



## The Characteristics of the Repair Cost Distribution in Apartment Housing

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### ABSTRACT

**Purpose:** The repair would require to conserve and improve the building function and performance since built. Each household is responsible for maintaining the public facilities and paying the required cost. Therefore, it needs to get the tool or method to forecast the required cost in the future. Before the repair cost is provided, it needs to catch the repair cost distribution and provide the unit cost for the repair cycle.

In this study, it aimed at providing the repair cost unit and analyzing the repair cost distribution in a roof proofing work, elevator work and building painting, which are divided into a fully work and partly change. Results of this study are shown that first, the average repair cost for roof proofing work is provided with  $166.59 \times 10^3$  won/household and  $1.59 \times 10^3$  won/m<sup>2</sup> of a full change,  $33.22 \times 10^3$  won/household and  $0.33 \times 10^3$  won /m<sup>2</sup> for a partly work. In addition, elevator work is  $557.45 \times 10^3$  won /household and  $5.38 \times 10^3$  won /m<sup>2</sup> for a full change,  $32.92 \times 10^3$  won /household and  $0.56 \times 10^3$  won /m<sup>2</sup> for a partly repair. Painting has a  $304.48 \times 10^3$  won /household and  $2.94 \times 10^3$  won/m<sup>2</sup>. Second, the distribution pattern of repair unit cost has a weibull-typed distribution which has a long tail to the right.

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### KEYWORD

단위비용, 수선, 유지관리, 공종, repair cost distribution

unit cost, repair, maintenance, repair work, repair cost distribution

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## 1. Introduction

### 1.1. Background And Purpose

Building maintenance should be approached from various aspects (technical, economic and social). In technical aspect, repair, material, structural method, and so on should be considered to maintain the physical performance and functions of a building. In economic aspect, the cost required for building maintenance should be optimum and thus a strategy for building maintenance should be designed to fulfill the best environment with the optimum cost. In social aspect, building maintenance should be implemented so as to improve building environment agreeable with surrounding environment.

Apartment housing is a residential form of multiple households living together in a building. Therefore, it is common that the opinions of a community is more reflected on improving or changing building function and performance, rather than individual opinions. In particular, individual houses have to share repair cost for building maintenance in economic aspect. On the other hand, repair cost should be decided compared with that of other apartment housing complexes or considering construction type.

By type, repair works can be applied to various areas of a building from its external space to the top. Therefore, repair cost should be well distributed according to the characteristics of construction such as location, scope, and technical and physical requirements. In general, repair cost has a bell-typed distribution. However, the distribution shape of repair cost can be different depending on the types and characteristics of construction and so can be statistical functions.

In the present paper, repair cost distribution is presented by construction type. Understanding the right and left of the distribution graph from average repair cost, which is a reference point, can provide basic data in deciding on whether repair cost is excessive or not sufficient. Furthermore, it can be an yardstick of the level of cost required when repair is planned.

### 1.2. Method And Scope

In apartment housing, many different households live in one complex, equally taking responsibility for managing common facilities. To facilitate managing it, residents organized such consultative bodies as tenant representatives' meeting and management center (office) and do several activities such as decision making and preparation for repair cost. In this case, the size of repair cost is determined and the cost is charged to individual households, depending on the

area of management and the number of individual households. However, there is a limit to calculating and expressing repair cost in discrete numbers due to the diversity in the characteristics of construction by type. Therefore, proposing repair cost distribution by construction type will be helpful to understand repair cost. The present study is aimed to analyze the characteristics of repair cost distribution by construction type. To attain the objective, research method and scope are set as follows.

First, this study suggested repair unit cost by construction type and scope. It was analyzed largely according to the number of households and management area. Repair unit cost means average repair cost per unit and repair cost distribution was schematized using probability distribution function.

Second, this study collected data by construction type from the records of repair works supervised under 22 boroughs in Seoul for 4 years (from 2011 to 2014)<sup>1)2)</sup>. These data are records of actual construction projects done in apartment housing complex. The data were organized by repair period, repair cost, number of households, and gross management area.

### 1.3. Research Scope

The characteristics of repair cost distribution were analyzed for 4 types of construction: roof waterproof construction, elevator construction, painting work, and roof repair construction. Of them, roof waterproof construction and elevator construction were divided into overall construction and partial construction. And painting work was examined for overall repair while roof repair work was analyzed for partial work as seen in Table 1

Table 1. Gross Area And Targets

Area	Repair Scope	Number Of Samples
A. Water Proofing	Partly	220
	Fully	277
B. Elevator	Partly	594
	Fully	89
C. Exterior Paintings	Fully	317
D. Roof Repair	Partly	55

As seen in Table 1, the survey samples consist of 277 complexes for roof waterproof construction (partial repair) and 220 complexes for overall roof waterproof repair works (full replacement). The samples of elevator construction consist of 89 complexes (full replacement) and 594 complexes

for partial elevator repair. The samples of exterior painting work and roof construction consist of concerning works from 317 and 55 complexes, respectively.

## 2. Estimation Repair Cost And Consideration

Repair cost of apartment housing is generated in future, rather than in the present. It is burdensome for individual households to carry repair cost at the occurring point. Therefore, it is necessary to continue reserving fund at present, preparing for repair work by type and characteristic, which occurs in future. It can relieve households of sudden burden. To facility it, a measure is needed to estimate repair cost by construction type. For estimating repair cost, it is also necessary to use an estimation model that calculates it based on the number of households or management area, or unit cost per household or management area. Besides, a variety of tools or approaches are needed to forecast repair cost.

Recently, BMI, which emerged as an alternative of construction design, uses information of building and maintenance data entered in the stage of building design and construction to estimate long-term repair cost occurring in future<sup>3)</sup>. This study proposes an estimation model that associates information of material and unit cost used in quotation with that of repair period and repair scope necessary in establishing a long-term repair plan to estimate repair cost. It should be admitted that this estimation model has been done at conceptual level, not for practical application to construction field.

Ha, H.S., Song, C.Y. and Kim, Y.S.(2007) studied a method to estimate repair cost occurring in future through surveying and analyzing the history of expenditure on school facilities constructed under Build Transfer Lease (BTL) project<sup>4)</sup>. In their study, repair cost was classified into main construction types: such as construction and civil engineering and analyzed the calculation method of long-term repair reserve. It applied the method to the schools for case study and proposed detailed repair costs that occur for 20 years after the completion of construction by repair type: construction, civil engineering, machinery, and electricity. In addition, the paper suggested long-term repair reserve/100m<sup>2</sup>. However, the present study has a limit to specific and detailed classification of construction type.

Heo, J. and Lee, J.(2011) examined the factors to determine

1) According to building and construction cost index (year 2000 = 100), it turns out that 2011 is 107 and 2014 is 114. Therefore, it is known that the cost increased slightly 1% every year from 2011 to 2014 when discount rate is not considered.

2) From the results of the collected data, it is found that the cost was not recorded according to 6 main categories set when long-term repair was planned. Rather, it was recorded mainly on the parts and members used on construction sites. As a result, the data are mainly classified into building exteriors and others.

3) Song, A.R., Kim, J.Y., Yoon, S.H.(2013), "A Study on the Forecasting of Using BIM Long-Term maintenance Cpst Model for Apartment", Proceedings of JKIBC 13(1), pp215-217

4) Ha, H.S., Song, C.Y. and Kim, Y.S.(2007), A case Study on the Prediction of Sinking Funds for Long-Term Maintenance Expenses through the Anayis of BTL School Projects", J. of CM8(6), pp207-215

the maintenance fee of apartment housing in Seoul area<sup>5)</sup>. This paper showed that local characteristics affect it most and building deterioration, heating system, complex size, and corridor type have a significant impact on the maintenance fee of apartment housing. Of the influential factors, heating system and complex size were proposed as the most important internal factors. And, overall, local factors were proved to have more significant relation with the fee than the characteristic factors of apartment complex. However, the statistics of explanatory power of the estimation model were not satisfactory.

Cho, C.H and Lee, H.R(2008) surveyed facility maintenance fee of schools and proposed reasonable maintenance fee<sup>6)</sup>. In that research, about 1,000 facilities of the schools in Kyunggi Province were surveyed and maintenance cost per unit area or student was suggested. In that paper, the measure was attempted to be an major unit criterion with which middle- and long-term maintenance cost can be set for school facility constructed under BTL project. Meanwhile, maintenance cost includes both facility-related operation cost and costs in technical aspect in the estimation model of the present study. It turned out that the ratio of facility cost to operation cost is about 10%. With 2006 as reference year, it turned out that operation cost per school facility area is 71,500KRW, and facility cost per area is 9,000KRW.

Kang, H., Seo, J.(2003) surveyed repair and maintenance cost of 7 years of 125 permanent rental housing complexes, which were supervised by the same organizations<sup>7)</sup>. In that paper, the factors that have impact on the maintenance cost of public rental housing maintenance cost were first examined and the extent of impact was analyzed. The findings showed that lapse year, initial investment construction cost for gross area, heating system, installation of septic tanks for waste water, water tank material, internal piping material were the factors. Therefore, it indicated that a better estimation of repair cost requires including information of lapse year of a building and installations. However, the findings proved that the number of households and floor area are insignificantly correlated to repair and maintenance cost. Presumably, the result is attributed to the scope of that study, which was the repair cost spent on the common areas of the rental housing complex.

Besides the studies examined above, other methods of

estimating repair cost have been proposed, like calculating maintenance fee based on building area or applying various factors into one analytic tool. For such studies, securing various and diverse data of factors affecting or related to repair cost is a precondition, when it is not easy to collect data such as the characteristics of a building and/or a facility, however, basic measures such as unit area or the number of households can be used alternatives in estimating repair cost. Besides, it is assumed that repair cost distribution curve has asymmetric shape: it is incurred densely when construction is expected to come and starts to happen sparsely after construction period. It is important to consider these characteristics of repair cost distribution when estimating the period and extent of repair cost.

### 3. Repair Cost Distribution By Construction Type

The concept of repair cost per unit can be used as a method to estimate the cost of repair work by type after the completion of construction. The present study analyzed the distribution and characteristics of repair for construction types: overall repair (1) and partial repair (2) of roof waterproof construction; overall replacement (3) and partial repair (4) of elevator construction; overall painting work (5); and partial roof construction (6). The results are described as follows.

#### 3.1. Roof Waterproof Construction

##### 1) Overall Replacement

Repair cost distribution for overall replacement of roof waterproof was separately analyzed with two different references: per household and per management area. First, Figure 1 shows repair cost distribution per household.

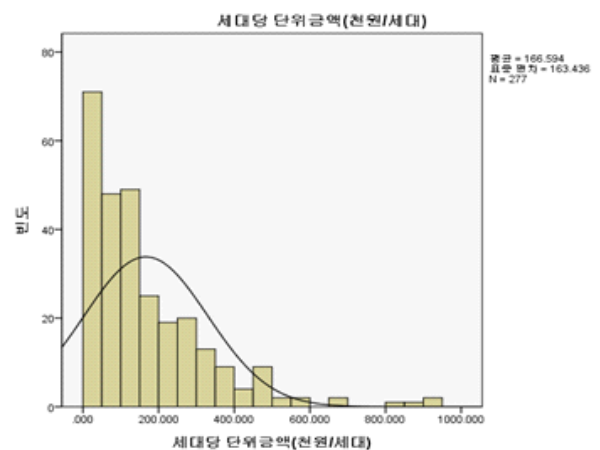


Fig 1. Distribution of Repair cost per household in fully change of roof proofing

5) Heo, J. and Lee, J.(2011), "An empirical study on the determinants of management fee of multi-family housing in Seoul", J. of Korean Urban Management Association 24(2), pp173-185.  
 6) Cho, C.H and Lee, H.R(2008), "A Survey Study on the Maintenance & Operation Costs of Elementary, Middle and High School Facilities", J. of AIK 24(4), pp87-96  
 7) Kang, H., Seo, J.(2003), "A Study on the Factor of Repair and Maintenance Costs of Public Rental Housing", AIK Journal in Structural Area 19(1), pp145-152

According to Figure 1, repair cost distribution per household in case of overall repair (full replacement) looks biased to the left with a tail down to the right. The distribution has a asymmetric pattern that a longer downward tail lies to the right from the average point than from the left. Table 2 shows the values of repair cost distribution of roof waterproof construction per household. In case of full replacement of roof waterproof, the average repair cost per unit (household) is 166,590KRW/household. And repair cost in 25% percentile is 44,010KRW/household and that in 75% percentile is 231,530KRW/household. Judging from this result, average repair cost is closer to 75% percentile than to 25% percentile, and is characterized with distribution shape having a longer downward tail to the right from the average repair cost.

Table 2. Repair cost/household of the roof proofing in fully change

	25%	Average	75%
repair cost/household (10 <sup>3</sup> won/household)	44.01	166.59	231.53

Figure 2 shows the distribution shape of repair cost per management. As seen in the graph of Figure 2, repair unit cost distribution for overall repair has a long downward tail to the right.

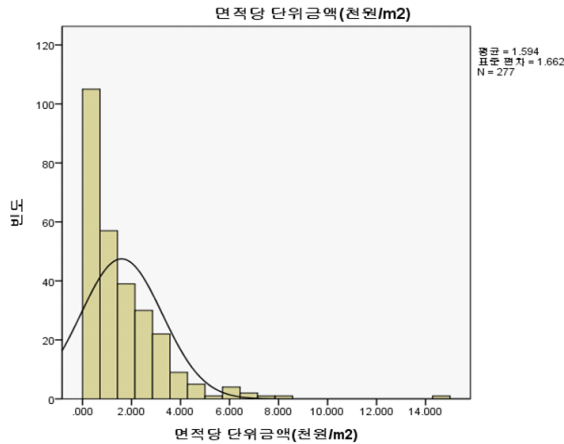


Fig 2. Distribution of Repair cost per management area in fully change of roof proofing

Table 3 shows the values of repair cost distribution of roof waterproof construction per management area. In case of full replacement of roof waterproof, the average repair cost per unit (m<sup>2</sup>) is 1,590KRW/m<sup>2</sup>이다. And repair cost in 25% percentile is 450KRW/m<sup>2</sup> and that in 75% percentile is 2,310KRW/m<sup>2</sup>. Judging from this result, average repair cost is weibull-typed where it is closer to 75% percentile than to 25% percentile, and is characterized with distribution shape having a longer downward tail to the right from the average repair cost.

Table 3. Repair cost/m<sup>2</sup> of the roof proofing in fully change

	25%	Average	75%
repair cost/area (10 <sup>3</sup> won/m <sup>2</sup> )	0.45	1.59	2.31

## 2) Partial Repair

Partial repair cost of roof waterproof is lower than overall repair, but the cycle of partial repair is shorter than overall repair. Figure 3 shows repair cost distribution per household. As seen in Figure 3, the cost distribution for partial repair of roof waterproof has a long downward tail to the right. The distribution has a asymmetric pattern that a longer downward tail lies to the right from the average point than from the left.

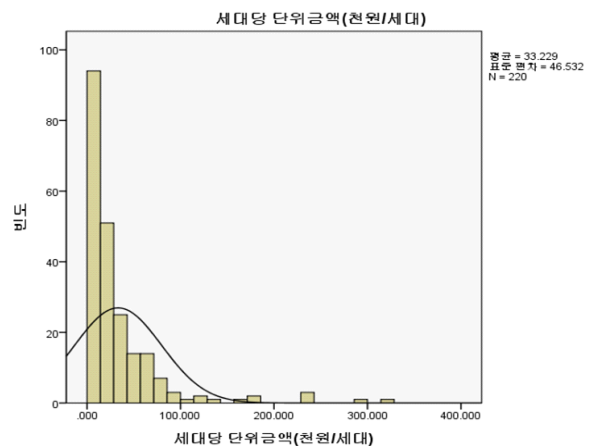


Fig 3. Distribution of Repair cost per household in partly change of roof proofing

Table 4 shows the values of cost distribution of partial roof waterproof construction per household. The average repair cost per household is 33,230KRW/household. And repair cost in 25% percentile is 7,440KRW/household and that in 75% percentile is 39,730KRW/household. Judging from this result, the average repair cost is closer to 75% percentile than to 25% percentile, and is characterized with distribution shape having a longer downward tail to the right from the average repair cost.

Table 4. Repair cost/household of the roof proofing in partly change

	25%	Average	75%
repair cost/household (10 <sup>3</sup> won/household)	7.44	33.22	39.73

Figure 4 shows repair cost distribution per management area. As seen in Figure 4, the cost distribution for partial repair of roof waterproof has a long downward tail to the right. The distribution has a asymmetric pattern that a longer downward tail lies to the right from the average point than from the left.

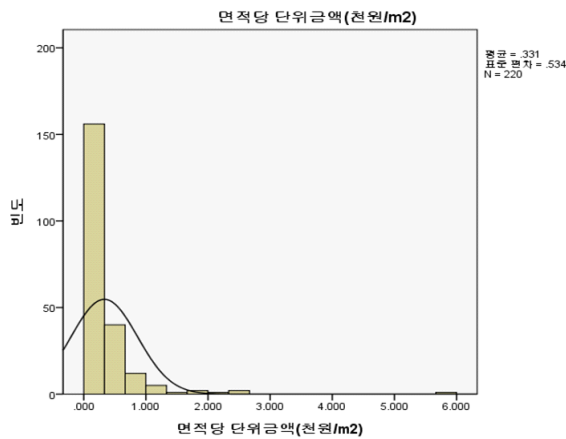


Fig 4. Distribution of Repair cost per management area in partly change of roof proofing

Table 5 shows the values of cost distribution of partial roof waterproof construction per unit (m<sup>2</sup>). The average repair cost per management area is 330KRW/m<sup>2</sup>. And repair cost in 25% percentile is 70KRW/m<sup>2</sup> and that in 75% percentile is 400KRW/m<sup>2</sup>. Judging from this result, the average repair cost is closer to 75% percentile than to 25% percentile.

Table 5. Repair cost/m<sup>2</sup> of the roof proofing in partly change

	25%	Average	75%
repair cost/area (10 <sup>3</sup> won/m <sup>2</sup> )	0.07	0.33	0.40

### 3.2. Elevator Construction

#### 1) Overall Replacement

Figure 5 shows unit cost distribution of overall repair work of elevator in graph. As seen in Figure 5, the unit cost distribution has a long downward tail to the right. What is particular here is that the overall repair cost per household has constant frequency as it moves to the right, rather than.

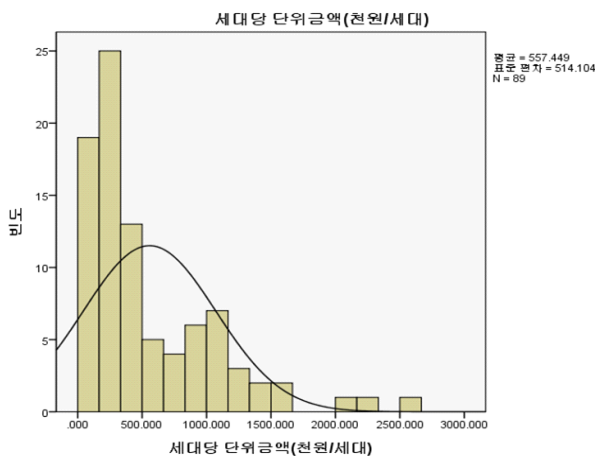


Fig 5 Distribution of Repair cost per household in full change of Elevator

Table 6 shows the values of repair cost distribution of elevator per household in case of full replacement. The average repair cost per unit (household) is 557,450KRW/household. And repair cost in 25% percentile is 191,840KRW/household and that in 75% percentile is 858,890KRW/household. Judging from this result, average repair cost is closer to 75% percentile than to 25% percentile, and is characterized with distribution shape having a downward tail to the right.

Table 6. Repair cost/household of Elevator in full change

	25%	Average	75%
repair cost/household (10 <sup>3</sup> won/household)	191.84	557.45	859.89

Figure 6 shows the distribution shape of elevator repair cost per management for full replacement. As seen in Figure 6, the distribution has an asymmetric pattern that a longer downward tail lies to the right.

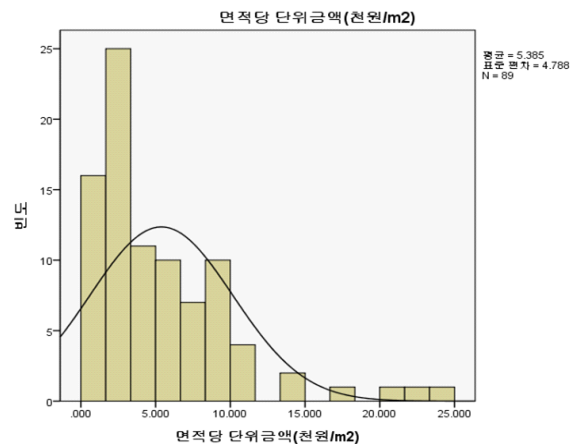


Fig 6. Distribution of Repair cost per management area in full change of Elevator

Table 7 shows the values of full repair cost distribution of elevator construction per unit (management area/m<sup>2</sup>). In case of full replacement of elevator, the average repair cost per unit is 5,380KRW/m<sup>2</sup>. And repair cost in 25% percentile is 2,150KRW/m<sup>2</sup> and that in 75% percentile is 7,680KRW/m<sup>2</sup>. Although they are overall distributed like a short tail to the left and a long to the right from the average repair cost, the average repair cost is closer to 75% percentile than to 25% percentile, having a bell shape.

Table 7. Repair cost/m<sup>2</sup> of Elevator in full change

	25%	Average	75%
repair cost/area (10 <sup>3</sup> won/m <sup>2</sup> )	2.15	5.38	7.68

2) Partial Repair

Figure 7 shows cost distribution of partial elevator repair construction. As seen in Figure 3, the cost distribution is asymmetric, having a short tail to the left and a long tail to the right from peak frequency.

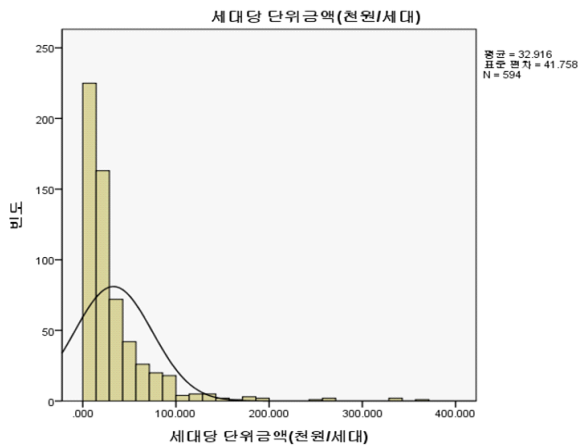


Fig 7. Distribution of Repair cost per household in partly repair of Elevator

Table 8 shows the values (25% percentile, average, and 75% percentile) of cost distribution of partial elevator repair construction per household. The average repair cost per household is 32,920KRW/household. And repair cost in 25% percentile is 9,760KRW/household and that in 75% percentile is 39,780KRW/household.

Table 8. Repair cost/household of Elevator in partly change

	25%	Average	75%
repair cost/household (10 <sup>3</sup> won/household)	9.76	32.92	39.78

As seen in Table 6, when compared with full repair cost of elevator per household, the partial repair is about 5%. Although the partial repair cost is distributed closer to 75% percentile than to 25% percentile, it is characterized with distribution shape having a downward tail to the right.

Figure 8 shows the cost distribution of partial elevator repair construction per management area. Unlike other construction types, it is relatively more symmetric.

Table 9 shows the values of partial repair cost distribution of elevator per management area (m<sup>2</sup>). The average repair cost per unit (m<sup>2</sup>) is 560KRW/m<sup>2</sup>. And repair cost in 25% percentile is 90KRW/m<sup>2</sup> and that in 75% percentile is 370KRW/m<sup>2</sup><sup>8)</sup>. Overall, the distribution looks short to the left and long to the

right, but it is relatively symmetric.

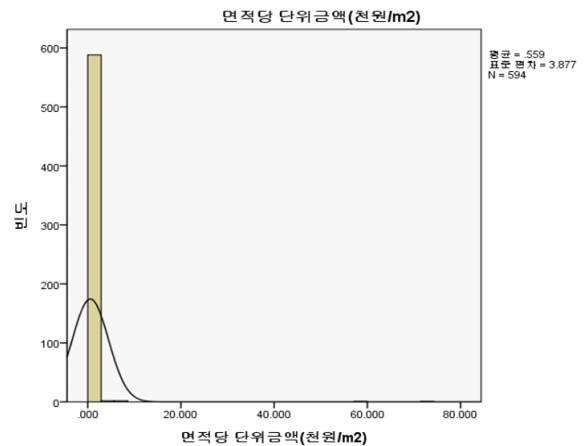


Fig 8. Distribution of Repair cost per management area in partly change of Elevator

Table 9. Repair cost/m<sup>2</sup> of Elevator in partly change

	25%	Average	75%
repair cost/area (10 <sup>3</sup> won/m <sup>2</sup> )	0.09	0.56	0.37

3.3. Painting Work

It is stipulated that building exterior painting for apartment housing be done every 5 years according the requirements of a long-term repair plan. However, it is more common that the exterior painting work is given every 7 to 9 years in practice. Figure 9 shows unit cost distribution of overall exterior painting work per household in graph. As seen in Figure 9, it looks symmetric as a whole, but the distribution to the right is longer.

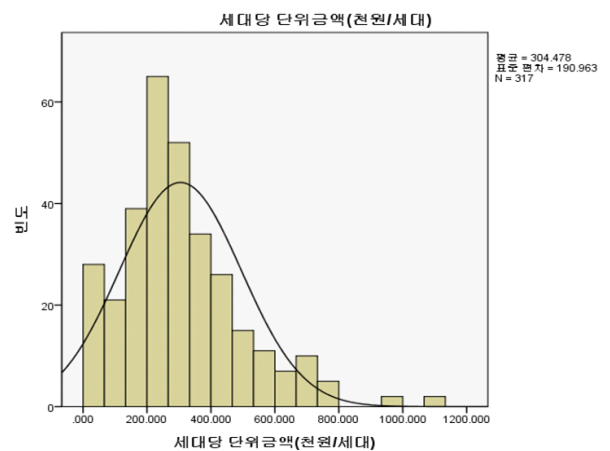


Fig 9. Distribution of Repair cost per household in full change of Paintings

Table 10 shows the values (25% percentile, average, and 75% percentile) of cost distribution of exterior painting work per household. The average cost of exterior painting work per household is 304,480KRW/household. And the cost of exterior

8) The reason why the values of 75% percentile are smaller than the average is that partial construction cost for elevator occurred in relatively greater samples in the right side. It turned out that median is 194KRW/m<sup>2</sup>.

painting in 25% percentile is 181,950KRW/household and that in 75% percentile is 419,880KRW/household. As a whole, it is distributed short to the left and long to the right, but relatively symmetric.

Table 10. Repair cost/household of Painting

	25%	평균	75%
repair cost/area (10 <sup>3</sup> won/household)	181.95	304.48	419.88

Figure 10 shows the values of cost distribution of exterior painting per management area (m<sup>2</sup>). Unlike other construction types, it looks symmetric. The average exterior painting cost per unit (m<sup>2</sup>) is 2,940KRW/m<sup>2</sup>. And exterior painting cost in 25% percentile is 1,680KRW/m<sup>2</sup> and that in 75% percentile is 4,170KRW/m<sup>2</sup>. (See Table 11).

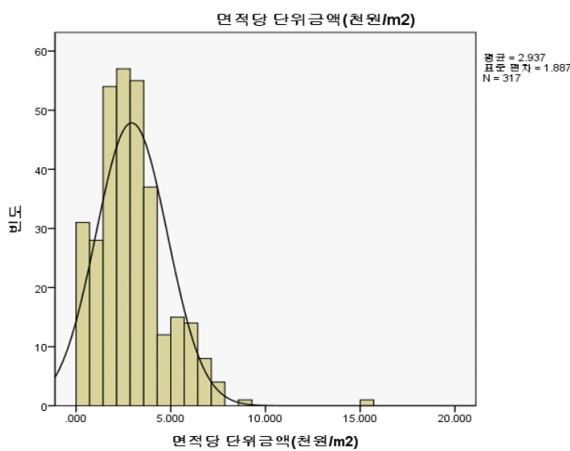


Fig 10. Distribution of Repair cost per management area in Painting

Table 11. Repair cost/m<sup>2</sup> of Painting

	25%	평균	75%
repair cost/area (10 <sup>3</sup> won/m <sup>2</sup> )	1.68	2.94	4.17

#### 4. Conclusion and Future Research

In apartment housing, many households share the same facilities, taking responsible part in facility management. Of the responsibilities, repair cost is charged to individual households. Therefore, the cost is reserved on a long-term base according to repair plan. Therefore, it is necessary to estimate construction cost on which the reserve level for repair cost can be forecast. In addition, repair cost needs to be estimated by construction type and repair cost for apartment housing also needs to be compared with that of other complexes. Therefore, the presents study calculated and proposed repair unit cost for major construction types such as

roof waterproof construction, elevator, and exterior painting and analyzed the characteristics of repair cost distribution. The results can be summarized as follows.

First, average repair cost of roof waterproof construction in case of full replacement is 166,590KRW/household and 1,590KRW/m<sup>2</sup>. Average cost of roof waterproof construction in case of partial repair is 33,220KRW/household, management area당 330KRW/m<sup>2</sup>.

Second, average repair cost of elevator construction in case of full replacement is 557,450KRW/household and 5,380KRW/m<sup>2</sup>. Second, average cost of elevator construction in case of partial repair is 32,920KRW/household and 560KRW/m<sup>2</sup>.

Third, average exterior painting cost is 304,480KRW/household and 2,940KRW/m<sup>2</sup>.

Fourth, repair cost distribution per household or management (m<sup>2</sup>) turned out to have a bell shape (Weibull distribution). Therefore it is characterized with a longer tail to the right than to the left from peak frequency. Judging from this fact, it is necessary to consider the characteristics in estimating repair cost, rather than uniformly.

when repair cost per unit is known or can be estimated by construction type, it can be used as a reference for repair cost reserve. In addition, it can be also used as an important yardstick in deciding or comparing construction amount. However, the findings of this study has a limit to estimating repair cost for parts or materials because it proposed unit repair cost by construction type. Furthermore, complex should more break down in size or its physical nad social aspects should be considered in estimating repair unit cost. That is, it is necessary to develop an estimation model of repair cost considering number of households, management area, and number of unit buildings. In the meantime, it is also necessary to find an alternative to meare the level of repair cost based on repair period, which can be known by repair cost distribution.

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