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Full length research paper

Deduction of critical influence factors on defect judgment in apartment housing using fail mode and effect analysis

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The number of apartment housing defect lawsuits has been gradually increasing in Korea. Wasted time and costs in social terms resulting from defect lawsuits are becoming a serious issue. Apartment housing defect lawsuits occur due to disputes on defects caused by conflicts among participants related to defects. It is necessary to minimize conflicts among participants.Therefore, the purpose of this study is to deduct critical influence factors that affect judgment on apartment housing defects using failure mode and effect analysis (FMEA) and to minimize conflicts among participants related to defects. The methods and procedures used in this study are as follows. First, potential influence factors were selected by interviewing defect assessment companies and court appraisers. Second, a survey on defect assessment companies and court appraisers was conducted based on selected potential influence factors for occurrence, severity, and detection (three evaluation scales of FMEA), and the top 10 factors for the three scales were compared. Finally, critical influence factors were derived by calculating the risk and risk grades of potential influence factors. The results of this study are follows.Among 22 potential influence factors, the factors that affect judgment on apartment housing's defects deducted 'selection of a defect assessment company with a low price bidding method' and factors related to capabilities of participants. These findings will be used to devise strategies to minimize conflicts among participants in the process of apartment housing defect lawsuits.

Keywords: Apartment housing; Defect Lawsuit; Failure Mode and Effect Analysis (FMEA); Critical influence factors

INTRODUCTION

Defects in apartment housing are one of the most important issues in Korea. According to the *Korean Apartment Newspaper* (2009), the number of apartment housing defect lawsuits was 60 in 2003, 78 in 2004, 87 in 2005, 101 in 2006, 167 in 2007, and 290 in 2008; the number increased every year from 2003 to 2008.Such increase in defect lawsuits is due to the rise in defect disputes among participants related to apartment housing defects (Cho, 2011). One of the reasons is that there are differences in the appraisal amount determined by defect assessment companies, appraisal amount determined by court appraisers (Seo, 2013), and judgment amount determined by the court. The difference causes conflicts between participants. Here, participants are residents, defect assessment companies, construction firms, court appraisers, and the justice department. Conflicts among the participants prolong the defect lawsuit period, triggering wasted time and costs to society as a whole as well as the participants (Shin, 2009; Kim, 2011).

In order to minimize conflicts among participants in apartment housing defect lawsuits, influence factors that affect defect judgment should be produced, and measures to improve the factors are needed. Previous studies have presented modifications of laws and standards related to defects, the construction of a defect database, and changes in court appraiser selection

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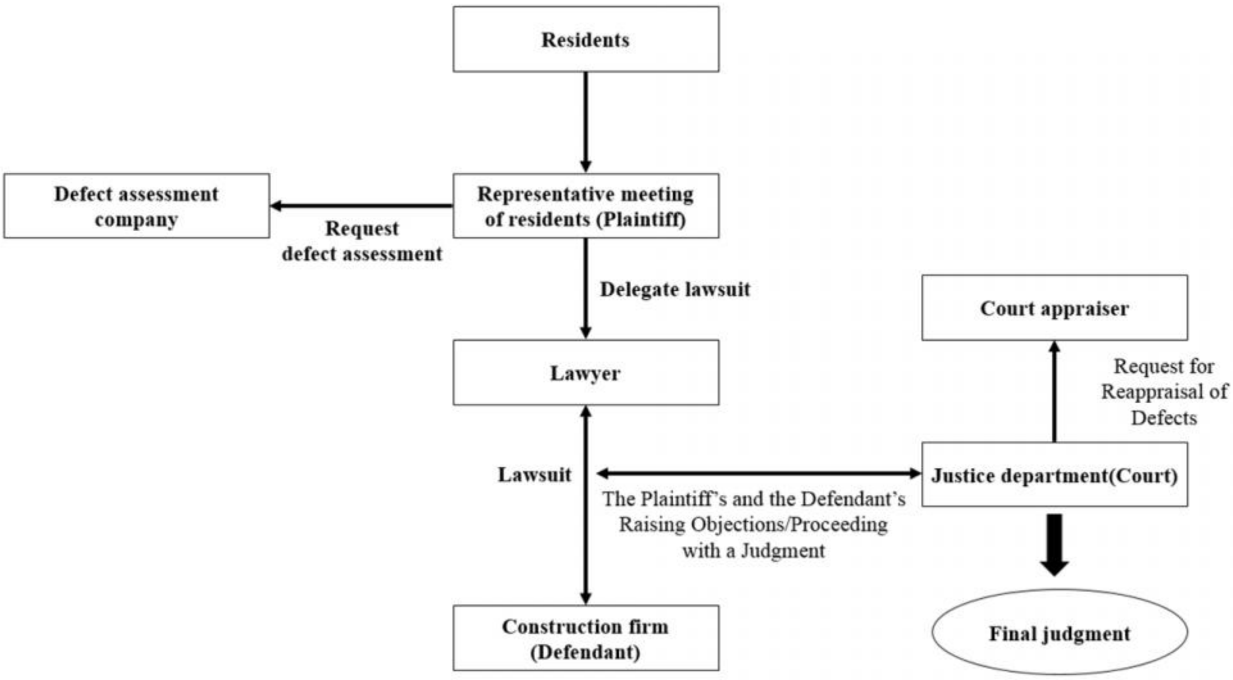

Figure 1. Flowchart of Judgment on Apartment Housing Defects in Korea

standards as measures for improvement. However, they have failed to present measures for improvement by resolving practical problems or deriving critical influence factors.

Therefore, the aim of this study is to select potential influence factors that affect defect judgment on Korean apartment housing by interviewing defect assessment companies and appraisers and deriving critical influence factors that should be enhanced among selected potential influence factors using failure mode effect analysis (FMEA). Thereby, measures that minimize conflicts among those who participate in apartment housing defect lawsuits will be presented in this study.

Literature review

Defect judgment of apartment housing in Korea

Repairs of defects including cracks, water leakages, and surface condensation and fraudulent construction works that occur in Korean apartment housing are requested to construction firms through collective lawsuits to protect the rights and interests of residents. When such requests for defect repairs are not well-accepted, residents file defect lawsuits, claiming defective guaranty costs and punitive damages (Doo, 2010).

The flow of defect judgment on Korean apartment housing is illustrated in Figure 1. Residents organize a representative meeting of residents for a defect lawsuit. The representative group of residents is a major interested party in a defect lawsuit and hires a lawyer to entrust overall matters. Then, the grouprequests a defect appraisal by a defect assessment company in order to obtain materials to prove defects. Based on the appraisal result by this defect assessment company, the group proceeds with a defect lawsuit with the construction firm, the defendant. During a defect lawsuit, the justice department reappraises the appraisal results reported by the defect assessment company through a court appraiser belonging to the court and constructs data for judgment. Finally, the justice department (court) makes a defect judgment based on the appraisal results from the defect assessment company and the court appraiser. However, in this process, serious conflicts for each party's own interest occur between residents and the construction firm.

Failure Mode and Effect Analysis

FMEA is a method used to evaluate the influence on the entire system or the severity of the influence when a failure in each process, each element of the system, takes place (Stamatis, 1997). FMEA evaluates the occurrence of failures due to potential risk factors, the severity of the result when a failure occurs, and the detection of failures from customers; it derives a risk priority number (RPN) by multiplying the three elements. FMEA prevents the occurrence of failures and minimizes their impact by concentrating on a small number of high-risk prioritized items (Pyzdek, 2003).

FMEA techniques are divided into five types: system, design, process, facility, and service FMEA. They also may be differentiated into functional, realizable, and process FMEA according to the developmental stage. Unlike failure tree analysis and failure mode and critical analysis, FMEA is the most widely used risk evaluation method and an effective method to predict and remove potential problems in advance. Moreover, unlike system FMEA and design FMEA, process FMEA has focused on methods to decrease defective products and may review the possibility of a failure increase by determining the detection number of potential process problems (Lawson, 1983).

This study aims to produce critical influence factors that affect judgment on apartment housing defects. In order to derive critical influence factors, this study applied process FEMA that easily identifies faulty product decreases and fatal and crucial characteristics among the FMEA techniques.

Previous study

Various studies related to apartment housing defects have been conducted. Kim (2008) surveyed the causes of defect discontent from the staff in charge and experts who working on defect-related businesses and finally proposed a countermeasure scheme on lawsuits of defect discontent. Kim et al. (2008) proposed a personal digital assistant (PDA) and wireless web-integrated quality inspection and defect management system (QIDMS) that can collect defect data at a site in real time and effectively manage the statuses and results of the corrective works performed by crews. Yoon (2008) categorized the problems with the disputes over apartment house defects by reviewing those defects theoretically and analyzing the court decisions in lawsuits to claim guaranty money for defects to suggest some improvement measures and a search model to prevent any risk for defects, and ultimately to make a contribution to the resolution of such disputes. Shin (2009) analyzed different categories of defects in relation to apartment housing to understand the status of legal disputes over such defects and prepare basic data to provide input to such disputes. Cho (2011) analyzed defect lawsuits leading to action taken against contractors, and strategic countermeasures were proposed according to the type and size of the defect. Kim (2011) drew on the cases of defects occurring in apartments houses constructed domestically to investigate the differences in the recognition of defect-related experts and to survey/analyze the problems 25 apartment houses' defect management plans in order to suggest an improvement plan for efficient management. Lee (2011) analyzed the types of construction defects based on repair records and status reports for 14,762 households at 17 apartment complexes in the greater Seoul area for the purpose of classifying the types of construction defects. Jung (2012) analyzed defect management through judicial precedents of landscape construction defects and suggested methods for improving defect management. Park et al. (2013) presented a conceptual system framework for construction defect management with a comprehensive and proactive mechanism by linking ontology and augmented reality with building information modeling.

Previous studies of apartment housing defects have largely attempted to preempt construction and elemental critical defects using appraiser results provided by defect assessment companies. Other researchers have developed measures to minimize disputes by presenting defect management methods or each participant's measures to cope with defect lawsuits. However, they failed to derive critical influence factors affecting judgment on apartment housing defects and to take into account practical matters. Accordingly, this study will derive critical influence factors that affect judgment on apartment housing defects through interviews with working groups and FMEA, and present practical measures to improve such factors.

RESEARCH METHODOLOGY

This study was divided into two stages. In the first stage, potential influence factors were selected, and the second stage involved producing critical influence factors. During the first stage, interviews with working groups from defect assessment companies and court appraisers were conducted. Then, potential influence factors were selected by examining previous studies. During the second stage, evaluation scales for a survey and risk grades for FMEA were determined. An FMEA questionnaire was composed based on the selected potential influence factors and evaluation scales, and a survey to calculate risk and risk grades was carried out. In addition, reliability analysis was made using SPSS Statistics 18 in order to determine the reliability of the survey results. Lastly, the top 10 factors for the occurrence, severity, and detection numbers were derived and compared, and risk grades were calculated to produce critical influence factors affecting judgment on apartment housing defects.

Selection of potential influence factors

Potential influence factors affecting judgment on apartment housing defects were selected by examining previous studies and interviewing working groups of defect assessment companies and court appraisers. Table 1 shows the potential influence factors that were chosen. There were 22 influence factors in four items. The four items are defect assessment companies'

Table 1. Selected potential influence factors

Item	Influence factors	Code
Measurement and appraisal	Involvement of defect measurers' subjective views	A-01
	Differing defect measurement methods according to defect assessment companies and court appraisers (defect measurement locations and equipment)	A-02
	Selection of differing defect repair methods according to defect assessment companies and court appraisers	A-03
	Application of differing costs (material cost and labor cost) according to defect assessment companies and court appraisers	A-04
Institutions and guidelines	Inconsistent reduction of appraisal amount due to restricted responsibility of the justice department	B-01
	Insufficiency in receivables transfer rate by the representative meeting of residents (plaintiff)	B-02
	Unclear standard for defect judgment	B-03
	Lack of guidelines by defect assessment companies for defect measurement standard and methods	B-04
	Lack of application standard and guidelines by defect assessment companies for defect repair methods	B-05
	Lack of consistent guidelines by defect assessment companies for cost application standard	B-06
	Selection of a defect assessment company with a low price bidding method	B-07
Capabilities	Performance of appraisal by a non-professional court appraiser	C-01
	Lack of professionals (facilities, electricity, and landscaping) owned by the defect assessment company	C-02
	Selection of court appraisers with lack of expertise	C-03
	Residents' lack of special knowledge	C-04
	Lack of technical understanding of the justice department	C-05
	Differences in defect investigation scope resulting from defect assessment companies' technological differences	C-06
	Lack of technical human resources due to petty status of court appraisers	C-07
Mind	Lack of residents' interest in defect appraisal	D-01
	Lack of defect assessment companies'responsibility for appraisal outcomes	D-02
	Excessive appraisal by defect assessment companies aligned with the plaintiff's interest	D-03
	Differences in perspectives among defect assessment companies	D-04

measurement and appraisal, institutions and guidelines on a national level, capabilities of defect appraisal participants, and perspectives of participants related to defect appraisal.

Determination of evaluation scales and risk grades

Determination of evaluation scales

Evaluation scales were established as the occurrence, severity, and detection numbers in consideration of the different characteristics of the construction industry from those of the manufacturing industry. Table 2 displays the concept and evaluation scales for the occurrence, severity, and detection numbers. To evaluate each item, the 10-point scale most universally adopted in FMEA was applied.

The occurrence number is a scale that evaluates the frequency with which a given influence factor affects judgment on apartment housing defects. The severity number is a scale that evaluates a given influence factor's influence on defect judgment. The detection number is a scale that evaluates a given influence factor's influence on the defect judgment result.

Determination of risk grades

The determination of risk grades is the most important part of FMEA. Risk grading involves objectively evaluating what influence a given factor has and providing a grade; it is the standard to determine a factor's priority through the objective evaluation of factors and to developmeasures (Stamatis, 2003).

In many cases, RPN is used as the standard to determine ordinary risk grades using FMEA. This study intended to derive risk ranking through RPN, but the

Table 2. Evaluation scales for the occurrence, severity, anddetection numbers

Score	occurrence number	severity number	detection number
1point	Little possibility for the influence factor to occur	The severity number of the influence factor is very small	The influence of the defect judgment on the result is much smaller than expected
2points	Low possibility for the influence factor to occur	The severity number of the influence factor is small	The influence of the defect judgment on the result is smaller than expected
3points	Relatively low possibility for the influence factor to occur	The severity number of the influence factor is relatively small	The influence of the defect judgment on the result is relatively smaller than expected
4points	Not so low possibility for the influence factor to occur	The severity number of the influence factor is slightly small	The influence of the defect judgment on the result is slightly smaller than expected
5points	Moderate possibility for the influence factor to occur	The severity number of the influence factor is moderate	The influence of the defect judgment on the result is close to what was expected
6points	Not so high possibility for the influence factor to occur	The severity number of the influence factor is not so large	The influence of the defect judgment on the result is not so large than expected
7points	Slightly high possibility for the influence factor to occur	The severity number of the influence factor is slightly large	The influence of the defect judgment on the result is slightly greater than expected
8points	High possibility for the influence factor to occur	The severity number of the influence factor is relatively large	The influence of the defect judgment on the result is relatively greater than expected
9points	Very high possibility for the influence factor to occur	The severity number of the influence factor is large	The influence of the defect judgment on the result is greater than expected
10points	Almost inevitable possibility for the influence factor to occur	The severity number of the influence factor is very large	The influence of the defect judgment on the result is much greater than expected

number of potential influence factors was relatively large at 22, and the number of overlapping ranks became large. Therefore, this study simultaneously considered risk ranking and risk grading.

For risk ranking and risk grading, grade element i for a factor is determined, the coefficient for each element Ci is evaluated by technical judgment, and risk (Cs) is calculated. In this study, risk (Cs) may be interpreted as the degree of the given factor affecting defect judgment. Risk is calculated using the geometric average of coefficients determined by an expert's technical judgment (Yoon, 2013).

$$Cs = \sqrt[i]{C1 \times C2 \times C3 \ldots Ci} \quad (1 \le Ci \le 10)$$

Where Cs: risk; i: grade element; C1: occurrence numbervalue; C2: severity numbervalue; C3: detectability numbervalue

Here, grade element i may be arbitrarily selected, but it is good to include the degree of importance and the occurrence number if possible. Risk is divided into four grades—grade I, grade II, grade III, and grade IV—according to the score of influence factors, and the classification of risk grades is shown in Table 3.

RESULTS AND DISCUSSION

Outline of the survey

This study employed FMEA to derive critical influence factors affecting judgment on apartment housing defects. In order to utilize FMEA, a survey should be conducted, and for the survey, an expert team consisting of four to ten experts according to the characteristics of study subjects should be formed (Mikulak et al., 1996). In FMEA, team members' opinions are reflected during the project, and fatal factors are derived and addressed. This process is repeated. However, most of the prior studies using FMEA have only conducted a survey once due to the difficulty in deriving factors by forming a team.

Table 3. Classification of risk and risk grades

Risk Grades of Influence factors	Risk Grade(Cs)
I. Fatal influence factor	7~10points
II. Significant influence factor	4~7points
III. Minor influence factor	2~4points
IV. Very small influence factor	0~2points

Table 4. Results of reliability analysis

Item	Evaluation Scale	Cronbach's α	Number of Items
	Occurrence number	0.769	
Measurement and appraisal	Severity number	0.826	4
	Detection number	0.782	
	Occurrence number	0.826	
Institutions and guidelines	Severity number	0.805	7
	Detection number	0.838	
	Occurrence number	0.746	
Capabilities	Severity number	0.778	7
	Detection number	0.790	
	Occurrence number	0.793	
Mind	Severity number	0.808	4
	Detection number	0.825	

Accordingly, this study included a total of 21 subjects in consideration of the number of surveys, survey period, and survey reliability. The subjects were defect assessment companies and court appraisers who had taken part in apartment housing defect lawsuits; the survey period was five days, from March 3 to March 7, 2014.

Reliability analysis results

This study used SPSS Statistics 18 program to verify the reliability of the survey results. Reliability analysis is used to produce consistent results when a subject is measured by similar measurement tools several times or repetitively measured by a single measurement tool. In other words, the reliability of a scale is high when consistent results are achieved. Methods used to evaluate the reliability of a scale include internal consistency, test-reliability, and alternative-form reliability, and the most widely used method among them is internal consistency. Internal consistency concerns whether items are consistent or homogenous when measurementincludes multiple items. Internal consistency is evaluated by correlating items, and the more highly correlated items are, the higher internal consistency is. The most commonly used method to evaluate the reliability of a scale using internal consistency is Cronbach's coefficient alpha(Cronbach's α). Reliability analysis is evaluated based on Cronbach's α coefficient, case effectiveness means the number of effective questionnaires, and the number of items is the deterioration factor.

Table 4 illustrates the reliability analysis results. Overall, Cronbach's α coefficient ranged from 0.746 to 0.838, which was larger than 0.6, the standard for good internal consistency; therefore, internal consistency was obtained and the results were reliable.

Derivation of critical influence factors

Occurrence number: Table 5 displays the top 10 factors and the occurrence, severity, and detection numbers among potential influence factors.

First, the top 10 influence factors for the occurrence number were A-03, B-07, C-01, C-03, C-04, C-05, C-06, C-07, D-01, and D-02. The occurrence number of low-price bidding methods used to select defect assessment companies(B-07) was highest at 8.8, and that of differences in the defect investigation scope according to

Table 5. Analysis results of the occurrence, severity, anddetectionnumbers

Occurrence number			Severity number			Detectability number		
Code	**Avg.**	**Ranking**	**Code**	**Avg.**	**Ranking**	**Code**	**Avg.**	**Ranking**
B-07	8.8	1	B-07	9.2	1	B-07	9.0	1
C-06	7.6	2	C-03	7.6	2	C-03	7.6	2
C-04	7.0	3	C-06	7.4	3	C-06	7.4	3
C-05	7.0	4	C-05	7.2	4	C-05	7.0	4
C-03	6.8	5	C-01	7.0	5	C-01	6.8	5
C-01	6.6	6	A-03	6.6	6	A-03	6.4	6
D-02	6.6	7	D-02	6.4	7	C-04	6.4	7
C-07	6.4	8	C-07	6.4	8	B-01	6.4	8
D-01	6.4	9	C-04	6.2	9	C-02	6.2	9
A-03	6.0	10	C-02	6.2	10	A-01	6.0	10

differences in the technological power of defect assessment companies (C-06) was high at 7.6. Overall, the top 10 influence factors for the occurrence number mostly consisted of factors for defect assessment companies' capabilities. Such results indicate that there should be a change in the bidding methods in the process of selecting defect assessment companies and measures to complement defect assessment companies' capabilities.

Severity number: The top 10 factors for the severity number were A-03, B-07, C-01, C-02, C-03, C-04, C-05, C-06, C-07, and D-02. Similar to the occurrence number, the severity number of low-price bidding methods used to select defect assessment companies(B-07) was highest at 9.2, and the severity number of the selection of court appraisers with a low level of expertise (C-03) was high at 7.6. Similar to the occurrence number, overall, the severity number was mostly composed of factors related to defect assessment companies' capabilities. Therefore, B-07 and factors related to defect assessment companies' capabilities had a high possibility of occurring, and their severity number was high as well.

Detectability number: The top 10 factors for the detection number were A-01, A-03, B-01, B-07, C-01, C-02, C-03, C-04, C-05, and C-06. Similar to the occurrence number and the severity number, the detection number of low-price bidding methods used to select defect assessment companies(B-07) was highest at 9.0 and the severity number of the selection of court appraisers with a low level of expertise (C-03) was high at 7.6. Similar to the occurrence number and the severity number, overall, the detection number was mostly composed of B-07 and factors related to defect assessment companies' capabilities.

According to the results of the occurrence, severity, and detection numbers, A-03, B-07, C-01, C-03, C-04, C-05, and C-06 were commonly included in the top 10 factors. This means that low-price bidding methods for defect appraisals and differing defect repair methods used by defect assessment companies and court appraisers affect defect judgment. This also means that the capabilities of defect assessment companies, the justice department, and court appraisers who partake in a defect lawsuit affect the results of defect judgment.

Risk and risk grades: Table 6 illustrates the determination of risk grades based on 21 calculated risks. According to the ranking based on the risks of influence factors, the ranking of low-price bidding methods (B-07) for the selection of defect assessment companies was highest at 9.00, which differed by 1.53 from the ranking of differences in the defect investigation scope resulting from the differing technological power of defect assessment companies(C-06). Together with B-07 and C-06, critical influence factors of risk grade I were the selection of court appraisers with a low level of expertise (C-03) and the justice department's lack of technical understanding (C-05).

To look at influence factors according to risk grades, the number of grade I was 4, the number of grade II was 13 (59%), and the number of grade III was 5. In the risk grade standard, grade I included influence factors whose scores were from 7 to 10 points. The number of influence factors whose score was 9 points was one and the number of influence factors whose score was 7 points was three. Then, grade II was significant influence factors that included the widest range of scores from 4 points to 7 points. Within grade II, there were diverse scores of 4, 5, and 6 points. In detail, there were seven influence factors with a score of 6 points, and they were largely factors related to participants' capabilities. Three influence factors had a score of 5 points, and they were largely factors related to participants'. Two influence factors had a score of 4 points, and they were factors concerning institutions and guidelines. Seven influence factors belonged to grade III, and they were mostly factors related to institutions and guidelines and measurement and appraisal.

Table 6. Analysis results of risks and risk grades

Code	Influence factors	RPN	Risk (Cs)	Risk Ranking	Risk Grade
B-07	Selection of a defect assessment company with a low price bidding method	728.64	9.00	1	I
C-06	Differences in defect investigation scope resulting from defect assessment companies' technological differences	416.18	7.47	2	I
C-03	Selection of court appraisers with lack of expertise	392.77	7.32	3	I
C-05	Lack of technical understanding of the justice department	352.80	7.07	4	I
C-01	Performance of appraisal by a non-professional court appraiser	314.16	6.80	5	II
C-04	Residents' lack of special knowledge	277.76	6.52	6	II
A-03	Selection of differing defect repair methods according to defect assessment companies and court appraisers	253.44	6.33	7	II
C-07	Lack of technical human resources due to petty status of court appraisers	237.57	6.19	8	II
D-02	Lack of defect assessment companies'responsibility for appraisal outcomes	228.10	6.11	9	II
C-02	Lack of professionals (facilities, electricity, and landscaping) owned by the defect assessment company	222.95	6.06	10	II
B-01	Inconsistent reduction of appraisal amount due to restricted responsibility of the justice department	222.72	6.06	11	II
A-01	Involvement of defect measurers' subjective views	167.04	5.51	12	II
D-01	Lack of residents' interest in defect appraisal	166.40	5.50	13	II
D-04	Differences in perspectives among defect assessment companies	151.63	5.33	14	II
D-03	Excessive appraisal by defect assessment companies aligned with the plaintiff's interest	151.42	5.33	15	II
B-03	Unclear standard for defect judgment	101.20	4.66	16	II
B-02	Insufficiency in receivables transfer rate by the representative meeting of residents (plaintiff)	80.96	4.33	17	II
B-05	Lack of application standard and guidelines by defect assessment companies for defect repair methods	51.98	3.73	18	III
B-04	Lack of guidelines by defect assessment companies for defect measurement standard and methods	51.84	3.73	19	III
A-02	Differing defect measurement methods according to defect assessment companies and court appraisers (defect measurement locations and equipment)	41.62	3.47	20	III
A-04	Application of differing costs (material cost and labor cost) according to defect assessment companies and court appraisers	30.72	3.13	21	III
B-06	Lack of consistent guidelines by defect assessment companies for cost application standard	26.88	3.00	22	III

According to the above results, in terms of institutions and guidelines, low-price bidding methods in selecting defect assessment companies should be improved to minimize conflicts among participants resulting from the results of defect judgment. Low-price bidding methods are likely to degrade the quality of defect appraisals and make fair and precise defect appraisals difficult. The defect investigation scope of defect assessment companies should also be made clear so that defects are not omitted when appraisals are made. In addition, technical support and training for petty defect assessment companies is considered necessary to enhance participants' capabilities. Lastly, educational support to improve the justice department's and residents' technical understanding and a fair judgment standard for the selection of court appraisers are considered necessary.

Conclusion

In Korea, an increase in apartment housing defect lawsuits has led to wasted time and costs in social terms and intensified conflicts. Nonetheless, research deriving critical influence factors affecting defect judgments aimed at minimizing such problems and conflicts has been lacking.

Accordingly, the aim of this study was to analyze the factors that affected judgment on apartment housing defects using FMEA and to present measures for improvement. Potential influence factors that affected judgment on apartment housing defects were chosen by interviewing defect assessment companies and court appraisers. Based on the selected potential influence factors, critical influence factors were derived using FMEA, and measures to improve critical influence factors were presented.

The findings will be used to devise strategies to minimize conflicts among participants due to the results of defect judgment that are problematic in the process of apartment housing defect lawsuits. Future researchers should come up with specific measures to improve derived critical influence factors affecting defect judgment and reflect the opinions of residents, lawyers, construction firms, and the justicedepartment as well as defect assessment companies and court appraisers.

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