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Analysis of the Current Scoring Distribution by Evaluation Criteria in Korean Long-Life Housing Certification System Cases

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Abstract: Peoples lifestyles are diversifying due to an increase in the types of residents housing and family structures. The ratio of apartment housing in Korea was 59.9% (9806 households) in 2015, and this type accounts for the largest ratio among all housing types. However, the life of the physical housing is approximately 30–40 years, which is relatively shorter in comparison to that of overseas houses. Therefore, the certification system for long-life housing, which had longer social and physical service life, was newly established in 24 December 2014. However, all apartment houses only acquired the normal grade (grade 4). The purpose of this study is to investigate all long-life housing certification cases and analyze the acquired score and status of each evaluation item. The total number of certification cases was 283, and the data analysis and FGI (Focus Group Interview) investigation method were used as the methods of study. As a result of analysis and summary, 173 cases (61.13%) received 50 points and 106 cases (37.46%) received 51 points. All these cases were considered normal grade. The result of this study is as follows. First, a system to maintain the long-life housing certification system operation agency is necessary. Second, the reason for an item with no score was the evasion by construction companies due to an increase in both the construction expense and sale price. Therefore, various incentive plans are necessary and should be executed accordingly. Third, it is necessary to improve the detailed evaluation standards of the certification system and reexamine its scoring system. Long-life housing is a housing type in preparation for changes in the residential environment in future. The significance of this study is that the content shall be utilized as preliminary data for improving the system through the analysis of evaluation items in the certification system.

Keywords: long-life housing; apartment housing; open housing; certification system; policy assessment

1. Introduction

1.1. Why Is the Service Life of Apartment Housing in Korea Gradually Decreasing?

Peoples lifestyles are diversifying due to a change in the types of residents' housing and an increase in varied family structures, including the single-person family and two-person family. The ratio of single-person households and two-person households in Korea is expected to increase to 36.3% and 35%, respectively, until 2045, while the ratio of four-person households is expected to decrease to 7.4% [1].

According to the ratio of existing housing types, the ratio of apartment housing has gradually increased from 37.5% (3455 households) in 1995 to 59.9% (9806 households) in 2015 (Figure 1). This housing type accounts for the highest ratio among all housing types [2].

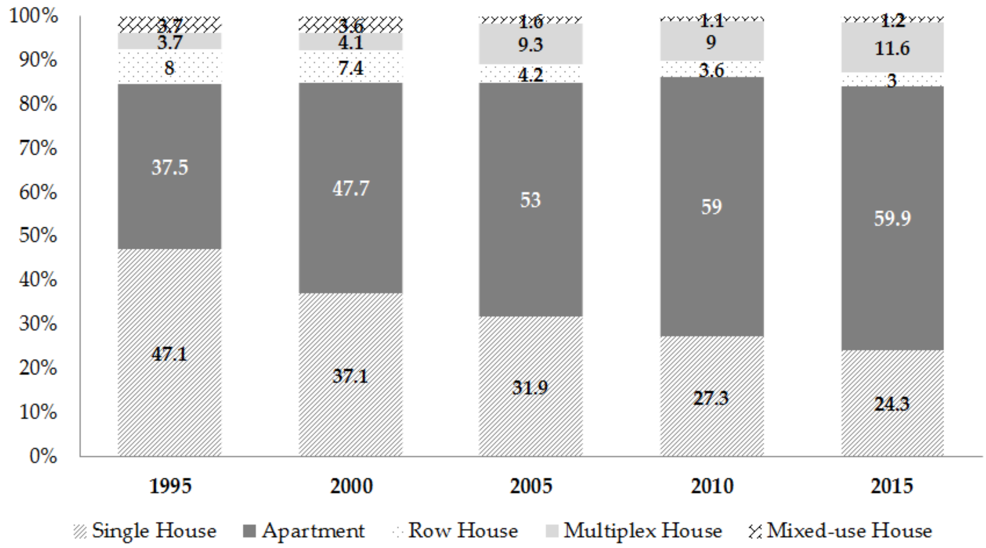

Figure 1. Ratio of existing houses by housing type.

Social requirements for housing are also changing. One such requirement is the life of housing. For apartment houses in Korea, the reconstruction term for general apartment housing has been reduced from up to 40 years to 30 years in the scope of dilapidated and low-quality structures according to Article 2 of the Enforcement Decree of the Act on the Maintenance and Improvement of Urban Areas and Dwelling Conditions for Residents. The Act has since been partially amended (18 January 2015), resulting in a shorter service life of apartment housing in Korea [3,4].

It is possible to secure more than 40 years for the physical life cycle of a building due to a number of attributes. These factors include the development of construction technologies for apartment housing parking structures, noise between floors, air conditioning and heating facility, and durability since the 2000s. However, the present condition does not address the social requirement mentioned earlier, that is, the social life cycle. Therefore, such apartment housing types are sometimes removed in their early stages [5–8].

According to a study on CO_2 reduction of long-life housing, the author compared the physical life span of a typical apartment (40 years) and long-life housing (100 years) with the CO_2 emissions. As a result, at least 33.04% to 36.18% of CO_2 emissions have been reduced during the life cycle of long-life apartment. This study proves that long-life housings are socially sustainable housing [9].

The service life status of apartment housing in Seoul and Gyeonggi-do, the most densely populated areas in Korea, is as follows. The status of number of apartment buildings by service life in Seoul for the last three years (2014–2016) was examined (Table 1). The number of apartment buildings aged over 21 years was 7243 buildings (36.99%) in 2014, 7819 buildings (39.13%) in 2015, and 8038 buildings (40.27%) in 2016, indicating that its ratio is gradually increasing in comparison to newly constructed apartment buildings aged less than five years [10]. Compared with the past, the reconstruction of old housing complexes due to the declining population in Korea is more difficult than before. In addition, frequent reconstruction of housing (average 35–50 years) causes construction waste and social cost increase. An improvement of policy was required, and a long-life housing certification system was introduced.

Table 1. Number of buildings by the service life of apartment housing (Seoul).

	Number of Buildings	Number of Buildings and Houses by Service Life (Based on the Day of Inspection for Use)				
		Less than 5 Years	6–10 Years	11–15 Years	16–20 Years	Over 21 Years
		Number of Buildings	Number of Buildings	Number of Buildings	Number of Buildings	Number of Buildings
2014	19,582	2645	3433	4005	2256	7243 36.99%
2015	19,980	2225	3117	3999	2820	7819 39.13%
2016	19,959	1710	2914	3999	3298	8038 40.27%

1.2. Introduction Background of Long-Life Housing Certification System

According to Article 18 of the Regulations on the Housing Construction Standards, etc. the long-life housing certification is evaluated in accordance with the total scores from the evaluation of each performance based on the durability, flexibility, and maintainability (exclusive area and common area) [11].

Due to a growing need of apartment housing with longer social and physical life, the Ministry of Land, Infrastructure and Transport newly established the long-life housing construction and certification standards based on Article 38 of the Housing Act in 24 December 2014 requiring the long-life housing certification for the construction of 1000 or more apartment houses [12]. However, all apartment houses have received the normal grade assessment, and, until now, there has been no case of acquiring the excellent grade or higher.

This study intends to analyze the acquired score and status of each evaluation item by investigating all long-life housing certification cases to date since the introduction of the long-life housing certification system. Through this process, the reasons for low certification grades, such as biased scoring on a specific item or an item with no score and relevant problems, will be identified and utilized for a basic study to improve the long-life housing certification system.

1.3. Collection of Certification Data and FGI Investigation

In this study, data for 283 cases were collected from January 2015 to June 2017 from seven certification agencies since the implementation of the long-life housing certification system. Such data account for 81.6% of the total 347 cases and exclude data from agencies that suspended the certification service and omitted data. Based on the collected data, the scoring status of each evaluation item was identified, and the biased scoring status of a specific item and instances of no grading were analyzed.

To investigate the reasons for such scoring status along with the data analysis, the FGI investigation was conducted using the interview method. Interview subjects comprised working-level personnel of long-life housing certification agencies [13,14]. FGI (Focus Group Interview) is a quantitative research method and it is carried out in the form of collecting opinions from research subjects with homogeneous characteristics. The method also incorporates facilitated discussions on a specific subject (Figure 2).

The research subjects comprised working-level personnel who handled the long-life certification service at certification agencies. The evaluation standards and status of long-life certification system were identified. The research method was utilized concurrently to collect opinions regarding the status and problems of various certification agencies. The opinions that were gathered supplemented the contents for the data analysis which was in the form of a qualitative survey.

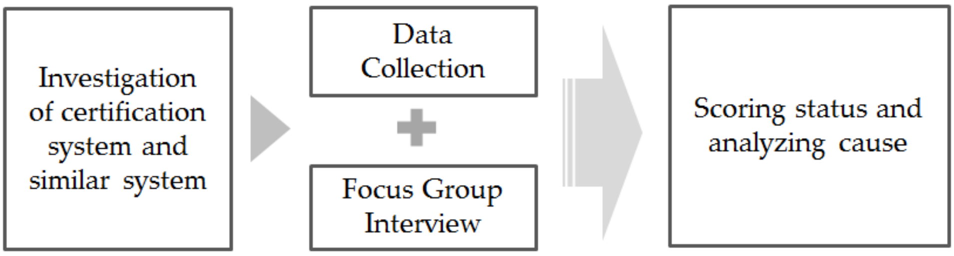

Figure 2. Research flowchart.

2. Related System of Overseas Case Studies

2.1. Case Investigation Regarding the Evaluation Items of Overseas Apartment Housing Certification System

The case investigation regarding domestic and overseas apartment housing-related certification systems and history was conducted prior to analyzing the detailed evaluation items of the long-life housing certification system. Its association with G-SEED (Green Standard for Energy & Environmental Design), which was the most similar system in Korea, was subsequently analyzed by evaluation item.

(1) LEED in the United States

This rating system is operated by the USGBC (U.S. Green Building Council) in the U.S. and there are six fields of evaluation including sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and design innovation.

A newly constructed apartment housing falls under LEED NC (Leadership in Energy and Environmental Design, New Construction), and 8 evaluation items including minimum energy performance, optimization of energy performance, renewable energy in the sites, commissioning, management of refrigerants, M&V (Measurement and Verification), green power, and heat island effect fall under the energy and environmental pollution guidelines in the Korean system [15–18].

(2) BREEAM in the UK

This is the certification system developed by BRE (Building Research Establishment) Global in the UK. This system combines the evaluation standards operated separately for the previous business facilities, commercial facilities, industrial facilities, educational facilities, medical facilities, and multi-family residential facilities. Multi-occupancy residential buildings and mixed-use residential buildings are also included as the evaluation targets. There are 10 fields of evaluation including management, health and well-being, energy, transportation, water resources, material, waste, land use and ecology, environmental pollution, and innovation [19–21].

(3) CSH in the UK

As the housing environment performance certification system based on BRE Global's Eco Homes in the U.K., CSH(Code of Sustainable Homes) is the national standard and Mandatory System for sustainable housing. There are nine fields of evaluation including energy and carbon dioxide emissions, water resources, material, emission of surface water, waste, environmental pollution, health and well-being, management, and ecology. The items related to the domestic system include greenhouse gas emissions, building skin energy efficiency, energy consumption display unit, space for natural drying of laundry, high efficiency home appliances, exterior lighting, low and zero carbon technology, home office, insulation's GWP (Global Warning Potential), and NOx emissions [22,23].

(4) Japan, CASBEE

CASBEE (Comprehensive Assessment System for Built Environment Efficiency) is the integrated performance evaluation system for sustainable buildings. The system was developed in collaboration by the Japanese government, universities, and corporations. Scores for the built environment quality and built environment load reduction parts are obtained, respectively, and the building environment efficiency is evaluated accordingly. The items related to the domestic system include thermal load of building, direct use of natural energy, use of renewable energy, efficiency of facility system, prevention of use of material containing pollutants, consideration of global warming, air pollution and heat island effect [24,25].

2.2. History of Certification System Related to Apartment Houses in Korea

Prior to analyzing the evaluation items of the long-life housing certification system, the changes of apartment house-related domestic certification system policies are reviewed through precedent studies as follow (Table 2). Various housing-related policies have been implemented since the 2000s, starting with the establishment and abolition of the excellent housing material recognition system in 1990. Of note, the long-life housing certification system was formerly the Special Exception in Preparation for Remodeling and the guideline for sustainable type apartment housing [26–30].

Table 2. History of certification system related to apartment houses in Korea.

<table>
<tr><th>Classification</th><th>Relevant Law</th><th colspan="2">History</th></tr>
<tr><td>Recognition of excellent housing material</td><td>Regulations on the Housing Construction Standards, etc.</td><td colspan="2">Established in 15 January 1991 Abolished in 29 September 1999</td></tr>
<tr><td>Special Exception in Preparation for Remodeling</td><td>Building Act</td><td colspan="2">Newly established in 8 November 2005</td></tr>
<tr><td>Guideline for sustainable type apartment housing (Seoul)</td><td>Housing Review Criteria in Seoul</td><td colspan="2">Established in 1 June 2008</td></tr>
<tr><td>Environmental-friendly Building Certification System</td><td>Rules on the Certification of Environmental-friendly Building</td><td>Established in 27 May 2008</td><td rowspan="2">Integrated with G-SEED</td></tr>
<tr><td>Housing Performance Grading Indication System</td><td>Regulations on the Housing Construction Standards, etc.</td><td>Newly established in 6 January 2006 Abolished in 20 February 2013</td></tr>
<tr><td>G-SEED</td><td>Green Building Establishment Support Act</td><td colspan="2">Wholly amended on 28 June 2013</td></tr>
</table>

2.3. Comparison of Association between Detailed Evaluation Items of G-SEED

Additionally, according to the amendment of the Green Building Establishment Support Act [31] in 2013, the Environmental-friendly Building Certification System and the Housing Performance Grading Certification System are integrated and implemented as G-SEED [26–30]. Among these, the association by evaluation item with the apartment housing section of G-SEED most similar to the long-life housing certification system was reviewed (Table 3).

The durability, flexibility, and maintainability are evaluated, and there is an association with the hierarchical classification system of evaluation items. However, the evaluation standards of detailed evaluation items are either partially the same or different. Upon closer examination, most detailed evaluation standards for the durability were similar. For the maintainability (exclusive and common areas), there was a slight difference in the terms and expressions according to the evaluation standard in the guide, but the evaluation items were partially the same. The most distinctive section is the flexibility, and more subdivided and specific evaluation items are presented according to the characteristics of long-life housing.

Table 3. Comparison of association between detailed evaluation items of G-SEED.

Sort	G-SEED	Long-Life Housing Certification	Association
DU	Building shape and details	-	×
	Minimum member section	-	×
	Thickness of bar cover	Thickness of bar cover	○
	Specified design strength	Specified design strength	○
	Slump	Slump	○
	Unit quantity of water	-	×
	Unit binder content	Unit binder content	○
	Water-to-binder ratio	Water-to-binder ratio	○
	Air content	Air content	○
	Chloride content	Chloride content	○
FL	Length ratio of bearing wall and column	Length ratio of bearing wall and column	○
		Drywall ratio	×
		Easy variability method	×
		Piping above slab type	×
		Height increase	×
		Dry double floor	×
		Movement of bathroom	×
		Movement of kitchen	×
		Outer wall replacement method	×
ME	Dry bathroom floor	Separation of common pipes	×
	Bathroom access hole	-	-
	Laying of pipe structure	No laying of pipe structure	○
	PS door	Dry ondol (Korean traditional floor heating system)	×
	Exclusive box for heating distributor	-	-
	Horizontal double pipe	Easy-to-repair pipes	▲
	Ball valve for each distributor	Horizontally separated equipment plan	▲
	Union coupled valve	Horizontally separated space plan	×
MC	Common vertical pipes	Common piping space	▲
	Possible to assemble pipes	Possible to assemble pipes	○
	Inspection and measuring facility	-	-
	Preparation for increase in electric capacity	-	-
	Repair and inspection of electrical panel	Pipe in piping space	▲
	Secure access hole	Secure access hole	○
	Reserve pipe	More than 1 reserve piping space	▲
	PS additional placement plan	20% margin for vertical pipes	▲

Notes: Same: ○; Partially the same: ▲; Different: ×; Not applicable: - .

3. Evaluation Purpose and Method of Long-Life Housing Certification System

According to Article 4 of the long-life housing construction certification standards, the evaluation purpose of the certification system is as follows [32] (Table 4).

First, the durability of structures such as column, beam, slab, bearing wall, public facilities and corridor (supports) is improved for the longevity of physical apartment houses. At the same time, infill, which is the material used to fill the space or hole of specific structures, such as ceiling, wall, floor, kitchen, bathroom, and other exclusively used facilities with shorter life, should not be laid in the structure and it should be separable [32] (Figure 3).

Second, the elements, such as a bearing wall in the internal space of a house that obstructs variability are minimized. The column type structure, rather than wall type structure, is selected in order to improve variability.

Third, the system must adaptably respond to changes in the family composition and life cycle to promote functional long-life of housing. To meet this purpose, ease of repair should be established to facilitate easy maintenance such as inspection, repair, and replacement in preparation for deteriorating equipment or interior.

Table 4. Evaluation purpose and method of long-life housing certification system.

Sort	Evaluation Item	Evaluation Purpose	Evaluation Method	Computation of Score
DU	Thickness of bar cover	Extend the life of building and reduce the maintenance cost	Evaluate drawings and specifications	Apply the lowest grade uniformly
	Concrete quality			
FL	Length ratio of bearing wall and column	Secure spatial variability and meet the demand of variability	Estimate the length ratio of bearing wall and column in housing unit	Apply weight
	Drywall ratio		Estimate the length ratio of drywall	Total score
	Easy variability method	Prevent damage to adjacent materials	Estimate the number of items where the structural method is applied	
	Piping above slab type	Secure the variability of water-using area	Apply the construction method	
	Height increase	Promote spatial variability by securing the height	Height over 3000 mm	Total score and additional points
	Dry double flooring	Easy-to-replace pipes	Application and height of double flooring	
	Movement of bathroom	Secure the variability of water-using area	Number of bathrooms that can be moved	Total score
	Movement of kitchen		Availability to move the kitchen	
	Outer wall replacement method	Meet the demands of residents	Availability to replace the outer wall	
ME	Separation of common pipes	Security maintainability	Secure the separation	
	No laying of pipe structure	Secure accessibility of repair and inspection	Apply easy repair method	
	Easy to repair pipes		Separate pipe installation	
	Dry ondol		Apply dry ondol	
	Horizontally separated space plan	Response to a change in family structure	Separate the front door and secure distribution board for each house	
	Horizontally separated equipment plan			
MC	Common piping space	Secure easiness of repair and inspection	Install common piping space	
	Common pipe access hole		Secure access hole	
	Pipe in piping space		Mutual interference	
	Availability to assemble pipes	Ability to repair and replace	Apply pipes possible to assemble	
	More than 1 reserve piping space	Consider increased demand in future and house separation	Secure margin and install reserve shaft	
	20% margin for vertical pipes			

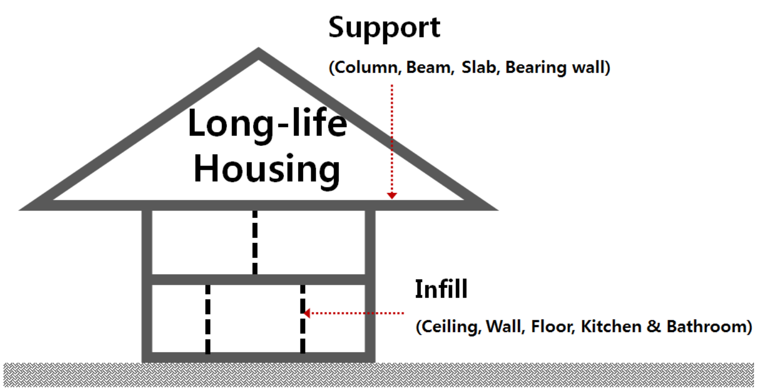

Figure 3. Support and Infill of Long-life Housing Concept.

Fourth, unit planning that can reflect residents' opinions should be carried out when planning spaces for various floor plans and elevation compositions. The association between a change of space and equipment plan should also be secured by considering the division and integration of future housing.

4. Analysis of Evaluation Items in Certification Cases

4.1. Evaluation Standards and Scoring Method

According to the attached Tables 1–3 of the long-life housing construction certification standards, the evaluation standards and grading are provided [32]. For durability, the results with the lowest grade by evaluation items are totaled and displayed as the final grade. In the case of flexibility and maintainability, scores by detailed evaluation item are totaled, converted according to the relevant grade, and displayed as the final grade (Table 5).

Table 5. Evaluation standards by item of long-life housing certification system.

Certification Division	Grade	Grade Labeling	Grading Standards	Total Score of Evaluation Item
DU	Grade I	★★★★	Durable period over 100 years	-
	Grade II	★★★	Durable period over 65 years and less than 100 years	-
	Grade III	★★	Durable period over 30 years and less than 65 years	-
	Class IV	★	Durable period less than 30 years	-
FL	Grade I	★★★★	Grade 3 or higher for required + Optional	Over 40 points
	Grade II	★★★	Grade 3 or higher for required + Optional	30–39 points
	Grade III	★★	Grade 3 or higher for required + Optional	20–29 points
	Class IV	★	Grade 4 for required + Optional	10–19 points
ME MC	Grade I	★★★★	Required + Optional	Over 17 points
	Grade II	★★★	Required + Optional	14–16 points
	Grade III	★★	Required + Optional	12–12 points
	Grade IV	★	Including required items	10–11 points

Note: The number of star means ★★★★; Grade I, ★★★; Grade II, ★★; Grade III, ★; Class IV in long-life certification system.

In summary of DU, FL, ME and MC, the standards are classified into four grades: normal (≥50 points), satisfactory (≥ 60 points), excellent (≥ 80 points), and best (≥ 90 points) (Table 6).

Table 6. Scoring standards by certification grade.

Classification	Durability	Flexibility	Maintainability		Level
			Exclusive Area	Common Area	
Grade I	35 points	35 points	15 points	15 points	Best
Grade II	28 points	26 points	13 points	13 points	Excellent
Grade III	20 points	18 points	11 points	11 points	Satisfactory
Class IV	15 points	12 points	9 points	9 points	Normal

4.2. Durability

In the case of durability, the criteria consists of seven items including six items with respect to the concrete quality: specified design strength (fck), slump, unit binder content, water-to-binder ratio, air content and chloride content, and thickness of bar cover. According to Article 5 of the long-life housing construction certification standards notification, the durability is evaluated according to the performance grading standards set by grade, and, provided that each item has a different grade in the condition that Grade 4 is met, it should be evaluated for the total grade based on the lowest grade.

The main evaluation purpose of durability is to extend the physical life of a building through a high durability plan and promote the reduction of maintenance costs accordingly. For the thickness of bar cover, it is impossible to evaluate the degree of damage in the cases of newly constructed buildings. Therefore, the structural plan, thickness of bar cover, and concrete quality are evaluated using drawings and specifications (Figure 4). The analysis result is as follows (Table 7).

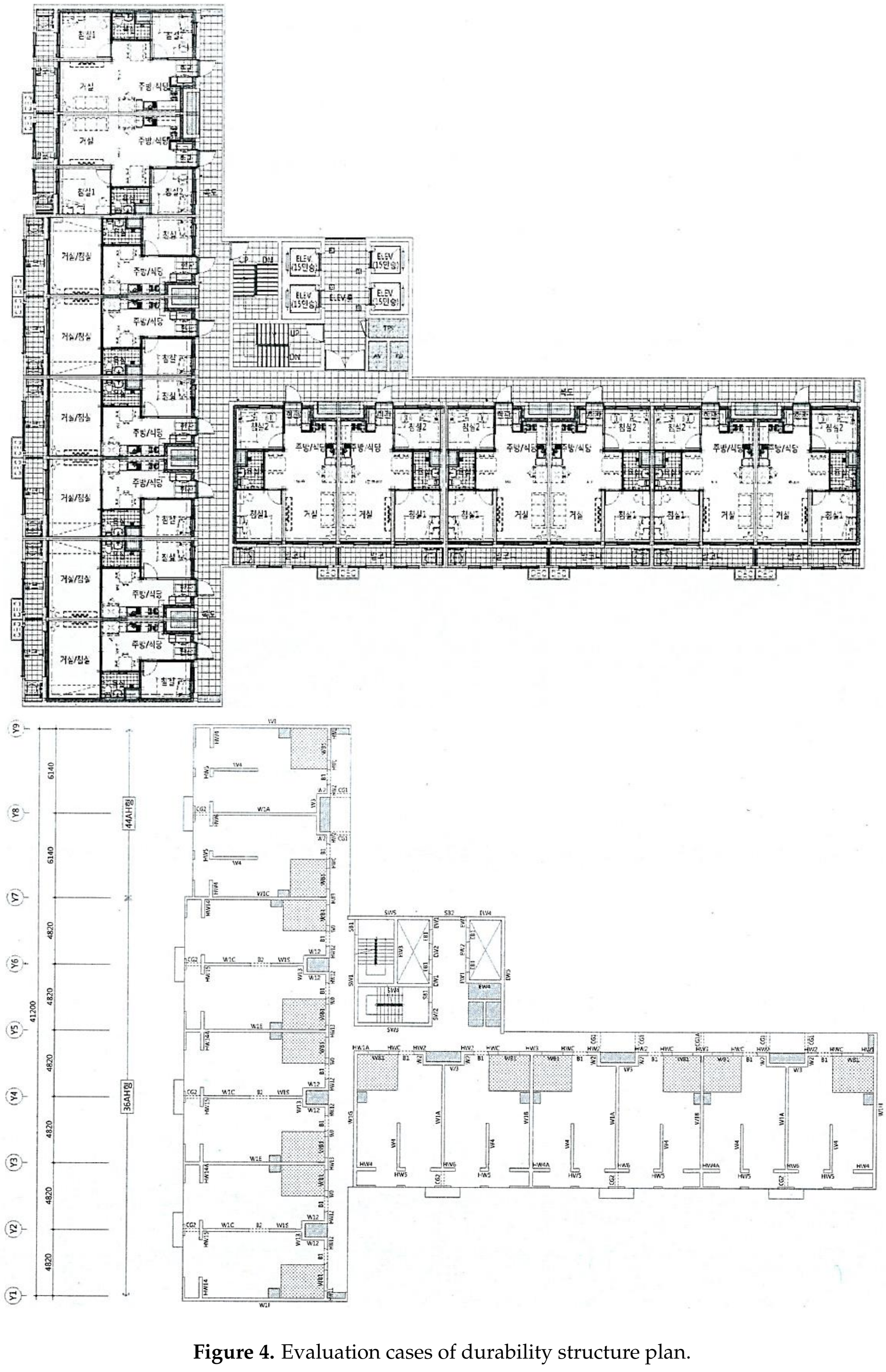

Figure 4. Evaluation cases of durability structure plan.

Table 7. Obtained scores by evaluation item for durability.

Classification	Evaluation Item	Grade	Number of Cases	Ratio (%)
Thickness of bar cover	Thickness of bar cover	1	-	-
		2	2	0.70%
		3	179	63.25%
		4	102	36.04%
Concrete Quality	Specified design strength (fck)	1	-	-
		2	-	-
		3	202	71.38
		4	81	28.62
	Slump	1	-	-
		2	21	7.42
		3	89	31.45
		4	173	61.13
	Unit binder content	1	-	-
		2	24	8.48
		3	154	54.42
		4	105	37.10
	Water-to-binder ratio	1	-	-
		2	6	2.12
		3	117	41.34
		4	160	56.54
	Air content	1	22	7.77
		2	1	0.35
		3	66	23.32
		4	194	68.56
	Chloride content	1	-	-
		2	28	9.89
		3	148	62.19
		4	107	
Distribution by grade (overall)		1	-	-
		2	-	-
		3	175	61.84
		4	108	38.17
Total		-	283	100

The highest grade for the thickness of bar cover was Grade III. No case obtained Grade I and two cases obtained Grade II (Figure 5). Many civil complaints for the standards for thickness of bar cover were raised due to the condition for the standards of Grade IV as well as the deduction of 10 mm for the minimum thickness of cover.

The reason that no case received Grade I was as follows. Although it would be possible to apply technology that falls under a new construction technology while satisfying Grade II, it is difficult to apply such technology in terms of expiration date for the new technology (three years on average) and costs. Moreover, when Grade 1 is applied, the thickness of cover increases, which increases the thickness of wall as well as the cost. Therefore, construction companies tend to avoid this process. Since durability is a key element to determining the physical life of long-life housing, quality assurance and system improvement in terms of technology and cost should be conducted concurrently.

Furthermore, no case received Grade 1 for all five items with the exception of air content. The ratio of Grade II also did not exceed 10%. The explanation is that the current certification standards correspond to neither technical levels nor specification standards in the field.

Specified design strength (fck) was found to be difficult to receive scores in slab strength. In the case of air content, 22 cases received one point. The permissible range of air content was ±1.5% and the grading was evaluated within the standards of 4.0–6.0%. As a result, there was a difference in the interpretation of minimum and maximum scores by the certification agency. As a cost increase also occurs when meeting Grades 1 and 2, which are higher grades for each item, most cases intended to obtain scores while maintaining Grades 3 and 4.

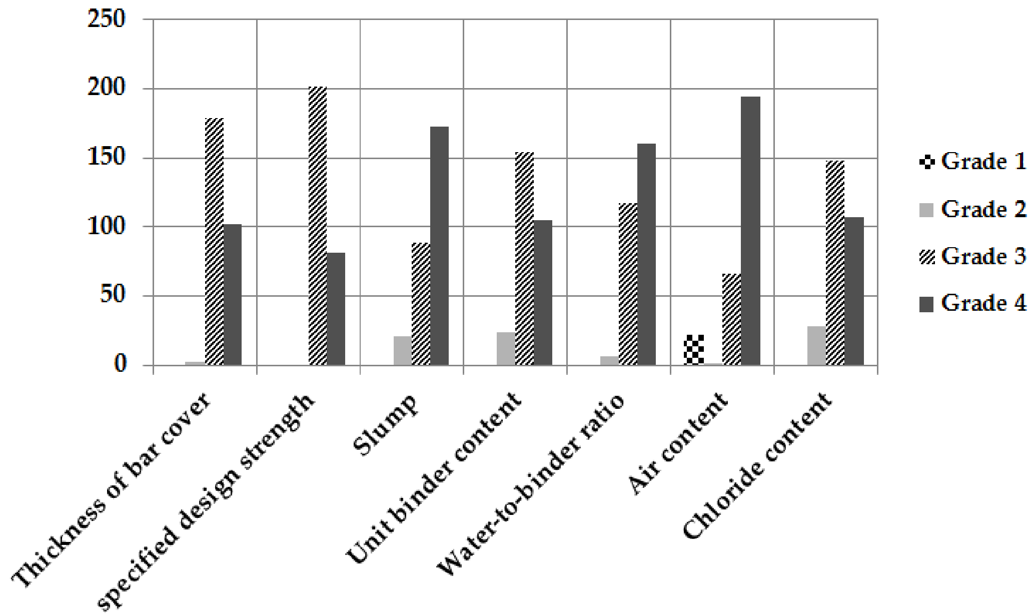

Figure 5. Distribution of acquired score by durability evaluation item.

4.3. Flexibility

According to Article 5 of the long-life housing construction certification standards notification, the application of the flexibility construction method to the support and infill is evaluated for variability. The Figure 6 is evaluated with the sum of scores for required items and optional items in the condition that required items are met [32]. The main evaluation purpose of flexibility is to respond to various spatial variability demands of residents flexibly according to the spatial variability in the house and the movement of water-using space.

The detailed evaluation standards consist of nine items including the length ratio of bearing wall and column (Table 8), ratio of dry wall among total internal walls in the house, easy variability structural method (a method which does not demolish the earlier process of final finishing materials on the floor, wall, ceiling, and modularization), piping above slab type method for bathroom and toilet, height increase (3000 mm or higher), installation of dry double floor, movement of bathroom, movement of kitchen, industrialization products, and replaceable methods for outer wall. The analysis result is as follows (Table 9).

Evaluation items showing the highest scoring rate were generally the length ratio of bearing wall and column and the ratio of drywall (Figure 6). Although the lowest grade was received for the length ratio of bearing wall and column among all houses based on the inside of the house, the flexibility accounted for the largest number of points. Grade III (10 points) showed the highest distribution as 53.36%, and this is the case in which the bearing wall ratio is over 40% and below 70%. Grade 4 was the mostly distributed score for the ratio of drywall in the house, followed by Grade III (over 30% and below 70%) (Figure 7).

Because the ratio of bearing wall structure was lower, it was more difficult to receive a higher grade or reduce the ratio by more than a half. Moreover, in the cases in which the inner wall was not present, such as in studio apartments, Grade 4 was given uniformly. Therefore, it was difficult to receive more points. Additionally, the reason for a low drywall ratio was that it was not easy to apply the dry construction method even to non-bearing wall.

With respect to the easy flexibility method, 50.53% received Grade III which was the highest scoring rate, and one method is applied in the modularization field. The next highest score was Grade IV, and many cases received Grade IV as per conditions similar to the aforementioned studio apartment example. Currently, a method that does not demolish the earlier method for final finishing materials for floor, wall, and ceiling is being developed by companies. The new method would therefore take more time to be commercialized. Next, most cases neither received a score for the piping above slab type of bathroom and toilet, height increase, dry double flooring, movement of bathroom and kitchen, and outer wall replacement method nor were attempts made. The reason is that most items, with the exception of non-bearing wall and drywall, increase construction costs. Therefore, construction companies tend to avoid these items. Because increased construction costs also lead to increased sale prices, it is necessary to develop a technology that can save costs and provide an institutional strategy to offset the cost.

Figure 6. Case of computation of length ratio of bearing wall and column unit floor planning.

Table 8. Calculation case of drywall and bearing wall application ratio.

	Type	Drywall Application Ratio			Bearing Wall Application Ratio		
		Length of Drywall (mm)	**Total Length of Wall in the House (mm)**	**Application Rate (%)**	**Length of Bearing Wall (mm)**	**Total Length of Wall in the House (mm)**	**Application Rate (%)**
Housing Unit	36A	3425	7095	48.27	0	7095	0.00
	36AH	3425	7095	48.27	0	7095	0.00
	36AHS	3425	7095	48.27	0	7095	0.00
	44AH	3325	10,093	32.94	3148	10,093	31.19
	44AHS	3325	10,093	32.94	3148	10,093	31.19
	44B	4895	10,590	46.22	5695	10,590	53.78
	44BH	4895	10,610	46.14	5715	10,610	53.86

Table 9. Obtained scores by evaluation item for variability.

Classification	Evaluation Item	Score Distribution		Number of Cases	Ratio (%)
(Support) Structure method	Length ratio of bearing wall and column (%)	7	Grade 4	88	31.10
		10	Grade 3	151	53.36
		13	Grade 2	39	13.79
		15	Grade 1	5	1.77
(Infill) Wall material and construction method	Ratio of drywall among total internal walls in the house (%)	2	Grade 4	215	75.98
		3	Grade 3	67	23.68
		5	Grade 1	1	0.35
	Easy variability method	0		1	0.36
		1	Grade 4	82	28.98
		4	Grade 3	143	50.53
		6	Grade 2	23	8.13
		8	Grade 1	34	12.01
(Infill) Piping	Bathroom, toilet piping above slab type	0		260	91.88
		3	Grade 4	22	7.77
		6	Grade 3	1	0.36
(Support) Floor height	Floor height (additional points for over 3000 mm)	0		281	99.29
		1		1	0.35
		2		1	0.35
(Infill)Variability of space	Dry double flooring	0		283	100
(Infill) Variability of water using area	Movement of bathroom	0		283	100
	Movement of kitchen	0		280	98.94
		2		3	1.06
(Infill) Variability and industrialization of outer wall	Industrialization products and replaceable methods for outer wall	0		283	100
Distribution by grade (overall)		Grade 1		-	-
		Grade 2		-	-
		Grade 3		71	25.09
		Grade 4		212	74.91
Total				283	100

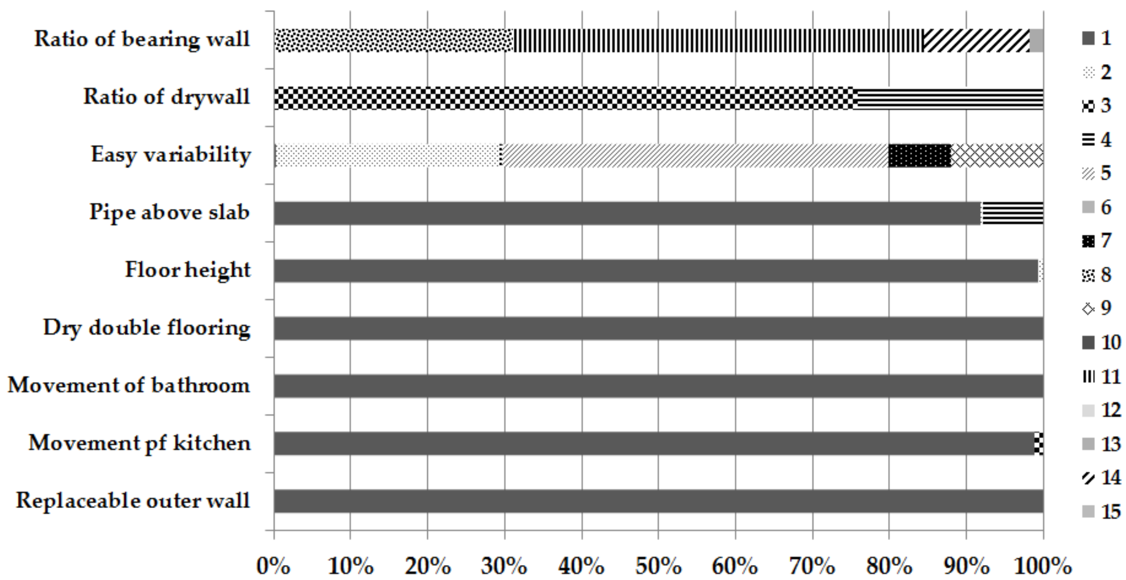

Figure 7. Distribution of obtained scores by evaluation item for flexibility.

4.4. Maintainability (Exclusive Area)

According to Article 5 of the long-life housing construction certification standards notification, easiness of repair and inspection along with horizontal house separation plan are evaluated for the maintainability in exclusive areas [32]. The main evaluation purpose of maintainability (exclusive area) is to secure easiness of maintenance of apartment houses by separating common pipes and exclusive pipes, securing the easiness of repair and inspection, and clarifying the matter of responsibility. It also aims at responding to a change in population structure and family members through the horizontal house separation. The detailed evaluation standards for maintainability (exclusive area) consist of six items including securing of independence between common pipe and exclusive facility spaces, designing to facilitate the repair and replacement of pipes and wires, no laying of pipe and wire structure, dry ondol and application of horizontal house separation space plan, and facility plan for divided ownership of plane when planning for divided use.

The analysis result is as follows (Table 10).

Table 10. Distribution of obtained scores by evaluation item for maintainability (exclusive area).

Classification	Evaluation Item	Score Distribution	Number of Cases	Ratio (%)
Easiness of repair and inspection	Secure independence between common pipe and exclusive facility spaces	5	283	100
	Design to facilitate the repair and replacement of pipes and wires	5	283	100
	No laying of pipe and wire structure	0	267	94.35
		2	16	5.65
	Dry Ondol (Korean floor heating system)	0	283	100
Horizontal house separation plan	Apply space plan	0	283	100
	Apply equipment plan	0	283	100
Distribution by grade (overall)		Grade 1	-	-
		Grade 2	-	-
		Grade 3	16	5.65
		Grade 4	267	94.35
Total			283	100

All cases received five points for the securing of independence between common pipe and exclusive facility spaces and designing to facilitate the repair and replacement of pipes and wires, showing a bias in specific items (Figure 8). This is one of the piping methods that are also utilized in normal apartment housing, and not considered for long-life multi-family housing. Scores are accepted in the following cases of piping methods. The piping method facilitates the separation of connection between common vertical pipes and exclusive horizontal pipe. The piping method minimizes the effects on surrounding members such as double piping. The method, in which piping use is inside of the drywall, is applied.

In addition, four items did not receive a point with the exception of two cases. "No laying of pipe and wire structure" and "dry ondol" were the items avoided by construction companies. Both items were avoided due to a cost increase when applying such items to all houses on the premise of securing margins, such as double flooring and dry method. The horizontal house separation plan also became a reason for increasing construction cost since it would be necessary to secure a margin such as distribution board for each house, electric capacity, and a parking lot to prepare for increased usage.

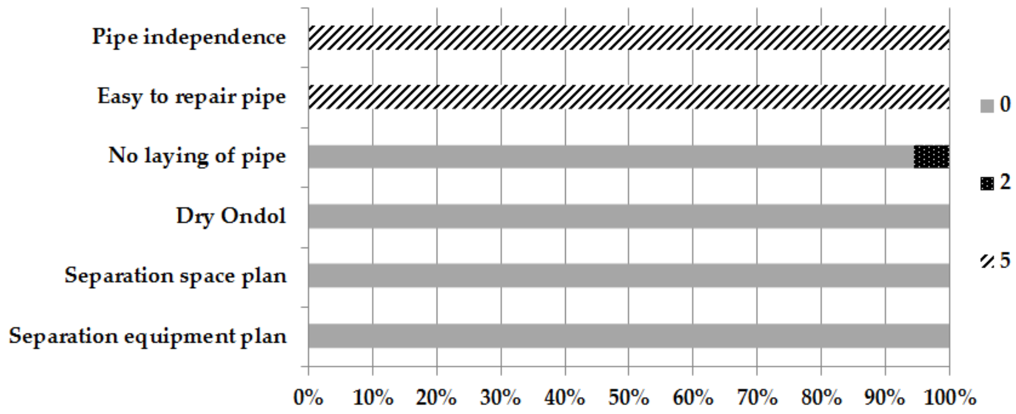

Figure 8. Distribution of obtained scores by evaluation item for maintainability (exclusive area).

4.5. Maintainability (Common Area)

For the common area of ease of repair, the easiness of repair and inspection, acceptance in the future, and response to a change in energy sources are evaluated. The exclusive space and common space are evaluated separately and these spaces are evaluated with the sum of scores for required items and optional items in the condition that required items are met. The evaluation purpose of ease of repair (common area) is the installation of common area piping structure that is easy to repair, inspect, and assemble. The purpose also aims at securing extra space of common PS (Pipe Shaft) by considering an increase in the demand and house separation in the future.

The detailed evaluation standards for maintainability (common space) are six items including the placement plan of piping space on the common area space, access hole on common piping space, placement of pipes in the piping space, piping structure possible to assemble, securing of 20% margin for main common vertical piping space, and the installation of one or more reserve piping space (Shaft) separately. The analysis result is as follows (Table 11).

Table 11. Distribution of obtained scores by evaluation item for maintainability (common area).

Classification	Evaluation Item	Score Distribution	Number of Cases	Ratio (%)
Easiness of repair and inspection	Placement plan of piping space (Shaft) on the common area space	5	283	100
	Access hole on common piping space	5	283	100
	Placement of pipes in the piping space (Shaft)	0	248	87.63
		2	35	12.37
	Application of piping structure possible to assemble	0	249	87.99
		2	1	0.35
		3	33	11.67
Horizontal house separation plan	Securing of 20% margin for main common vertical piping space	0	251	88.69
		2	31	10.95
		5	1	0.36
	Installation of one or more reserve piping space (Shaft) separately	0	282	99.64
		3	1	0.35
Distribution by grade (overall)		Grade 1	24	8.48
		Grade 2	15	5.30
		Grade 3	1	0.35
		Grade 4	243	85.87
Total			283	100

All cases obtained five points for the placement plan of piping space on the common area space and access hole on common piping space (Figure 9). The analysis result showed that the common vertical pipes (water supply, hot-water supply, heating, and fire extinguishing system pipes) were located in the common area and the access hole on common piping space (600 × 1500) was installed on all floors. For the placement of pipes in the piping space, 35 cases received two points, which was a partial score. The score was given according to the placement of a pipe with long durable years, a pipe with short durable years, and securing of reserve space.

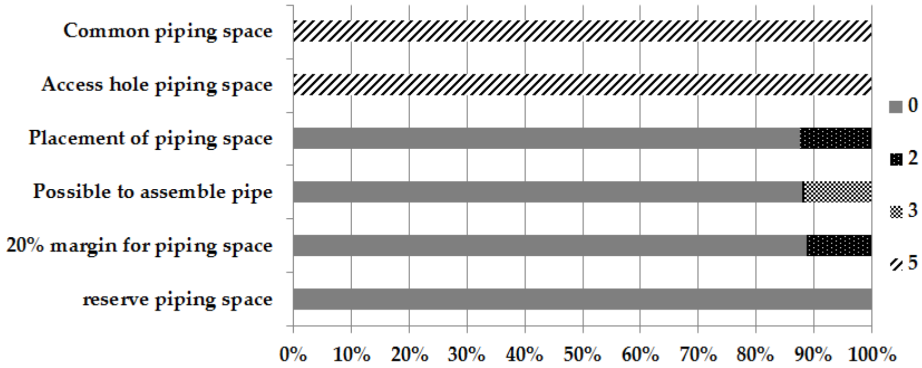

Figure 9. Distribution of obtained scores by evaluation item for maintainability (common area).

For the application of piping structure possible to assemble, 33 cases received three points when it was designed to facilitate the repair and replacement of common horizontal pipes (plumbing and machine equipment pipes). For the securing of 20% margin for the main common piping space, 31 cases obtained two points and one case obtained five points through the securing of margin and separate installation of the reserve shaft.

5. Overall Analysis

Since the implementation of the long-life housing certification system, all cases received a normal grade as a result of analyzing the scoring status of 283 cases collected to date (June 2017). One hundred seventy three cases (61.13%) received 50 points, followed by 106 cases (37.46%) that received 51 points, and two cases (0.71%) that received 52 points. The results indicated an overwhelmingly higher ratio of cases with 50 points and 51 points (Figure 10). Only one case each received 56 points and 57 points, which were the highest scores allowable within normal grade (Table 12).

As a result of reviewing the case receiving 57 points that represented the highest score, 15 points for durability (Grade IV), 18 points for flexibility (Grade III), 9 points for maintainability (exclusive area) (Grade IV), and 15 points for ease of repair (common area) (Grade I) were received. The following reasons are why Grade I was received for maintainability (common area): points were obtained in all four items and a 20% margin in the main common vertical pipe (PS) area was secured to receive an additional two points.

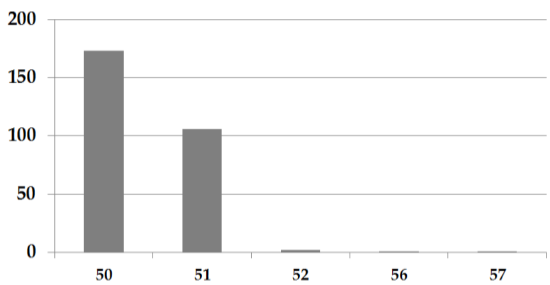

Figure 10. Total certification score acquisition status.

Table 12. Total certification score acquisition status.

Grade	Score	Number of Cases	Ratio (%)
Normal grade	50	173	61.13%
	51	106	37.46%
	52	2	0.71%
	56	1	0.35%
	57	1	0.35%
Total		283	100%

The total score by field is as follows. In the case of durability, 175 cases (61.84%) received Grade III that accounted for the highest ratio, followed by 108 cases (38.17%) that received Grade IV. In the case of variability, 212 cases (74.91%) received Grade IV that accounted for the highest ratio, followed by 71 cases (25.09%) that received Grade III, and no case received Grades I and II. In the case of ease of repair (exclusive area), 267 cases (94.35%) received Grade IV, followed by 16 cases (5.65%) that received Grade III, showing the highest ratio of Grade IV among all evaluation fields. No case received Grades 1 and 2. As a result of summarizing the grades for maintainability (common area), 243 cases (85.87%) received Grade IV and one case (0.35%) received Grade III. In other fields, no case received Grades I and II. However, 24 cases (8.48%) received Grade I and 15 cases received (5.30%) Grade II (Figure 11). This is due to the placement of piping space on the common area space of the apartment building, installation of access hole (600 × 600), and the application of piping structural technology possible to assemble.

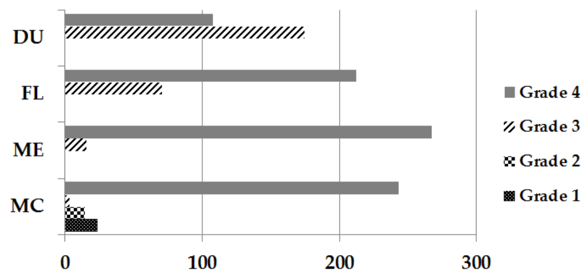

Figure 11. Grade acquisition status by whole evaluation field.

6. Conclusions

In this study, the acquired score and status of each evaluation item were analyzed by investigating all long-life housing certification cases to date since the introduction of the long-life housing certification system. The study was intended to identify reasons for all certification cases remaining at normal grade and relevant problems such as biased scoring on a specific item or an item with no score.

The conclusions are as follow:

1. Currently, the Korea Green Building Certification System is designated as an operating agency by Korea Institute of Construction Technology. However, the long-life housing certification system has not yet established the operating agency and information disclosure regulations. Therefore, it was necessary to follow various steps to collect certification cases and investigate the certification status. An operation agency and institutional measure to maintain the certification system more systematically are necessary.
2. Upon review of the scoring status of 283 target cases for investigation by durability, flexibility, and maintainability (exclusive area and common area), it was found that relevant long-life technologies were not actively distributed. Conversely, such technologies exist but led to an increase in the construction expense primarily on items with 0% scoring rate. An incentive up to 115% for building coverage ratio and floor-area ratio should be provided for cases with an

excellent grade or higher. However, construction companies avoided this as the effectiveness of the increased construction expense paled in comparison to the value of the incentive. An increase in construction expense also leads to an increase in sale price. Therefore, it is necessary to prepare various incentives accordingly.

3. The detailed evaluation standards were vague and the scores varied according to the interpretation method upon summarizing the certification cases and details of civil complaints regarding the certification. Therefore, it was necessary to improve overall detailed evaluation standards of the certification system. For example, the evaluation standards of thickness of bar cover and concrete quality for durability should be reexamined according to the specifications and the field situation. Moreover, complexes including studio apartments should receive Grade 4 for flexibility due to its specific conditions. However, as the demand for studio apartments gradually increases due to an increase in the number of single-person households, an improvement measure to receive a score in the flexibility is required. No ratio for the horizontal separation of house is currently prepared for maintainability. At present, the maximum ratio of multi-family housing units divided into each household should not exceed 1/3 of all households in the apartment housing. However, as there is no minimum standard, it is necessary to hold a discussion to establish the minimum standard.

Long-life housing is a type of housing customized for population change and lifestyle of residents in preparation for a change in housing environments in the future. From a long-term perspective, this type of housing is also considered an eco-friendly alternative in terms of construction waste and material saving. The long-life housing certification system passed its early stage. Various efforts, trials, and errors to revitalize the system are being made in comparison to other similar systems that have already been implemented and stabilized. The analysis of certification system cases to date sets a significant precedence. The result can be utilized as preliminary data for short-term and long-term improvement of the certification system. The findings also serve as the foundation for the research in the preparation of more effective policies.

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Nomenclature

DU	Durability
ME	Maintainability (Exclusive area)
FL	Flexibility
MC	Maintainability (Common area)

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