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Post-Handover Housing Quality Management and Standards in Korea

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Abstract: Housing quality is a subject of dispute worldwide, and these disputes are increasing due to the significant differences in the views of producers and consumers on quality standards. To arbitrate disputes, an objective evaluation of housing quality is necessary. In Korea, disputes over housing quality in the post-handover stage result in lawsuits, thus becoming a social issue. This study analyzed the results of lawsuits against housing complexes in Korea. The ratio of defect repair cost to construction cost (DRCCC) was adopted as an indicator, and the quality level of the building was evaluated using a control chart to select failures. The findings showed that there were more cases where the construction cost was small, the housing quality was poor, the deviation was wide, and the quality defect exceeded the limit level of the control chart. To improve housing quality, it is necessary to strengthen quality management, to control the quality within the management limit, and to adjust standards by reflecting the consumer's viewpoint.

Keywords: housing quality; defect lawsuit; ratio of defect repair cost to construction cost; quality failure case

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1. Introduction

Housing quality or value can be defined from various perspectives [1,2]. The quality of housing can also be expressed in lyrical or abstract terms, such as safe and comfortable housing [3] and houses suitable for living [4]. If one emphasizes a more realistic aspect, seismic resistance is the most important quality indicator for housing in earthquake-prone countries such as Taiwan and Japan [5]. For the residents of Frankfurt, housing with stepless accessibility to the building is essential, and this difference in quality even affects housing prices [6]. In the case of India, which is one of the largest countries in terms of economy and population, there are still poor classes, and for them, having individual water supply facilities and sanitary equipment in their homes is an essential criterion for evaluating quality [7].

Meanwhile, banners that indicate positive reviews from third parties were signs of good housing quality. For example, some buildings won the top award from the National Association of Home Builders of the United States in 2023 [8], while others won the Royal Academy Architecture Award in 2022 [9]. From an economic point of view, housing quality is mentioned based on the price or construction cost. For example, in a City of London district, terraced homes cost an average of GBP 1,869,125 in 2022 [10]; in Los Angeles, house construction costs averaged between USD 400 and USD 480 per square foot in 2023 [11]; and in Seoul, the price of a new apartment reached KRW 30.62 million per 3.3 m^2 as of March 2023 [12].

In addition, although the consumer-oriented era had already arrived in the last century [13], disputes over the quality of construction, including housing, are ever-increasing [14]. According to a study of three residential buildings in Poland, 202 defects occurred in one year [15]. In Parand, New City, where 16,080 houses were being built in Iran, 935 defects were reported due to non-conformance [16].

The UK Home Builders Federation conducts a yearly satisfaction evaluation, including one on quality for new home buyers [17]. If the evaluation results from 2009 to 2023 are expressed as an average, it is evaluated as 4.27 out of 5 points. However, even with this assessment conducted by the homebuilder, quality ratings by UK homebuyers have been declining since 2013, but this issue has been addressed recently. This survey was conducted by the subjective evaluation of the non-professional home buyers, and the evaluation was conducted at the beginning of home occupation; therefore, the defect was not properly identified, which might not elaborate the issues. According to the study examining defects 12 months after the handover of 327 houses in the UK, 3209 defects were identified, implying significant housing quality problems [18].

The Korea Productivity Centre has been announcing the satisfaction evaluation of the top 8 housing construction companies since 1998. According to the evaluation results, satisfaction increased steadily until 2010, but it decreased until 2015 and was reported to have recovered to the level of 2010 in 2022 [19]. Nevertheless, the number of cases of housing defect disputes submitted to the Apartment Defect Dispute Mediation Committee under the Ministry of Land, Infrastructure, and Transport from 2010 to 2022 reached 40,143, indicating that an average of more than 3000 housing defect disputes are filed yearly [20]. While the disputes submitted to the Apartment Defect Dispute Mediation Committee are on the rise, it seems quite contradictory that the Korea Productivity Centre is providing satisfactory evaluation results.

As reviewed above, housing quality problems are a common social phenomenon in developed and developing countries, either small or large. At the same time, there is a significant difference in evaluation between the housing suppliers and the home buyers. How can one objectively judge to which extent housing quality problems are occurring then? From the facts described above, the quality and values of the housing can be defined based on the cost of repairing the damage, either as a faulty part is found and reworked at the stage of building a house or as defects occur when the house is already completed and is currently inhabited.

According to a study that analyzed housing in the United States, it is known that, concerning housing quality issues, on average 5.4% of the construction costs for in-house projects and 2.2% of the construction costs for contract projects are spent on rework [21]. In addition, the cost of repairing defects, which is a quality problem of housing, is 4% of the construction cost in Australia [22], 2.75% in Spain [23], 4.95% in China [24], and 0.538% in Korea [25]. However, although the average cost for repairing the housing defect is known through these prior studies, the range of repair costs and the number of cases of poor quality are not disclosed in most cases.

As reviewed above, according to previous studies, there is no objective standard or index to define housing quality; various measures and methods have been used. Several scales can be used to evaluate housing quality depending on the purpose. Among them, construction cost, defect repair cost, and the combination of the two can be objective indicators for assessing quality in the post-handover stage of housing. However, in the previous studies, it was possible to evaluate the level of the study's entire case and subjects, although a comparison between the different cases has not been conducted.

In this regard, this study uses the chart technique by Shewhart, one of the traditional quality control methods, for Korean housing defect lawsuits to set the level of defects currently occurring as a quality standard and set indicators according to the limit level. Subsequently, this paper discusses whether housing quality was good or bad. The analysis focuses on the following contexts.

First, whether there was a significant difference in the ratio of defect repair cost to construction cost, depending on the scale of the housing construction cost.

Second, if there was a difference, the quality level was identified by analyzing with the Shewhart control chart technique for each group classified according to the size of the construction cost.

Third, this paper checked whether cases exceeded the threshold level through the Shewhart control chart. If there were cases that exceeded the threshold level on the control chart, they were defined as poor-quality cases.

Fourth, regarding the cases of poor quality, the issue outlined in the housing defect lawsuit was examined, and the relationship with quality was reviewed.

The above analysis proposes measures to improve housing quality management and quality standards.

2. Literature Study

2.1. Definition of Housing Quality

This study was intended to define housing quality using the number of defects in housing. More precisely, it was based on the scale of the repair cost compared to the construction cost of housing. Among the related preceding studies, there are studies on the types of defects occurring in housing [26–28], studies focusing on the frequency of defects [29–31], and studies using defect repair costs [32–34]. In the previous studies mentioned above, the level of housing defects was determined as the ratio of defect repair cost to construction cost (ratio of DRCCC), and those levels were compared [21–25].

Defect types are subdivided by the location, object, work detail, and phenomena of the defects that occur in a house. These types can be used to establish specific standards for quality, but it is not easy to see them as quality standards or criteria. The defect occurrence frequency can be used as a quality standard and criterion since it shows the number of defects that occurred in the entire house or for each defect type. Furthermore, individual evaluation is possible since each type's standards and criteria differ; however, this is not appropriate for a comprehensive evaluation. For example, concrete cracks, a typical defect in reinforced concrete work, are measured and managed in units of length or area. On the other hand, the lighting failure of the lamp, a typical defect in electrical work, is quantified by counting the number of lamps. Therefore, since the standard unit is different for each defect type, it is difficult to assert which one has more frequent or greater defects.

In the case of defect repair costs, it is difficult for non-experts to understand the cost calculation process, but since it is measured in money, even an ordinary person can understand it quickly and easily. In other words, a house with a high defect repair cost can be of inferior quality, and conversely, a house with a low defect repair cost can be of excellent quality. However, it should be noted that each building is different in terms of construction cost, area, and number of households. For example, in comparing the cases where the defect repair cost for House A with an area of 500 m^2 is calculated at USD 10,000, and the repair cost for House B with an area of 1500 m^2 is calculated at USD 20,000, House B, with a higher repair cost, is of poorer quality if repair cost alone is compared. The conclusion is changed when the area of the house is considered. House A was calculated for a repair cost of USD 20 per square meter, and House B was calculated for a maintenance cost of USD 13 per square meter. Therefore, the quality of House B, which has a lower maintenance cost per unit area, is better. Likewise, judging the quality of a house based only on the repair cost is limited to cases where other conditions are the same.

Let us look at the case where a ratio of DRCCC is used as a quality standard and criterion, considering the relationship with the construction cost. The construction cost tends to increase proportionately to the area or number of households. Therefore, since the size of the building is considered in the ratio of defect repair cost to the construction cost, comparing two buildings with different conditions, as mentioned above, is possible. Because of these points, using the ratio of defect repair cost to housing construction cost as a standard for housing quality is more reasonable. Therefore, the ratio of defect repair cost to housing construction cost was also adopted for this study.

On the other hand, previous studies using a ratio of DRCCC as a criterion utilized the overall statistical analysis [21–25]. However, unlike this study, the previous studies did not select a method of measuring the quality of the entire subject through a control chart analysis and comparing the quality to each other.

2.2. Quality Control Chart

Statistical quality control is a technique based on statistical data analysis [35]. The control chart proposed by Shewhart is the first management technique that ensures a stable quality state of the object [36]. In the control chart, as in Equation (1), quality control can be performed by setting the average of the control subject as the reference value (Centre Line; CL) and setting various control limits. The most common P control chart proposed by Shewhart uses the mean and standard deviation of the data as shown in Equations (2) and (3) below and manages based on the Upper Control Limit (UCL) and the Lower Control Limit (LCL) with an error range of 3σ against average.

$$\mathrm{CL} = \mathrm{p}, \tag{1}$$

$$\mathrm{UCL} = \overline{\mathrm{p}} + 3\sqrt{\frac{\overline{\mathrm{p}}(1-\overline{\mathrm{p}})}{\overline{\mathrm{n}}}}, \tag{2}$$

$$\mathrm{LCL} = \overline{\mathrm{p}} - 3\sqrt{\frac{\overline{\mathrm{p}}(1-\overline{\mathrm{p}})}{\overline{\mathrm{n}}}}, \tag{3}$$

Control charts are widely used in all fields, including manufacturing [37], service [38], and construction [39]. In addition, as a tool to reduce variability and promote process safety, control charts are often used to produce the same manufacturing process or continuity [40]. Since the detailed work related to housing construction, such as foundation, frame, equipment, and finishing, has continuity as the same work is repeated for each floor or room, the constructor can manage quality using a control chart. Therefore, the control chart is helpful as a quality control tool in the construction stage.

In addition, control charts can analyze a specific point in time or a clustered part [41]. Furthermore, it can be applied not only to the production stage but also to the maintenance stage [42]. In addition to low-level unit work, it is also helpful in high-level management, such as leadership [43]. Control charts are also used to monitor customer satisfaction and complaints in addition to producer-centered evaluations [44], so it is possible to perform post-monitoring or post-evaluation using control charts. Therefore, the control chart makes evaluating and managing defects and repair costs in the post-handover stage possible.

2.3. Quality Failure

The definition of housing quality, a method to measure quality and compare differences, and deriving the quality failures according to quality differences are discussed in this section. As stated in Section 2.2, control charts use the mean and standard deviation to set control limits. Typically, control limits are defined as UCL and LCL at ±3σ of the mean. Therefore, quality is managed to maintain an average amount between UCL and LCL.

On the other hand, when the ratio of defect repair cost to housing construction cost is used as a criterion, cases exceeding the UCL mean that the repair cost is excessive compared to the overall average, so it can be determined as an issue of quality, which in this case indicates bad quality. However, since a case below the LCL means that the defect repair cost is less than the overall average, this case can be classified as a case of excellent quality. Generally, the quality level is evaluated between the control limit levels of UCL and LCL on the control chart. However, in the case of using a control chart with a ratio of DRCCC as a criterion, as in this study, LCL is not an issue, and UCL is the subject of the study. Therefore, cases where the ratio of DRCCC exceeds the UCL were classified as failure cases.

2.4. Quality Issue

Several studies have been conducted on various issues in housing defect litigation in Korea [45–51]. However, there are many legal criteria, and their interpretation [45,48–51] and research on technical standards is lacking [46,47]. On top of this, they mainly dealt with concrete defects [46] or conducted a mere analysis of the overall situation [47].

As a result, Korean courts have established a standard for construction appraisal practices [52]. This standard greatly contributed to the standardization of the inspection of defects and the calculation of repair costs. However, as the number of defect lawsuits increases, the number of disputes increases, while the scope covered by this standard is limited. In addition, since defect investigations and maintenance cost calculations are performed by specialized engineers, their judgments are determined from the viewpoints of the industry. Therefore, there is still a significant difference from the consumer's point of view, and the dispute is ever-expanding.

It is necessary to examine the technical issues of quality failure cases and determine the difference in viewpoints between producers and consumers. This can help to find a reasonable solution by recognizing and understanding the problem from each party's point of view in a dispute.

From the literature review, the housing quality and defects could be evaluated using the type of defect, defect repair cost, and defect repair cost ratio to construction cost (DRCCC). Among them, comparing the quality levels of housing with the DRC would be the most reasonable. Therefore, this study also adopted the DRCCC as a criterion of housing quality.

Previous studies presented the average quality level of the entire study subjects but could not explain the difference in quality level for each case. There has also been no study selecting poor quality cases in terms of defects and the extent of the defects. In this research, the quality of the entire case is defined using control chart analysis, a representative technique of statistical quality control, and the quality of each individual case was compared to select cases with poor quality. The control chart technique has been used for a long time in many fields of quality control, so it is a proven technique in terms of reliability. Therefore, the control chart technique is expected to be useful in housing defects and quality.

In addition, the technical issues of the defect lawsuit for the case of inferior quality should be considered. Through this, it will be possible to know how the viewpoints of producers and consumers differ. We will discuss how the consumer's point of view is reflected in the standards and customs of the housing sector, which has been established as producer-oriented, and how to improve it.

3. Materials and Methods

3.1. Data Collection

The housing in this study consists of newly built apartment complexes in Korea where a defect lawsuit was filed. It is stipulated in Korean law that multi-unit dwellings in Korea should comply with the basic design standards prepared by the government [53]. According to this standard, standardized apartment buildings have many similarities, such as a reinforced concrete structure, a high-rise building, and a floor heating method unique to Korea. For this reason, these buildings are highly likely to have similar types of defects. However, each building inevitably has differences in detailed design, and the finishing materials and facilities are not the same. There may be differences in quality, but securing the information on each case's design drawings or exact specifications in the data collection process was difficult. Therefore, in this study, the differences between each building were considered by classifying the cases according to the size of the construction cost. Construction costs are normally expected to increase if quality materials and equipment are used. In addition, multi-unit dwellings can easily provide data because of the many units being built. Therefore, a statistically significant result can be expected from the quality comparison of apartments [34].

Construction cost (CC) and defect repair cost (DRC), which are fundamental data for indicating housing quality, are based on the amount determined by the court through a defect lawsuit against these housing complexes. This judgement amount means the total cost of repairing defects in the post-handover stage [54]. A post-handover defect refers to externally manifested problems such as cracks, omissions, leaks, and breakages.

The court ordered a professional engineer and certified architect to inspect the housing complex. The assigned experts visit the housing complex, investigate, and identify the types of defects that occurred; then, they calculate the repair cost, and submit a report to the court [55]. In addition to the contents of this report, the court determines the judgement amount by determining the liability and the scope of the case in consideration of the legal applicability [45].

As explained in Section 2.4, Korean courts follow the construction appraisal practice, the standard for defect investigation and repair cost calculation [52]. According to this standard, design drawings are checked, and repairs are made based on materials and facilities of the same specifications. In addition, if the defect is minor, it is repaired to the level of replacing parts or reconstructing a part of the finishing material. Conversely, if the flaw is serious, the entire facility or the area where the finishing material is installed is removed, and the repair cost is calculated based on the standard of reconstruction at the same level.

In this study, data collected in previous studies were used [25,46], and a total of 285 housing complex cases were used for analysis, as shown in Figure 1, except for cases where there was no repair cost incurred for defects after handover.

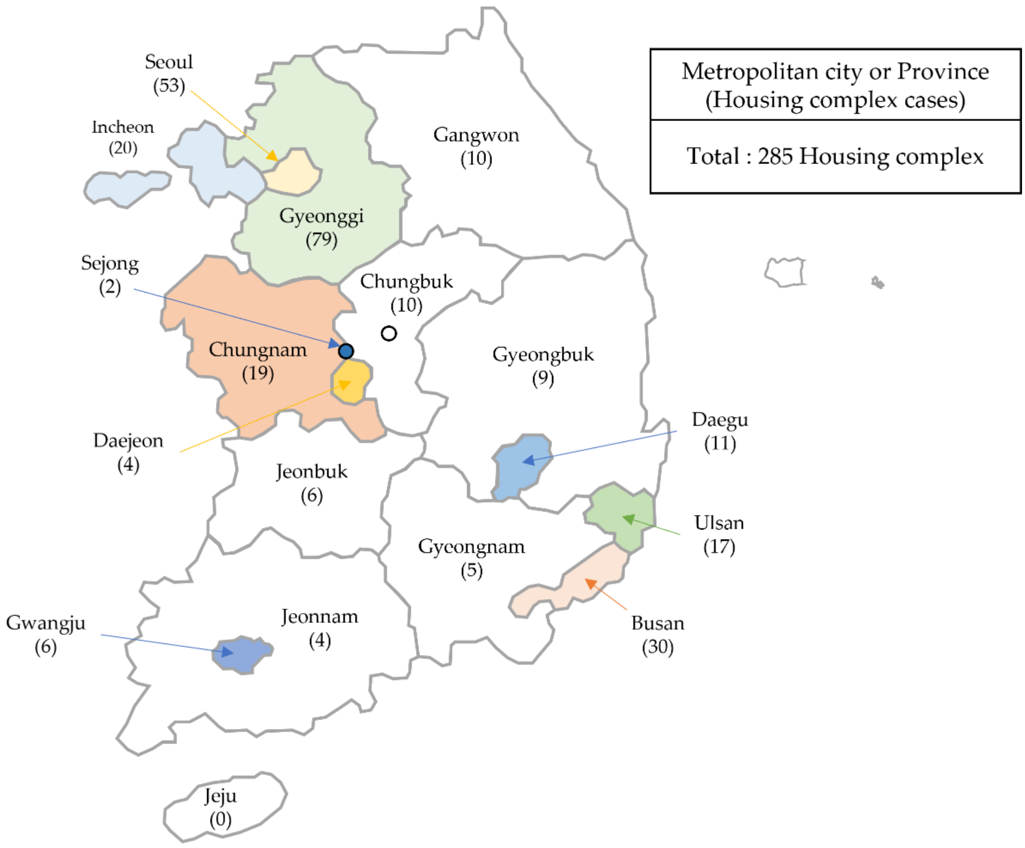

Figure 1. Distribution of case location.

3.2. Cost Value Adjustment

On the other hand, in these cases, there is a difference in the time of completion and the period of litigation, so the calculation time of the construction cost and defect repair cost are different. It is then necessary to adjust the cost value equally based on the same period [44]. The time of this study is the future from when the construction and defect repair costs of each case were determined. Therefore, the repair cost of each case was converted by the future value (FV) method as of 2022, the research time point. The future value, as in Equation (3), can be calculated as shown in Equation (4) below, assuming the discount rate (interest: i) and the elapsed period from the reference point (year: n) on the present value (PV). The discount rate was determined by applying 3.25%, the base rate announced by the Bank of Korea, to adjust each case's construction and repair costs. As of the end of March 2023, the adjusted construction and defect repair costs were expressed in British pounds by applying KRW 1305.73 per USD 1, the exchange rate between United States dollar, British pounds, and Korean won. The key statistics of construction and defect repair costs for all cases are presented in Table 1.

$$FV = PV \times (1+i)^n, \tag{4}$$

Table 1. Cost statistics.

Cost	N	Sum (Million USD)	Mean (Million USD)	Std Dev.
Construction cost	285	48,237	169	164
Defect repair cost	285	176	0.62	0.67

3.3. Classification to Groups

In addition, according to the results of previous studies, it is known that there are differences in housing defect repair costs depending on the size of the construction costs [25]. If all cases are compared without considering the difference in construction cost, the analysis result may be distorted. Therefore, this study also checked whether there was a difference in the ratio of DRCCC according to the size of the construction cost, and if there was a difference, the quality of the housing for each size of the construction cost was compared.

The difference according to the size of the construction cost was classified using the decision tree technique. The decision tree algorithm used a Chi-squared Automatic Interaction Detection (CHIAD) algorithm. CHIAD is an algorithm that forms a decision tree while repeating separation and merging using the chi-square test and the F-test of an ANOVA [56]. The CHIAD algorithm performs multiple partitions using the chi-square test for discrete target variables and the F-test of an ANOVA for continuous target variables. F, the F-test statistic, is calculated as the ratio of the variance of the sample group, and the likelihood ratio is obtained through Equation (5) [57]. In this study, since the ratio of construction cost to defect repair cost, which is the dependent variable, is continuous, the CHIAD algorithm is applied according to the F-test. The IBM SPSS Statistics 21 program classified it as a decision tree.

$$x^2 = 2\sum_{i,\,j} f_{i,\,j} \times \log_e\left(\frac{f_{ij}}{e_{ij}}\right) \tag{5}$$

The dependent variable is the ratio of DRCCC, and the independent variable is the construction cost. With the decision tree analysis results, as shown in Figure 2, the cases were classified into a group with a construction cost of less than USD 115.64 million, a group with a construction cost ranging from USD 115.64 million to USD 254.03 million, and a group with a construction cost exceeding USD 254.03 million. These groups were named Groups A, B, and C, respectively. The ratio of DRCCC showed that the average was 0.439% for all cases, 0.529% for Group A, 0.383% for Group B, and 0.301% for Group C. Compared to the entire case, the ratio of DRCCC ratio of Group A was higher, while those of Groups B and C the ratios were lower. Table 2 shows the main statistics for each group. A control chart analysis was conducted for each group.

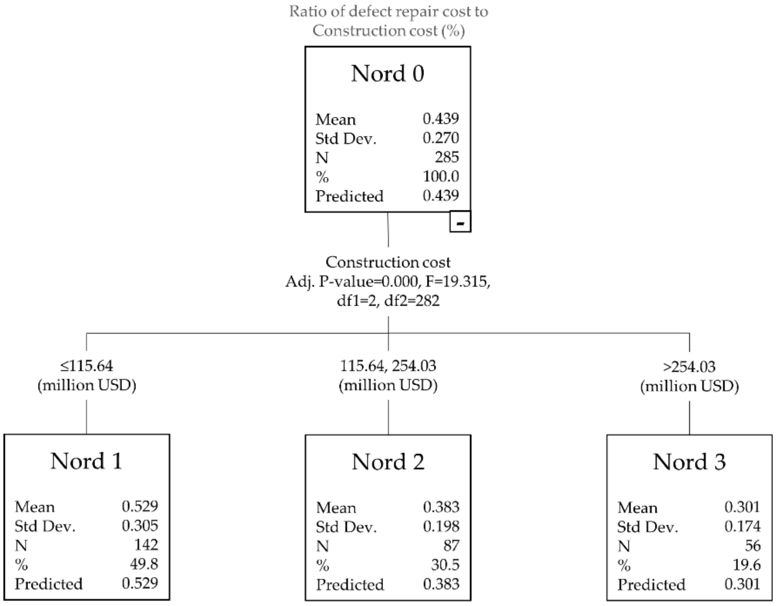

Figure 2. Decision tree analysis results.

Table 2. Statistics of each group.

Group	Cases	Mean (%)	Std Dev. (%)	Max (%)	Min (%)
A	142	0.5287	0.3051	1.6993	0.0623
B	87	0.3831	0.1977	1.1424	0.0842
C	56	0.3007	0.1741	0.7587	0.0388

3.4. Review on Quality Issue

Through the control chart analysis above, this study examines technical issues in housing defect lawsuits for the cases selected as poor-quality cases. The technical problems stated in the litigation judgment on poor quality were discussed, and the arguments between the producers and consumers surrounding them were reviewed. Through this, the difference between the viewpoints of producers and consumers was identified, and ways to narrow the gap were sought.

However, the number of issues in a housing defect lawsuit can be as little as 10 per case. Still, in many cases, it is diverse enough to approach 100. Therefore, data collection and analysis on all these issues would take considerable time. To confirm the factual relationship of each detail, it is necessary to collect appraisal reports, drawings, and even specifications. However, there is a limitation in managing all these data. Therefore, this study is limited to examining the technical issues of quality defect cases that exceed the control chart limits.

For that, the cases were reviewed through the following methods and procedures. First, precedents for defects lawsuits in cases of poor quality were selected, and the issues described in the precedents were summarized. Second, among all issues, issues that have affected quality or were related to quality standards were selected. Third, reviewing the contents of each quality-related issue, the relationship with quality, how the quality standard was interpreted, and the difference in perspective between the homeowner and the housing developer were reviewed. Finally, the results derived from reviewing the issues of poor-quality cases were discussed, and ways to improve quality were sought.

4. Results

4.1. Comparison of Quality

Figure 3, below, shows the control chart for 142 cases belonging to Group A. The x-axis of Figure 3 represents each case, and the y-axis displays the ratio of defect repair cost to the construction cost. The control charts in Figures 4 and 5 are all the same. The average ratio of defect repair cost to construction cost of Group A was 0.5287%, and the control limit, UCL, was 1.4438%. In Group A, four cases exceeded the UCL, which accounted for 2.82%.

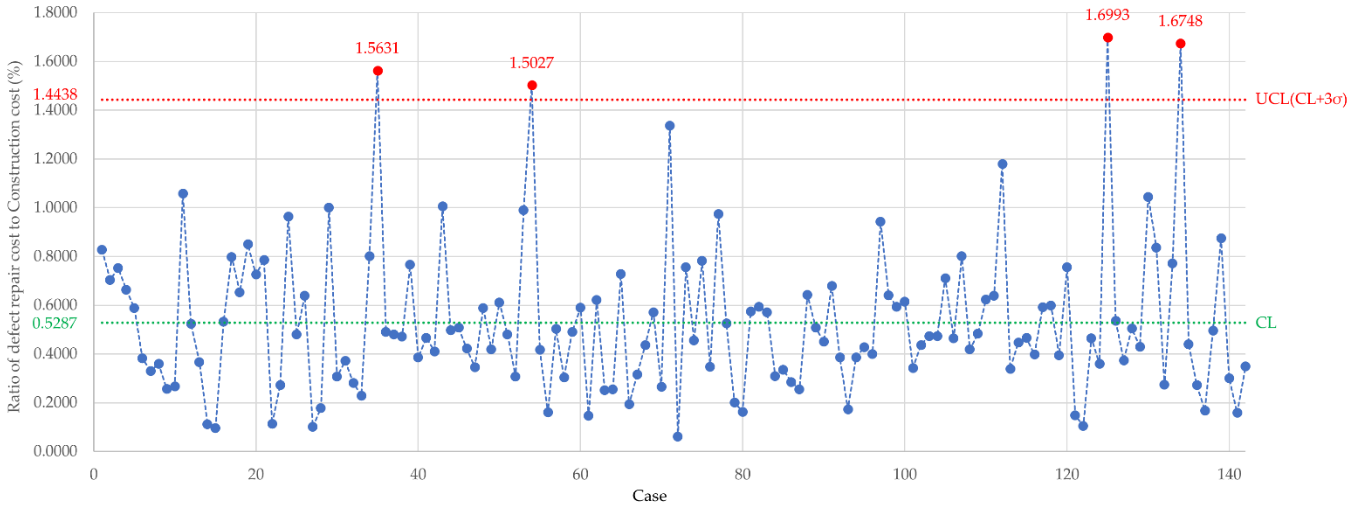

Figure 3. Quality control chart of Group A.

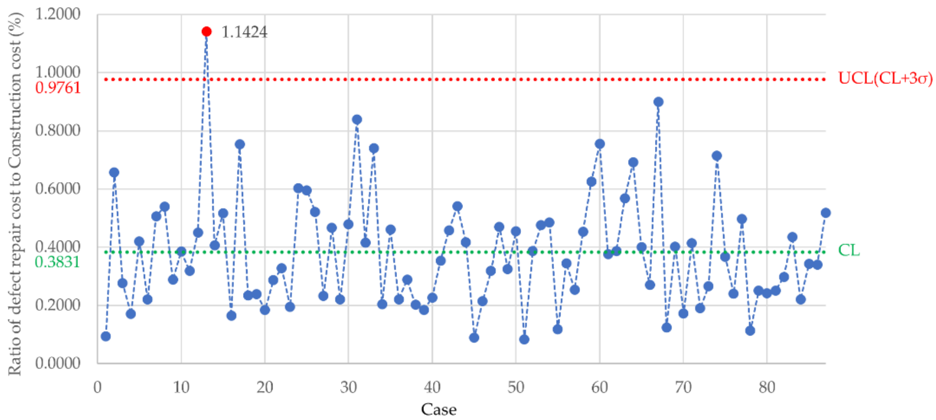

Figure 4. Quality control chart of Group B.

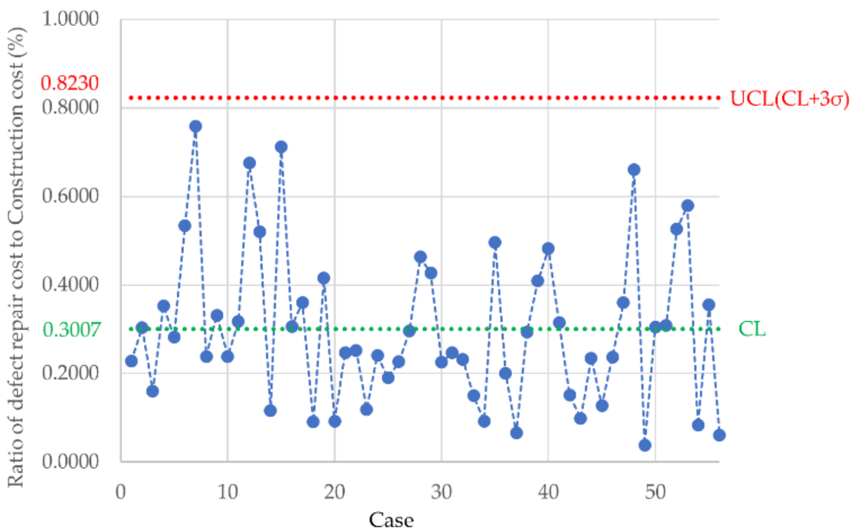

Figure 5. Quality control chart of Group C.

Figure 4, below, shows the control chart for 87 cases belonging to Group B. The average ratio of defect repair cost to construction cost of Group B was 0.3831%, and the control limit, UCL, was 0.9761%. Among Group B, one case exceeded the UCL, which occupies 1.15%.

Figure 5, below, shows the control chart for 56 cases belonging to Group C. The average ratio of defect repair cost to construction cost of Group C was 0.3007%, and the control limit, UCL, was 0.8230%. It was thus confirmed that there were no cases exceeding the UCL in Group C.

According to the previous control chart analysis results, the quality of the three groups, classified according to the size of the construction cost, differs and can be summarized as follows.

First, the CL of each group indicated in Table 3 showed that Group A, with the smallest construction cost, had the highest ratio of defect repair cost to construction cost, while Group C, with the largest construction cost, had the lowest repair cost to construction cost. This implies that as the scale of construction cost increases, the ratio of DRCCC tends to decrease.

Table 3. Comparison of three groups.

Group	Cases	CL (%)	UCL (%)	Quantities of Failure	Percent of Failure (%)
A	142	0.5287	1.4438	4	2.82
B	87	0.3831	0.9761	1	1.15
C	56	0.3007	0.8230	0	0.00

Second, the UCL of each group in Table 3 was 1.4438% for Group A, 0.9761% for Group B, and 0.8230% for Group C. The UCL of Group C was the lowest. This is similar to the trend of the average value of the ratio of DRCCC according to the size of the construction cost.

Third, for the number of failure cases (quantities of failure) and the percentage of failure cases compared to the number of cases in each group indicated in Table 3, there were four failures in Group A, and the failure rate in Group A was 2.82%, which was the highest among the three groups. Group B had one failure, and the failure rate in Group B was 1.15%, which was lower than that of Group A. There were no failures in Group C. Therefore, the higher the construction cost, the lower the number of quality defect cases and the lower the failure ratio.

The above analysis results show that, compared to cases where the size of the housing construction cost was small, the average ratio of defect repair cost to construction cost, the UCL, the quality control limit on the control chart, the number of bad-quality cases, and the ratio of bad-quality cases were all lower for cases with higher construction costs. Therefore, the housing quality evaluated at the post-handover stage was better when the construction cost was higher.

Meanwhile, the analysis results of this study were compared with those of previous studies. As mentioned in Chapter 1 and Section 2.1, previous studies used the ratio of DRCCC. These were divided into a case where the ratio of DRCCC increased as the size of the housing construction cost increased [21] and a case where it decreased as housing construction cost increased [24,25]. However, even when the ratio of DRCCC increased proportionately to the size of the housing construction cost, only the group with the highest construction cost among the four groups had a meager ratio of DRCCC [21]. Therefore, this study's analysis results are consistent with previous studies' opinions.

4.2. Quality Issue to Failure

In Section 4.1, above, four cases of poor quality were derived from Group A and one from Group B. The technical issues presented in the defect lawsuit are discussed in this section.

Table 4 summarizes the outline of the five cases of poor-quality housing. There is a significant difference between groups regarding the number of households, total floor area, construction cost, and defect repair cost. However, one thing is common: the ratio of repair cost to construction cost was about three times the average of each group, and at the same time, the percentage of repair cost to construction cost exceeded the quality control limit of each group. From this point of view, these poor-quality cases can be considered to have more defects and worse quality than other cases.

Table 4. Outline of the failure case.

Case	1	2	3	4	5
Group	A	A	A	A	B
Household	2182	208	236	429	1196
Total floor area (m^2)	366,425.4	30,547.7	34,978.6	38,095.1	157,227.9
Construction cost (million USD)	112.2	15.49	36.65	21.39	138.99
Defect repair cost (million USD)	1.88	0.26	0.57	0.32	1.59
Ratio of DRCCC (%)	1.6748	1.6993	1.5631	1.5027	1.1424
CL (mean, %)	0.5287	0.5287	0.5287	0.5287	0.3831
Std. Dev (%)	0.3051	0.3051	0.3051	0.3051	0.1977
UCL (CL + 3σ, %)	1.4438	1.4438	1.4438	1.4438	0.9762
DRCCC to CL	3.17	3.21	2.96	2.84	2.98
Exceed to UCL	Yes	Yes	Yes	Yes	Yes

In the defect lawsuit for five cases of poor quality, nine issues were raised, as shown in Table 5 below. These can be divided into those concrete cracks and others, and the details of each technical issue will be discussed.

Table 5. Quality issue of failure case.

Object or Work	Technical Issue and Defect Type	Failure Case				
		1	2	3	4	5
Concrete crack	Allowable crack width	O			O	
	Concrete interlayer crack to the outer wall		O			
	The unit price of repair cost	O				
	Surface treatment after crack repairing	O				
	Repair surcharge for building height		O		O	
	Repair method to wet concrete cracking		O			
Landscaping tree	Wither of trees				O	
Sanitary apparatus	Corrosion of bathroom mirror				O	O
Dew condensation	Dew condensation on a private balcony			O		

4.2.1. Concrete Cracks

The disputes related to concrete cracks in poor-quality cases are as follows.

(1) Should the allowable crack width be recognized as a criterion for determining defects?

It is essential to manage concrete appropriately because cracks inevitably occur at a certain level due to material characteristics. From this point of view, quality is defined using cracks occurring in the concrete as a criterion of width, called allowable crack width. The allowable crack width differs according to the usage environment and by country. The standard for the allowable crack width in Korea is set at 0.3 mm. If the crack width is less than 0.3 mm, the trend of whether the crack expands in the future should be observed. On the other hand, when the crack width exceeds 0.3 mm, it should be repaired.

However, in Korea's housing defect litigation, a crack width of less than 0.3 mm is considered a defect and is sometimes judged to be repaired. If, at present, the crack width may widen or cause other problems, it would be reasonable to repair it. However, even though no proof has been produced in the defect lawsuit, it is argued that the cost of repairing it as a defect should be recognized as the defect repair cost.

This can be interpreted as a difference in perspective on quality between home builders and consumers. Homeowners' attorneys who are non-experts in the field of construction maintain the position that cracks should be regarded as defects because, not only do not look aesthetically unappealing, but may adversely affect the durability or safety of the building. However, most home builders, who are experts in the construction field, maintain the position that if the allowable crack width level determined by considering the characteristics of concrete is maintained, it is not a defect; that is, it is not a quality problem but a matter of maintenance.

(2) Should a concrete interlayer crack to the outer wall be recognized as a defect?

Modern Korean homes are mainly constructed as high-rise buildings with reinforced concrete structures. The third floor and the floor below are finished by attaching stones or bricks, emphasizing aesthetics, while the rest are finished with paint on the concrete surface. In the concrete structure, an inter-floor joint, which is a construction joint, occurs between a lower floor constructed first and a higher floor constructed later.

In Korea's housing defect lawsuit, the homeowner's attorneys continue to argue that the interlayer joint of the outer wall should be regarded as a crack, and since this is a defect, the repair cost for it should be compensated. However, as with the allowable crack width, housing developers who are experts in the construction field are vehemently protesting that interlayer joints are construction joints that inevitably occur during the construction of concrete structures and that they are not defects.

(3) What should be recognized as the unit price of repair cost?

Since concrete is Korea's most used building material, there is a high demand for concrete crack repair materials. Accordingly, Korean or global concrete material companies are developing distinctive repair materials that can be used under various conditions, and there are dozens of concrete repair materials on the market. In Korea, companies that manufacture or distribute concrete repair materials disclose the prices of their products every month in a market price information magazine. Since the products offered by each company are diverse, the price range is also quite different, but there is no specific quality standard or judging standard for the superiority or inferiority between products.

With this scenario, the homeowner's attorneys in Korea's housing defect lawsuit insist that the repair cost be calculated based on the market's most expensive concrete repair materials. On the other hand, housing developers are fighting back that they should calculate the repair cost based on the cheapest product.

(4) Is surface treatment after crack repair necessary?

As mentioned earlier, the outer walls of Korean buildings are finished by painting the concrete surface. Therefore, when a crack is repaired, the surface must be repainted. To repair cracks, foreign substances are removed around the cracks using sandpaper or wire brush, and then repair materials are applied to the surface of the cracks or injected into the cracks to fill them. When the crack repair is completed, the repaired area is finished by applying paint using a paint roller or brush.

Generally, surface treatment or pretreatment work removes foreign materials from the surface and ensures evenness before painting. However, there is a difference between painting as a whole, or for the first time, and painting after a repair, where only the repaired area is painted.

However, in Korea's housing defect lawsuit, the homeowner's attorneys insist that the painting process after repairing the cracks should include the surface treatment work and that the repair cost be recognized, including the surface treatment. On the other hand, housing developers are in a position where it is unnecessary to perform the surface treatment in the painting process after repairing the cracks because the surface treatment has already been performed while repairing cracks.

(5) Should a repair surcharge for building height be applied to crack repair work?

Most Korean homes are high-rise buildings, and for crack repair, mechanical equipment such as a telescopic handler, scissor lift, gondola scaffolding, or rope access scaffolding, installed using a rope on the roof, is used for the work. In Korea, the construction works standard estimating system, one of the standards for calculating the cost of new construction works in the public sector, specifies the surcharge standard considering the risk of working at heights. However, in general, it is rare to use a telescopic handler, scissor lift, or gondola scaffolding due to the cost and workability, and most work is completed using rope access scaffolding. Since the repair contractors are used to working at heights, the repair cost is quoted considering this, and a separate surcharge for working at heights is not appropriated.

However, in Korea's housing defect litigation, the homeowner's attorneys insist that the surcharge for working at heights should be applied to the crack repair cost based on the construction work standard estimating system. On the other hand, housing developers argue that since the construction work standard estimating system is used only in new construction, it has nothing to do with defect repair. Moreover, since they are used only in the public sector, they cannot be enforced in the private sector. To top this, it is also appealing because it is against the cost calculation practices of crack repair parties.

(6) Which one should be applied as a repair method to wet concrete cracks?

For concrete crack repair, an appropriate process is applied depending on the width and location of the crack, and it is also divided into dry cracks and wet cracks depending on the environmental conditions. Wet concrete cracks occur in a wet environment or are accompanied by water leakage. Since these wet cracks are highly likely to carbonate the inner concrete and cause the corrosion of reinforcing bars, synthetic resin materials such as acrylic and epoxy are added, increasing the cost. However, even in this case, no objective index to evaluate that particular material is superior, and no such evaluation has ever been made.

In a housing defect lawsuit in Korea, homeowner's attorneys claim that wet concrete cracks must be repaired by applying only products sold by a specific manufacturer. On the other hand, housing developers give an opinion that since there is no apparent reason the homeowner's attorneys insist on a particular product, inexpensive or at least average-priced products can be used unless there are exceptional circumstances that make it unreliable among the various products on the market.

4.2.2. Other Issues

The issues other than concrete cracks in the case of poor quality are as follows.

(1) Wither of trees:

Korea has traditionally had a culture of not planting landscaping trees around homes. However, since the civil war in 1950 and the period of industrialization that began with restorations from the war, most traditional housing disappeared, large-scale housing complexes adapted from western-style residential plans were created, and landscaping trees began to be planted in the complexes. Currently, planting a certain number of trees in Korea is compulsory when constructing a housing complex based on local ordinances. Therefore, various landscaping trees are planted in all housing complexes.

Unlike the other issues mentioned above, planting landscaping trees at the time of housing construction and the maintenance of trees after house completion, is critical, affecting the occurrence of defects. Landscaping trees are living organisms, so management after planting is vital. Growth is affected by the amount of sunlight, precipitation, or drainage, and maintenance such as disease prevention, pruning, manure, and replacement of tree stakes must be performed periodically. It is known that landscaping trees, rooted in the soil, take at least two years before they can survive without regular maintenance. For this reason, housing developers often perform follow-up management, such as replacing withered or poorly established trees, during the warranty period of 2 to 3 years after the completion of the building.

However, in Korea's housing defect lawsuit, the homeowner's attorneys claim that the housing developer is solely responsible for the death of landscaping trees without considering their characteristics. On the other hand, housing developers are protesting that they have performed follow-up management, which should be considered.

(2) Corrosion of bathroom mirror:

In the bathroom of Korean houses, a mirror is attached to the upper wall where the sink is installed and to the storage closet. However, since the washbasin is a space where water is continuously used, the lower part of the mirror installed above is often in contact with water, and various detergents used while washing the face or brushing teeth are likely to splash and remain. Therefore, if ventilation is insufficient or residual detergent is not removed in time, discoloration and corrosion may occur at the lower edge of the mirror. In particular, using alkaline or acidic detergents affects the silver component of the mirror, resulting in severe discoloration.

In the housing defect lawsuit in Korea, the homeowner's attorneys claim that the corrosion of the bathroom mirror that has been used for years is entirely due to the fault of the housing developer. On the other hand, housing developers refute that it is not a defect as it is a problem caused by the influence of the usage environment.

(3) Dew condensation on private balconies.

Korean apartments are designed with balconies that can be entered and exited through doors, with attached storage facilities, and are often used as spaces to hang laundry or grow pots, and the balconies are rather significant. In addition, Korea has four seasons, and the temperature difference between summer and winter is considerable. Heat loss is exceptionally high in winter from windows and walls in contact with balconies. Therefore, except for areas in the south that are mild in winter, most balconies have additional windows installed.

If a window is installed on the balcony, it is less cold, but condensation can quickly occur due to poor ventilation. To prevent condensation, ventilation is essential because the moisture generated in the house or on the balcony must be controlled below a certain level. To prevent moisture from cooling below the dew point and forming condensation on the balcony walls and ceilings, it is necessary to install insulation materials on the walls and ceilings inside the balcony. Even in the case where windows are installed on balconies, products with excellent insulation and airtightness should be used. However, it is difficult to ventilate in winter due to frequent cooling and energy problems. In addition, the additional cost of insulation and window construction inevitably increases housing construction costs. Moreover, since the balcony is not an indoor space, insulation of the balcony is not compulsory even in Korea's housing construction standards. Therefore, most balconies of Korean apartments are not insulated.

In Korea's housing defect lawsuit, the homeowner's attorneys claim that the condensation on the uninsulated balcony is a defect caused by the housing developer's fault. On the other hand, housing developers refute that it is a problem in use, citing that balconies are not mandated to be insulated and can be managed through proper ventilation in winter.

4.3. Review Results of Technical Dispute

The disputes over the quality defect cases discussed above (Table 6) can be classified into three categories: presence or absence of quality standards, presence or absence of industry practices, and problems in use.

Table 6. Classification of quality issue.

Detailed Issue and Defect Type	Quality Standard	Industry Practice	Problem in Use
Allowable crack width	O		
Concrete interlayer crack to the outer wall	O		
Unit price of repair cost		O	
Surface treatment after crack repairing		O	
Repair surcharge for building height		O	
Repair method to wet concrete cracking		O	
Wither of tree			O
Corrosion of bathroom mirror			O
Dew condensation on the private balcony			O

First, there are quality standards established by academia and industry, and there are issues that are not accepted by homeowners, even if these are judged as not defective according to that standard. Such cases include the allowable crack width of concrete and construction joints.

Second, although there is no clearly defined quality standard, some are not recognized by homeowners even though they have been settled as an industry practice for decades and are treated like customary law. Four issues, such as the unit cost of concrete repair and the surface treatment after crack repair, fall under this category. Moreover, these are not defects in themselves but are about the method of repairing defects. However, they are critical issues because they significantly impact repair costs.

Third, there is no separate quality standard, and it is seen as a problem in use. These include the withering of trees, corrosion of bathroom mirrors, and dew condensation on private balconies. Since these show a significant difference in the tendency of defect generation according to the user's management, it is a problem that can be considered as having a profound influence on use.

5. Discussion

As reviewed above, this study proposes a comparison result using a control chart by dividing the construction cost by the repair cost ratio for defects in the post-handover stage. Based on the results, quality standards, limit levels, and quality defect cases that exceed the limit levels were derived for each construction cost size. In addition, the types of quality issues raised explicitly in defect lawsuits for poor-quality cases were investigated. Based on these research results, measures to improve housing quality management and quality standards are discussed in this chapter.

5.1. Housing Quality Management

Disputes over housing quality are increasing worldwide. In the case of Korea, housing defect litigation has become an ex-post evaluation, and it was found that significant defects occurred and existed in the housing. The lawsuit itself began with consumers' distrust of housing producers. Therefore, housing developers must evaluate quality at the levels of the entire industry, each company, and each site and restore consumer trust by independently defining, disclosing, and guaranteeing quality.

According to the results of this study, which compared housing quality using the ratio of defect repair cost to the construction cost as a criterion, there is a difference in housing quality according to the scale of construction cost. In particular, quality control is weak in housing complexes with small construction costs, which seems necessary to improve. In general, the smaller the construction cost, the more difficult it is to achieve economies of scale in terms of construction cost. Therefore, securing an appropriate budget and managing quality is necessary to reduce errors and waste in housing construction projects with small construction costs. It is also necessary to supplement the labor and actively introduce a systematic approach.

On the other hand, lessons learned from poor-quality cases should be fully utilized. Among the construction industries, the housing sector is easy to enter, and many construction companies are active as housing developers in Korea, which causes fierce competition. Therefore, even though there is less room for profit without a surplus of construction costs, the orders are accepted with a low profit or even deficit to operate companies, and more cases are operated like zombie companies. If housing quality issues are raised and maintenance expenses are continuously spent, a considerable hindrance to corporate management will result, and there is a risk that the entire industry will face a crisis. To prevent housing defects, improve quality, and maintain excellent conditions, quality failure cases should be reviewed, and long-term research and investment should be observed.

For that, accumulating big data and utilizing information will be helpful in follow-up management and evaluation. Just as housing developers have built a company by acquiring knowledge over a prolonged period while designing and constructing for decades, it is necessary to accumulate and analyze data on follow-up management and evaluation and use it as helpful information. As in the analysis of housing defects using control charts in this study, it is vital to recognize the problem and devise specific improvement plans by comparing the entire industry and the entire business or by comparing the entire business and individual businesses. Collaboration and cooperation between the entire industry or related companies are required. Diagnosing problems and receiving guidance on improvement plans in connection with experts in academia are also crucial.

Based on the results, improving quality management is strongly recommended, as illustrated in the control chart of Group A (Figure 6). First, all cases' quality levels must be below the UCL, the current quality control limit. Second, a future target point should be set, and the quality control limit should be strengthened from the current CL+3σ to the CL+2σ level. Third, the future quality average CL should be lower than the current quality average CL.

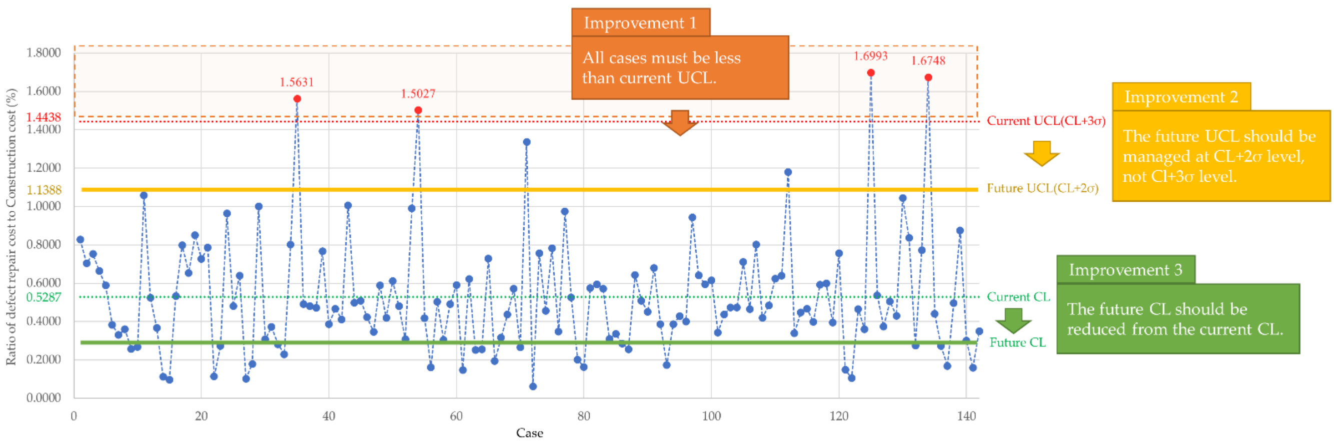

Figure 6. Improvement in quality management.

5.2. Consumer-Centered Housing Quality Standard

To improve the quality of housing, the perspectives of consumers, home buyers, and house owners must be accepted. Korea has just gone from a developing country to a developed country, and the mindset of the industrialization period, the producer-centered mindset, is still dominant. Since the Korean housing market is not perfectly competitive and is like an oligopoly market, consumers cannot exercise their rights properly because they do not have many opportunities to choose from. However, with the entry into developed countries, new housing demand is declining, and the construction and housing industries have become stagnant, which implies severe competition in the future. If the industry does not think in a consumer-oriented way and does not listen to the voices of consumers, getting away from a producer-centered mindset, its survival will be at stake. If the quality of housing is not improved, only some consumers will lose in recent years, but after all, the catastrophe of lawsuits can cause significant or irreparable damage. Therefore, this study can be a lesson for developing countries that will join the ranks of developed countries in the future.

From this point of view, the quality standard related to housing is established through hundreds of years of research; they may not be understood from the consumer's point of view. In other words, it may be regarded as not customer-friendly at all. For example, the allowable crack width in concrete should be considered among the quality issues mentioned above. Based on various standards and technical data, Korean housing developers and the concrete industry claim that microcracks that are less than the allowable crack width in concrete are not defects. However, consumers do not want to understand intricate technical knowledge such as allowable crack width, and having cracks in their homes is unpleasant and worrying. That is, the consumer's point of view seeks to even prevent cracks that are less than the allowable crack width from occurring or to manage them if they do occur. To improve quality to a level that meets the expectations of these consumers, it is necessary to reduce the number of cracks and strengthen follow-up management so that the width of cracks does not widen.

On the other hand, there are no related quality standards, and improvements are needed for practices that have become well-settled in the industry. Consider the case of height surcharge according to the height of a building. Construction disasters and accidents have recently increased in Korea, and unfortunate loss of life due to collapse and fall accidents during new housing construction and maintenance has become a social issue. These are due to insufficient safety measures, mainly caused by reducing the number of workers and monitoring personnel or not installing protective facilities and safety equipment. According to their practice, the industry does not calculate the cost by setting separate items applicable for height surcharge during quotation, but they answer that they are estimating the cost considering the risk of working at height during construction. However, since the social atmosphere is shifting in such a way that it is challenging to trust construction safety, it becomes a matter of concern for the public. Considering the consumer's point of view, the surcharge for work at height was reflected when calculating the cost of repairing cracks, and now it is necessary to clarify the cost calculation system to confirm the surcharge matter.

It is also necessary to consider the customer's viewpoint for the issues which are difficult to ascertain as defects due to irrelevant quality standards and those which are caused by the users' management and use habits. For example, the corrosion of bathroom mirrors is due to the use of water and detergent, which causes a tremendous functional and aesthetical hindrance from the user's point of view. Considering the original function of a mirror is to manage oneself by reflecting a user's face, mirror corrosion can be seen as a severe problem because it interferes with an original function. Although mirror corrosion is primarily the result of user habits, that alone is not a reason to neglect what can be improved. Housing developers are producers, not consumers, who often encounter the quality problem of mirror corrosion. Therefore, since housing developers know that consumers' habits of using water and detergent in the bathroom cause mirror corrosion, they need to inform consumers of this to prevent it entirely.

In most cases, mirror corrosion occurs on the lower edge of the mirror, where water or detergent can easily reach, so it is possible to prevent corrosion by changing the shape of the mirror or attaching a protective material so that water or detergent does not directly touch this part. Therefore, when designing bathrooms and procuring mirrors, housing developers can prevent quality problems by constructing mirrors and protective materials that have these functions. It is not to neglect saying that the problem is due to the consciousness and habits of the consumer. Instead, housing developers should proactively prevent quality issues and help reduce defects, ensuring the customer's satisfaction and raising their trust in housing developers.

Combining the above discussions, the following improvement measures can be suggested for individual quality issues, as shown in Figure 7 below. First, the existing quality standards must be reviewed and supplemented to restore consumer trust in the quality standards of the academia and the industry. Second, the industry's unclear practices should be corrected, and clear standards should be introduced. Third, the use problem should be considered from the consumer's point of view, not the producer's, and the producer should step forward to improve the quality.

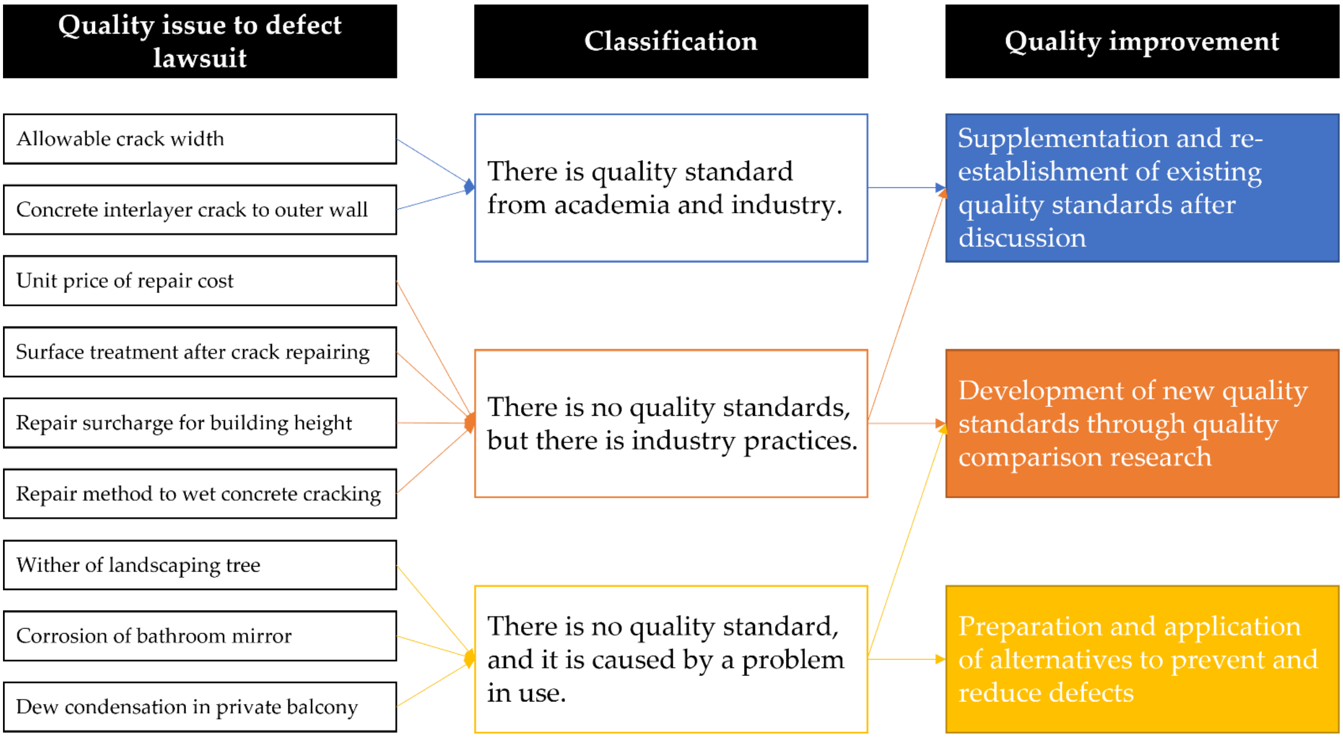

Figure 7. Quality improvement plan through the viewpoint of the consumer.

6. Conclusions

An appropriate level of housing quality must be supported to lead a stable and comfortable residential life. However, there is a significant difference between the level suggested by producers and the level desired by consumers regarding housing quality. As a result, disputes over housing quality are increasing worldwide. In this regard, efforts are being made to address problems after defining and evaluating housing quality. Thanks to the efforts of previous studies, housing quality can be defined and evaluated using various standards, but there are fewer methods for quantitative and objective evaluation. In this regard, previous studies compared the number of defect occurrences, the defect repair cost, and the defect repair cost ratio to the construction cost to assess the magnitude of defects. Among them, the number of defects cannot be compared between items of different scales, and with the defect repair cost, the difference in scale, such as the construction cost, area, and number of households, cannot be figured out. On the other hand, the ratio of repair cost to construction cost can be compared relative to the size difference. Therefore, this study adopted it as a criterion for quality comparison.

This study targeted Korean housing complexes and classified the repair costs against construction costs using the decision tree method. An ANOVA test result, the F-test, showed a difference according to the size of the housing construction cost, and it was classified into three groups. The repair cost ratio to construction cost was used as a dependent variable for each group and was analyzed using the control chart technique. It was possible to classify five defective cases. The repair cost ratio to construction cost was almost 3 times the average of each group. It exceeded the upper limit line on the control chart.

This study found that the larger the scale of the housing construction cost, the lower the ratio of the repair cost to the construction cost, and the lower the number and rate of cases exceeding the control limit. That is, the group with a considerable construction cost was superior in quality compared to the group with a small construction cost. As a method of measuring and comparing housing quality, the ratio of repair cost to construction cost and the control chart technique might have helpful aspects. However, it is unfortunate that variables that indicate the house size other than the construction cost were not reflected. The results of this study are expected to help understand the Korean housing industry's quality level and be used in critical decision-making, such as the level of their current business and how to set future quality improvement goals.

The control chart analysis showed that there were cases of poor quality that exceeded the control limit. The quality issues in the defect lawsuit were divided into cases where there is a dispute even though there are existing quality standards, contradicting with industry practice though there are no quality standards and usage issues. However, there is a limit to that. Although the housing industry is not responsible for this quality dispute or has a meager responsibility, it did not consider the customer's perspective. In this study, therefore, it is requested that the academia and the industry make joint efforts by actively accepting the consumer's point of view. This must be proceeded not only in Korea but also worldwide.

On the other hand, this study also has the following limitations. The housing complex in the litigation data collected for this study includes only pre-sale housing and does not include social housing such as rental housing. Generally, there seems to be a difference in their quality because pre-sale housing uses better products in terms of finishing and facilities than rental housing. However, it is difficult to accept the conclusion that the quality of rental housing is unconditionally low and that poor quality is taken for granted. To stabilize housing for the socially underprivileged, rental housing must maintain an appropriate level of quality, and it is believed that the involvement and effort of the whole society are necessary to achieve improvements. It is essential to investigate and evaluate the quality level of rental housing and prepare reasonable quality standards and management plans according to the results.

In addition, it was not possible to make a quantitative comparison of the extent to which the defect repair cost differs according to technical issues in housing defect lawsuits. To adjust the difference more rationally in viewpoints between the producers and consumers, a follow-up study on this is necessary.

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