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The Estimation Analysis Method of the Annual Operation Cost of Korean High-rise Condominiums

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Abstract

In today's building industry the emphasis has been geared more towards construction, thus building maintenance and life cycle have been neglected until now. A direct result of this neglect is the rapid aging of building, which leads to more cost-effective decision making methods for the prolongation of building life span. The following study is conducted in the area of Daegu and Seoul in order to develop the estimation analysis method of the annual operation cost of the Korean high-rise condominiums for the cost-effective decision making support through mathematical and statistical analyses including the present value and standardized measurement corrections. Based on the assumption that the life expectancy of the high rise condominium is 50 years, initial cost is ₩421,212/㎡, and a total sum of yearly operation cost during life expectancy is ₩2,154,499/㎡), yearly accumulated operation cost is shown as below:

$AOC = 0.7097t^4 - 38.803t^3 + 806.95t^2 + 11045t - 496.52$ ($R^2 = 0.98$)

(Here, AOC = Accumulated Operation Cost, t = given years)

Keywords: building life span, cost-effective decision making, life cycle cost, operation cost

1. INTRODUCTION

Generally speaking, the life span of a reinforced concrete building is more than 50-60 years. However, the high rise condominium is usually demolished after 20 years because of the limitation on the social and functional life span in spite of its remaining life expectancy. Therefore, it is necessary to provide a cost-effective decision making method for the life span of the high rise condominium as high rise condominiums are a major housing typology in Korea.

To support cost-effective decision makings, we should approach it through the concept of the life cycle cost because sustainable prolongation of a building life's span means to provide the most cost-effective time to demolish the structure after it is built. In this context, it is the operation cost that has the greatest influence on the life cycle cost. But it is almost impossible to acquire annual operation cost data after the 21st year because the average life span of Korean high-rise condominium is 21.6 years (Ko, 1998). This is the reason why we need both the present value and standardized measurement corrections and the approaches of the mathematical and statistical analyses at the same time.

The purpose of this paper is to develop, by means of mathematical and statistical analyses, the estimation analysis method of the annual operation cost of the Korean high-rise condominiums for the cost-effective decision making support. It is based on the actual condition of initial cost and operation cost.

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2. METHODS

(1) Survey

Classification of Items

As many as five survey items have been classified. Table 1 lists each of these items and their variables considering the relationship with the life span of high-rise condominium. The operation cost has been divided into management expense, sanitation expense, energy expense,

Table 1. Classification of Items

Items		Variables
General	Property Age	Substantial Completion Year
	Property Size	Number of Units
		Area of Units
		Area of Site
		Gross Area
		Floor Area Ratio
	Facilities	Heating Method
		Elevator
	Etc	Type of Management
Expense		Management expense
		Sanitation expense
		Energy expense
		Maintenance expense

and maintenance expense based on legal operation cost (Table 2).[1]

Table 2. Adjustment of Items

Management expense		Personnel expenses
		Accountant business expenses
		Transportation and correspondence expenses
		Tax
		Clothing expenses
		Training
		Incidental expenses
		Etc
Sanitation expense		Cleaning
		Waste collection
		Disinfection
Energy expense	Individual	Heating
		Hot water supply
		Electricity
		Water supply
		Gas
	Public	Heating
		Hot water supply
		Electricity
		Water supply
		Gas
Maintenance expense	Long term repair expense	Replacement and repair expenses for main facilities
	Reserve for special repairs	--
	Running expense	Replacement and repair expenses
		Elevator

[1] Legal operation cost is composed of management expense, individual energy expense and long term repair expense by the Condominium Management Ordinance 15.

Surveys

Surveys have done four times including the preliminary one. The overview of these surveys is shown in Table 3.

During the preliminary survey, the literature examination and the interview with staffs of the Korean Housing Management Association (KHMA) were conducted to find out the distribution of aged high-rise condominium, which enabled us to select Seoul and Daegu; there were more than 1,800 aged high-rise condominium complexes in Seoul and we were able to research them directly in Daegu.

Table 3. Overview of surveys

	preliminary	1st	2nd	3rd
Period	3.23 - 3.29	4. 1 - 4. 15	4.17 - 6.20	6.25 - 8. 3
Area	-	Daegu	Daegu	Seoul
Methods	Literature examination, Interview	Visiting	Visiting	Post service

* It was done based on 1997.

Following the preliminary one, the three main questionnaire surveys were conducted. The first survey was done by undergraduate and graduate students who had themselves lived at high-rise condominiums. These students visited maintenance offices of their own high-rise condominium complexes to examine and acquire data of annual operation cost. This approach was not very effective because they were not allowed to access to documents that were conducted for official use only. That is the reason why we decided to conduct additional surveys.

In the second survey, the research staff visited maintenance offices of selected high-rise condominiums with a letter of recommendation issued by the president of Daegu branch of KHMA. This enabled us to collect data for operation cost based on the account books and intensified interviews with the managers of the selected high-rise condominiums.

In order to intensify the quality and the quantity of the data, I sorted out the 200 oldest high-rise condominium complexes in Seoul from the list of 1,800 aged ones based on the official recommendation of Seoul branch of KHMA. Table 4 lists the physical value of variables in case of aged high-rise condominium.

Table 5 lists the status of annual operation cost acquisition. The marked cells indicate the attainability for the data acquisition. For example, for Dss2, we have two annual operation cost data in 1995 and 1996 or the 7th year and the 8th year after construction in 1989. Thus Dss2 has two marked cells. At the bottom of the Table 5, the quantity of acquired annual operation cost for each of the 19 years is indicated.

Table 4. Physical Value of Variables in case of Aged High-rise Condominiums

Name		SCY (yr)	Age (yr)	AS (m^2)	GA (m^2)	NU (unit)	FAR (%)	AU (m^2, pyung)	HM	E
1	De1	1979	18	6,825	11,329	110	166	103(31.2)	C	X
2	De2	1987	10	51,204	82,045	917	165	89(27.0)	C	○
3	Ds1	1979	18	5,596	22,453	223	473	101(30.6)	C	○
4	Ds2	1980	17	24,047	59,489	441	247	135(40.9)	C	○
5	Ds3	1981	16	16,628	46,667	553	280	84(25.5)	C	○
6	Ds4	1984	13	36,751	132,314	648	360	204(61.8)	C	○
7	Ds5	1986	11	35,564	74,554	672	210	110(33.3)	C	○
8	Ds6	1988	9	82,272	172,960	1162	210	148(44.8)	C	○
9	Dn1	1979	18	18,949	44,748	198	236	96(29.1)	C	○
10	Dm1	1993	4	51,932	130,777	1058	259	124(37.6)	C	○
11	Dss1	1980	17	129,515	168,379	1776	130	95(28.8)	C	○
12	Dss2	1989	9	32,834	69,241	542	211	127(38.5)	C	○
13	Dss3	1991	7	23,760	59,756	455	251	131(39.7)	C	○
14	Dss4	1991	7	23,657	65,217	425	276	153(46.4)	C	○
15	Dss5	1991	6	26,314	69,382	526	263	135(40.9)	C	○
16	Dss6	1994	3	9,631	38,719	281	402	138(41.8)	I	○
17	Dss7	1995	2	19,385	52,650	600	272	88(26.7)	I	○
18	Dd1	1989	8	18,810	25,629	320	136	80(24.2)	I	X
19	Dd2	1993	4	23,008	63,699	440	277	144(43.6)	I	○
20	Dd3	1993	4	20,045	46,997	415	234	113(34.2)	I	○
21	Dd4	1993	4	37,448	101,599	718	271	141(42.7)	C	○
22	Dd5	1994	3	60,848	214,413	1521	352	141(42.7)	C	○
23	Sg1	1978	20	15,404	33,125	308	215	108(32.7)	C	○
24	Sg2	1983	15	16,447	32,179	230	196	140(42.4)	R	○
25	Sg3	1984	14	10,652	20,396	90	175	227(68.8)	C	○
26	Sg4	1986	12	6,734	14,807	142	220	104(31.5)	R	○
27	Sg5	1987	11	45,684	128,756	911	282	141(42.8)	C	○
28	Sg6	1993	5	15,272	37,566	330	245	114(34.5)	I	○
29	Sy1	1991	6	3,195	10,693	94	334	114(34.5)	R	○
30	Sw1	1989	8	3,863	10,447	110	270	95(28.8)	C	○
31	Sp1	1985	13	17,235	34,030	264	197	129(39.1)	C	○

* D: Daegu, S: Seoul, e: East division, s: South division, n: North division, m: Central division, ss: Suseong division, d: Dalseo division, g: Gangnam division, y: Yangcheon division, w: Seocho division, p: Songpa division

* Legend: SCY = Substantial Completion Year; AS = Area of Site; GA = Gross Area; NU = Number of Units; FAR = Floor Area Ratio; AU = Area of Units; HM = Heating Method; C = Central; I = Individual; R = Regional; E = Elevator

Table 5. the Status of Annual Data

Name		Substantial Completion Year	Acquired Annual Data																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	De1	1979																	95		
2	De2	1987								94											
3	Ds1	1979															93	94			
4	Ds2	1980										89	90	91	92						
5	Ds3	1981											91	92	93	94					
6	Ds4	1984								91	92										
7	Ds5	1986										95									
8	Ds6	1988	88			91	92														
9	Dn1	1979																	95		
10	Dm1	1993	93		95																
11	Dss1	1980																95			
12	Dss2	1989							95	96											
13	Dss3	1991		92	93	94	95														
14	Dss4	1991	91	92	93	94	95	96													
15	Dss5	1991	91	92	93	94	95														
16	Dss6	1994		95																	
17	Dss7	1995	95																		
18	Dd1	1989							95												
19	Dd2	1993		94	95																
20	Dd3	1993		94	95																
21	Dd4	1993	93	94																	
22	Dd5	1994	94	95																	
23	Sg1	1978														91	92	93	94	95	96
24	Sg2	1983									91	92	93	94	95	96					
25	Sg3	1984								91	92	93	94	95							
26	Sg4	1986					90	91	92	93	94	95									
27	Sg5	1987							93	94	95	96									
28	Sg6	1993			95	96															
29	Sy1	1991	91	92	93	94	95														
30	Sw1	1989			91	92	93	94	95												
31	Sp1	1985								92	93	94	95	96							
total number of acquired data			**8**	**9**	**9**	**7**	**7**	**3**	**5**	**7**	**6**	**7**	**5**	**5**	**3**	**3**	**2**	**3**	**3**	**1**	**1**

(2) Correction of present value and standardized given measurement of data

The data acquired through a lot of surveys have different periods and property sizes. Therefore, it is impossible to compare and analyze them directly without corrections. That is the reason why I need to correct them based on the present value and standardized given measurement. The standard point of time was set for 1996 because it was the time when the latest annual operation cost data was acquired. The correction of present value was applied to the earlier annual value considering consumers price index, fuel, light and water charges index, and house repair and maintenance price index of last 10 years.

In addition, 1 ㎡ was set for the standard measurement of property size to compare the different sizes effectively.

Calculation of corrected present value

Table 6 shows the values of three main indices and their corrected value for this research with the consideration of the characteristics of high-rise condominiums. The consumer price index was applied to the general expense, the sanitary expense and the reserve fund for long term repair. Though it was regarded as one of the repair expenses, the reserve fund for the long term repair was just savings for future repair. Fuel, light and water charges index was applied to the energy expense. And the maintenance price index was applied to the repair expense.

Table 6. Calculation of Present Value Correction

Year	Consumer price index		Fuel, light and water charges index		Maintenance price index	
	OV	CV	OV	CV	OV	CV
87	81.3	174.42	101.6	134.65	71.7	199.86
88	87.1	162.80	100.5	136.12	79.4	180.48
89	92.1	153.96	99.3	137.76	86.7	165.28
90	**100.0**	**141.80**	**100.0**	**136.80**	**100.0**	**143.30**
91	109.3	129.73	107.8	126.90	110.3	129.92
92	116.1	122.14	114.7	119.27	114.9	124.72
93	121.7	116.52	119.4	114.57	118.9	120.52
94	129.3	109.67	123.3	110.95	124.3	115.29
95	135.1	104.96	128.0	106.88	135.0	106.15
96	**141.8**	**100.00**	**136.8**	**100.00**	**143.3**	**100.00**

* Legend: OV = Original Value; CV = Corrected Value

It was recomposed from Korea Statistical Year Book (Economic Planning Board, 1997) and Yearly Statistics of Daegu (Daegu Metropolitan City, 1997)

Calculation of corrected standardized given measurement

The concept of the correction of standardized given measurement is critical for the analysis of operation cost of high-rise condominiums because each of them have totally different property size one another. Therefore, it is essential to standardize the unit of the property size for valid comparison and effective analyses. The equation for it is shown as below:

$$\textit{Operation Cost with the Corrected Value}\,(₩/㎡) = \frac{\textit{the Present - valued Operation Cost}\,(₩)}{\textit{Total Floor Area}\,(㎡)} \quad \text{---------} (1)$$

3. RESULTS AND DISCUSSION

(1) Calculation of corrected annual operation cost

Calculated operation cost from the 1st to the 19th year through three surveys, present value correction and standardized given measurement correction is shown as below (Table 7). An examination of the yearly correction value of standardized given measurement and present value of data shows that it periodically increases every 7-8 years in a given form (Figure 1).

Table 7. Calculation of Operation Cost

Age (yr)	GE (₩/㎡)	SE (₩/㎡)	EE (₩/㎡)	MTE (₩/㎡)	OC (₩/㎡)
1	5491	700	4577	329	11097
2	6613	721	5102	747	13183
3	6727	742	6330	1020	14819
4	7471	692	6597	1318	16078
5	7221	641	6947	1690	16499
6	5879	596	8142	1627	16244
7	6021	750	6636	1547	14957
8	6906	885	7220	2004	17015
9	6993	1079	9359	2374	19805
10	7978	934	8117	2288	19316
11	8621	948	7710	2164	19443
12	8727	1098	7665	2556	20046
13	7662	1007	6507	2433	17609
14	7290	1211	6650	3896	19047
15	6579	932	6350	1316	15177
16	7731	844	6617	2006	17198
17	5965	780	9969	3013	19727
18	7076	1371	9978	1668	20093
19	7442	1367	10774	2457	22040

* Legend: GE = General Expense; SE = Sanitation Expense; EE = Energy Expense; MTE = Maintenance Expense; OC = Operation Cost

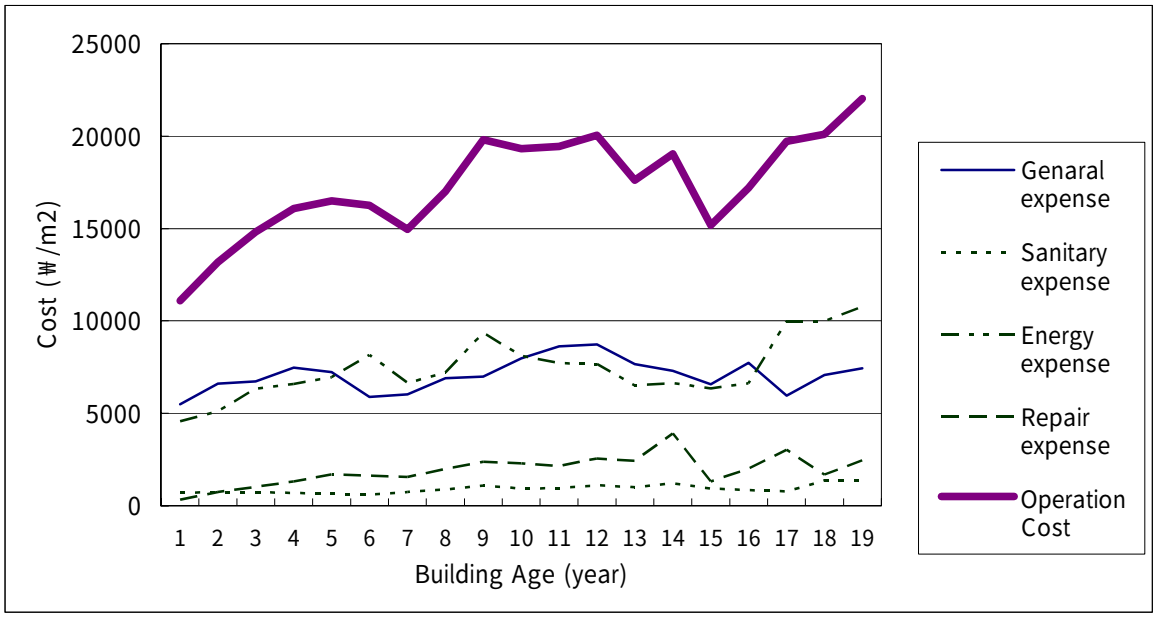

Figure 1. Annual Operation Cost

(2) The estimation analysis of operation cost

According to the Korean Corporation Tax Law, the maximum life expectancy of reinforced concrete building is 50 years. (Ministry of Finance Ordinance 1736, Corporation Tax Law enforcement regulations Article 297)

But, in reality, the average life span of Korean high-rise condominiums is 21.6 years (Ko, 1998). This means that annual operation cost data between the 20th and the 50th year are hardly acquired by surveys. From this viewpoint, mathematical and statistical analyses are essential to estimate annual operation cost of high-rise condominiums during the last half of life expectancy.

In this research, we were able to acquire annual operation cost data from the 1st to the 19th year using surveys and calculations through the present value and standardized measurement corrections. And the 20th to the 50th annual operation cost data were able to be estimated by the mathematical and the statistical approach, based on the data from the 1st to the 19th year and precedent standards from advanced researches. Three steps needed to be applied in order to do the estimation. These are listed as below:

1. The calculation of the total sum of operation cost through the whole life span of high-rise condominium
2. The calculation of yearly accumulated operation cost based on the acquired yearly operation cost data
3. The estimation of annual operation cost through the ratio distribution and the regression analyses

For more reasonable standard, we have examined advanced researches and case studies from developed countries which have a lot of achievement in the field of the life cycle cost and the building management. These can be summarized as below:

First, the operation cost during the whole life span is 4-7 times as much as initial cost, based on the actual building usage (Dell'Isola and Kirk, 1981).

Second, according to the Grand Plan for a New Architecture, published by Architectural Institute of Japan, the total sum of operation cost during the life span of office building with gross area of 6,000 ㎡ is 5.4 times as much as that of initial cost. In other words, it is 83.5% of the whole life cycle cost.

Third, Ishitsuka Yositaka calculated the life cycle cost of a reinforced-concrete structured office building. He applied real data and standards of Japan Ministry of Construction to the office building with gross area of 6,494 ㎡. Table 8 (Center for Architectural Conservation, 1993) shows the cost and the percentage of every item as parts of life cycle cost. We found out that the total sum of operation cost during the whole life span was 5.115 times as much as initial cost through the real application.

We selected Ishitsuka's standard of 5.115 times of initial cost as the total sum of operation cost during the life span of the high-rise condominium because among the three standards, it is the one that has been proved by real application.

The initial cost containing material cost, labor cost, profit, value-added tax, and a bond is calculated as ₩421,212/㎡. It is based on the average value of the standard construction cost which had been used by five Korean major construction companies for high-rise condominium construction. (Ko, 1998) Based on assumption that the life expectancy of the high-rise condominium is 50 years and initial cost is ₩421,212/㎡, a total sum of yearly operation cost during life expectancy is ₩2,154,499/㎡.

Table 8. Life Cycle Cost of 6,494 ㎡ Office Building

Items		Cost (1,000￥)	Perce-ntage (%)	RPCC (%)
PD	Planning	3,600	0.5	
	Field work	4,000		
	Land Acquisition	2,100		
	Designing	43,600		
	Impact analysis	1,100		
	Environmental management	1,100		
	Design support	2,600		
	Subtotal	58,100	0.7	4.1
C	Contract	1,000	16.1	100.0
	Construction	**1,402,000**		
	Construction Management	13,900	0.2	
	Examination	800		
	Environmental management	800		
	Construction support	3,900		
	Subtotal	1,422,400	16.3	101.5
OM	Conservation	2,791,000	32.1	
	Repair	1,219,700	14.0	
	Improvement	136,400	1.6	
	Operation	2,679,200	30.8	
	General Management	172,400	2.0	
	Operation Support	172,400	2.0	
	Subtotal	**7,171,100**	**82.5**	**511.5**
D	Dismantlement	46,300	0.5	
	Disposal	4,500		
	Environmental Control	300		
	Subtotal	42,100	0.5	3.0
Total		8,693,700	100.0	620.1

* Legend: RPCC = Relative Percentage to Construction Cost; PD = Planning and Designing; C = Construction; OM = Operation and Maintenance; D = Demolition

(2) The result of estimation analysis of annual operation cost

Every annual operation cost during the life expectancy of 50 years was calculated (Table 9) through the regression analysis and the ratio distribution based on the result of 3 surveys (Table 7) and the assumption mentioned before. Because of its periodical increase as shown in Figure 1, high-order regression analysis will be more suitable for this research.

Table 9. Calculation of Annual Operation Cost

Age (yr)	OC (₩/㎡)	PC (%)	AOC (₩/㎡)	APC (%)
1	11097	0.52	11097	0.52
2	13183	0.61	24280	1.13
3	14819	0.69	39099	1.81
4	16078	0.75	55177	2.56
5	16499	0.77	71676	3.33
6	16244	0.75	87920	4.08
7	14957	0.69	102877	4.77
8	17015	0.79	119892	5.56
9	19805	0.92	139697	6.48
10	19316	0.90	159013	7.38
11	19443	0.90	178456	8.28
12	20046	0.93	198502	9.21
13	17609	0.82	216111	10.03
14	19047	0.88	235158	10.91
15	15177	0.70	250335	11.62
16	17198	0.80	267533	12.42
17	19727	0.92	287260	13.33
18	20093	0.93	307353	14.27
19	22040	1.02	329393	15.29
20	19305	0.90	346311	16.07
25	22466	1.04	450902	20.93
30	30240	1.40	584284	27.12
35	44755	2.08	775907	36.01
40	68140	3.16	1065863	49.47
45	102525	4.76	1504892	69.85
50	150038	6.96	2154499	100.00

* Numbers in solid-lined areas were calculated based on real surveys and corrections, while numbers in dotted-lined areas were estimated through regression analysis.
* Legend: OC = Operation Cost; PC = Percentage; AOC = Accumulated Operation Cost; APC = Accumulated Percentage

$$* PC(n) = \frac{OC(n)}{₩2{,}154{,}499/㎡}$$

$$* APC(n) = \frac{AOC(n)}{₩2{,}154{,}499/㎡}$$

Based on the assumption that the life expectancy of the high rise condominium is 50 years, initial cost is ₩421,212/㎡, and the total sum of yearly operation cost during life expectancy is ₩2,154,499/㎡ (5.115 times of initial cost), yearly accumulated operation cost is shown as below (Figure 2):

$$AOC = 0.7097t^4 - 38.803t^3 + 806.95t^2 + 11045t - 496.52 \quad (R^2 = 0.98) \quad \text{---------- (2)}$$

(Here, AOC = Accumulated Operation Cost, t = given years)

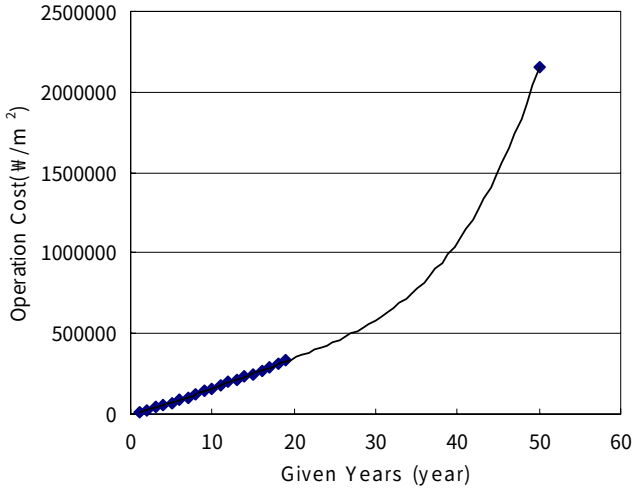

Figure 2. Calculation of regression

4. CONCLUSION

Based on the major findings of this study, we are able to make a few concluding remarks. I believe that the suggestions will be helpful in analyzing operation cost and life cycle cost of high rise condominiums in Korea.

1. I have adjusted operation cost items into management expense, sanitation expense, energy expense, and maintenance expense based on legal operation cost item. I have obtained yearly operation cost data from 1 to 19 years through 3 surveys (Table 5). An examination of the yearly correction value of standardized given measurement and present value of data shows that it periodically increases every 7-8 years in a given form (Table 7, Figure 1).

2. The estimation analysis method of the annual operation cost needs three steps; the calculation of the total sum of operation cost through the whole life span of high-rise condominium, the calculation of yearly accumulated operation cost based on the acquired yearly operation cost data, and the estimation each of annual operation cost through the ratio distribution and the regression analyses.

3. Yearly accumulated operation cost is calculated as below, based on the assumption that the life expectancy of the high rise condominium is 50 years, initial cost is ₩421,212/㎡, and the total sum of yearly operation cost during life expectancy is ₩2,154,499/㎡:

$$AOC = 0.7097t^4 - 38.803t^3 + 806.95t^2 + 11045t - 496.52 \quad (R^2 = 0.98) \quad \text{---------- (2)}$$

(Here, AOC = Accumulated Operation Cost, t = given years)

The results of this study can be applied to the prolongation of building life-span for the cost-effective decision making support. Future studies should broaden this estimation analysis to include social factors as well as cost factors to reflect various needs of residents.

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