.*[17] investigated and showed the economic benefits of the Korean green building certification system.

Many researchers conducted improvement studies of G-SEED in many aspects; however, studies done on the certification score analysis are insufficient. Research on improvement concerning the opinions of certification specialists is necessary, due to their important role in the operating certification system.

With this background, the aim of this research is to suggest improvement directions of G-SEED certification criteria and standards. To accomplish this, the certification scores of 97 certified apartments were

analyzed by category and criteria to verify problems. In addition, improvement directions were surveyed by certification specialists.

2. Methodology

The range of research is G-SEED certification for apartments, which comprise the majority of applicants for the Korean certification system. The certification category and criteria for apartments in G-SEED are shown in Table 1.

Table 1. Certification Criteria for the Apartment

Category	Item	Criteria	Point
Land Use and Transportation	Ecological Value	Ecological value of the construction site	2
	Influence on the surrounding site	Daylight interference prevention plan	2
	Residential environment plan	Community center and facility plan	3
		Pedestrian pathway plan in the apartment	3
		Connection to the outer pedestrian network	2
	Transportation load reduction	Access to public transportation	2
		Bicycle storage and pathway plan	2
		Distance between the center of the apartment and center of the locality/city	2
Energy and Environ-mental Pollution	Energy saving	Energy performance	12
	Sustainable energy use	Renewable energy use	3
	Global warming prevention	CO_2 emission reduction	3
		Specific material prevention regarding ozone layer	3
Materials and Resources	Resource saving	Floor plan for life-style change	3
	Waste reduction	Living furniture use prevention plan	3
	Living waste separate collection	Separate collection of recyclable material	2
		Food waste reduction	2
	Sustainable resource use	Certified green product use for valid resource recycling	3
		Carbon emission footprint of material	2
	Optional for remodeling	Structure reuse	7
		Non-bearing wall reuse	2
Water Circulation Management	Water circulation system	Rainwater load reduction plan	4
	Water resource saving	Daily water use reduction plan	4
		Rainwater use	4
		Graywater installation	3
Maintenance	Systematic site management	Reasonability of construction site management plan	1
	Efficient building maintenance	Providing operation/maintenance document and guideline	2
	Efficient unit maintenance	Providing user manual	1
	Easy maintainability	Private area	2
		Public area	2
Ecological Environment	Green area plan in site	Connected green axis plan	2
		Natural soil green area rate	2
	Ecological function of outdoor and building surface	Ecological area rate	10
	Habitat Plan	Biotope plan	4
Indoor Environment	Atmosphere environment	Low emission material use for indoor air pollution substance	6
		Natural ventilation plan	3
		Ventilation performance of unit	3
	Thermal environment	Auto thermostat in each room	2
	Sound Environment	Light floor impact sound prevention	2
		Heavy floor impact sound prevention	2
		Noise protection between units	2
		Indoor/outdoor noise level from transportation	2
		Noise protection from the toilet	2
	Light environment	Daylight ratio in the unit	4
Housing Performance	Lifetime management	Durability	-
	Inclusive design	Private area	-
		Public area	-
	Home network	Home network system	-
	Security and safety	Security and safety contents	-
	Fire fighting	Sensors and alarms	-
		Smoke extraction system	-
		Fire resisting capacity	-
	Evacuation safety	Horizontal evacuation distance	-
		Width of corridor and stairs	-
		Evacuation facilities	-
+ Note			
Daylight interference prevention plan		Evaluating height of the apartment and parallel distance to the other site in the north direction to prevent blocking sunlight in the neighboring site	
Living furniture use prevention plan		Evaluating storage area per room area to prevent and reduce material use for living furniture such as closet and cabinet.	
Rainwater load reduction plan		Evaluating connected area rate to the rainwater reduction facility to prevent urban flooding and reduce rainwater related facility construction cost	
Noise protection from the toilet		Evaluating the number of applied noise reduction methods from the toilet and air duct to prevent noise from the neighboring residential unit	

To verify the present condition and improvement points, the certification scores of 97 apartments which achieved certification from March 2011 to December 2012 were analyzed. Preliminary improvement directions were deduced, and based on this, certification specialist interviews were conducted intensive. The interviewees were the CEO, committee members and senior researchers in the certification organization, research institutes, design firms, and consulting companies. Ten interviewees with long-term certification work experience were selected by purposive sampling, and the problems, reasons, and improvement directions of each certification criteria were surveyed.

Based on this, specialist questionnaires were collected for 4 certification organizations, 5 research institutes, 4 design firms, and 4 certification-consulting companies. The questionnaires consisted of 4 demographic questions, 5 general questions about G-SEED, and multiple-choice questions about improvement directions of certification criteria. The answers in the multiple-choice questions were deduced by synthetic analysis of related studies and specialist interviews. There were nine answers for each choice; 'Increase Point', 'Decrease Point', 'Increase Standard', 'Decrease Standard', 'Thorough Revision', 'Weight Revision', 'Maintaining the Present', 'Deletion', and a free answer.

The survey was conducted from September 27 to October 11, 2013, and 182 questionnaires were distributed. Seven disqualified questionnaires were excluded from the analysis, and 132 questionnaires were analyzed. The reliability and differences between values were verified by cronbach α (0.738) and t-test. In addition, certification scores and survey results were analyzed by matrix analysis to establish synthetic improvement directions of criteria concerning similar tendencies. Based on this, the final improvement directions of G-SEED criteria were established.

3. Certification Score Analysis Results

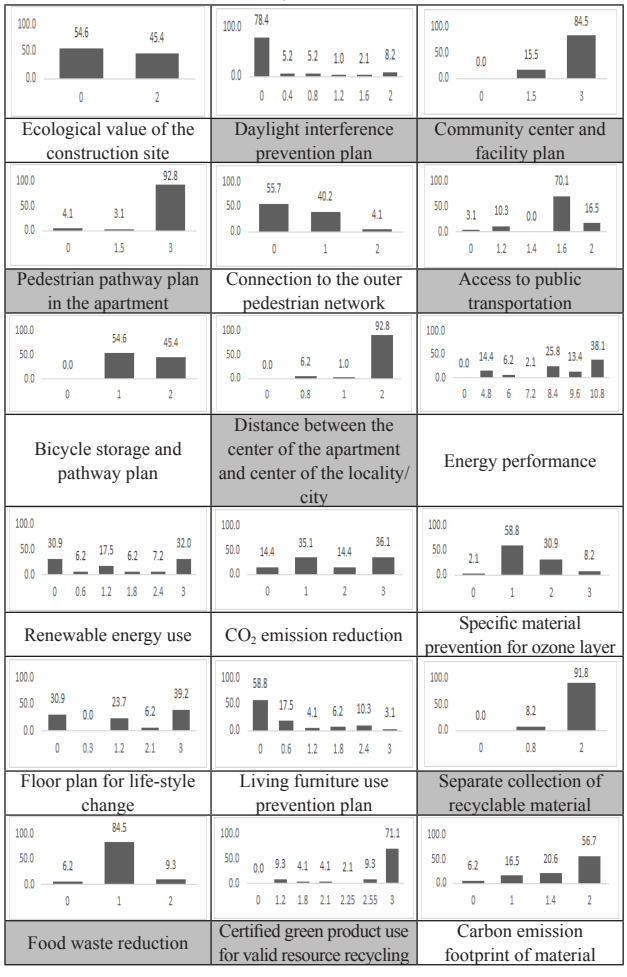
The average certification score of 97 apartments was 69.68 (out of 122), which indicates the second level in the G-SEED. The allotted points, average score, and score rate by category are shown in Table 2., and score distributions of criteria are shown in Table 3.

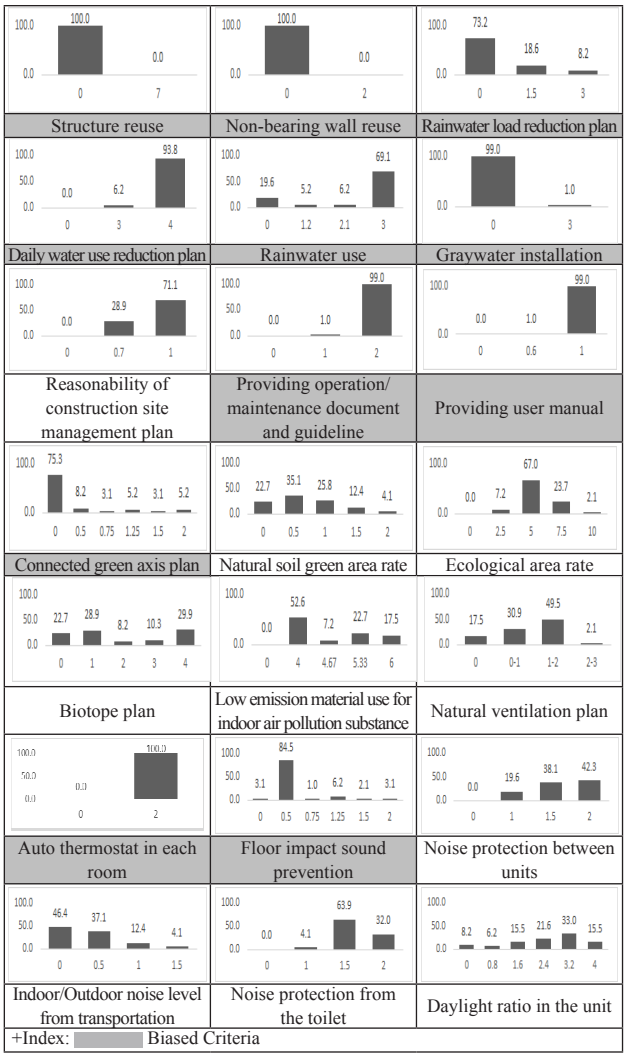
In the analysis result by category, the Maintenance and Transportation category scored high. However, Water Resources and Environmental Pollution Prevention demonstrated relatively low scores, and Ecological Environment showed less than 50% of allotted points. In particular, these three categories are directly related to environmental load reduction. Thus, due to the basic purpose of certification, these categories required urgent improvement.

Table 2. Certification Scores by Category

Category	Allot Points	Avg. Score	Score Rate (%)
Land Use	12.00	7.26	60.52
Transportation	6.00	4.92	82.06
Energy	15.00	10.27	68.49
Materials and Resources	15.00	9.60	64.03
Water resources	13.00	6.76	51.99
Environmental Pollution Prevention	6.00	3.18	52.92
Maintenance and Management	4.00	3.89	97.37
Ecological Environment	18.00	8.44	46.88
Indoor Environment	24.00	15.34	63.94

Table 3. Score Distribution by Criteria





In score distribution analysis results by criteria, the differences between criteria were large, from 0 to 100. All 97 apartments achieved a perfect score in *Harmful substance prevention from construction material* and *Auto thermostat in each room. Providing operation/ maintenance document and guideline* and *providing user manual* in the Maintenance category showed the average at 99.48%, which indicated almost every apartment scored 100%. In addition, *Daily water use reduction plan*, *Separate collection of recyclable material*, and four other criteria showed average scores above 90%, and the average scores of 13 criteria appeared higher than 80%.

However, none of the apartments received scores in two criteria for remodeling, which are optional in certification, and *Graywater installation* was analyzed very rarely. In addition, *Daylight interference prevention plan*, *Rainwater load reduction plan*, *Connected green axis plan*, and *Indoor/Outdoor noise level from transportation* scored less than 20%, and including these four, 12 certification criteria achieved an average lower than 30%.

Furthermore, many criteria showed bias on specific points. In particular, biased criteria, which scored either 0 or 100, and the criteria where the difference between

the best and the second point was larger than 50% need to be improved. Therefore, score distribution analysis was conducted through detailed analysis and specialist survey, and the improvement directions of criteria were suggested from a practical perspective.

4. Survey Result Analysis and Discussions

Specialist questionnaires were distributed equally to synthesize the opinions of various organizations: 31 for certification organizations, 34 for research institutes, 38 for consulting companies, and 36 for design firms.

4.1 Demographic and General Analysis Results

The number of male respondents was twice as many as female respondents, and half of the respondents were in their 30s. The education level was M.A (42.4%), B.A. (39.4%), and Ph.D. (15.9%), which indicates a high level of education. Fifty four point six percent of the respondents have worked more than 5 years, so the respondents were well experienced for the survey.

Ninety seven point seven percent of the respondents knew G-SEED, which showed high awareness. The average number of certification projects (design, construction, evaluation, research, consulting, etc.) was 37. In addition, half of the respondents (49.6%) had participated in the certification projects for more than 3 years, so they were experienced enough to create an accurate survey.

In the 7-point scale question about the necessity of G-SEED, the average was 6.1, which indicated that the majority agreed with its necessity. However, 49.2% of the respondents answered that the mandatory approval requirement is the reason for certification achievement. Thus, understanding of the purpose of certification appeared low in the specialist group. In addition, the respondents answered 5.1 (on a 7-point scale) about the effect of certification for the spread of green buildings and construction technology transfer, which indicated that G-SEED effectiveness is weak.

4.2 Analysis Results

The accumulated choice rate by the improvement direction of criteria is shown in Figs.1. and 2.

Sixty one point five percent of the respondents answered that the improvement of criteria is required, and it was higher than 'Maintaining the Present' (38.5%). In the accumulated choice rate by improvement direction, 'Increase Standard' received the highest score. 'Thorough Revision', 'Increase Points', 'Weight Revision' demonstrated a high rate, and 'Deletion' appeared relatively low.

To accomplish the improvement directions in detail, the certification score by criteria and the improvement direction response rate were compared and analyzed by matrix analysis. During the analysis, *Harmful substance prevention from construction material* was excluded due to deletion in the 2012 update. In addition, *Auto thermostat in each room* is mandatory due to another certification, so it was also deleted. The average certification score (56.8%) was set as the X-axis and the average of improvement direction response rate (62.4%) was set as the Y-axis. The analysis results are shown in Fig.3. and Table 4.

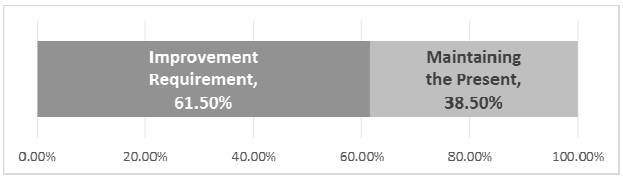


Fig.1. Accumulated Improvement Response Rate

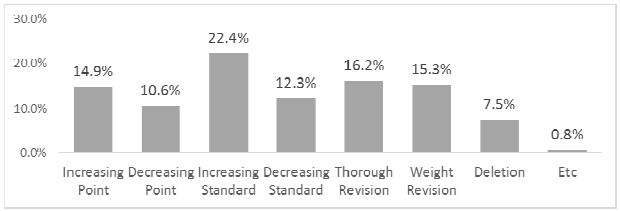


Fig.2. Accumulated Improvement Directions

Fig.3. Matrix Analysis Results (Index: Table 4.)

Table 4. Score and Improvement Requirement Rate

#	Criteria	S.	LR.
	Average	56.8	62.4
1	Ecological value of the construction site	45.4	66.4
2	Daylight interference prevention plan	13.6	74.0
3	Community center and facility plan	92.3	61.8
4	Pedestrian pathway plan in the apartment	94.3	51.5
5	Connection to the outer pedestrian network	24.2	64.1
6	Access to public transportation	78.4	47.0
7	Bicycle storage and pathway plan	72.7	47.0
8	Distance between the center of the apartment and the center of the locality/city	95.2	54.6
9	Energy performance	73.2	63.4
10	Renewable energy use	49.7	65.2
11	Floor plan for life-style change	59.8	59.8
12	Living furniture use prevention plan	20.2	77.1
13	Separate collection of recyclable material	95.1	55.4
14	Food waste reduction	51.5	56.2
15	Certified green product use for valid resource recycling	89.5	61.5
16	Carbon emission footprint of material	79.4	54.2
17	Structure reuse	0.0	98.9
18	Non-bearing wall reuse	0.0	70.2
19	Rainwater load reduction plan	17.5	73.8

20	Daily water use reduction plan	98.5	47.3
21	Rainwater use	75.5	61.5
22	Graywater installation	1.0	70.5
23	CO_2 emission reduction	57.4	57.7
24	Specific material prevention for ozone layer	48.5	70.5
25	Reasonability of construction site management plan	91.0	51.9
26	Providing operation/maintenance document and guideline	99.5	56.2
27	Providing user manual	99.5	52.3
28	Connected green axis plan	13.1	74.6
29	Natural soil green area rate	35.1	71.8
30	Ecological area rate	55.2	61.8
31	Biotope plan	49.0	71.2
32	Low emission material use for indoor air pollution substance	78.3	62.1
33	Natural ventilation plan	31.2	56.5
34	Floor impact sound prevention	29.6	69.5
35	Noise protection between units	80.7	59.2
36	Indoor/Outdoor noise level from transportation	18.6	56.8
37	Noise protection from the toilet	82.0	54.6
38	Daylight ratio in the unit	62.3	61.3
+ Index: S – Score (%) / I.R - Improvement Requirement (%)			

According to the results, tendency and improvement directions of certification criteria were distinguished by each quadrant. The largest number of criteria (19) appeared in the fourth quadrant and the second quadrant also contained a relatively large number of criteria (13). The first quadrant, on the other hand, only included one criterion, and the third contained only 4, which is a relatively small number. The specific analysis and improvement directions of certification criteria in each quadrant are as follows.

(1) The First Quadrant

The criteria in the first quadrant indicates a high certification score and high improvement requirement, and it included *Energy performance* (Table 5.). 'Increase Weight' had the highest number of improvement directions for these criteria; however, 'Increase Points' and 'Increase Standard' also showed high necessity. Therefore, the standard, allotted points, and weight need to be elevated.

Table 5. The Improvement Directions of the First Quadrant

Criteria	Improvement Requirement (%)	Improvement Direction (%)
Energy performance	63.4	Weight Revision (15.3) Increase Point (14.5) Increase Standard (14.5)

(2) The Second Quadrant

The second quadrant includes low-score and high improvement-required criteria, and these criteria needed improvement most urgently (Table 6.). Diverse improvement directions were established for three criteria in 'Increase Standard', one criterion each for 'Deletion' and 'Thorough Revision', and five criteria for 'Decrease Standard'.

'Increase Standard' was the dominant opinion for *Specific material prevention for ozone layer*. However, it is already mandatory by government environmental standards, so 'Thorough Revision' was suitable for this direction. In *Rainwater load reduction plan*, it was discovered that the standard for permeable pavement area needs to be reintroduced through specialist interviews, which was excluded in the last update.

Table 6. The Improvement Directions of the Second Quadrant

Criteria	Improvement Requirement (%)	Improvement Direction (%)
Specific material prevention for ozone layer	70.5	Increase Standard (17.4) Thorough Revision (16.7)
Rainwater load reduction plan	73.8	Increase Standard (16.9) Decrease Standard (13.8) Increase Point (12.3)
Floor impact sound prevention	69.5	Increase Standard (22.1) Increase Point (17.6)
Structure reuse	70.2	Deletion (21.4) Thorough Revision (15.3)
Non-bearing wall reuse	68.9	Thorough Revision (16.7) Decrease Point (13.6)
Natural soil green area rate	71.8	Increase Point (19.1) Weight Revision (15.3)
Daylight interference prevention plan	74.0	Increase Point (16.8) Decrease Point (11.5) Thorough Revision (11.5) Weight Revision (11.5)
Renewable energy use	65.2	Increase Point (22.0) Increase Standard (18.9)
Ecological value of the construction site	66.4	Weight Revision (16.8) Decrease Standard (14.5) Increase Standard (12.2)
Biotope plan	71.2	Weight Revision (16.7) Decrease Standard (16.7)
Connection to the outer pedestrian network	64.1	Weight Revision (14.5) Decrease Standard (14.5)
Living furniture use prevention plan	77.1	Decrease Standard (15.3) Thorough Revision (14.5)
Connected green axis plan	74.6	Decrease Standard (20.0) Thorough Revision (16.2) Increase Point (15.4)
Graywater installation	70.5	Decrease Standard (13.6) Increase Point (12.9)

Various opinions appeared for improvement directions such as 'Increase/Decrease Standard', 'Increase Points', and thus requires further study.

The largest number of resident complaints concerned *Floor impact sound prevention*[12], therefore increasing the standard and points are required. *Non-bearing wall reuse* and *Structure reuse* are difficult to apply for new construction, so no cases were reported concerning these criteria. Therefore, 'Thorough Revision' is a proper direction or development, and operation of an exclusive standard for remodeling is urgently required.

'Increase Point' and 'Weight Revision' were investigated for the *Natural soil green area rate*. This criteria is expensive to achieve, thus the allotment points need to be increased and weight revised. Various directions were surveyed for the *Daylight interference prevention plan* such as 'Increase Point', Decrease Point', 'Through Revision', and 'Weight Revision', which required further study.

'Increase Point' and 'Weight Revision' showed a high response rate for *Renewable energy use*, and this is a reasonable improvement direction to meet the demands of the times. *Ecological value of the construction site* is decided by site condition, so the achievements are limited. Thus, thorough analysis is required before improvement and revision.

Biotope plan installation would cost a lot, thus decreasing the standard or increasing weight are required to increase the number of installation. 'Decrease Standard' and 'Weight Revision' had the

same response rate for *Connection to the outer pedestrian network*. The site condition is absolute for this criterion, so as the survey showed it needs to be improved.

In the specialist interview, one issue brought up was that the present standard does not evaluate storage space in the living room, entrance or kitchen for the *Living furniture use prevention plan*. It also showed a high response rate in the 'Thorough Revision', thus this needs further study.

Multiple directions were identified, such as 'Decrease Standard', 'Thorough Revision', and 'Increase Point' for the *Connected green axis plan*, so this also required additional research. *Graywater installation* is a difficult criterion to apply due to high cost, engineering level, and lack of understanding. It was surveyed that deriving score achievement is required by decreasing the standard and increasing allotment points.

(3) The Third Quadrant

The criterion in the third quadrant indicates a low certification score and improvement requirement, and it includes four criteria (Table 7.). However, all of them are close to the average score, and although 'Increase Standard' was dominant in all criteria, various opinions were investigated at a similar rate. Therefore, these criteria need further studies.

Table 7. The Improvement Directions of the Third Quadrant

Criteria	Improvement Requirement (%)	Improvement Direction (%)
Food waste reduction	56.2	Increase Standard (16.9) Thorough Revision (12.3)
Ecological area rate	61.8	Increase Standard (15.4) Increase Point (12.3) Weight Revision (12.3)
Natural ventilation plan	56.5	Increase Standard (14.5) Increase Point (13.0) Thorough Revision (10.7)
Indoor/Outdoor noise level from transportation	56.8	N/A (p>0.05)

The installation of a resource recovery facility appeared very rarely due to its low usefulness for *Food waste reduction*, and 'Thorough Revision' was suggested for the improvement direction. *Ecological area rate* criteria have limits due to the building coverage and profitability. Thus, it was shown in the survey that 'Increase Point' or 'Weight Revision' is suitable for improvement.

Natural ventilation plan is calculated by floor area versus opening areas. However, the floor area includes balconies, thus decreasing the open area rate. Therefore, revising the standard is necessary. *Indoor/Outdoor noise level from transportation* is greatly affected by the surrounding environment. Various opinions were suggested and none of them were significant by t-test, so this also needs further review.

(4) The Fourth Quadrant

The fourth quadrant includes criteria with a relatively high score and low improvement requirement (Table 8.). In particular, 12 of the 19 criteria were required 'Increasing Standard', and also needed 'Thorough Revision' (2) and 'Deletion' (2). This demonstrated that the certification specialists understood that most criteria in this quadrant require fundamental improvement.

Table 8. The Improvement Directions of the Fourth Quadrant

Criteria	Improvement Requirement (%)	Improvement Direction (%)
Community center and facility plan	61.8	Increase Standard (16.2) Thorough Revision (11.5) Deletion (11.5)
Pedestrian pathway plan in the apartment	51.5	Increase Standard (19.2)
Separate collection of recyclable material	55.4	Increase Standard (13.8) Thorough Revision (13.1)
Certified green product use for valid resource recycling	61.5	Increase Standard (18.5) Weight Revision (10.8)
Carbon emission footprint of material	54.2	Increase Standard (16.8) Weight Revision (9.2)
Rainwater use	61.5	Increase Standard (22.3)
CO_2 emission reduction	57.7	Increase Standard (13.8) Increase Point (13.8)
Providing operation/ maintenance document and guideline	56.2	Increase Standard (13.8) Thorough Revision (9.2) Weight Revision (9.2)
Low emission material use for indoor air pollution substance	62.1	Increase Standard (19.7) Weight Revision (15.9)
Noise protection between units	59.2	Increase Standard (29.2)
Noise protection from the toilet	54.6	Increase Standard (22.3)
Daylight ratio in the unit	61.3	Increase Standard (21.4)
Reasonability of construction site management plan	51.9	Thorough Revision (11.6) Increase Standard (10.1)
Floor plan for life-style change	59.8	Thorough Revision (14.4) Decrease Point (14.4)
Providing user manual	52.3	Deletion (13.8) Increase Standard (10.0)
Distance between the center of the apartment and center of the locality/city	54.6	Deletion (16.9) Thorough Revision (10.8) Increase Standard (10.8)
Daily water use reduction plan	47.3	Maintaining the Present (52.7) Increase Standard (14.7)
Access to public transportation	47.0	Maintaining the Present (53.0)
Bicycle storage and pathway plan	47.0	Maintaining the Present (53.0) Increase Standard (12.1)

There were many opinions concerning the *Community center and facility plan*, and 'Increasing Standard' was the dominant response. According to the specialist interviews and a related study (Lee & Yeom, 2012), *Pedestrian pathway plan in the apartment* is strongly related to the residents' satisfaction. The highest response rate was 'Increasing Standard', but there were also many opinions on 'Thorough Revision' and 'Deletion'. Therefore, additional studies are required.

Separate collection of recyclable material is a prerequisite criterion and 90% of the apartments achieved a perfect score. Thus, it requires 'Increasing Standard' or 'Thorough Revision'.

To improve *Certified green product use for valid resource recycling*, 'Increasing Standard' was required due to product expansion. In addition, weight revision was suggested by the specialist interview concerning the different feasibility of each green product certification. The related products are also expanding for the *Carbon emission footprint of material*. Thus, 'Increasing Standard' was determined to be dominant,

and it also needed a minor revision in weight.

To achieve *Rainwater use*, in most cases a retention facility was installed, but it was determined that practical use needs to be evaluated after installation. *CO_2 emission reduction* showed the same response rate on 'Increasing Standard' and 'Increasing Point', so a general raise is required.

According to the specialist interview, site-oriented documents and general documents needed separate evaluation for *Providing operation/maintenance documents and guidelines*. Also, there were various suggestions on this, so it needs further review. Applicable products are increasing for the *Low emission material use for indoor air pollution substance*, so the standard needs to be increased.

The contents of *Noise protection between units* and *Noise protection from the toilet* are hot social issues in Korea, so continuous 'Increasing Standard' was suggested. For the *Daylight ratio in the unit*, it was indicated that the present standard was not suitable for the purpose of criteria, and restoring the old standard which evaluated daylight time is needed. It was also suggested that the standard concerning the limited number of perpetual shadowed units needs to be restored.

Many of the specialists questioned the effectiveness of *Reasonability of construction site management plan* and *Floor plan for life-style change* in the interview, so 'Thorough Revision' was recommended.

A user manual is always provided to residents, thus the deletion of the *Providing user manual* criteria was suggested. The *Distance between the center of apartment and the center of locality/city* are limited by the site location, and there are many arguments about the definition of locality/city center. Also, the improvement directions were surveyed in diversity. Therefore, developing criteria to evaluate centers more specifically is needed and requires further studies.

Finally, *Daily water use reduction plan*, *Access to public transportation*, and *Bicycle storage and pathway plan* were deemed 'Maintaining the Present', so the present standard is reasonable.

4.3 Synthetic Analysis

To clarify the improvement directions, analysis results were synthesized and arranged by the improvement directions which were discussed and concluded in chapter 4.2. The synthetic improvement directions for certification criteria are shown in Table 9.

The dominant improvement direction was 'Increase Standard' which appeared in 11 criteria. Also, widespread improvement-required criteria were investigated, such as 'Thorough Revision' (6) and 'Deletion' (1). This proves that certification specialists understand the necessity of increasing standards, thus urgent improvement is needed.

The criteria that required 'Increasing Point', 'Weight Revision', and 'Decreasing Point' indicates limits to scoring due to practical matters or requirement for specific revisions. These criteria were suggested to improve the standard for deriving score achievement.

The criteria in further studies showed similar improvement directions or possibilities for argument. These criteria need intensive cause analysis and improvement direction research through further studies.

Finally, three criteria, which indicated maintaining the present standard, need a gradual standard increase to elevate the certification level from a long-term perspective.

Table 9. Synthetic Improvement Direction

Improvement Direction	Certification Criteria
Increase Point	Floor impact sound prevention
	Pedestrian pathway plan in the apartment
	Separate collection of recyclable material
	Certified green product use for valid resource recycling
	Carbon emission footprint of material
	Rainwater use
	CO_2 emission reduction
	Low emission material use for indoor air pollution substance
	Noise protection between units
	Noise protection from the toilet
	Daylight ratio in the unit
Thorough Revision	Daylight ratio in the unit
	Structure reuse
	Non-bearing wall reuse
	Reasonability of construction site management plan
	Floor plan for life-style change
	Food waste reduction
Deletion	Providing user manual
Increase Point	Daylight interference prevention plan
	Renewable energy use
	Ecological area rate
Weight Revision	Biotope plan
	Connection to the outer pedestrian network
Decrease Standard	Graywater installation
Further Study Required	Community center and facility plan
	Energy performance
	Rainwater load reduction plan
	Natural soil green area rate
	Ecological value of the construction site
	Living furniture use prevention plan
	Connected green axis plan
	Natural ventilation plan
	Indoor/Outdoor noise level from transportation
	Providing operation/maintenance document and guideline
	Distance between the center of the apartment and center of the locality/city
Maintaining the Present	Daily water use reduction plan
	Access to public transportation
	Bicycle storage and pathway plan

5. Conclusion

The purpose of the research was to suggest improvement directions of G-SEED certification criteria and standards. To accomplish this, the certification scores were analyzed by category and criteria to verify the problems, and improvement directions were suggested concerning the certification specialist survey. The results are as follows:

(1) According to the score analysis on the 97 certified apartment projects, unequal score distribution was significant in 19 criteria, and needs improvement. In addition, 13 criteria in which the average score was over 80% and 12 criteria where the average was under 30% required improvement urgently.

(2) 61.5% of the respondents chose answers related to improvement. This proves that certification specialists consider that the present standard is at a low level, thus the necessity for increasing the standard and improvement appeared high.

(3) In the matrix analysis, the first quadrant, which indicates a high score and high improvement requirement, only contained one criterion. This requires a gradual standard increase from a theoretical perspective. The second quadrant, which showed low scores and a high improvement requirement, included 14 criteria. These criteria were deemed as highly needing thorough revision or increase, such as 'Increasing Standard', 'Thorough Revision', and 'Deletion'. In addition, some criteria limited by the site and project conditions needed deriving by 'Increasing Point' and 'Decreasing Standard'. The criteria belonging to the third quadrant indicated low scores and improvement requirement. However, these showed scores close to the average, and diverse improvement directions were suggested, thus requiring further studies. The fourth quadrant, which indicates a low score and high improvement requirement, included 19 criteria. The majority of improvement directions were 12 'Increasing Standard', 2 'Through Revision', and 1 'Deletion', and this proves that the necessity for increasing standards and improvement of certification specialists are high in this quadrant.

(4) 18 improvement directions called for increasing standards and wide revision, which included 'Increasing Standard' (11), 'Thorough Revision' (6), and 'Deletion' (1). The criteria where the improvement directions were suggested as 'Increasing Point' (3), 'Weight Revision' (2), and 'Decreasing Point' (1) need improvement to derive score achievement. The 11 criteria for further study need intensive further research for improvement, and 3 criteria for 'Maintaining the present' (3) need standard increases from a long-term perspective.

This research proved the bias of certification scores through certification score analysis, and it is significant that improvement directions of criteria were suggested from a practical perspective. In addition, improvement studies for other building types are required in the future.

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References

1) Bae, S. and Song, O. (2010) A Study on the Actual Condition and the Effect of KGBCC – Based on Apartment Houses. Journal of Architectural Institute of Korea, 26(12), pp.61-70.
2) Choi, Y. and Lee, S. (2012) Analyzing the Weight of Assessment Criteria in Korea Green Building Certification System - Focused on Certification Standards for Multi-unit Apartment Projects. Journal of Korea Institute of Ecological Architecture and Environment, 12(1), pp.83-90.
3) Han, K., Kim, A., and Kim, S. (2007) An Analysis of Domestic Environment-Friendly Building Design Certification. Workshop of the Korea Institute of Ecological Architecture and Environment, 13(11), pp.53-56.
4) Jung, Y., Kim, J., Baek, H., & Song, O. (2012) A Study on the Improvement of Green Building Rating System through Analysis of Each Assessment Item of KGBCC Certified Apartments. Journal of Architectural Institute of Korea, 28(2), pp.53-60.
5) Kim, B. (2006) Introduction and the Present Condition of Korean Green Building Certification Criteria. Journal of Korean Association of Air Conditioning, Refrigerating and Sanitary Engineers, 23(7), pp.34-15.
6) Kim, C (2013) A study on the Improvement of the Korea Green Building Certification Criteria by Assessing the Maintenance Categories. Journal of Korea Institute of Ecological Architecture and Environment, 13(2), pp.93-100.
7) Kim, D., Lee, S., Sadohara, S. (2014) A Comparison of Plan and Facility Items in Green Building Certification Criteria – Focused on Energy-related Items in Schools, Journal of Asian Architecture and Building Engineering, 13(2), pp.429-436.
8) Kim, H (2012) The Study on the Management Model Improvement of G-SEED, Ph.D. Dissertation, Department of Architecture, JoongAng University, Seoul, Korea.
9) Kim, S., Lee, D., and Kim, S. (2010) Comparative Analysis of Evaluation Items in Green Building Certification Case of Apartment Housing. Journal of Korea Institute of Ecological Architecture and Environment, 10(2), pp.31-38.
10) Kwon, H., Yeom, D., and Lee, K (2011) A Study on the Effect and Improvement Directions of KGBCC based on the Comparison of Green Residents Satisfaction. Journal of Korea Institute of Ecological Architecture and Environment, 11(5), pp.79-90.
11) Lee, K. and Yeom, D. (2009) Comparative Research of Residents' Satisfaction Level between Green Building-Certified Apartment Complexes and General Apartment Complexes in Korea. Journal of Asian Architecture and Building Engineering, 8(2), pp.423-430.
12) Lee, K. and Yeom, D. (2012) Comparative Research of Residents' Satisfaction Level in KGBCC-Certified Apartments in Korea. Journal of Asian Architecture and Building Engineering, 11(1), pp.55-62.
13) Lee, H. and Choi, C. (2011) A Study on Score Comparison between Preliminary and Main Certification of Green Building Certification Criteria for Educational Facilities. Journal of the Korean Solar Energy Society, 31(1), pp.68-76.
14) Mo, J., Koim, C., Lim, T., Kang, Y. & Kim, B. (2008) A Study of Case Analysis on Green Building Certification Criteria for Advanced Methods. Proceedings of the Korean Solar Energy Society, pp.178-183.
15) SBI Energy (2012) Green Building Materials and Construction, 3rd Edition, Maryland, U.S., SBI (Specialist in Business Information).
16) Seok, H and Hong, H. (2010) Study on the Management of Environmentally Friendly Design Features in Green Housing Estates. Proceedings of Korean Housing Association, 1, pp.355-360.
17) Son, L., Lee, S., Lim, C., Kim, S. (2014) Economic Analysis of Korea Green Building Certification System in the Capital Area Using House-Values Index, Journal of Asian Architecture and Building engineering, 13(2), pp.475-481.