KIEAE Journal, Vol. 14, No. 5, Oct. 2014, pp.21-28

KIEAE Journal

Korea Institute of Ecological Architecture and Environment

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Estimate of Additional Construction Cost as Certifying G-SEED of Office Building in Korea

Kim, Jea-Moon* · Shin, Sung-Joon** · Hur, In***

* *Corresponding author, Technical Research Institute, SAMOOCM Architecture and Engineering, South Korea (jaem0216@samoocm.com)*
** *Technical Research Institute, SAMOOCM Architecture and Engineering, South Korea (shinsj@samoocm.com)*
*** *SAMOOCM Architecture and Engineering, South Korea (hurin@samoocm.com)*

ABSTRACT

To improve environmental problem as globally climate changes, domestic and foreign government have been trying to reduce green gas emitted by all industries. With making the green building certification system that assess the substantiality and energy performance of building, a governments have been using by a way for reducing green gas emitted in building industry. G-SEED(Green Standard for Energy & Environmental Design) developed in Korea have been reinforcing, and a number of projects certifying the G-SEED have been increasing continuously.

As a demand of G-SEED certification is rising, a question on the additional cost data as certifying G-SEED is rising. It is because additional cost as getting the certification is important fact for G-SEED level decision and whether getting the certification or not.

Therefore, this study analyzed additional construction cost as certifying G-SEED through performance improvement and design change of general office building not to get G-SEED. In conclusion, an additional construction cost ratio of G-SEED projects to the reference building is drawn as certified level; +0.26%, silver level; +2.29%, gold level; +3.89%, and platinum level; +5.48%.

KEYWORD

G-SEED
Additional Cost
Office Building
EPI(Energy Performance Index)

ACCEPTANCE INFO

Received August 4, 2014
Final revision received September 24, 2014
Accepted September 26, 2014

1. Introduction

1.1. Background of research

As problems associated climate changes are becoming a global issue, government organizations both in/outside Korea are legislating policies to reduce CO_2 production and waste of natural resources. Korean government is also introducing and reinforcing regulations on CO_2 produced from all building and recycling of natural resources in all industries. To achieve this goal, a certification system that evaluates environment-friendliness of buildings and assign a characteristic of each country is being developed. Some of the well-known environment-friendly architecture certification system includes BREEAM in the UK, LEED in the US and CASBEE in Japan.

Korea adopted an environment-friendly building certification system in 2002 and has been making continuous revisions on them by reflecting unique characteristics of domestic architecture market via reinforcement on regulation, expansion in certification coverage, etc.

Laws to Support Development of Green Buildings, which came into effect in 2013, as part of efforts to promote low carbon green growth policy, has proclaimed laws on enhancing problems associated with the current environment-friendly and energy-related certification system and is gradually reinforcing detailed requirements. In particular, the existing environment-friendly certification system and residential performance grade system were integrated to green architecture certification system(G-SEED). Also, the 9 existing evaluation criteria were reorganized as 7 criteria and certification coverage was expanded. As a result of government's efforts on green building architecture certification system, the number of projects with G-SEED system is increasing every year, excluding 2011 and 2012. Fig. 1 is the achievements of projects that acquired G-SEED system from 2002 to 2013.

However, although private facilities that are not subject to certification review acquiring certification in the early phase of

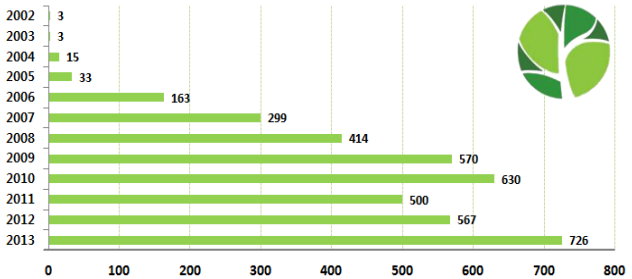


Fig. 1. Figures certified in G-SEED from 2002 to 2013

pISSN 2288-968X, eISSN 2288-9698
http://dx.doi.org/10.12813/kieae.2014.14.5.021

project, they often do not move forward with it due to the burden of making quantitative prediction on additional cost as well as paying for it. For this reason, the government is providing incentives such as relaxing requirement on construction criteria and acquisition tax and exempting property tax according to G-SEED grade, it has so far failed to provide data on cost that can be predicted according to G-SEED.

In the United States, many research reports on the analysis of additional construction cost and economic feasibility according to LEED certification has been published via public, association and private organizations and are being used as good information for decision making during certification. (Kim Jae-Moon, 2013). On the other hand, in Korea, such cost data is severely lacking.

Therefore, there is need for accumulating research data on additional construction costs according to the revised G-SEED system.

1.2. Goal of research

The goal of this research is to analyze additional construction cost resulting from G-SEED certification and estimate the additional costs by category and grade for domestic office buildings.

In doing so, we can provide quantitative cost data resulting from acquiring G-SEED certification during the early phase of the project, forecast additional construction cost by grade for similar projects in the future and support decision making of the vendor in order to ultimately promote G-SEED certification system.

1.3. Research process and method

The procedure and method used in this research were summarized in the 5 steps below. The following is the detailed explanation of the five steps.

1) Examination of previous researches: Previous researches done on environment-friendly certification in Korea and overseas are analyzed to plan research process and frame. Specific research methods were derived based on this and the final output was produced.

2) Select a project: The target project was selected from heavy demand projects done by SAMOOCM Architecture Offices for last 3 years based on the analysis of the size private office facilities and average construction cost.

3) Certification score (scenario): The target project was first analyzed if it satisfies certifications criteria. Then, original plan was analyzed to see if it satisfies G-SEED requirements. Also, classification was done for categories that require design change and performance enhancement as well as categories that cannot be acquired due to project characteristics such as land environment.

In addition, for categories that require design change and performance enhancement, the categories with low cost based on existing cases were combined together to create a scenario by G-SEED certification grade. After deriving additional costs by assessment categories, scenarios were then finally updated by reflecting the result of cost analysis.

4) Derive additional costs by assessment categories: Construction costs expended during performance enhancement and design changes to satisfy project requirements by certification categories were added up by construction types. Then, additional construction costs incurred were summarized for each derived category to calculate increase rate per total construction cost and cost ranking.

5) Derive additional construction cost by grade: Scenarios were updated using the cost ranking by category analyzed earlier and the result was used to calculate additional construction cost by grade.

2. Examination on previous researches

In terms of previous researches done on G-SEED (including environment-friendly building certification), although there are many researches done on enhancement of certification system and assessment categories, quantitative analysis on addition construction cost impact of assessment categories and economic feasibility are severely lacking. Previous researches include researches on additional cost for assessment category for G-SEED (Kim Shin-Eun, 2010), building database to forecast construction cost (Lee Heung-Geun, 2011) and analysis on additional project cost by construction project for certification (Jang Hyun-Sook, 2013). However, they were only basic researches or simple case study to forecast additional cost resulting from G-SEED certification. In short, there were no detailed researches done on quantitative impact of assessment category that could be used as data to support decision making process.

In the United States, in terms of researches done on the impact of LEED cost, active researches are being done by government/ private sector done on impact of additional construction cost incurred for obtaining environment-friendly construction certification or its economic feasibility. In particular, LEED Cost Study published in 2004 by US General Services Administration (GSA) is a widely known example. This research created scenarios for performance by certification grade and analyzed change in cost by grade resulting from application of LEED. In addition to cost analysis by category, certification fee and professional consulting costs were calculated and reflected on additional costs by grade. Moreover, the research analyzed cost variation by grade. Certified grade showed variation in the range of -0.4~2.1%; silver grade,

0.03~4.4%; and gold grade, 1.4~8.2%. In addition, the errors in cost calculation caused by double-counting were minimized by deriving related categories from assessment categories and indicating their relationship. For related categories explained earlier, items that affect more than two categories were derived to prevent double-costing. In this research, too, related categories were derived and reflected in scenario creation.

In this research, we used a research methodology of LEED Cost Study introduced earlier to some extent. In particular, when choosing a target building, as shown in the research report above, the buildings that did not acquire certification were used for research. The reason is, although the standard for design change or performance enhancement is clear according to detailed G-SEED category for buildings that did not acquire certification, since standard for base model's performance degradation and design changes was vague, for buildings that acquired certification, we chose uncertified buildings as analysis target.

3. Project selection

3.1. Selection criteria of a project

In order to increase usefulness of analysis results, the size and average construction cost of project being done recently were investigated and the projects that were most frequently done were selected. In addition, buildings that did not acquire certification were selected and the project that we could use drawings and history by construction type was selected for analysis target.

3.2. Selecting a project

Excluding factories and other facilities from more than 100 projects being implemented by SAMOOCM Architecture Office, the office building facilities accounted for 14.3%, the highest frequency. Size and construction cost Per square meters were 16,500㎡(5,000 pyung) and 1,545,000 won (based on design). Based on this, we selected a 13 story office facility with 7 basement levels with the total area of 17,320.89㎡(5,248pyung) from the projects that did not acquire G-SEED. We could use the overall

Table 1. Standard Floor Plan

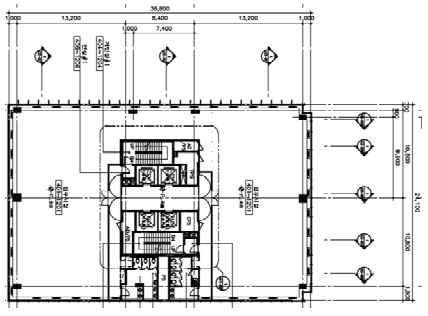
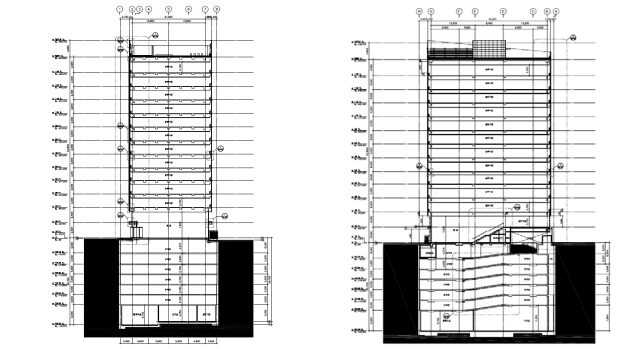


Table 2. longitudinal section and cross section



drawing and history documents for the target project. The total construction cost was 2.97 billion won (based on design), 1,714,600 won per square meters. In addition, the design for the project was completed on April, 2012. Construction period was 23 months and the facility was completed on March, 2014. Table 1 and Table 2 below are the floor plan (4F~12F) and cross-section/ longitudinal drawing.

4. Project analysis

4.1. Creating scenario for certification by grade

1) Criteria for selecting scenario

In order to create scenarios by grade, G-SEED performance of the buildings was analyzed and assessment categories in which scores can be obtained by design changes and performance enhancement were derived. Grades for applicable categories were calculated by applying assessment categories that are easy for obtaining scores and cost less. Also, extra scores for potential score decline during assessment were reflected from 1 to 5 points by grade. To determine early phase scenario, calculation was done based on G-SEED certification experience and existing performance data. After deriving the results of cost analysis for all categories, low-cost related categories were reviewed to update the final scenario.

2) Scoring strategy by grade

G-SEED certifications are divided into 7 environment-friendly categories for evaluation. Each part is then divided into detailed assessment categories to evaluate environment-friendliness of building. The number of assessment categories differ according to certification use. There are 35 assessment categories for office buildings. Moreover, although each assessment category has variances in score depending on detailed criteria, 2.1.1 Energy Efficiency Category has the highest total scores and values.

Allocation of assessment categories were done in descending order of additional costs via cost analysis in order to improve

grades. "Based" is a original design plan and describes categories in which scores can be obtained and the corresponding scores. Also, "Total Point" in Table 3 is the total sum of the scores for each category. (rounded up from the decimal point). Finally, “Total Point applied for Weight” is the sum of all weighted values for 7 categories and defines the grade level.

4.2. Assessment by detailed category

1) Land use and transportation

Land use and transportation category evaluates its relationship to land environment and public transportation. Excluding 1.1.1 Ecological Value of Existing Land, the rest of 3 categories satisfied the standard for the original design plan. The elevation of the street border north of the land (the border between the building's top part and the north direction or the angle made by "street border or borderline of the land") is 17° and gets 2 points; gets 1.6 points because of easy accessibility to public transportation within 50m; obtains 2 points because bicycle storage place and shower facilities will be built on the 1st floor and in the basements.

2) Energy and environmental pollution

Energy and environmental pollution parts evaluates energy saving and atmospheric environmental impact and consists of 6 categories. Most categories are based on original design that could not be obtained. Requirements for all categories could be satisfied via performance enhancement and installation of additional system.

For 2.1.1 Energy Efficiency Enhancement, scores are assigned based on EPI (Energy Performance Index : Detailed evaluation category based on building energy saving design standard. Performances are based on total 4 categories of building/ machine/electricity/new renewable energy) scores or energy efficiency grade. However, the target project did not acquire energy efficiency grade. Therefore, EPI performance was re-evaluated and performances as detailed work types was enhanced to satisfy category requirement. The target project obtained the score of 65.7 points based on 2010 building energy saving design standard. However, when evaluated based on the current building energy savings design standard (as of May, 2013), it obtained the score of 41.7, which did not satisfy the minimum point (65 points and above) required. During analysis of this category, re-evaluation was done based on current legal standard. For score allocation based on G-SEED grade, EPI performance was analyzed based on 4 cases of 65, 75, 85 and 95 points. Major enhancement points to obtain EPI score of 65 points and above in the original plan (existing EPI performance of 41.7 points) was enhancement on exterior insulation; for 75 points and above, additional exterior insulation and enhancement in electric facility efficiency; for 85

Table 3. Score Card of Each Level for Certifying the G-SEED

Evaluation Area	Evaluation Category		Point	Based	Good ★	Great ★★	Excellent ★★★	Best ★★★★
Land Use & Transportation	1.1.1	The ecological value of the existing land	2.0	-	-	-	-	-
	1.2.1	The validity of measures to secure solar access night	2.0	2.0	2.0	2.0	2.0	2.0
	1.3.1	Proximity of public transportation	2.0	1.6	1.6	1.6	1.6	1.6
	1.3.2	Create of bicycle storage in land	2.0	2.0	2.0	2.0	2.0	2.0
Energy &Environmental Pollution	2.1.1	Improvement of energy efficiency	12	-	4.8	7.2	9.6	12
	2.1.2	Metering installation	2.0	-	2.0	2.0	2.0	2.0
	2.1.3	Light energy conservation	4.0	4.0	4.0	4.0	4.0	4.0
	2.2.1	Use of new renewable energy	3.0	-	-	-	-	3.0
	2.3.1	Reduction in Co_2 emission	3.0	2.0	2.0	2.0	2.0	2.0
	2.3.2	The ozone protection	2.0	2.0	2.0	2.0	2.0	2.0
Material &Resource	3.1.1	Consumer Goods Saving used in the bathroom	1.0	1.0	1.0	1.0	1.0	1.0
	3.2.1	Use of certified Green products for effective recycling	3.0	2.7	2.7	2.7	2.7	2.7
	3.2.2	Separative collection of recyclable resources	2.0	-	2.0	2.0	2.0	2.0
	3.2.3	Information display for carbon emissions of materials	2.0	2.0	2.0	2.0	2.0	2.0
	3.2.4	The re-use of existing principal structural parts	7	-	-	-	-	-
	3.2.5	The re-use of existing principal non-structural parts	2	-	-	-	-	-
Water Resource	4.1.1	The validity of rainwater load reduction	3.0	-	-	-	3.0	3.0
	4.2.1	The validity of water-saving measures in life	4.0	4.0	4.0	4.0	4.0	4.0
	4.2.2	Use of rainwater	3.0	-	-	-	3.0	3.0
	4.2.3	Use of wastewater reuse system	3.0	-	-	-	3.0	3.0
Maintenance	5.1.1	Site management plan in considering the environmental	1.0	1.0	1.0	1.0	1.0	1.0
	5.2.1	Providing on operation document and guidance	2.0	2.0	2.0	2.0	2.0	2.0
	5.2.2	TAB & Commissioning	2.0	1.0	1.0	1.0	1.0	1.0
	5.3.1	Reliability of spatial arrangement	4.0	2.0	2.0	2.0	2.0	2.0
Ecological Environmental	6.1.1	Green space ratio	2.0	-	-	-	-	-
	6.2.1	Ecological area ratio	6.0	-	-	1.5	1.5	1.5
	6.3.1	Biotop creation	4.0	-	-	-	-	-
Indoor Environment	7.1.1	Use of low VOC material	3.0	3.0	3.0	3.0	3.0	3.0
	7.1.2	Securement of natural ventilation	3.0	2.77	2.77	2.77	2.77	2.77
	7.1.3	Plan of air supply& exhaustion equipment	3.0	1.0	1.0	1.0	1.0	1.0
	7.1.4	Restriction of other hazardous substances emitted	1.0	1.0	1.0	1.0	1.0	1.0
	7.2.1	Adapt of thermostat for each room	2.0	2.0	2.0	2.0	2.0	2.0
	7.3.1	Indoor noise level by traffic noise	2.0	-	-	1.0	1.0	1.0
	7.4.1	Place provision for relaxation and refreshments	3.0	-	-	3.0	3.0	3.0
	7.4.2	Arrangement of pleasant indoor environment for residents	4.0	2.0	2.0	2.0	4.0	4.0
Total Point			98	37.6	48.8	57.7	71.2	77.6
Total Point applied for Weight			100	39.9	54.6	63.1	74.4	81.5

points and above, additional wall, performance enhancement on windows and doors and LED light replacement to improve efficiency of light density. Finally, to obtain 95 points and above, triple glass (with argon), electric blind and recyclable facility installation to enhance performance. Detailed performance enhancement and additional cost for each case can be found in Table 4, Cost Impact by Category analysis table.

For 2.1.2 Measurement Device Installation category, 1 point was obtained by installing additional submetering for A/C & heating and hot water and additional 1 point was obtained by installing submetering for lighting and electric outlet, which satisfied the requirement for this category. In 2.1.3. Lighting Energy Savings category, the lighting density for this design is 9.91W/㎡, which satisfied the requirement and earned 4 points. Since new recyclable facility was not installed, a point could not be obtained for 2.2.1 New Recyclable Energy category. Therefore, the requirement for the category was satisfied by adding additional 25RT for geothermal system. In 2.3.1 CO_2 emission reduction category, 2 points could be obtained for the zone where local heating was applied. In addition, additional 1 point could be according to application of new recyclable facility system.

Also, when linked to 2.2.1 to obtain the highest grade, it was applied as 3 points for this category. In 2.3.2 Ozone Layer Protection Category, R-410a and fire extinguisher not including halo was basically applied to obtain 2 points.

3) Materials and resources

For 3.1.1. Toilet Supplies Saving category, two of automatic sensor hand dryers were installed on each floor to satisfy the category requirement. For 3.1.2 Effective Resources Recycling category, internal/external materials were reviewed and 9 internal and 6 external materials were applied. There were no additional

Table 4. Cost Impact Analysis on Evaluation Item

Number	Field	Score	Addition Cost (Unit : KRW)	Increased Ratio of Total Construction Cost	Priority	Design Change and Performance Improvement	Description on Synergistic* & Cost Impact Item
1.3.2	Arch.	2	-	-	-	(Bicycle Storage and Shower Room)**	Cost Impact Item
2.1.1	Arch /Mech /Elec	12	67,800,860	0.23%	1	Improvement of EX-Wall Insulation/Chiller Efficiency	Cost Impact Item
			509,721,072	1.70%		Improvement of Insulation/Window/Elec Part Efficiency	Cost Impact Item
			846,222,842	2.83%		Improvement of Insulation/Window/Illumination efficiency	Cost Impact Item
			1,172,222,842	3.92%		Installation of EX-Window Blind/Ground Source Heat	Cost Impact Item
2.1.2	Mech	2	132,150,000	0.44%	2	Sub-Metering Installation of Cooling, Heating/Hot Water	Cost Impact Item
2.1.3	Elec	4	-	-	-	-	2.1.1 Synergy & Cost Impact Item
2.2.1	Mech	3	148,500,000	0.50%	8	Ground Source Heat Installation with 25RT	2.1.1 Synergy & Cost Impact Item
2.3.1	M/E	3	-	-	-	-	2.2.1 Synergy & Cost Impact Item
3.1.1	Mech	1	-	-	-	(Automatic Hand-dry as Each Bathroom)	Cost Impact Item
3.2.1	Arch	3	568,000	0.001%		Recycled Pillar for supporting Wood	Cost Impact Item
3.2.2	Arch	2	4,550,000	0.02%	9	Waste Bins with 5categories as Each Floor	Cost Impact Item
			7,191,143	0.02%	8	Waste Bins(5) & Separated waste storage area	Cost Impact Item
			8,101,143	0.03%	7	Waste Bins(6) & Separated waste storage area	Cost Impact Item
4.1.1	Arch /Mech	3	-	-	-	System Improvement for Rain-water Storage, Use	4.2.2 Synergy & Cost Impact Item
4.2.1	Mech	4	-	-	-	(High Efficiency Sanitary fixture)	Cost Impact Item
4.2.2	Arch /Mech	3	63,030,000	0.21%	4	Rain-water Storage, Use system Installation with 30ton	4.2.2 Synergy
4.2.3	Arch /Mech	3	80,460,000	0.27%	3	Waste-water Storage, Use system Installation with 30ton	Cost Impact Item
5.2.2	A/M/E	2	-	-	-	(TAB & Commissioning)	Cost Impact Item
5.3.1	A/M/E	4	-	-	-	(OA Floor)	Cost Impact Item
6.2.1	Arch /Landscape	6	10,105,117	0.03%	6	Additional green area plan of 112㎡	Cost Impact Item
6.3.1	Arch /Landscape	4	-	-	-	-	Cost Impact Item (as installing the Biotop)
7.2.1	Mech	2	-	-	-	(Automation Thermostat with Thermostat sensor)	Cost Impact Item
7.3.1	Arch	2	15,000,000	0.05%	5	Measurement of Indoor Noise Level	Cost Impact Item
7.4.1	Arch /Landscape	2	852,952	0.03%	10	Indoor Lounge Room Plan with Green	Cost Impact Item
7.4.2	Arch /Mech	2	-	-	-	(FCU and Automation Light Adjustment)	Cost Impact Item

* Synergistic Item, the Green Building measures used to achieve that one G-SEED item will also apply to a number of addition G-SEED items.
** ( ), Contents designed to Current design document, but Items having reasons of cost increases

costs according to change in internal raw materials (domestically produced plaster board, glass wool insulator, tile, OA floor and paint and most products obtained environmental sign and GM mark certification). Category requirements were satisfied by adding additional external supporting bar/supporting panel. For 3.2.2 Recyclable Resources Separate-Removal category was satisfied by adding 5 types of separate-removal container on each floor. Also, in order obtain higher grade, 1st level basement was used to create storage space for recyclable product waste. Moreover, 6 types of separate-removal container were placed on each floor and certification grades were applied according to additional costs incurred. For 3.2.3 Carbon Emission Information Sign for Raw Materials, category requirements were satisfied by transforming existing raw materials into carbon certified product. No additional costs were incurred.

4) Water recycle management

The original plan did not include rain water tank and does not satisfy the requirements of 4.1.1. Rain Water Weight Reduction Plan category. Additional rain water tank (30 ton) was installed to meet 4.1.1 and 4.2.2 requirements at the same time. 4.2.1 Living Water Reduction Plan requirement was satisfied by installing water saving facility on washing bowl, toilet, shower heads and electronic sensor toilet. Also, waste water facility was additionally planned to satisfy the requirements of 4.2.3 Waste Water Installation category.

For rainy water tank (30 ton) and waste water (30 ton), it was hard to secure an area. Therefore, additional floor (8 Fl) was planned on 7 story building. When estimating additional cost, not only rain water and waste water tanks but building/construction work load was reflected.

5) Maintenance management

The target project was a project currently in progress by a company that acquired ISO 14001. It satisfied the requirements of 5.1.1 Reasonableness of Field Management Plan with Environmental Consideration. Assuming that the company will provide 7 types of operational guideline according to 5.2.1 Operation/Maintenance Management Documents Standard, the requirements were considered satisfied without incurring additional cost. Moreover, TAB and OA Floor were planned for the current project, which satisfied the requirements of 5.2.2 TAB and Commissioning category and 5.3.1 Space Allocation and Ease of System Changes at grade 2 level. If it became necessary to obtain additional scores, commissioning costs were supposed to be reflected additionally. However, target scores were achieved and the terms were not applied.

6) Ecological environment

The current project, which is being developed in metropolitan urban area, has 2% green zone and 17.55% ecological zone and therefore could not obtain scores for 6.1.1 Nature-Based Green Zone Rate and 6.2.1 Ecological Zone categories. As a result, rooftop and 1 Fl. floor finishing were used to add 112㎡ in green area to satisfy the minimum requirement of 6.2.1 category. Also, the requirements for 6.3.1 Biotop Creation category were not satisfied. Since it was not possible to secure space for green zone in the area of 180㎡ and the category was also not satisfied.

7) Interior environment

For 7.1.1 Interior Atmospheric Pollution Low Emission Materials category, scores were assigned based on the number of products that acquired environmental mark, HB mark and other certification. However, most interior space finishing materials produced by large companies already have the certification and there were virtually no differences between their cost to that of general products. Therefore, the category requirements were satisfied by changing all 18 types of products to interior space atmospheric pollution low emission materials.

For 7.1.2 Natural Ventilation category, all floors excluding 1F satisfied the category requirements and obtained the score of 2.77. 7.1.3 External Exhaust Pipe Design also satisfied 30% above the category requirements of using external devices. No materials used in this project contained asbestos and therefore 7.1.4 category requirements were satisfied. For 7.2.1 Interior Space Automatic Temperature Control Device, 1~4 devices were installed on each floor to satisfy the category requirements. For 7.3.1 Traffic Noise categories, actual noise measurement cost was additionally added for calculation. Interior space traffic nose of 3rd grade was applied. To satisfy 7.4.1 Rest and Refreshment category requirements, existing rest place was expanded and indoor green space was planned to satisfy the requirements. Additional costs incurred for construction and this cost were calculated in Landscape Works. For 7.4.2 Creating Pleasant Interior Space Environment, FCU was installed on external space to enable temperature control. For lighting equipment, system that enables 100% automatic control was built and satisfied the category requirements without incurring additional costs.

5. Analysis of additional costs by grade

5.1. Analysis of additional cost by grade and increase rate

As it can be confirmed in Table 5, the cost impact by category according to grade increase is the highest cost increasing factor in all grades in energy area. The energy area accounts for the highest share of grades among all categories. EPI scores will be the most

Table 5. Additional Cost as G-SEED Level

Total Construction Cost : 29.89billion(KWN)				
Categories	Good ★	Very Good ★★	Excellent ★★★	Best ★★★★
1. Land	-	-	-	-
2 Energy	67,800,860	641,871,072	978,382,842	1,452,872,842
3.Material	8,669,943	8,669,943	8,669,943	8,669,943
4.Water	-	-	143,520,000	143,520,000
5.Maintenance	-	-	-	-
6.Ecological	-	10,105,117	10,105,117	10,105,117
7.Indoor	-	23,521,952	23,521,952	23,521,952
Additional Cost	76,470,803	684,168,084	1,164,189,854	1,638,689,854
Ratio	0.26%	2.29%	3.89%	5.48%

important criteria to certify G-SEED grade qualification. Water circulation has the highest share of cost impact after the energy area. It is the cost of creating rain water and waste water tanks.

Not only cost but also securing the area is crucial. As shown in analysis results, it is an important facility that must be applied in order to acquire good grade or better. For materials and interior environment, scores can be obtained based on relatively low cost. Also, we can see that there are virtually no differences between environment-friendly products and general products. Moreover, in land and ecological environment area, excluding bicycle storage installation, most categories impacted obtaining of scores with/without cost.

5.2. Analysis of additional cost by construction type and additional cost per point

As shown in Table 6, architectural construction exhibited significantly high additional cost compared to other types. This is the cost for exterior wall insulation and windows-doors enhancement to acquire additional costs in the energy area. For mechanical construction, it was mostly cost increase according to installation of geothermal, rain water and waste water tank system. In electronics construction, it was mostly cost associated LED installation according to lighting density enhancement. Accordingly, for G-SEED certification and grade enhancement, insulation function of buildings, lighting efficiency enhancement of new recyclable facility system and application of rain water/waste water system had the most cost impact. In terms of additional cost per 1 point for each category, the category in which the sum of additional costs by each construction type tended to be high. In particular, additional cost per score was high in energy and water circulation area. However, 2.1.1 Energy Efficiency/2.2.1 New Recyclable Energy/4.2.2 Rain Water Tank Reduction categories were relatively high in additional costs incurred per 1 point. However, these 3 categories were linked to 2.1.3 Lighting Energy/2.3.1 CO_2 Emission/4/1/1 Rain Water Weight Reduction categories to obtain additional scores. In addition, they are categories that are highly effective in energy and water use reduction in operational stage. Therefore, they are not categories that can be used to make decision on whether to apply additional costs base on whether additional costs can be incurred.

6. Conclusion

In this research, we analyzed cost impact for each grade by performing cost analysis for G-SEED categories for additional costs incurred. In terms of method, we selected office facilities that were constructed this year and performed analysis on whether they satisfied all G-SEED categories. For any categories they failed to satisfy, we analyzed the additional costs incurred in changing plans and enhancing performances to meet the category requirements. Based on results, scenarios were updated for each grade and were

Table 6. Additional Cost as G-SEED Level

Total Construction Cost : 29.89billion(KWN)

Evaluation Category		2.1.1				2.1.2	2.1.3	2.2.1	2.3.1	3.2.1	3.2.2	4.1.1	4.2.2	4.2.3	6.2.1	7.3.1	7.4.1	Total
Point		4.8	7.2	9.6	12	2	3	3	3	3	2	3	3	3	6	2	3	
Field		A/M/E	A/M/E	A/M/E	A/M/E	M/E	E	M/E	M/E	A	A	A/M/E	A/E	A/E	E/L	Specialized Company	A/L	
Additional Construction Cost (O) / Synergy		O	O	O	O	O	Synergy (2.2.1)	O	Synergy (2.2.1)	O	O	Synergy (4.2.2)	O	O	O	O	O	
Additional Construction Cost by Work Classification	Arch.	54,600	407,901	494,825	820,825	-	-	-	-	-	8,101	-	-	-	-	15,000	2,853	846,780
	Ratio(%)	0.18%	1.36%	1.66%	2.75%	-	-	-	-	-	0.03%	-	-	-	-	0.05%	0.01%	2.83%
	Landscape	-	-	-	-	-	-	-	-	568	-	-	-	-	10,105	-	5,667	16,341
	Ratio(%)	-	-	-	-	-	-	-	-	0.002%	-	-	-	-	0.03%	-	0.02%	0.05%
	Mechanic	13,200	59,200	59,200	59,200	33,500	-	148,500	-	-	-	-	63,060	80,460	-	-	-	384,720
	Ratio(%)	0.04%	0.20%	0.20%	0.20%	0.11%	-	0.50%	-	-	-	-	0.21%	0.27%	-	-	-	1.29%
	Electric	-	42,620	292,197	292,197	98,650	-	-	-	-	-	-	-	-	-	-	-	390,847
	Ratio(%)	-	0.14%	0.98%	0.98%	0.33%	-	-	-	-	-	-	-	-	-	-	-	1.31%
Sum of Construction Cost By Category		67,800	509,721	846,222	1,172,222	132,150	-	148,500	-	568	8,101	-	63,060	80,460	10,105	15,000	8,521	1,638,689
Net Construction Cost Comparision (%)		0.23%	1.70%	2.83%	3.92%	0.44%	-	0.50%	-	0.002%	0.03%	-	0.21%	0.27%	0.03%	0.05%	0.03%	5.48%
Additional Construction Cost per 1 Point (Rank)		14,125 (8)	212,383 (3)	352,592 (2)	488,426 (1)	66,075 (4)	-	49,500 (5)	-	189 (13)	4,050 (10)	-	21,020 (7)	26,820 (6)	1,684 (12)	7,500 (9)	2,840 (11)	-

compared to buildings that were not certified and derived additional costs per grade. For average grade, the cost increased by 76,470,803 won (+0.26%); good grade, 684,168,084 won (+2.29%); excellent grade, 1,164,189,854 won (3.89%) ; superior grade, 1,638,389,854 won (5.48%). Among G-SEED grade areas, cost increase was highest in energy efficiency and water circulation. This is a crucial cost element in acquiring G-SEED certification and for obtaining higher grades. However, the analysis showed that application of categories based on synergy among different categories are needed.

Moreover, in the results for additional cost by construction type, cost increase was highest in architecture construction compared to other construction types. This shows that, for enhancing energy efficiency of buildings, cost increase resulting from exterior wall insulation and enhancement in windows-doors tend to be much higher than performance enhancement for mechanical/electrical (including new recyclable energy) construction.

Moreover, in case of energy and water circulation categories that consume relatively higher additional costs, the benefit from operational cost reduction is much higher. Therefore, an economic analysis must be done to decide appropriate level of applicability.

Finally, in this research, we analyzed the cost effect according to G-SEED for medium size office facilities. In the future researches, there is need for cost analysis for more diverse use and size.

References

[1] Jang, Hyun-Sook, Lee, Sang-Ho, “A study on Problem of the G-SEED Process and their Improvement, Journal of Korea Institute of Ecological Architecture and Environment”, Vol.14, No.1 Feb. 2014)

[2] Kim, Shin-Eun, Lee, Won-Suk, Lee, Dong-Hoon, Kim, Sun-Kuk, “A Basic Study on the Cost Impact of Environment-friendly Residential Building”, Journal of Korea Institute of Ecological Architecture and Environment, Vol10, No.1, 2010)

[3] Kim, Heung-Keun, Lee, Hyun-Soo, Park, Moon-Seo, Kim, Soo-Young, “A Database Framework for Early Cost Estimation Of Sustainable Building Projects”, Korea Institute of Construction Engineering and Management, 2010)

[4] Kim, Jae-Moon, Eun, Jong-Won, Lee, Ki-Ho, Choi, Yong-Eui, “Management Guideline based on Cost Efficiency of Itemized Criteria in Energy Performance Index”, Korea Institute of Construction Engineering and Management, 2013)

[5] Kim, Jae-Moon, Yang, Won-Young, Kang, Ho-Seok, Min, Joon-ki, “A Study on Estimate of Additional Construction Cost as Certifying LEED of Office Building in Korea ”, Architectural Institute of Korea , 2012)

[6] Steven Winter Associates, Inc., GSA LEED Cost Study Final Report, October 2004

[7] Ministry of Environmental, International Environmental Trend, 2014-2, pp.18-20

[8] Minister of Land, Infrastructure and Transport, Assistance Act on making Green Building, Article3(Basic Principle), 2013.03