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A Study on Securing Objectivity in Small-Scale Environmental Impact Assessments Using Delphi Analysis

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Abstract

Purpose: Since August 2000, the small-scale environmental impact assessment system has prevented indiscriminate development. However, its qualitative reports lack objectivity and consistency. This study analyzes these issues through literature and expert surveys and proposes improvements. **Research Methodology:** Samples were selected based on regional consultation numbers. Mitigation measures were categorized into qualitative and quantitative factors. Issues were identified, and improvements suggested. The Delphi method helped select evaluation items and propose a scoring table. **Results and Conclusions:** The Delphi method selected 14 absolute and 22 relative evaluation items, excluding 3 invalid ones. A 100-point scoring table was created, with points assigned based on element significance. A 1-point bonus was added for top-scoring elements to promote eco-friendly planning.

Keywords : Small-scale environmental impact assessment, Qualitative and Quantitative assessment factor, Delphi Method, Environmental Impact Assessment Information Support System(EIASS)

JEL Classification Code : I30, I31, I38

1. Introduction

South Korea's small-scale environmental impact assessment was introduced in August 2000 as a preliminary environmental review. In 2011, it was renamed and integrated into the Environmental Impact Assessment Act, where it remains in use today.

Over 24 years, the small-scale environmental impact assessment has curbed harmful development in protected areas. Enhanced techniques and data are now shared via the EIASS, providing key environmental and consultation information for development projects.

However, several issues have emerged in the preparation of small-scale environmental impact assessment reports. These include failure to reflect project types and local conditions, reliance on merely listing related standards without ensuring the implementation of mitigation measures, and the qualitative nature of these measures, which does not guarantee their effectiveness.

Additionally, consulting agencies, relying on qualitative assessment reports, often provide consultation opinions that lack objectivity and consistency.

Therefore, it is crucial to prepare quantitative assessment reports that reflect project types and local conditions, and to base consultation opinions on these reports. This approach ensures the implementation of consultation outcomes, maximizes the effectiveness of the assessment system, and promotes sustainable development by balancing preservation and development.

2. Research Methodology

The research procedure first involved selecting a sample for analysis proportional to the number of consultations conducted by each regional environmental office. The sample was drawn from all small-scale environmental impact assessment consultations related to factory projects recorded in the Environmental Impact Assessment Support System (EIASS) from 2020 to 2022.

Secondly, the mitigation measures in the selected reports were categorized into qualitative and quantitative evaluation factors. The study then identified issues with the formulation of qualitative mitigation measures and the resulting consultation process, highlighting the need for improvements.

Third, the Delphi method was used via expert surveys to select evaluation items and propose a quantification scoring table.

Finally, key variables from the Delphi method were extracted using Principal Component Analysis (PCA) or Factor Analysis, and then validated using the Scree Plot technique.

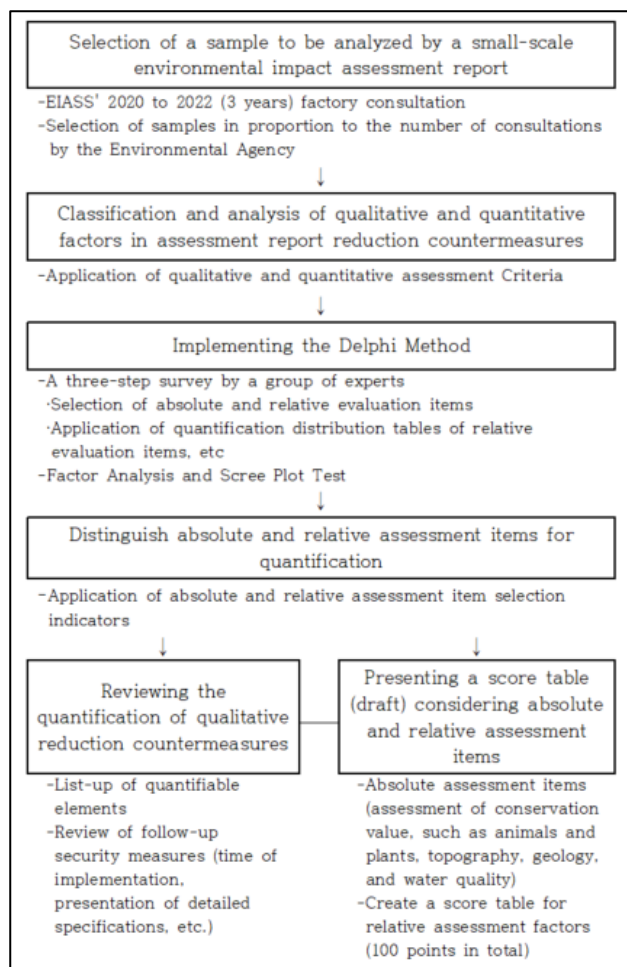


Figure 1: Study Flowchart

3. Research Results

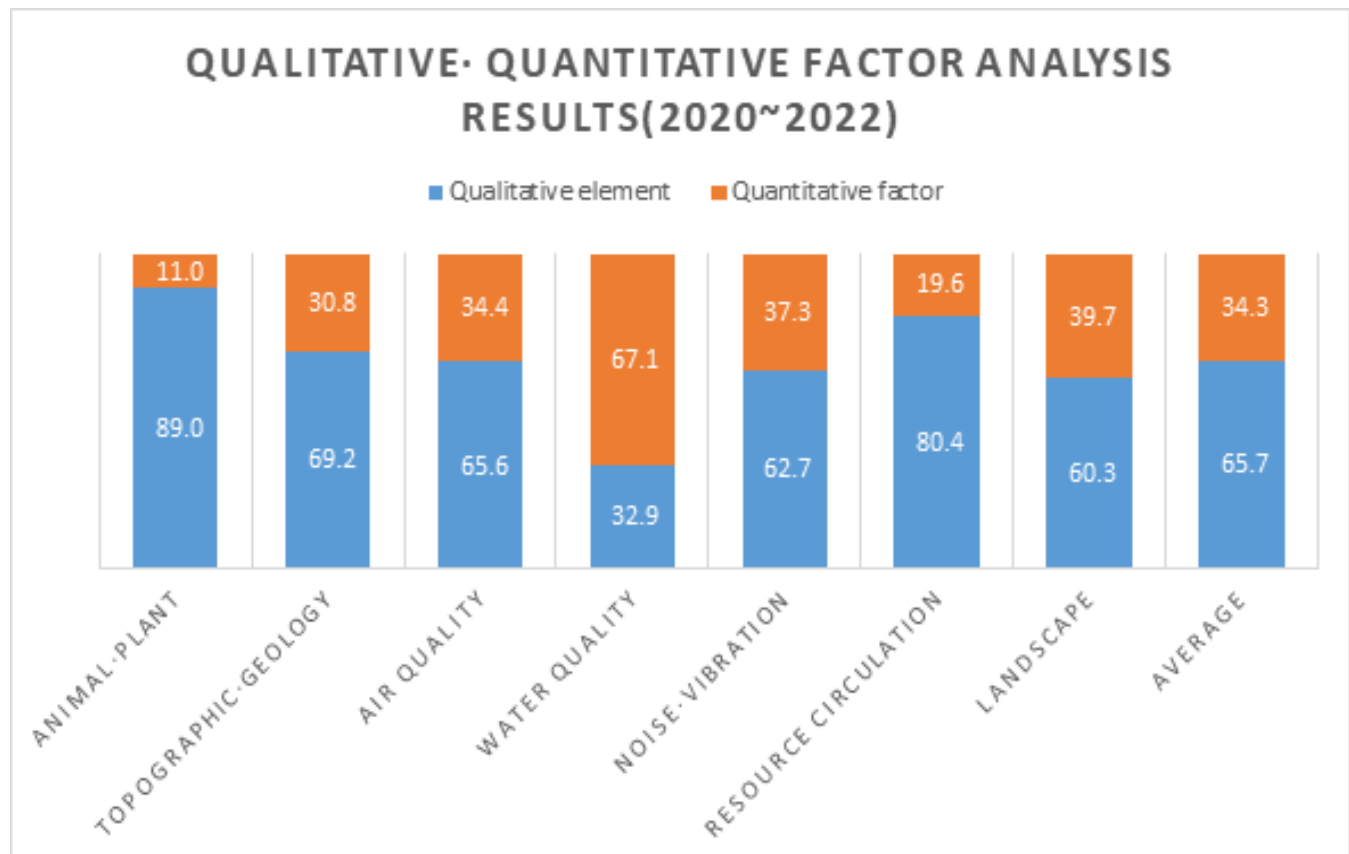
3.1. Literature Review

The analysis showed that, from 2020 to 2022, qualitative factors accounted for 65.7% (714) and quantitative factors 34.3% (389) of the total mitigation measures across 36 projects.

Qualitative factors were lowest in water quality (32.9%) and highest in flora and fauna (89.0%). Quantitative factors were the opposite, lowest in flora and fauna (11.0%) and highest in water quality (67.1%).

Table 1: Results of Qualitative and Quantitative Elements Analysis(2020-2022)

Assessment Item	Qualitative assessment factors		Quantitative assessment factors	
	Numbers	Ratio(%)	Numbers	Ratio(%)
Animals and Plants	162	89.0	20	11.0
Topography and Geology	90	69.2	40	30.8
Air quality	139	65.6	73	34.4
Water quality	72	32.9	147	67.1
Noise and Vibration	84	62.7	50	37.3
Eco-friendly resource circulation	123	80.4	30	19.6
Landscape	44	60.3	29	39.7
Total(Ave.)	714	(65.7)	389	(34.3)

**Figure 2:** Analysis of Assessment Factors(2020-2022)

3.2. Expert Survey

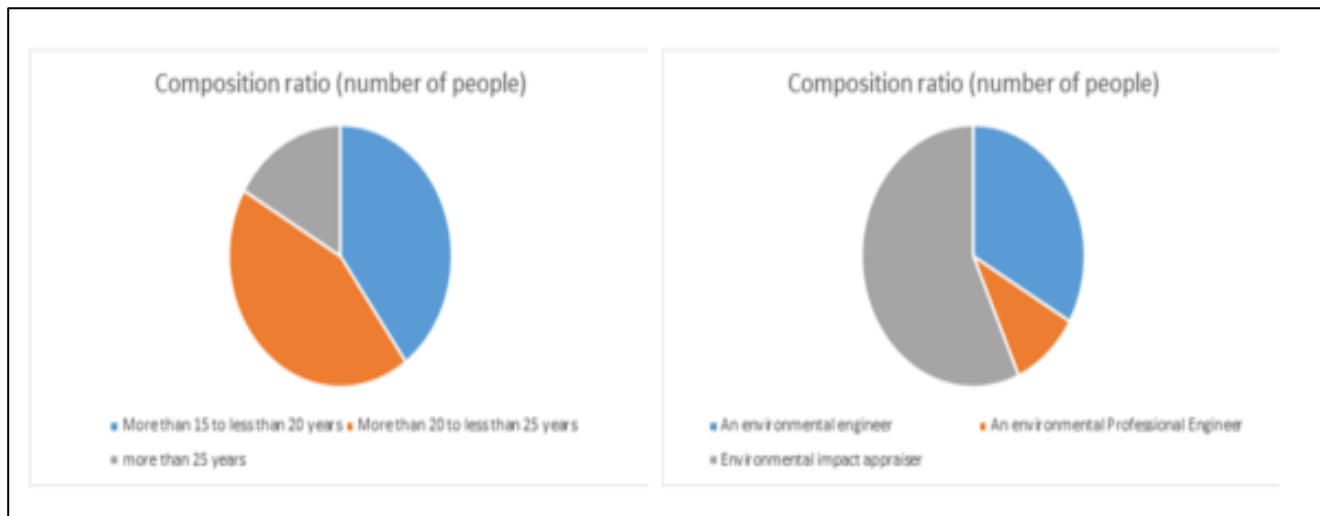
3.2.1. Expert Panel Composition

The expert panel, with over 15 years of experience, included environmental assessors and engineers. The survey

was conducted in three rounds from April 1 to May 10, 2024.

Table 2: Organizing Expert Group

	Div.	Number of people
Experience in evaluation work	More than 15 to less than 20 years	12
	More than 20 to less than 25 years	13
	More than 25 years	5
Qualifications	Environmental engineer	10
	Environmental Professional Engineer	3
	Environmental impact appraiser	17

**Figure 3:** Expert Group Configuration Status

3.2.2. Survey Content

The first survey was open-ended, focusing on the need for and methods of quantification. The 2nd and 3rd surveys were closed-ended, based on previous results.

Open-ended questions allowed participants to freely express their opinions. Closed-ended questions were

evaluated on a 5-point Likert scale ranging from "very necessary (very appropriate)" to "not necessary at all (very inappropriate)." The survey content is presented in Tables 3 and 4.

Table 3: Contents of 2nd Survey (1/2)

Div.		Selection status
Absolute Assessment Items	1.1 Animals and Plants	<ol style="list-style-type: none"> 1. Ecological and natural map I grade area 2. Regions with Grade 2 or higher vegetation preservation grade 3. Natural monuments, endangered wildlife habitats 4. Wildlife (special) protected area 5. Wetland Protection Area 6. Ecological Landscape Conservation Area 7. Natural Environmental Conservation Area 8. Nature Park
	1.2 Topography and Geology	<ol style="list-style-type: none"> 1. Key areas of Baekdudaegan protected area and veins(within 150m) 2. The area where the vein(300m) and the veinlet(100m) are in conflict 3. 6th sub-function line in the forest area (urban area is 5th sub-function line) 4. Specific book protection area 5. Areas with high preservation value due to their excellent natural scenery, etc
	1.3 Water quality and etc.	<ol style="list-style-type: none"> 1. Waterfront area 2. Water source protection areas and areas within 10 km of falling distance 3. Areas that have already exceeded environmental standards or that have exceeded environmental standards in cumulative evaluation 4. Location restricted by individual laws
Relative Assessment Items	2.1 Animals and Plants	<ol style="list-style-type: none"> 1. Ratio of incorporation of ecological and natural islands into 2nd grade areas 2. Ratio of incorporation into Grade 3 vegetation conservation area
	2.1 Animals and Plants	<ol style="list-style-type: none"> 3. Ratio of incorporation into the management area and improvement area around the wetland 4. Simultaneous winter census survey area 5. Set absolute evaluation item separation distance from protected area 6. Transplant ratio of damaged trees 7. Establishment of a management plan for quantification of ecological disturbance plants
	2.2 Topography and Geology	<ol style="list-style-type: none"> 1. Ratio of overlapping areas with a vegetation preservation grade of 3 or higher and a slope of 20 degrees or higher 2. Maximum cutting and stacking slope 3. Ratio of the area of the artificial surface (mounting wall) to the area of the generated surface 4. Topographic change index (soil volume/business area) 5. Set absolute evaluation item separation distance from protected area (see 1.2) 6. Establishment of measures for quantifying the generated soil

Very necessary to completely unnecessary
5-point Likert scale applied

	2.3 Air quality·Odor	<ol style="list-style-type: none"> 1. Ratio of the concentration of the target concentration of the plan to the emission allowance standard (when constructing and operating) 2. Establishment of a new and renewable energy quantification plan 	
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Table 3: Contents of 2nd Survey (1/2)

Div.		Selection status	
Relative Assessment Items	2.4 Topography and Geology	<ol style="list-style-type: none"> 1. Ratio of the concentration of the target concentration of the plan to the emission allowance standard (when constructing and operating) 2. Distance from water source protection area 3. Establishment of measures to quantify non-point sources during operation (natural and device types) 	Very necessary to completely unnecessary 5-point Likert scale applied
	2.5 Noise and Vibration	<ol style="list-style-type: none"> 1. Ratio of noise and vibration of the maintenance target of the plan compared to the emission allowance standard (when constructing and operating) 	
	2.6 Landscape	<ol style="list-style-type: none"> 1. Ratio of green space to total area 2. Establishment of a plan for quantifying landscape planting materials 	

Table 4: Contents of 3rd Survey

Div.		Setting the distribution points for each section of the relative evaluation item	
Relative Assessment Items	1. Animals and Plants	<ol style="list-style-type: none"> 1. Ratio of incorporation of ecological and natural islands into 2nd grade areas 2. Ratio of incorporation into Grade 3 vegetation conservation area 3. Ratio of incorporation into the management area and improvement area around the wetland 4. Set absolute evaluation items and distance from protected areas 5. Establishment of a management plan for quantification of ecological disturbance plants 	very appropriate to very appropriate 5-point Likert scale applied
	2. Topography and Geology	<ol style="list-style-type: none"> 1. Ratio of medium-sized paper with a vegetation preservation grade of 3 or higher and a slope of 20 degrees or higher 2. Maximum cutting and stacking slope 3. Ratio of the area of the artificial surface (mounting wall) to the area of the generated surface 4. Topographic change index (soil volume/business area) 5. Set absolute evaluation item separation distance from protected area 	

	3. Air quality-Odor	1. Ratio of the concentration of the target concentration of the plan to the emission allowance standard (when constructing and operating) 2. Establishment of a new and renewable energy quantification plan	
	4. Water quality	1. Ratio of the concentration of the target concentration of the plan to the emission allowance standard (when constructing and operating) 2. Distance from water source protection area 3. Establishment of measures to quantify non-point sources during operation (natural and device types)	
	5. Noise and Vibration	1. Ratio of noise and vibration of the maintenance target of the plan compared to the emission allowance standard (when constructing and operating)	
	6. Landscape	1. Ratio of green space to total area 2. Establishment of a plan for quantifying landscape planting materials	

3.2.3. Survey Results

(1) Reliability Testing of Survey Items

The third survey showed high reliability with Cronbach's Alpha over 0.82 for each item, an overall score of 0.843, and a Hotelling T-test score of 136.041. Results are in Table 5.

Table 5: Validation of Reliability(Internal Consistency) of Survey Items (1/2)

Div.		Cronbach's α
1. Animals and Plants	1) Q1_1 The ratio of ecological and natural level 2 areas to be incorporated	0.838
	2) Q1_2 Plant conservation grade 3 regional incorporation rate	0.839
	3) Q1_3 Distance from the management area around the wetland and the wetland improvement area	0.830
	4) Q1_4 Absolute assessment item setting distance from protected area	0.840
	5) Q1_5 Establishment of Quantification Management Plan for Ecosystem Disruptor Plants	0.843
2. Topography and Geology	1) Q2_1 The ratio of overlapping areas with a vegetation preservation grade of 3 or higher and a slope of 20 degrees or higher	0.833

	2)	Q2_2 Maximum sharpening and stacking slope height	0.842
	3)	Q2_3 The ratio of the area of the artificial surface (mountain wall) to the area of the generated surface	0.841
	4)	Q2_4 Geographic change index	0.846
	5)	Q2_5 Absolute assessment item setting distance from protected area	0.840
3.Air quality ·Odor	1)	Q3_1 Ratio of maintenance target concentration to environmental standards (construction period)	0.830
	2)	Q3_2 Ratio of maintenance target concentration to emission allowance standard (operation period)	0.833
	3)	Q3_3 Establishment of new and renewable energy quantification plan	0.834
	4)	Q3_4 Ratio of maintenance target concentration to emission allowance standard (Odor_operation period)	0.841

Table 5: Validation of Reliability(Internal Consistency) of Survey Items (2/2)

Div.		Cronbach's α	
4.Water quality	1)	Q4_1 Ratio of maintenance target concentration to emission allowance standard (construction period)	0.827
	2)	Q4_2 Ratio of maintenance target concentration to emission allowance standard (operation period)	0.822
	3)	Q4_3 Distance from water source reserve	0.833
	4)	Q4_4 Efficiency of non-point source treatment facilities in operation	0.836
5.Noise and Vibration	1)	Q5_1 Ratio of maintenance target noise and vibration compared to noise and vibration control standards (construction period)	0.837

	2)	Q5_2 Ratio of maintenance target noise and vibration compared to noise and vibration control standards (operation period)	0.834
	1)	Q6_1 Green area ratio to total area	0.840
6.Landscape	2)	Q6_2 Planning for the Quantification of Landscape Plant	0.836

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.843	0.845	22

Hotelling's T-test

Hotelling's T-Squared	F	df1	df2	Sig
136.041	2.010	21	9	0.140

(2) Second Survey Results

Table 6: Analysis of the 2nd Survey Results (1/2)

Div.		Ave.	Standard deviation	Median value	First quartile	Third quartile	Quaternary deviation
1.1 Animals and Plants	Q1	1.1	0.4	1.0	1.0	1.0	0.0
	Q2	1.5	0.6	1.0	1.0	2.0	0.5
	Q3	1.3	0.5	1.0	1.0	1.0	0.0
	Q4	1.5	0.7	1.0	1.0	2.0	0.5
	Q5	1.2	0.5	1.0	1.0	1.0	0.0
	Q6	1.7	0.8	1.0	1.0	2.0	0.5
	Q7	3.6	1.4	4.0	3.0	5.0	1.0
	Q8	3.6	1.4	4.0	3.0	5.0	1.0
1.2 Topography and Geology	Q1	1.2	0.5	1.0	1.0	1.0	0.0
	Q2	1.7	0.6	2.0	1.0	2.0	0.5
	Q3	2.0	0.6	2.0	2.0	2.0	0.0
	Q4	3.6	1.2	4.0	3.0	4.8	0.9

	Q5	1.6	0.9	1.0	1.0	2.0	0.5
1.3 Water quality and etc	Q1	1.3	0.6	1.0	1.0	1.8	0.4
	Q2	1.7	0.6	2.0	1.0	2.0	0.5
	Q3	1.6	1.0	1.0	1.0	2.0	0.5
	Q4	2.0	0.8	2.0	2.0	2.0	0.0
2.1 Animals and Plants	Q1	2.0	0.6	2.0	2.0	2.0	0.0
	Q2	2.1	0.5	2.0	2.0	2.0	0.0
	Q3	2.1	0.6	2.0	2.0	2.0	0.0
	Q4	3.5	0.9	3.0	3.0	4.0	0.5
	Q5	2.1	0.6	2.0	2.0	2.0	0.0
	Q6	2.6	0.9	2.0	2.0	3.0	0.5
	Q7	2.3	0.8	2.0	2.0	2.0	0.2
2.2 Topography and Geology	Q1	1.7	1.0	1.0	1.0	2.0	0.5
	Q2	2.0	0.8	2.0	2.0	2.0	0.0
	Q3	2.3	0.7	2.0	2.0	2.8	0.4
	Q4	1.9	1.0	2.0	1.0	2.0	0.5
	Q5	2.1	0.7	2.0	2.0	2.0	0.0
	Q6	2.4	0.8	2.0	2.0	3.0	0.5
2.3 Air quality·Odor	Q1	1.6	0.9	1.0	1.0	2.0	0.5
	Q2	2.1	0.8	2.0	1.3	3.0	0.9
2.4 Water quality	Q1	1.6	0.8	1.0	1.0	2.0	0.5
	Q2	1.9	0.6	2.0	1.3	2.0	0.4
	Q3	1.6	0.8	1.0	1.0	2.0	0.5
2.5 Noise and Vibration	Q1	1.5	0.7	1.0	1.0	2.0	0.5
2.6 Landscape	Q1	1.7	0.7	2.0	1.0	2.0	0.5
	Q2	2.0	0.7	2.0	2.0	2.0	0.0

The validation of the second survey results showed that the Content Validity Ratio (CVR) for several items—specifically items 7 and 8 in the 1.1 flora and fauna category, item 4 in the 1.2 geology category, items 4 and 6 in the 2.1 flora and fauna category, and item 6 in the 2.2 geology category—were 0.33 or below, indicating a lack of content validity for these items.

Convergence for items 7 and 8 in the 1.1 flora and fauna category, item 4 in the 1.2 geology category, and item 2 in

the 2.3 air quality and odor category exceeded 0.5. This indicates that expert consensus was somewhat lacking for these items.

Consensus was found to be below 0.75 for 5 items in the 1.1 flora and fauna category, 3 items in the 1.2 geology category, 3 items in the 1.3 water quality and other categories, 3 items in the 2.1 flora and fauna category, 4 items in the 2.2 geology category, 3 items in the 2.3 air quality and odor category, 3 items in the 2.4 water quality category, 1 item in the 2.5 noise and vibration category, and

1 item in the 2.6 landscape category.

Table 7: Analysis of the 2nd Survey Results

Div.		Number of positive respondents	CVR	Convergence	Consensus
1.1 Animals and Plants	Q1	29	0.93	0.0	1.00
	Q2	28	0.87	0.5	0.00
	Q3	29	0.93	0.0	1.00
	Q4	26	0.73	0.5	0.00
	Q5	29	0.93	0.0	1.00
	Q6	23	0.53	0.5	0.00
	Q7	6	-0.60	1.0	0.50
	Q8	6	-0.60	1.0	0.50
1.2 Topography and Geology	Q1	29	0.93	0.0	1.00
	Q2	28	0.87	0.5	0.50
	Q3	24	0.60	0.0	1.00
	Q4	5	-0.67	0.9	0.56
	Q5	23	0.53	0.5	0.00
1.3 Water quality and etc	Q1	28	0.87	0.4	0.25
	Q2	28	0.87	0.5	0.50
	Q3	24	0.60	0.5	0.00
	Q4	25	0.67	0.0	1.00
2.1 Animals and Plants	Q1	26	0.73	0.0	1.00
	Q2	25	0.67	0.0	1.00
	Q3	23	0.53	0.0	1.00
	Q4	4	-0.73	0.5	0.67
	Q5	23	0.53	0.0	1.00
	Q6	16	0.07	0.5	0.50
	Q7	23	0.53	0.5	1.00
2.2 Topography and Geology	Q1	23	0.53	0.5	0.00
	Q2	23	0.53	0.0	1.00
	Q3	22	0.47	0.4	0.63
	Q4	23	0.53	0.5	0.50
	Q5	23	0.53	0.0	1.00
	Q6	19	0.27	0.5	0.50
2.3 Air quality·Odor	Q1	25	0.67	0.5	0.00
	Q2	21	0.40	0.9	0.13
2.4 Water quality	Q1	25	0.67	0.5	0.00
	Q2	26	0.73	0.4	0.63

	Q3	25	0.67	0.5	0.00
2.5 Noise and Vibration	Q1	27	0.80	0.5	0.00
2.6 Landscape	Q1	27	0.80	0.5	0.50
	Q2	23	0.53	0.0	1.00

(3) Third Survey Results

After the second survey, experts received feedback to compare and, if necessary, revise their opinions, promoting consensus.

The survey results are shown in Table 8. Items with a CVR below 0.33 from the second survey, which lacked content validity, were excluded. The survey then focused on assessing the appropriateness of score allocation for relative evaluation items.

Table 8: Analysis of the 3rd Survey Results

Div.		Ave.	Standard deviation	Median value	First quartile	Third quartile	Quaternary deviation
1. Animals and Plants	Q1	1.8	0.5	2.0	2.0	2.0	0.0
	Q2	1.9	0.6	2.0	2.0	2.0	0.0
	Q3	2.1	0.4	2.0	2.0	2.0	0.0
	Q4	2.0	0.4	2.0	2.0	2.0	0.0
	Q5	2.1	0.5	2.0	2.0	2.0	0.0
2. Topography and Geology	Q1	1.6	0.5	2.0	1.0	2.0	0.5
	Q2	1.9	0.3	2.0	2.0	2.0	0.0
	Q3	2.1	0.4	2.0	2.0	2.0	0.0
	Q4	2.0	0.6	2.0	2.0	2.0	0.0
	Q5	1.9	0.5	2.0	2.0	2.0	0.0
3. Air quality·Odor	Q1	1.9	0.4	2.0	2.0	2.0	0.0
	Q2	2.1	0.4	2.0	2.0	2.0	0.0
	Q3	2.0	0.6	2.0	2.0	2.0	0.0
	Q4	1.7	0.5	2.0	1.0	2.0	0.5
4. Water quality	Q1	1.7	0.6	2.0	1.0	2.0	0.5
	Q2	1.8	0.6	2.0	1.0	2.0	0.5
	Q3	1.9	0.5	2.0	2.0	2.0	0.0
	Q4	1.8	0.5	2.0	1.3	2.0	0.4

5. Noise and Vibration	Q1	2.2	0.6	2.0	2.0	2.0	0.0
	Q2	2.1	0.5	2.0	2.0	2.0	0.0
6. Landscape	Q1	1.8	0.6	2.0	1.0	2.0	0.5
	Q2	2.0	0.5	2.0	2.0	2.0	0.0

The validation of the third survey results showed that the CVR was above 0.33 for all items, indicating that the survey content was valid. Convergence was also below 0.5 overall, suggesting that expert consensus was effectively achieved.

Consensus was below 0.75 for one item in the 2. geology category, one in the 3. air quality and odor category,

three in the 4. water quality category, and one in the 6. landscape category, indicating some lack of agreement among experts. However, this was an improvement compared to the second survey results.

The third survey results showed that the coefficient of variation for all responses was below 0.5, so no further surveys were conducted.

Table 9: Results of the 3rd Survey Verification

Div.		Number of positive respondents	CVR	Convergence	Consensus	Coefficient of variation
1. Animals and Plants	Q1	28	0.87	0.0	1.00	0.3
	Q2	26	0.73	0.0	1.00	0.3
	Q3	26	0.73	0.0	1.00	0.2
	Q4	27	0.80	0.0	1.00	0.2
	Q5	24	0.60	0.0	1.00	0.3
2. Topography and Geology	Q1	30	1.00	0.5	0.50	0.3
	Q2	30	1.00	0.0	1.00	0.2
	Q3	27	0.80	0.0	1.00	0.2
	Q4	26	0.73	0.0	1.00	0.3
	Q5	28	0.87	0.0	1.00	0.3
3. Air quality-Odor	Q1	28	0.87	0.0	1.00	0.2
	Q2	26	0.73	0.0	1.00	0.2
	Q3	26	0.73	0.0	1.00	0.3
	Q4	29	0.93	0.5	0.50	0.3
4. Water quality	Q1	28	0.87	0.5	0.50	0.4
	Q2	27	0.80	0.5	0.50	0.4

	Q3	28	0.87	0.0	1.00	0.3
	Q4	29	0.93	0.4	0.63	0.3
5. Noise and Vibration	Q1	23	0.53	0.0	1.00	0.3
	Q2	26	0.73	0.0	1.00	0.3
6. Landscape	Q1	28	0.87	0.5	0.50	0.3
	Q2	27	0.80	0.0	1.00	0.2

3.2.4. Factor Analysis Results and Validation

(1) Factor Analysis Results

Experts rated 22 items on a Likert scale, and the responses were analyzed using Principal Component Analysis (PCA) with Orthogonal Varimax rotation.

Six factors were identified with eigenvalues above 1.0, accounting for 74.7% of the total variance.

The first factor, showing high agreement on maintaining target levels for noise, vibration, and air quality, was named "Consideration of Target Levels."

The second factor, with high agreement on items like "Efficiency of non-point source pollution treatment during operation" (0.885), "Quantitative landscaping plan" (0.701), and "Ratio of target concentration to environmental standards (air quality during construction)" (0.613), was named "Consideration of Efficiency."

The third factor, with high agreement on items like "Distance from protected areas for absolute evaluation

items (flora and fauna)" (0.924) and "Area ratio of artificial slopes (retaining walls) within the total slope area" (0.870), was named "Consideration of Setting/Classification."

The fourth factor, with high agreement on items like "Distance from protected areas for absolute evaluation items (geology)" (0.714), "Green space ratio relative to total area" (0.694), and "Overlap ratio of vegetation preservation grade 3 or higher with slopes over 20 degrees" (0.661), was named "Consideration of Ratios/Scales."

The fifth factor, with high agreement on items like "Maximum cutting and filling slope height" (0.825) and "Incorporation ratio into ecological and natural grade 2 zones" (0.688), was named "Consideration of Application/Incorporation." The sixth factor, with high agreement on "Quantitative planning for new and renewable energy" (0.891) and "Quantitative management plan for invasive species" (0.678), was named "Consideration of Quantification Plans." Detailed results are shown in Table 10.

Table 10: Analysis of Factors by Evaluation Sector(n=30) (1/2)

Div.		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Consideration of maintenance objectives	Q5_2 Ratio of maintenance target noise and vibration compared to noise and vibration control standards (operation period)	0.869	0.134	0.060	-0.077	-0.014	-0.023

	Q3_2 Ratio of maintenance target concentration to emission allowance standard (operation period)	0.809	0.194	0.084	0.045	0.046	-0.140
	Q5_1 Ratio of maintenance target noise and vibration compared to noise and vibration control standards (construction period)	0.749	0.168	0.071	0.186	0.175	0.277
	Q4_2 Ratio of maintenance target concentration to emission allowance standard (operation period)	0.728	0.359	-0.009	-0.100	-0.377	0.126
	Q4_1 Ratio of maintenance target concentration to emission allowance standard (construction period)	0.547	0.070	-0.065	0.223	0.516	0.349
Consideration of efficiency	Q4_4 Efficiency of non-point source treatment facilities in operation	0.099	0.885	-0.025	-0.124	0.023	0.145
Consideration of efficiency	Q6_2 Planning for the Quantification of Landscape Plant	0.366	0.701	-0.184	0.026	-0.081	0.051
	Q3_1 Ratio of maintenance target concentration to environmental standards (construction period)	0.457	0.613	-0.003	-0.052	0.245	0.053
	Q4_3 Distance from water source reserve	0.272	0.599	-0.132	0.215	0.205	0.125
	Q1_2 Plant conservation grade 3 regional incorporation rate	-0.059	0.510	0.468	-0.048	0.434	-0.206

Table 10: Analysis of Factors by Evaluation Sector(n=30) (2/2)

Div.		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Consideration of Setting/classifying	Q1_4 Absolute assessment item setting distance from protected area	0.111	-0.088	0.924	0.057	0.175	-0.138

	Q2_3 The ratio of the area of the artificial surface (mountain wall) to the area of the generated surface	-0.043	-0.061	0.870	0.149	0.096	-0.026
	Q2_4 Geographic change index	0.056	-0.121	0.686	0.083	-0.065	0.270
	Q1_3 Distance from the management area around the wetland and the wetland improvement area	0.154	0.365	0.543	0.320	-0.020	0.357
Consideration of a ratio/magnification	Q2_5 Absolute assessment item setting distance from protected area	0.244	-0.264	0.205	0.714	0.042	0.220
	Q6_1 Green area ratio to total area	-0.066	0.045	0.181	0.694	0.210	0.303
	Q2_1 The ratio of overlapping areas with a vegetation preservation grade of 3 or higher and a slope of 20 degrees or higher	0.128	0.528	0.185	0.661	0.066	-0.079
	Q3_4 Ratio of maintenance target concentration to emission allowance standard (Odor_operation period)	0.401	0.062	0.039	-0.595	0.387	0.323
Consideration of Application/Extraction	Q2_2 Maximum sharpening and stacking slope height	0.040	-0.009	0.101	-0.113	0.825	0.023
	Q1_1 The ratio of ecological and natural level 2 areas to be incorporated	-0.030	0.239	0.089	0.280	0.688	0.034
Consideration of a quantification plan	Q3_3 Establishment of new and renewable energy quantification plan	0.144	0.140	0.103	-0.047	0.118	0.891
	Q1_5 Establishment of Quantification Management Plan for Ecosystem Disruptor Plants	-0.058	0.064	-0.021	0.389	-0.054	0.678
Eigenvalues		3.538	3.079	2.806	2.330	2.154	2.046
Explanatory power(% of Variance)		16.082	13.995	12.755	10.592	9.790	9.299

No differences were found across all factors by experience level, as shown in Table 11.

Table 11: Experience Differences in Factors by Evaluation Sector(mean/pointⁱⁱ⁾)

Div.	(Number of cases)	Consideration of maintenance objectives	Consideration of efficiency	Consideration of Setting/classifying	Consideration of a ratio/magnification	Consideration of Application/Extraction	Consideration of a quantification plan
Less than 20 years	12	4.10	4.15	3.88	4.25	4.00	3.83
Less than 20 to 25 years old	13	4.02	4.12	4.02	4.33	4.35	4.08
More than 25 years	5	3.92	3.96	3.95	4.10	4.00	3.80
F-value ⁱ⁾		n.s	n.s	n.s	n.s	n.s	n.s

ⁱ⁾ F-test : *(90% significance level), **(95% significance level), n.s(not significance)

ⁱⁱ⁾ 5rating scale : (1)Very Inappropriate (2)Inappropriate (3)Neutral (4)Appropriate (5)Very Appropriate

(2) Validation of Factor Analysis Results

A Scree Plot shows how much each factor explains the total variance, with factor numbers on the x-axis and explained variance (eigenvalues) on the y-axis.

Each point on the Scree Plot represents the proportion of total variance explained by that factor. Typically, the first few factors explain most of the data's variance.

1. Elbow Point

In a Scree Plot, the critical part is the inflection point where the graph's slope becomes noticeably flatter. Identifying this point helps determine the number of significant factors. Factors before the inflection point are important as they explain the main variance in the data, while those after the inflection point are less significant, explaining less variance.

2. Determining the Number of Factors

The Elbow Method selects factors before the inflection

point on a Scree Plot. If the slope drops steeply for the first few factors and then flattens, those initial factors are considered key.

3. Scree Plot Interpretation

The Scree Plot generated in this analysis carries the following significance.

4. Identify the inflection point where the graph flattens; factors up to this point explain the main variance.

5. Choose factors up to the inflection point. If the slope flattens at factor 3, select 3 key factors.

6. Summary

The Scree Plot is a useful tool for determining the number of significant factors in factor analysis. By identifying the inflection point on the graph, you can select factors that explain the main variance in the data. In this analysis, the Scree Plot was used to visually confirm and decide the number of key factors

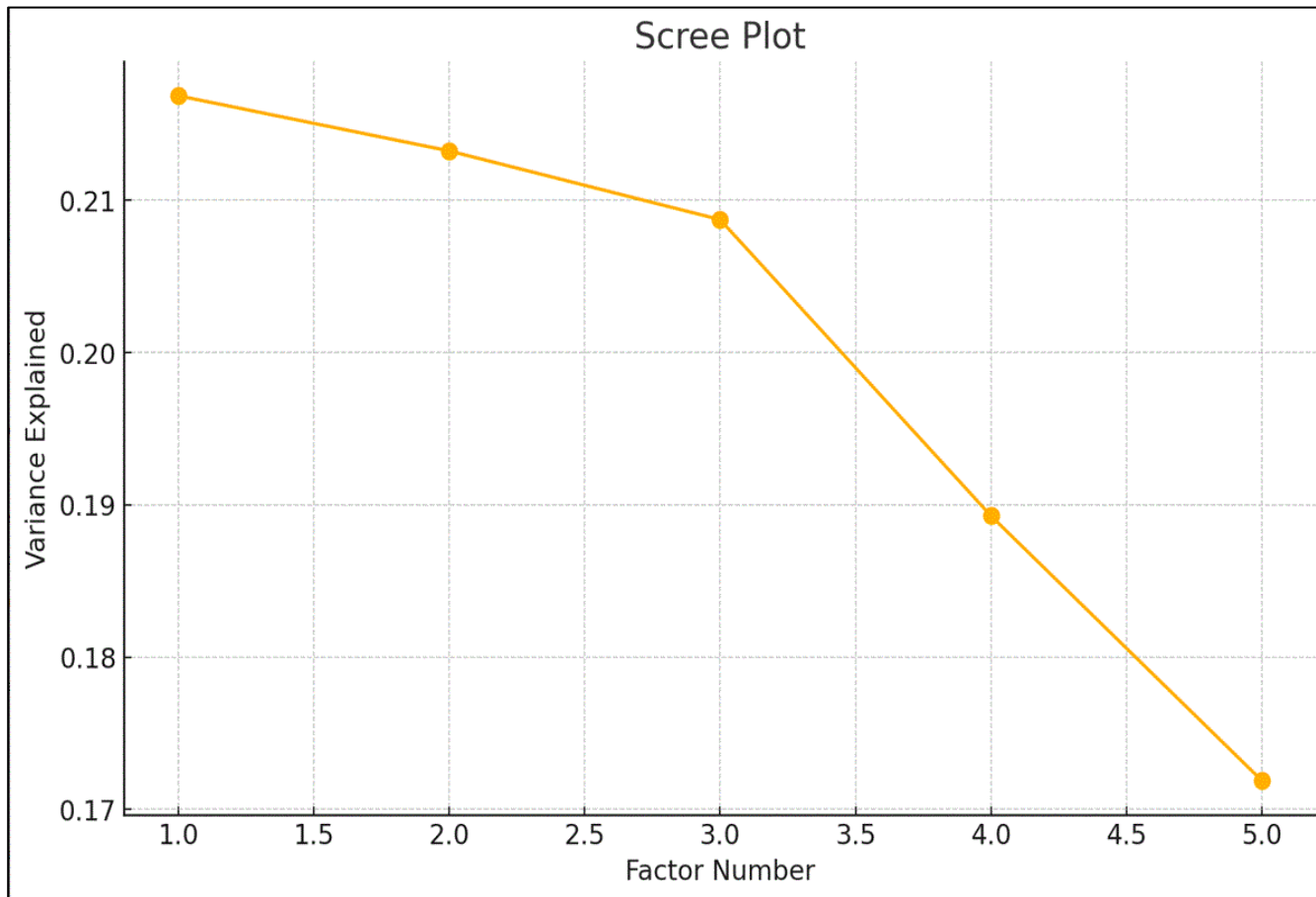


Figure 4: Scree Plot

3.3. Selection of Absolute Evaluation Items and Proposal for Quantitative Scoring Table

3.3.1. Selection of Absolute Evaluation Items

The results of the absolute evaluation item selection are

presented in Table 12. The selection focuses on areas with high conservation value or irreversible damage. Therefore, for selected absolute evaluation items, it is advisable to either entirely restrict or reduce development in these regions.

Table 12: Definition of Terms for Absolute Assessment Items

Div.	Applicable statutes and administrative rules
The ecological and natural I-class area	The natural environment conservation Act
An area with a vegetation conservation grade of 2 or higher	Regulations on natural environment survey methods and classification standards, etc
Natural monuments, endangered wildlife and plant habitats	Cultural heritage protection Act, etc
A wetland protected area	Wetland conservation Act
A wildlife sanctuary A special reserve for wildlife	Act on the protection and management of wildlife
Ecological and Landscape conservation area	The natural environment conservation Act

Baekdudaegan protection area and key area of Jeongmaek (within 150m)	Act on the protection of Baekdudaegan mountain range
An area of high conservation value due to its excellent natural scenery, etc	Natural environment conservation Act, etc
A waterfront area	Act on the Improvement of water quality and support for residents of Han river water system Act on the management of Nakdonggang river water system and support for residents, etc Act on the management of Geumgang water system and support for residents, etc Act on the management of water system of Yeongsan river and Seomjingang river and support for residents, etc
Water source reserve	Article 7 of the waterworks Act (designation of water source protection zones, etc.), enforcement decree of the same Act Article 12 (prohibited acts in water source protection zones, enforcement decree) Article 13 (standards for permission of action in water Resources protection zones)

3.3.2. Proposal for Quantitative Scoring Table for Relative Evaluation Items

The proposed quantitative scoring table is shown in Table 13. Based on expert survey results, scores from 1 to 5 are assigned for each evaluation item. Factors include the proportion of protected areas, distance from these areas, emission standards for air quality, odor, water quality, noise, and vibration, and green space ratio for landscape.

The score intervals are set at 1 point and are designed to be non-conflicting for each evaluation factor. To align with the purpose of small-scale environmental impact

assessments, scores are set relatively higher for the flora and fauna and geological fields. For air quality, odor, water quality, and noise/vibration, scores are based on emission standards and target levels, with higher scores for lower pollution levels.

Qualitative factors receive 1 to 2 points, with a total score of 100 points.

The results of the absolute

Table 13: Score Table for Quantitative Assessment (1/3)

Div.	Relative assessment items	Section	Allotment
Animals and Plants	The ratio of ecological and natural level 2 areas to be incorporated	More than 90%	1.0
		75% or more to less than 90%	2.0
		50% or more to less than 75%	3.0
		25% or more to less than 50%	4.0
		Less than 25%	5.0
	Plant Conservation Grade 3 Regional Incorporation Rate -Reflects on-site survey results	More than 90%	1.0
		75% or more to less than 90%	2.0
		50% or more to less than 75%	3.0
		25% or more to less than 50%	4.0
		Less than 25%	5.0
	Distance from the management area around the wetland and the wetland	0m or more to less than 30m	1.0
30m or more to less than 50m		2.0	

	improvement area -Restriction of entry when including the target site	50m or more to less than 80m	3.0
		80m or more to less than 100m	4.0
		More than 100m	5.0
	Absolute assessment item setting distance from protected area -Apply to the minimum separation distance when distributing multiple absolute assessment items	0m or more to less than 200m	1.0
		200m or more to less than 300m	2.0
		300m or more to less than 400m	3.0
		400m or more to less than 500m	4.0
		More than 500m	5.0
	Establishment of Quantification Management Plan for Ecosystem Disruptor Plants	Unestablished	0.0
		Established	2.0
Topography and Geology	The ratio of overlapping areas with a vegetation preservation grade of 3 or higher and a slope of 20 degrees or higher	More than 20%	1.0
		15% or more to less than 20%	2.0
		10% or more to less than 15%	3.0
		5% or more to less than 10%	4.0
		Less than 5%	5.0
	Maximum sharpening and stacking slope height -Apply to the maximum slope during cutting and stacking	12m or more to less than 15m	1.0
		10m or more to less than 12m	2.0
		8m or more to less than 10m	3.0
		6m or more to less than 8m	4.0
		Less than 6m	5.0
	The ratio of the area of the artificial surface (mountain wall) to the area of the generated surface -It is Divided into artificial and natural slopes, and vegetation blocks are classified as natural slopes	More than 90%	1.0
		75% or more to less than 90%	2.0
		50% or more to less than 75%	3.0
		25% or more to less than 50%	4.0
		Less than 25%	5.0
	Geographic change index -Soil volume ÷ project area	7 or more to less than 10	1.0
		5 or more to less than 7	2.0
		3 or more to less than 5	3.0
		1 or more to less than 3	4.0
		Less than 1	5.0
Absolute assessment item setting distance from protected area -Apply to minimum separation when distributing multiple absolute evaluation items	0m or more to less than 100m	1.0	
	100m or more to less than 150m	2.0	
	150m or more to less than 200m	3.0	
	200m or more to less than 300m	4.0	
	More than 300m	5.0	

Table 13: Score Table for Quantitative Assessment (2/3)

Div.	Relative assessment items	Section	Allotment
Air quality	Ratio of maintenance target concentration to environmental standards (construction period) -PM10, NO ₂ Maximum concentration standard among thermostatic facilities	More than 95%	1.0
		90% or more to less than 95%	2.0
		85% or more to less than 90%	3.0
		80% or more to less than 85%	4.0
		Less than 80%	5.0
	Ratio of maintenance target concentration to emission allowance standard (operation period) ⁷⁸⁾	More than 95%	1.0
		80% or more to less than 95%	2.0

	*Final outlet dust, NO ₂ average -Applies average when multiple workplaces are located	65% or more to less than 80%	3.0
		50% or more to less than 65%	4.0
		Less than 50% or not discharged	5.0
	Establishment of new and renewable energy quantification plan	Unestablished	0.0
		Established	2.0
Odor	Ratio of maintenance target concentration to emission allowance standard (operation period) ⁷⁹⁾ -Based on the combined odor of the site boundary line	More than 95%	1.0
		80% or more to less than 95%	2.0
		65% or more to less than 80%	3.0
		50% or more to less than 65%	4.0
		Less than 50% or not discharged	5.0
Water quality	Ratio of maintenance target concentration to emission allowance standard (construction period) ⁸⁰⁾ -BOD of sewage treatment facilities, SS average	More than 95%	1.0
		75% or more to less than 95%	2.0
		50% or more to less than 75%	3.0
		25% or more to less than 50%	4.0
		Less than 25% or linked treatment of public treatment facilities (no discharge)	5.0
	Ratio of maintenance target concentration to emission allowance standard (operation period) -Wastewater treatment facility BOD, SS average	More than 95%	1.0
		75% or more to less than 95%	2.0
		50% or more to less than 75%	3.0
		25% or more to less than 50%	4.0
		Less than 25% or linked treatment of public treatment facilities (no discharge)	5.0
	Distance from water source reserve -The capacity of the water intake facility is 200,000m ³ or more per day, or the metropolitan water source is applied with 5.0 points for 20km or more, and allocation points are applied in the same proportion section	Less than 4km	1.0
		4km or more to less than 6km	2.0
		6km or more to less than 8km	3.0
		8km or more to less than 10km	4.0
		More than 10km	5.0
	Efficiency of non-point source treatment facilities in operation	Less than 40%	1.0
		40% or more to less than 50%	2.0
		50% or more to less than 60%	3.0
		60% or more to less than 70%	4.0
		More than 70%	5.0

Table 13: Score Table for Quantitative Assessment (3/3)

Div.	Relative assessment items	Section	Allotment
Noise and Vibration	Ratio of maintenance target noise and vibration compared to noise and vibration control standards (construction period) ⁸¹⁾ -Application of average noise and vibration values by thermostatic facilities (residential areas, livestock houses, schools, etc.)	More than 95%	1.0
		90% or more to less than 95%	2.0
		85% or more to less than 90%	3.0
		80% or more to less than 85%	4.0

		Less than 80%	5.0
	Ratio of maintenance target noise and vibration compared to noise and vibration control standards (operation period) -Application of average noise and vibration values by thermostatic facilities (residential areas, livestock houses, schools, etc.)	More than 95%	1.0
		90% or more to less than 95%	2.0
		85% or more to less than 90%	3.0
		80% or more to less than 85%	4.0
		Less than 80% or No emission facility	5.0
Landscape		Green area ratio to total area	Less than 5%
	5% or more to less than 10%		2.0
	10% or more to less than 15%		3.0
	15% or more to less than 20%		4.0
	20% or more		5.0
	Planning for the Quantification of Landscape Plant	Unestablished	0.0
		Established	1.0
Total			100.0

4. Conclusions

This study aimed to create quantitative mitigation measures for small-scale environmental impact assessments, ensuring objective and consistent administrative decisions.

To achieve this, the study combined literature analysis and expert surveys to propose a quantitative scoring system considering absolute and relative evaluation criteria.

Applying the Delphi Method, 3 items with insufficient validity were excluded, resulting in 14 absolute evaluation items across 3 areas and 22 relative evaluation items across 6 areas.

The reliability test results showed that each item had a Cronbach's Alpha Coefficient of 0.82 or higher, with an overall coefficient of 0.843. Cluster analysis categorized 6 factors into 3 clusters: "Quantification/Criteria Experts" (56%), "Ratio/Proportion Experts" (37%), and "Average/Efficiency Experts" (7%).

The scoring table assigns 1-5 points for 19 factors across 6 areas and 1-2 points for 3 qualitative factors, totaling 100 points. A bonus point is given for maximum scores to promote eco-friendly land use.

The scoring results are categorized as follows: 80+ points for approval, 70-79 points for conditional approval, and below 70 points for conditional approval after revisions or disapproval.

The study is expected to enhance the objectivity and consistency of small-scale environmental impact assessments, providing a foundation for environmentally friendly development projects. If the proposed evaluation system is adopted, decision-makers will be able to process assessments objectively and consistently using the scoring table, while project developers are likely to invest more in environmental aspects. This should help achieve the original goal of preventing indiscriminate development in areas requiring conservation.

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