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 Europe¹⁵). 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 Korea¹²).

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 aspects⁸). 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 (¹¹), 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 analysis⁴), and studies on the importance analysis of certification criteria²).

In addition, Seok and Hong¹⁶) analyzed problems between pre-certification and certification, and demonstrated improvement directions. Lee and Yeom¹¹), 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     |
|                              | Pedestrian environment plans              | Community center and facility plan                                       | 3     |
|                              | Residential environment plans             | Pedestrian pathway plan in the apartment                                 | 3     |
|                              | Transportation load reduction             | Access to public transportation                                          | 2     |
|                              | Waste reduction                           | Bicycle storage and pathway plan                                          | 2     |
|                              | Living waste separate collection         | Distance between the center of the apartment and center of the locality/city| 2     |
|                              | 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     |
|                              | Sustainable resource use                  | Certified green product use for valid resource recycling                 | 3     |
|                              | Optional for remodeling                   | Structure reuse                                                           | 7     |
|                              | Water circulation system                  | Rainwater load reduction plan                                             | 4     |
|                              | Water resource saving                     | Daily water use reduction plan                                            | 4     |
|                              | 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     |
|                              | Green area plan in site                   | Connected green axis plan                                                | 2     |
|                              | Ecological function of outdoor and building surface | Ecological area rate                                      | 10    |
|                              | Habitat Plan                              | Biotope plan                                                              | 4     |
|                              | Atmospheric environment                   | Low emission material use for indoor air pollution substance              | 6     |
|                              | Thermal environment                      | Auto thermostat in each room                                              | 2     |
|                              | Sound Environment                         | Light floor impact sound prevention                                       | 2     |
|                              | Light environment                         | Daylight ratio in the unit                                               | 4     |

Table 2. Improvement Directions of Certification Criteria

| Category                        | Improvement Directions                          |
|---------------------------------|------------------------------------------------|
| Land Use and Transportation     | - 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 |
| Housing Performance             | 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          |

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Table 3. Score Distribution by Criteria

| Criteria                                                                 | Score Distribution |
|-------------------------------------------------------------------------|--------------------|
| Ecological value of the construction site                               | ![Score Distribution](image1) |
| Daylight interference prevention plan                                   | ![Score Distribution](image2) |
| Community center and facility plan                                      | ![Score Distribution](image3) |
| Pedestrian pathway plan in the apartment                                | ![Score Distribution](image4) |
| Connection to the outer pedestrian network                              | ![Score Distribution](image5) |
| Access to public transportation                                         | ![Score Distribution](image6) |
| Bicycle storage and pathway plan                                        | ![Score Distribution](image7) |
| Distance between the center of the apartment and center of the locality/ city | ![Score Distribution](image8) |
| Energy performance                                                      | ![Score Distribution](image9) |
| Renewable energy use                                                    | ![Score Distribution](image10) |
| CO2 emission reduction                                                  | ![Score Distribution](image11) |
| Specific material prevention for ozone layer                            | ![Score Distribution](image12) |
| Floor plan for life-style change                                        | ![Score Distribution](image13) |
| Living furniture use prevention plan                                    | ![Score Distribution](image14) |
| Separate collection of recyclable material                              | ![Score Distribution](image15) |
| Food waste reduction                                                    | ![Score Distribution](image16) |
| Certified green product use for valid resource recycling                 | ![Score Distribution](image17) |
| Carbon emission footprint of material                                   | ![Score Distribution](image18) |

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.
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 ‘Through 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’, 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)  |
| CO₂ 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                        | Decrease Standard (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 (19.8)  |
|                                       |                             | 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. CO₂ 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 |
| | CO₂ 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 area 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.

Acknowledgement

This study was conducted as a part of a Ph.D. dissertation: Yeom, D (2014) A Study on the Sustainability Improvement Model for G-SEED, Department of Architecture, Ajou University, Korea.

This work was supported by the National research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (NRF-2011-0018116).

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