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A maintenance cost prediction model for elementary schools by correcting FM budget history and performance data

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Abstract

Daejeon Office of Education which is located in one of the 5 largest city in Republic of Korea, has 292 elementary, middle, and high schools (total floor space of 2.45 million m²). About 70% of them was built more than 15 years before and they have spent a total of KRW 113.5 billion pre a year (2008 ~ 2012 average) for facility improvement. The budget shortage occurs every year due to the increase in the aged school facilities and the increase of the school facilities due to the construction of the new city. We want to predict the maintenance cost through the performance data, but it is difficult to secure it because the data retention period is five years.

In this study, based on the 30 year facility management budget history, we derive estimated maintenance cost from performance data and predict a model for proper maintenance cost of school facilities (elementary school) by regression analysis. Considering that the period of keeping the facility management budget data is not limited, 'Estimated maintenance cost from performance data' is derived based on the maintenance budget data for the past 30 years, and regression analysis is performed to calculate the 'prediction model of maintenance cost' and the error rate test for this prediction model and the adequacy of the case application are verified. The results of this study can be used as an objective criterion for long-term planning in school facilities, and realistic budgeting is possible.

Keywords: maintenance cost prediction model, facility management, educational facility, maintenance and repair costs

1. INTRODUCTION

Every provincial education office is investing considerable effort and management budget in school facilities to provide a comfortable and safe learning space as a training ground and to nurture future national talents. Approximately 70% of the educational facilities in D City are 15 years old or more, and the Education Office of this city is spending KRW 113.5 billion (2008 to 2012 average), which is 60% of the annual average budget, to maintain 292 elementary, middle, and high schools with a total floor space of 2.45 million m^2. While aging school facilities are an increasing problem, the demand for the expansion of school facilities is continuously growing due to the construction of new towns. The polarization phenomenon has created a budget shortage every year, and timely maintenance is not conducted, or minimum maintenance is carried out. Additionally, when organizing the maintenance budget, project size is decided according to the predefined budget of the Education Office rather than calculating the appropriate budget for maintenance. Alternatively, priority is given to the maintenance project, and the repair scale is decided based on the subjective judgment of the person in charge of facilities. And there is a significant problem in terms of the efficiency of maintenance budget investment, such as the accumulation of old or bad school facilities, the enormous budget being put in at once or replaced within a period of time. It is difficult to analyze the maintenance and repair costs of school facilities that are 20 to 30 years old because only the five-year maintenance and repair cost data can be obtained.

In this study, we derive the estimated maintenance and repair performance data based on 30-year maintenance budget history and conduct regression analysis to develop a model to predict the proper maintenance cost of elementary school facilities. This model will enable the reasonable budgeting of school facility maintenance expenses. In addition, this study method can be applied to various facilities, such as public facilities, business facilities, and school facilities, because this method can obtain long-term maintenance and repair cost estimation data for 30 years or more from existing five-year short-term data.

2. THEORETICAL CONSIDERATIONS

2.1 The definition of maintenance

Building Maintenance [1] implies all activities of the improvement, repair, and reinforcement of facilities that are required with the passage of time for preserving the functions of the facilities and enhance the convenience and safety of users. In other words, it means all the activities necessary to maintain initial performance by continuously improving

aging facilities depending on the time and frequency of use. The expenses associated with the activities are defined as maintenance cost.

The types of aging that need for maintenance are classified as follows. First, physical aging refers to accidental damages caused by aging, breakage, or abrasion that occur inevitably with the passage of time such as physical aging include natural or artificial aging and aging from disasters such as earthquakes or floods. Second, functional aging refers to deterioration in utility because the facilities do not respond to changes in the external environment. Examples of it include a lack of facilities and an outdated appearance and design compared to new buildings. It can be recovered through improvements and remodeling. Third, social aging has a causal relationship with functional aging and is typically caused by a decrease in profitability due to urban planning or land price increases and changes in building materials and construction methods.

2.2 Maintenance research trends in South Korea

As the aging of education facilities has become more frequent and maintenance costs have increased, studies on efficient maintenance are being conducted continuously as shown in Table 1. Particularly with the introduction of Build, Transfer, and Lease (BTL) projects which are similar to Private Investment Projects, studies on the prediction of maintenance costs have increased and studies on the improvement of aging school facilities, financial support, quality, and safety are also increasing [2]~[6].

Table 1: Current Studies for maintenance of educational facilities

No.	Title	Author / year	Content
1	A study on re-construction of maintenance in school facilities ; focused on Chung-nam Office of Education	B.M. Choi/2017	Re-development of the facilities maintenance management work that is scattered by each workforce, operation mode, and subject
2	Looking for ways to improve quality of school facility maintenance and management ; focused on school facilities in Ulsan metropolitan office of education	S.M. Park/2017	Establishment of 6 management process models and DB considering the application of ISO 90001 quality management system
3	A Study on financial support measures for improvement of worn-out facilities of private schools	S.K. Song/2016	Re-cognition of safety management of facility managers and financial support for improvement of aging schools based on the actual condition.
4	The Safety and Maintenance Planning of School Facilities in the Geojesangdong Elementary School	J.H. Kim/2016	Analysis of physical / emotional / environmental impacts according to school facility safety and maintenance considerations
5	An analysis of maintenance cost for school facility by development and application of data warehouse	M.K. Park/2014	Analyzing the actual condition and cost of school facilities, and proposing a plan to utilize data warehouse construction by questionnaire/survey for public servants in Gyeong-nam
6	Multi-dimensional analysis method of maintenance cost of school facility	H.K. Ryu/2014	Presenting how to use maintenance cost information based on data warehouse element technology
7	Drawing variables and weight per work type affecting repair and replacement standard for LCC analysis revision of school facilities according to climate and energy consumption changes	T.J Kim/2014	Providing a method to correct LCC through variables of climate change

2.3 Prediction method for estimated maintenance cost

Buildings begin to age after a certain period following the completion of construction, and repair and replacement activities at certain stages delay the aging of buildings. Maintenance costs are incurred at certain rates, and a typical repair plan can be expressed as a function of the number of elapsed years as follows:

$$P = \frac{F}{(1+i_e)^n} \qquad (1)$$

Where, P: maintenance cost, i_e: discount rate, n: number of elapsed years, F: maintenance cost at the time

Maintenance cost is adjusted by applying a discount rate for changes in value because the cost value varies depending on the currency value according to the repair time. However, the maintenance cost continues to increase for a certain period after construction, and then stays constant at a certain point in time. Therefore, it is possible to delay

aging through repair activities until a certain point of time; however, after this point, the natural aging of buildings cannot be prevented. When various equipment or parts of a building are old and can no longer be used or are broken, these will be unusable or has deteriorated because they have reached the end of their usable life. In this case, quick replacement or repair of them that have reached their limit can prevent the functional degradation of the entire building.

3. Maintenance Status of School Facilities

3.1 Status of elementary schools in the city

Daejeon City office of Education divides schools into east and west regions. There are 292 schools in total including 143 elementary schools, 88 middle schools, and 61 high schools. There are 20 more schools in the west area compared to the east area because a new population has moved in, and new schools were constructed in accordance with the student accommodation plan.

To examine the change in the number of schools over the last 10 years, the number of elementary schools increased by 26 because the commuting distance of elementary school students is typically shorter than that of middle and high school students, and elementary schools emphasize safety. By contrast, the number of students in the last 10 years decreased by 30,070 (approximately 25%), and the average class size decreased from 36 to 25. This is because new schools are constructed in newly developed areas, and students are more dispersed among schools.

According to the year of construction, the number of teaching buildings constructed before 2000 was 299 or approximately 70% of the 430 total, and the buildings that are older than 20 years also accounted for around 40% of the total. The schools in Dong-gu are older than those in Seo-gu, which should be reflected in the budget. The total school site was 4,424,487㎡, of which the teacher building sites accounted for 2,468,917㎡ or 55.8%, the playgrounds accounted for 1,737,747㎡ or 39.3%, and others accounted for 217,823㎡ or 4.9%.

3.2 Status of Facilities

To examine the facilities of elementary schools by year of construction(table 2), the teacher buildings constructed before 2000 accounted for 148 or approximately 68% out of 219 buildings in total, and teacher buildings older than 20 years accounted for approximately 32%. This shows that the educational facilities of Daejeon city are aging and some have already aged considerably.

Table 2: Status of elementary school buildings by construction year (Unit: buildings)

Administrative District	Daeduck-gu	Dong-gu	Jung-gu	Seo-gu	Yusung-gu	Total
Number of schools	20	23	27	37	36	143
1970 ~1979 year	1(2.8%)	3(12.0%)	6(10.0%)	8(15.1%)	6(13.3%)	24(11.0%)
1980 ~1989 year	10(27.8%)	5(20.0%)	18(30.0%)	8(15.1%)	6(13.3%)	47(11.0%)
1990 ~1999 year	17(47.2%)	8(32.0%)	15(25.0%)	25(47.2)	12(26.7%)	77(35.2%)
After 2000 year	8(22.2%)	9(36.0%)	21(35.0%)	12(22.6%)	21(46.7%)	71(32.4%)
Number of buildings	36	25	60	53	45	219

The total site (land area) of elementary schools was 2,228,092 m^2, of which teacher sites accounted for 1,290,120 m^2 (57.9%), and athletic fields accounted for 829,888 m^2 (37.2%). The teacher areas (total floor area of the building) were the largest areas at 2,438,581 m^2, followed by teaching and learning areas 885,650 m^2, shared areas 791,077 m^2, sports assembly areas 164,026 m^2, kitchen dining rooms 158,648 m^2, health and sanitation areas 150,825 m^2, others 83,852 m^2, and dormitory areas 1,021 m^2.

3.3 Budget for educational facilities

The annual budget of the D City's Education Office is approximately KRW 1.5 trillion (as of 2011) as shown in Fig. 2, and central and local government grants account for 95% of the total budget. Additionally, approximately 80% of the expenditure budget is used for human resources management, and 13.9% of the budget is used for the improvement of

education facilities. Therefore, the establishment of an efficient and balanced long-term maintenance plan is urgently needed because an enormous budget of approximately KRW 200 billion is spent on improving school facilities each year.

The budget for educational facilities of the Education Office of D City in the past five years shows that the average facility expense is KRW 191.3 billion won, and KRW 113.5 billion won (59.3%) is used for maintenance costs. The average number of maintenance and repair projects in the last five years is 1,113, accounting for 70.8% of total facility projects. The amount of construction work for each new construction project is substantial, whereas the amount of construction work for maintenance projects is relatively small, but the number of projects is considerably high.

Table 3: Budget status of FM work (Unit: KRW 100million)

Division	2008	2009	2010	2011	2012	Average	Ratio
New built	261	413	318	183	216	278	14.5%
expansion	347	312	777	677	385	500	26.1%
maintenance	536	1,522	1,238	1,228	1,151	1,135	59.3%
total	1,144	2,247	2,333	2,088	1,752	1,913	100%

3.4 Maintenance and repair standards of school facilities

The South Korea government issued notification no. 2005-4 based on Article 25 of the Enforcement Regulations of the Commodity Management Act to establish and effectively manage the durable years of goods, which is the period of economic use of goods, for the major commodities commonly used by national organizations. In addition, the criteria for establishing the long-term repair plan in Article 26 of the Enforcement Rule of the Housing Act presents repair criteria for the scope, replacement, and repair times of major facilities of apartment houses and specified by the provision concerning the accumulation of long-term repair reserves in Article 51 of the Housing Act.

The Chungnam Education Office provides repair criteria based on the budget execution results, and the results of the questionnaire survey on school facility managers for 50 elementary and secondary schools in Asan and the Chungnam and Asan Education Office (2006) were obtained [7]. However, the Daejeon Metropolitan Education Office presented a repair cycle and rate to be applied to the operation plan in "Private investment project for the new construction of Daejeon G Elementary School and two other schools." Tables 4 outline the repair cycles and rates comparable among the Housing Act, the Chungnam Education Office, and the Daejeon Metropolitan Education Office [8].

Table 4: Comparison table of repair cycle and ratio (Unit: year, %)

Division	The Hosing Act		Chungnam Education office		Daejeon Education office	
	Cycle	Ratio	Cycle	Ratio	Cycle	Ratio
Cement liquid waterproofing	5	18	3	6.5	6	12.6
Tile(Roof)	10	5	10	10.5	7	6.3
Steel window frame(Outside)	15	20	10	22.2	10	15
Floor board	7	15	7	11.8	9	17.1

4. Analysis of Maintenance Cost Performance and Budget History Data

4.1 Analysis of performance data for maintenance cost

The preservation period of maintenance documents related to public facilities is five years. The maintenance performance data, which are kept by the relevant law, include the maintenance work carried out by the Education Office of Daejeon city from 2008 to 2012. The data contain the actual maintenance expenses for each elementary school. However, maintenance and repair cost data are needed to derive the maintenance cost analysis and prediction model for elementary schools. In this study, 60 elementary schools were selected as eligible schools from the western region Education Office for collecting accurate performance data, and 1,011 maintenance works conducted for five years were analyzed. The cost of these maintenance works was classified into seven categories according to work type and sub-classified into 45 items.

The maintenance cost was analyzed by classifying the maintenance performance data and expenditure budget bills of elementary schools into seven types of construction work (construction, facility, electricity, communication, firefighting, civil engineering, and others) and subdividing them into 45 items (for example, classroom, interior painting, ceiling, floor, stairs, classroom door, restroom, food service, cafeteria, broadcasting room, exterior painting, exterior wall, roof waterproofing, exterior window). The maintenance cost was analyzed based on teacher buildings, which are the main structures built with reinforced concrete excluding the attached buildings such as steel-framed auditoriums and block-framed warehouses. The new construction and extension/reconstruction facility costs were excluded from the 45 maintenance items for accurate analysis.

The budget history data (five years) and the maintenance cost performance data (five years) were compared and analyzed, and the performance correction rate, which is the ratio of the maintenance cost to the budget amount, was derived for 45 maintenance cost items. Table 5 shows that the performance correction rate equation for each elementary school is as follows:

$$\text{Performacne ratio by item} = \sum_{i=1}^{n} \frac{Maintence\ cost\ by\ item}{Budget\ by\ item} \times 100 \qquad (2)$$

Table 5: Example of performance correction rate data for classroom (Unit: KRW 1,000)

No.	Year	Budget	Performance maintenance cost	Ratio	No.	Year	Budget	Performance maintenance cost	Ratio
1	2009	127,200	113,119	88.9	11	2008	21,300	19,644	92.2
2	2009	1,013,600	955,337	94.3	12	2012	34,000	27,724	81.5
3	2009	219,000	219,444	100.2	13	2011	159,480	131,657	82.6
4	2010	195,000	178,485	91.5	14	2010	118,950	110,330	92.8
5	2008	596,400	581,837	97.6	15	2009	246,000	256,113	104.1
6	2011	16,400	15,338	93.5	16	2012	302,000	293,953	97.3
7	2011	1,297,180	1,155,768	89.1	17	2012	102,000	88,210	86.5
8	2011	16,400	15,378	93.8	18	2010	45,000	41,109	91.4
9	2008	242,000	230,754	95.4	19	2009	124,800	117,755	94.4
10	2010	155,000	146,066	94.2	total		5,031,710	4,698,021	**93.4**

The average performance correction rate for all 45 elementary school items was 94.1%. By construction type, the performance correction rate was 94.7% for construction, 92.1% for facilities, 94% for electricity, 98.6% for communication, 91.8% for firefighting, 90.3% for civil engineering, and 90.4% for others. Thus, the performance correction rate for communication was the highest, and the performance correction rate for civil engineering was the lowest. Among the construction works, the performance correction rates of outer window and food service items were 107.9% and 100.6%, respectively, which were higher than 100%. This implies that the actual maintenance cost is higher than the budget. On the other hand, the performance correction rates for the internal painting and electricity items were the lowest, implying that the non-use ratio of budget for these items was higher than other items. The performance correction rates of 45 items for elementary schools are shown in Table 6.

Table 6: Performance correction rate by architecture item of elementary school

No.	Item	No. of work	Performance correction rate	No.	Item	No. of work	Performance correction rate
1	Classroom	19	93.4	9	cafeteria	7	96.0
2	Inner	16	81.0	10	Broadcasting	14	95.4
3	Ceiling	4	84.2	11	Outside painting	3	93.1
4	floor	28	94.4	12	Outside wall	12	98.5
5	Stairs	4	89.4	13	Roof	40	91.2
6	Door	10	98.5	14	External window	9	107.9
7	Restroom	36	93.2	total		216	94.7
8	Feeding	14	100.6				

Therefore, analysis of the performance correction rate showed that some items needed an increase in the budget unit price, and some items needed a reduction in the budget unit price. A reasonable adjustment in the budget unit price that is appropriate for reality and regulations is required, and the actual correction rate will be an objective standard to support this.

4.2 Analysis of the budget history data (30 years)

The budget history data refer to the budget for educational environment improvement facilities, the general facilities of schools, and educational environment improvement facility units established by the Education Office excluding student accommodation facilities and general school facilities. That is, the budget history data refer to the maintenance work of existing facilities except for new construction and extension/reconstruction project expenses. The maintenance budget for 30 years from 1983 to 2012 was classified into seven categories (including construction, facilities, electricity, communication, firefighting, civil engineering) with 45 items (including classrooms, interior painting, ceiling, flooring, stairs, classroom doors, restrooms, food services, cafeteria, broadcasting room, exterior painting, outer walls, roof waterproofing, exterior windows).The facility maintenance cost data for 30 years between 1983 and 2013 were collected by year, and the maintenance costs were classified into seven types of construction work (construction, facility, electricity, communication, firefighting, civil engineering, and others) and subdivided into 45 items (including classrooms, interior painting, ceiling, flooring, stairs, classroom doors, restrooms, food services, cafeteria, broadcasting room, exterior painting, exterior walls, roof waterproofing, exterior windows).

The annual maintenance expense budget data were converted by the number of years that had elapsed to analyze the amount of maintenance cost charged to certain maintenance items according to the number of years that had elapsed. Table 7 is an example of budget data according to the number of years that had elapsed.

Table 7: Maintenance expense budget data per year (Unit: KRW 1,000)

1983 Year/ 1st		~	**2011 Year/ 29th**		**2012 Year/ 30th**	
Item	**Budget**		**Item**	**Budget**	**Item**	**Budget**
External wall	5,000		stairs	144,000	bathroom	230,000
Equipment(outside)	6,500		Drain	59,800	pavement	98,400
			Roof waterproofing	8,000	floor	270,000
			Classroom(fire)	36000	classroom	890,650
					Internal	45,000
	11,500			**247,800**		**1,534,050**

In this study, it used the price index and inflation rate of the ECOS Economic Statistics System [9] of the Bank of Korea and the National Statistical Office. With the price index of 2010 set as 100, the price index of 1983 or 30 years ago was 32.65, which was calculated using the Laspeyres formula.

$$\text{Inflation Rate} = \left(\frac{\textit{the price index in T year}}{\textit{the price index in T-1 year}} - 1\right) \times 100\% \qquad (3)$$

The accumulated inflation rate was applied using the price index and the inflation rate with the year 2012 as the reference point of one. Then, the maintenance cost for 30 years was converted to the maintenance cost in 2012, which is the reference point. Table 8 illustrates the price index application method.

Table 8: Reflecting way of the price index

Year	**Budget**	**Price index**	**Inflation rate (%)**	**Cumulative inflation rate (%)**	**Re-correction Price to 2012 year**
2006	A	88.07	2.20 (=①)	②×③×④×⑤×⑥×⑦= a	A×a
2007	B	90.30	2.50 (=②)	③×④×⑤×⑥×⑦= b	B×b
2008	C	94.52	4.70 (=③)	④×⑤×⑥×⑦= c	C×c
2009	D	97.13	2.80 (=④)	⑤×⑥×⑦= d	D×d
2010	E	100.00	3.00 (=⑤)	⑥×⑦= e	E×e

2011	F	104.00	4.00 (=⑥)	⑦= f	F×f
2012	G	106.30	2.20 (=⑦)	1= g	G×g

5. ANALYSIS OF ESTIMATED MAINTENANCE COST AND DERIVATION OF FORECASTING MODEL

5.1 Analysis of average maintenance cost

The maintenance cost input status according to the number of elapsed years was analyzed based on the estimated maintenance performance data for 30 years. Maintenance cost remained almost unchanged for one to 10 years after the new construction. However, maintenance cost increases from 10 years to 20 years and, then, gradually decreases from 15 years to 20 years. From 20 years to 30 years, the overall performance cost increases steadily. As a result, most maintenance is performed in the 15th year, and maintenance is performed continuously until the 20th year.

In fact, classroom repair, restroom repair, and food service room modernization are performed in year 15 approximately. The cumulative input of average maintenance costs for 30 years shows that maintenance cost were not incurred in years one to seven, but maintenance costs increased after 27 years.

Table 9 shows that the total maintenance costs for 30 years were estimated at approximately KRW 5.9 billion.

Table 9: Average maintenance cost per unit in elementary school (Unit: KRW 1,000)

Year	Average maintenance cost		Maintenance cost per unit		Year	Average maintenance cost		Maintenance cost per unit	
	Annual	Cumulate	Annual	Cumulate		Annual	Cumulate	Annual	Cumulate
1	0	0	0.000	0.000	16	436,393	1,484,983	44.486	156.900
2	0	0	0.000	0.000	17	227,887	1,712,870	26.120	183.020
3	0	0	0.000	0.000	18	264,378	1,977,248	26.976	209.996
4	464	464	0.033	0.033	19	267,032	2,244,280	26.517	236.513
5	2,818	3,282	0.274	0.307	20	203,691	2,447,971	21.906	258.419
6	12,790	16,072	1.421	1.728	21	191,944	2,639,915	17.110	275.529
7	35,884	51,956	3.289	5.017	22	8,413	2,648,328	0.744	276.273
8	31,592	83,548	3.410	8.427	23	380,047	3,028,375	36.730	313.003
9	33,405	116,953	3.109	11.536	24	205,372	3,233,747	26.690	339.693
10	88,890	205,843	11.494	23.030	25	485,324	3,719,071	54.516	394.209
11	31,392	237,235	3.604	26.634	26	175,895	3,894,966	36.840	431.049
12	174,847	412,082	15.497	42.131	27	202,920	4,097,886	19.562	450.611
13	175,660	587,742	18.478	60.609	28	582,359	4,680,245	75.167	525.778
14	312,679	900,421	35.846	96.455	29	415,053	5,095,298	46.745	572.523
15	148,169	1,048,590	15.959	112.414	30	807,137	5,902,435	99.824	672.347
Average maintenance cost				5,902,435	**Maintenance cost per unit**				672.347

5.2 Analysis of maintenance cost by construction type

The maintenance cost per unit area (1 m^2) by construction type of elementary schools for 30 years (see Fig. 6) was KRW 348.853 thousand for buildings, KRW 168.378 thousand for facilities, KRW 80.884 thousand for electricity, KRW 19,240 thousand for communication, KRW 2,512 thousand for firefighting, KRW 51.924 thousand for civil engineering, and KRW 0.556 thousand for others. The maintenance cost ratio in descending order was maintenance (51.9%), facilities (25.0%), electricity (12.0%), civil engineering (7.7%), communication (2.9%), firefighting (0.4%), and others (0.1%).

5.3 Maintenance cost ratio by item

The maintenance cost ratio by item according to the number of elapsed years based on the budget history data was analyzed for 45 items according to seven processes. The construction type ratio in descending order was construction (51.89%), facilities (25.04%), electricity (12.03%), civil engineering (7.72%), communication (2.86%), firefighting (0.37%), and others (0.08%). The top five items were restrooms (12.40%), classrooms (10.53%), cooling and heating (10.49%), external windows (9.34%), and floors (8.82%).

5.4 Deriving a prediction model for the maintenance cost of elementary schools

The data collected for this study were analyzed using the statistical application SPSS for Windows 18.0. The data were analyzed as follows with a significance level (α) of 0.05. To investigate whether the maintenance cost and the cumulative maintenance cost increase each year for elementary schools, the correlation of these two variables was examined using Pearson's correlation coefficient. Pearson's correlation coefficient analyzed the linear correlation between two continuous variables and, if this correlation coefficient was close to 1, a high correlation was implied. If the correlation between the annual maintenance cost and the cumulative management cost was statistically significant, simple linear regression analysis was conducted to predict the maintenance cost and the cumulative management cost as the number of years increased.

A correlation analysis was conducted to investigate whether the maintenance cost and gross floor area increased with the number of elapsed years. In addition, a regression equation was derived to estimate the maintenance cost and total floor area through regression analysis when significant correlation between the two variables was found.

$$\mathrm{Edu(Y)} = a + bx_1 + cx_2 + dx_3 \qquad (4)$$

where, a = constant, b/c/d = coefficient
x_1= number of elapsed years, x_2= total floor area, x_3= school grade

At first, multiple linear regression analysis was conducted with the number of elapsed year and total floor area as independent variables and maintenance cost as the dependent variable. As a result, the following regression equation by school was obtained (Unit: KRW 1000).

$$\mathrm{Edu(Y)} = -2{,}616{,}375 + 185{,}014.4 \times t + 116.8 \times a \qquad (5)$$

where, Y = maintenance cost, t = number of elapsed years, a = total floor area

The regression equation for elementary schools was statistically significant, and the determination coefficient (R^2), which indicates the explanatory power of a model was 0.834 for elementary schools (Table 10). This implies 80% or higher explanatory power.

Table 10: The multiple regression analysis result of maintenance cost in elementary school

Division	Inclination	Standard error	Standardized β value	t	P-value	R^2	F
Constant	-2616375.3	487042.9		-5.372	<0.001	0.834	110.54***
Elapsed year	185014.4	12682.3	0.982	14.588	<0.001		
Floor area	116.8	34.9	0.226	3.351	0.020		

* p-value < .05, ** p-value < .01, *** p-value < .001

Next, figure 1 shows the maintenance cost input status per unit area by the number of elapsed years for classroom items among elementary school construction types. The calculation formula is Y = -0.0014x3 + 0.2075x2 - 2.5573x + 5.9715, and the determination coefficient (R^2) is 0.979 indicating high explanatory power above 90%. Maintenance cost were inputted starting from year 8 and increased relatively constantly as the years elapsed.

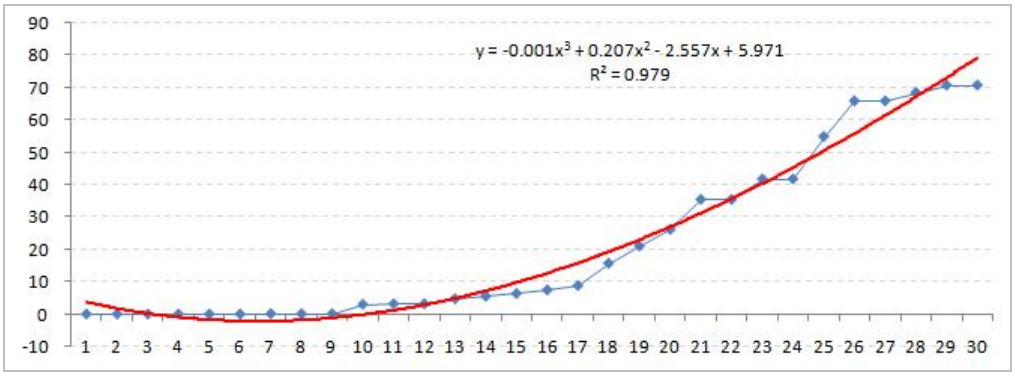

Figure 1: The maintenance cost by elapsed years for classroom items among elementary school

5.5 Verification of the forecasting model

Error rate and case verifications were performed to verify the regression analysis model of elementary school facilities. Among the schools with 10 or more elapsed years, 32 elementary schools were selected, and the difference between the maintenance cost and the prediction model value by the regression analysis was analyzed for error rate verification. For school facilities, almost no maintenance projects are supported by the Education Office until five years after construction. Therefore, schools aged 10 years or more were targeted. The equation for error rate verification is as follows. Absolute values were used for range verification.

$$|\text{Error Rate}| = \left|\left(1 - \frac{vale\ of\ forecasting\ model}{maintenance\ cost}\right) \times 100\%\right| \qquad (6)$$

Additionally, to verify the appropriateness of the regression analysis model, 10 elementary schools that were not used for regression analysis were selected, and the difference between the maintenance cost and the prediction model value by regression analysis was analyzed to verify the possibility of case application of the prediction model value. The method used for case verification is identical to the error rate verification of regression analysis. As a result of the error rate verification (table 11), the error rate of elementary schools was 10.4%. The error rate did not exceed 10%, and the prediction model value by the maintenance cost regression analysis had 90% or higher reliability. The deviation ranged from 0.3% and 25.2%.

Table 11: Verification result of error rates (Unit: KRW1,000)

No.	Elapsed years	Floor area	Repair cost	Forecast cost	Error rate
1	33	7,821	5,002,564	4,402,593	-12.0%
2	32	8,922	3,848,587	4,346,175	12.9%
3	30	9,872	4,200,949	4,087,107	-2.7%
4	29	11,001	4,994,355	4,033,959	-19.2%
5	28	12,567	3,872,625	4,031,854	4.1%
6	23	11,309	3,541,830	2,959,847	-16.4%
7	22	9,044	2,719,238	2,510,281	-7.7%
8	21	7,682	2,039,161	2,166,185	6.2%
9	21	9,512	2,372,223	2,379,929	0.3%
10	21	9,274	2,597,674	2,352,131	-9.5%
11	21	9,748	2,079,953	2,407,494	15.7%
12	20	9,950,	2,034,117	2,246,073	10.4%
13	20	9,948	2,177,183	2,245,255	3.1%
14	20	9,145	2,117,706	2,152,049	1.6%
15	20	11,569	2,608,752	2,435,172	-6.7%

16	20	10,356	2,252,889	2,293,494	1.8%
17	18	8,623	2,116,880	1,721,051	-18.7%
18	18	8,838	1,995,940	1,746,163	-12.5%
19	18	10,055	2,513,108	1,888,308	-24.9%
20	18	7,680	1,541,393	1,610,908	4.5%
21	17	11,674	2,528,389	1,892,393	-25.2%
22	17	7,675	1,398,408	1,425,310	1.9%
23	17	6,202	1,161,510	1,253,263	7.9%
24	17	7,732	1,584,313	1,431,967	-9.6%
25	14	8,298	1,094,097	943,033	-13.8%
26	14	8,514	1,194,181	968,262	-18.9%
27	13	14,309	1,177,874	1,460,103	24.0%
28	12	9,960	704,908	767,126	8.8%
29	11	11,289	753,088	737,339	-2.1%
30	11	9,043	440,517	475,006	7.8%
Average					**10.4%**

As a result of the case verification (table 12), the error rate of elementary schools was 11.3%, and the deviation ranged from 1.9% to 22.8%. The error rate was 9.1%, which did not exceed 10%, thus, confirming 90% or higher reliability of the prediction model value by the maintenance cost regression analysis. This analysis result did not differ significantly from the result of error rate verification.

Table 12: Verification result of cases (Unit: KRW1,000)

No.	Elapsed years	Floor area	Repair cost	Forecast cost	Error rate
1	32	12,595	4,150,706	4,775,182	15.0%
2	30	6,065	3,198,672	3,642,449	13.9%
3	25	5,763	2,183,997	2,682,103	22.8%
4	24	5,987	2,422,345	2,523,252	4.2%
5	24	7,182	3,074,372	2,662,828	-13.4%
6	24	10,526	3,711,638	3,053,407	-17.7%
7	24	7,684	2,671,098	2,721,462	1.9%
8	21	7,432	2,265,569	2,136,985	-5.7%
9	20	7,926	2,054,751	2,009,670	-2.2%
10	19	6,794	2,010,412	1,692,438	-15.8%
Average					**11.3%**

6. CONCLUSION

The ultimate purpose of this study was to develop a prediction model for the maintenance cost of school facilities, which has a tendency of increasing as the years elapse and to organize reasonable and systematic maintenance and maintenance cost budgeting. Therefore, based on 30-year maintenance budget history data, estimated maintenance cost performance data were analyzed by regression to develop a maintenance cost prediction model suitable for educational facilities. Then, the error rate and the appropriateness of case application were verified for the maintenance cost prediction model.

The maintenance cost prediction model for elementary schools derived in this study is expected to provide objective criteria for the establishment of mid- to long-term school facilities planning, thereby enabling rational and systematic maintenance cost budgeting. Additionally, by converting the maintenance cost budget history data to estimated maintenance cost performance data, we obtain long-term estimated maintenance cost performance data for 30 years or more instead of the short-term performance data for five years obtained with the existing method. This allows rational and systematic maintenance for a variety of facilities, such as public facilities, apartments, and business facilities, as well as school facilities.

However, to develop a more accurate maintenance cost prediction model with a lower error rate than the prediction model derived in this study, the estimated maintenance performance data based on more budget history data should be acquired.

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