Journal of the Korea Industrial Information Systems Research Vol. 20 No.5, Oct. 2015 :107-115
http://dx.doi.org./10.9723/jksiis.2015.20.5.107 ISSN:1229-3741

LCC Analysis to Determine an Appropriate Apartment Rent Rate for HVAC System Renovation Projects

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Abstract Residential building owners are turning toward renovating their existing buildings to improve old and inefficient HVAC systems. Due to the renovation, much of the added costs will inevitably be passed on to tenants by increasing rent rates. This increment often increases the vacancy rate in the buildings. To balance the interests of both owners and tenants, this paper suggested a method to determine an appropriate rental rate increment for the HVAC system renovation. A case study on residential buildings was conducted to determine a balanced point where the rental rate increment that offsets the amount tenants are willing to pay for the renovation. To calculate all costs incurred by the renovation, life-cycle cost analysis was carried out. Therefore, this paper ultimately provides a threshold value of rental rate increment such that building owners can make a reasonable decision on the HVAC system renovation.

Key Words : Renovating buildings, energy-efficiency, HVAC systems, life-cycle costs.

1. Introduction and Background

Over the past decade, sustainability issues have been rising in accordance with Tokyo agreement. These issues mainly concern of environmental, social and economic aspects. Sustainable development generally emphasizes the reconciliation of these three constituent parts to meet the current needs[1]. In this context, energy efficiency emerged as one of the highlighted issues in current building and facility management. New buildings and communities were rarely built with no consideration of energy efficiency. The sustainable buildings are generally designed to minimize the use of fossil fuel by utilizing energy efficiently. Accordingly, these buildings often provide residents with more comfortable places to live in and save a large amount of energy costs.

Despite the current needs, there are still many old buildings and communities that were built without consideration of insulation and efficient cooling and heating systems. These obsolete systems frequently cause a loud whirring sound and provide an uncomfortable indoor environment with high energy costs. As a result, many tenants make complaints about

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† This work was financially supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2014R1A1A2057560) and Changwon National University in 2015-2016.
Manuscript receivrd Septamber 25, 2015 / revised October 27, 2015 / accepted October 28, 2015
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the noise and move out into more comfortable places. To attract those discontented tenants, building owners are turning toward renovating their existing buildings to improve old and inefficient cooling and heating systems. The improved systems will provide tenants with a satisfactory dwelling environment by eliminating noise and improving energy efficiency.

For residential building owners, nevertheless, renovation of existing residential buildings is both opportunities and risks. It is recognized that the benefits of energy-efficiency often outweigh the renovation costs from the long-term perspectives[2]. Although renovating buildings typically requires higher construction costs, it may be worth to invest considering the long-term costs over the life of a building. It improves the old systems and increases energy efficiency, which saves a large amount of money, such as operation, maintenance, and energy costs. These benefits will be more appealing to tenants and ultimately reduce the vacancy rate.

Despite these benefits, many residential building owners still hesitate to invest on the existing buildings because of financial barrier. When owners invest most of the added costs, much of them will inevitably be passed on to tenants by increasing rent rates. This increase in rent rate, in turns, pushes tenants to move out to more affordable places. Tenants are fascinated by comfortable places with less rent rates; on the other hand, building owners are expecting to receive a good return on investment by increasing rent rates. These conflicting interests of owners and tenants frequently impede the owner's decision on investment. Therefore, it is important to predict the tenants' utility on insulation and efficient cooling and heating systems for building owners to make a safe and better decision on renovation buildings.

In general, it is uneasy to determine an appropriate rent rate with which most tenants can be satisfied because the rate follows the law of supply and demand and it is also determined by various characteristics, including location, size, and age[3-7]. François et al.[4] investigated the positive impact of landscaping on house values based on detailed field survey. In addition, Portnov[6] discovered the housing modification, neighbourhood environment and housing prices are correlated indirectly. However, the preference on energy-saving attributes can be investigated. A recent study has been conducted to identify the willingness to pay for energy efficiency attributes of rental apartments[8]. The study conducted a survey to determine the utility of the tenants on energy efficiency. The results showed that participants are willing to pay approximately 3 percent of the price for an enhanced insulated facade; while, 8 to 13 percent of the price for the ventilation systems in the buildings. This study revealed that tenants are willing to pay extra money for the improved systems.

The owner's returns on investment for the improved systems can be investigated through a life-cycle cost analysis. A life-cycle cost analysis is commonly used an engineering economic tool that can be employed to compare the relative economic benefits between different alternative systems. The analysis reflects various costs incurred during the life of a project, including construction costs, maintenance and replacement costs, energy costs, and residual values. As a result of the analysis, the equivalent uniform annual cost (EUAC) of each system can be produced and compared each other. This EUAC will provide a threshold values for the decision on whether or not the building owners will invest on the system renovation.

The purpose of this paper is to provide a method that determines an appropriate rental rate increment for a HVAC system renovation. The main idea is to find a balanced point where the rental rate increment that tenants are willing to pay for the renovation offsets the difference of the equivalent uniform annual cost (EUAC) for the renovated systems based on a life-cycle cost analysis. This balanced rental rate increment not only increases the tenant's satisfaction, but also reduces some of the owner's risks for the increase in vacancy rate which results from the rental rate increment. Consequently, this method enables to compromise the conflicting interests of building owners and tenants, ultimately benefiting to both of them. The following case study will provide a basic understanding of the procedure that determines an appropriate rental rate increment for a HVAC system renovation.

2. Brackenridge Apartment HVAC System Renovation Projects in the United States

2.1 Project Information

Brackenridge Apartment is one of the oldest apartment complexes in Austin, Texas of the United States The apartment opened in 1947 for married university students and it was rebuilt in 1983. The current window unit HVAC (Heating, Ventilating, and Air Conditioning) systems were installed in the early 1990s. In response to residents' complaints of frequent break-down, noise and lower energy efficiency of the systems, the apartment office decided to change the existing window-unit systems to modern centralized HVAC systems in 2003.

This case study used the project data of "HVAC System Renovation in Brackenridge Apartment in Austin, Texas - Phase 4" that was completed in 2006 for 20 apartment units. The project information is summarized below in Table 1:

Table 1 Project Summary

Cost	Description
Project Owner	University of Texas at Austin
Project Manager	Brackenridge Apartment Office
Contractor	Alpha Building Corporation
Project Duration	from June 2005 to July 2006
Project Cost	$518,480

The renovation activities included vacating, existing window-unit HVAC system removal, ventilation, wind outlets installation, outdoor boiler room construction, and new centralized unit system installation. The new system was designed to use electricity for cooling and gas for heating.

2.2 Performance Comparison of Window Unit and Centralized HVAC Systems

Ashrae[9] compared the performance of decentralized window-unit systems with centralized systems regarding to five performance categories: spatial requirements, initial costs, operation costs, maintenance costs, and reliability. Generally, the centralized systems require more expensive initial costs than the window-unit systems, but the centralized systems have longer service life with lower operating and maintenance costs. The centralized systems are usually installed outside HVAC control rooms; however, the window-unit systems generally are self-operated and installed in windows.

2.3 Analysis Methodology

Analysis methodology Fig. 1 was developed to estimate the proper rental cost increment due to HVAC system renovation. For the analysis two basic assumptions were made: (1) the university also pursues economic benefits from students as other private apartment companies do and (2) the HVAC renovation increases monthly rental rates. As shown in Fig. 1, owner's benefits were defined as a monetary benefit due to the replacement of existing window-unit HVAC systems with the centralized unit systems. Life-cycle cost analysis was able to explain this owner's perspectives. The resident's satisfaction on the improved system was measured as a rated value describing how much money the residents were willing to pay for the renovation. A survey was designed to rate the resident's relative satisfaction on the renovation.

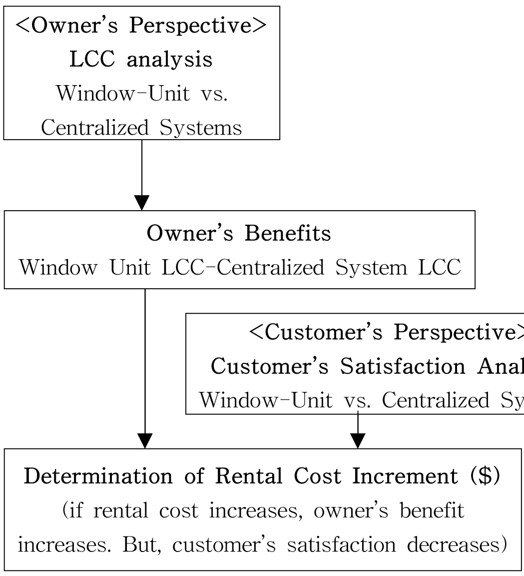

Fig. 1 Research Methodology

The values analyzed from these two different perspectives were then incorporated to determine an appropriate rental cost increment, which was a balanced point (P) shown in Fig. 2. Theoretically, if monthly increment of the rental cost increases, the owner's benefits also increase; however, the resident's satisfaction tends to decrease. The detailed analysis process will be discussed in the remaining sections.

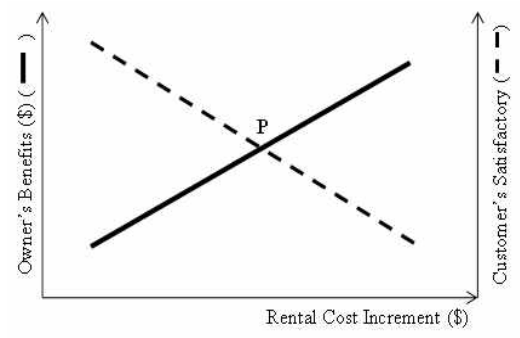

Fig. 2 Determination of Rental Cost Increment

2.4 Life-Cycle-Cost Analysis

Analysis Setup

Five different categories were considered for the life-cycle-cost (LCC) analysis of the HVAC renovation projects: (1) Initial costs-equipment costs, delivery costs, and construction costs, (2) Maintenance costs-maintenance and repair costs, (3) Replacement costs, (4) Residual values-resale and salvage values, and disposal costs, and (5) Energy (Operating) costs-electricity and gas expenditure Eq. 1. The apartment office provided detailed expenditure information.

System LCC = Initial Cost+Maintenance Cost +Replacement Cost+Residual Values +Energy Cost   Eq. 1

Several assumptions were made for the analysis. First, analysis period was set as 30 years based on the 30-year expected service life of the apartment. Second, constant maintenance costs were used for the entire analysis period. Third, the analysis was based on three different discount rates (0%, 4%, and 10%) and the energy costs were assumed to escalate 4.2% per year from 2006 until 2010 and 1% after 2010[10]. Last, the routine maintenance for existing window-unit systems was scheduled based on the actual observation of maintenance history as well as maintenance crews' opinions. New window unit replacement was scheduled in 4th, 13th, and 22nd year from the beginning of the analysis period. New baseboard heater replacement was set in 6th and 18th year. Routine inspections were performed twice a year and the annual maintenance costs were estimated by considering labor costs for inspections.

Cash Flow Diagrams

Table 2 summarized the cost information of both HVAC systems. The existing window-unit systems did not need to spend initial costs, but the initial cost for new centralized unit installation was $22,771. The annual maintenance costs were estimated based on labor costs for routine maintenance. The replacement costs for the existing systems were $1,300 for the window-unit replacement and $130 for the baseboard (BB) heater replacement. Salvage value of the existing unit was estimated at $138 for remaining service life of 1 year at the end of 30-year analysis period.

Table 2 Costs of HVAC Systems

Cost	Window-Unit Systems	Centralized Systems
Initial cost	-	$22,771
Maintenance cost	$90 per year	$90 per year
Window unit replacement cost	$1,300	-
Baseboard heater replacement cost	$130	-
Residual values	$138	-
Energy cost	$859 per year	$531 per year

Energy costs were estimated by considering actual use hours of the system, system's energy efficiency, and energy unit cost information obtained from actual electricity and heating bills Table 3. The average of actual use hours of the existing HVAC systems was estimated based on resident survey. The system capacity information (Btu per hour, Watt, or Cubic feet consumption per hour) was obtained from the system capacity manuals. Last, energy unit costs in Texas in 2006 were obtained from resident's actual electricity and gas bills.

Life-Cycle Cost Calculation

Based on the developed diagrams, life-cycle costs of two different HVAC systems were analyzed. Again, the analysis was based on the 30-year analysis period, three different discount rates (0%, 4%, and 10%), and the energy costs escalating 4.2% per year from 2006 until 2010 and 1% after 2010. Table 4 summarized analysis results for different discount rates and Table 5 shows the detailed analysis with the 4% discount rate. Regardless of the discount rates, analysis results showed that HVAC system renovation costs more despite of the higher energy efficiency than the existing window-unit systems. Owners thus need to increase the monthly rental rate to compensate additional costs for renovation. However, the residents may not want to pay high increments of the rate. Thus, it is important to find the balanced point for

Table 3 Computation of Energy Costs

	Use (hr/day)	Use (hr/year)	System Capacity	Total Energy Consumption	Unit Cost	Energy Cost
Window-Unit HVAC Systems: A/C						
Bedroom	12	1,200	11,700 Btu/hr	1,486.59 KW	$0.092/KW	$136.8
Living Room	15	1,500	14,700 Btu/hr	1,867.76 KW	$0.092/KW	$171.8
Window-Unit HVAC Systems: Heater						
Bedroom	4	400	4,090 W	1,636 KW	$0.075/KW	$122.7
Small Heater	4	400	2,000 W	800 KW	$0.075/KW	$60
Living Room	12	1,200	4,090 W	4,908 KW	$0.075/KW	$368.1
Centralized HVAC Systems: A/C						
Central Unit	15	1,500	24,000 Btu/hr	3,000 KW	$0.092/KW	$276
Centralized HVAC Systems: Heater						
Central Unit	12	1,200	0.25 Ccf/hr	300 Ccf	$0.85/Ccf	$255

estimating an appropriate amount of rental cost increment.

Table 4 Summary of Analysis Results

Discount Rate (%)	LCC(EUAC)	
	Window-Unit Systems	Centralized Systems
0	$1,467.66	$1,540.50
4	$1,443.28	$2,073.82
10	$1,408.46	$3,144.51

2.5 Owner's Benefits

The previous analysis results showed that the renovation project required owner's additional life-cycle costs. Thus, the owner may want to increase the monthly rental rate to compensate the addition costs and earn values from the renovation. The authors conducted sensitivity analysis of owner benefits to monthly rental cost increments. The owner benefit was defined as the different amount between the existing life-cycle cost (the window-unit system's LCC) and the renovation life-cycle cost (the centralized system's LCC). If the monthly rental rate increased, the renovation LCC subsequently decreased and the total owner benefit increased as a result. Table 6 explains the detailed analysis process with the 4% discount rate. The results showed that the owner would be able to expect positive benefits when the rate increased more than $50 per month; that was the balanced point.

2.6 Resident's Satisfaction

Resident's satisfaction is a qualitative value. To analyze the relative satisfaction, twenty apartment residents were participated in the survey. The first part of the questionnaire was prepared to score the qualitative benefits of the HVAC renovation from the very low value (1) to the very high value (5). Four different

Table 5 Results of the Life Cycle Cost Analysis with the Discount Rate of 4%

Window Unit *vs.* Central Unit / Project Life Cycle: 30 yrs		Discount Rate: 4%	Window Unit		Central Unit	
Initial Cost			Est.	PV	Est.	PV
Current Window Unit			0	0		
Revised New Central Unit					22,771	22,771
Total Initial Cost				0		22,770
Replacement Cost/ Salvage Value	Year	PV factor	Est.	PV	Est.	PV
Description						
A/C/ Units Replacement	4	0.855	1,300	1,111	0	0
BB Heater Replacement	6	0.79	130	103	0	0
A/C/ Units Replacement	43	0.601	1,300	781	0	0
BB Heater Replacement	48	0.494	130	64	0	0
A/C/ Units Replacement	22	0.422	1,300	549	0	0
Re-Sale Value (2-A/C Units)	30	0.308	-138	-43	0	0
Re-Sale Value (BB Heater)	30	0.308	0	0	0	0
Total Replacement/Salvage Costs				2,565		0
Annual Costs	**Scenario**	**PVA factor**	**Est.**	**PV**	**Est.**	**PV**
Description						
Energy/Fuel Annual Cost	Rising	21.755	859	18,688	531	11,552
Maintenance Annual Cost	Constant	17.292	215	3,718	90	1,556
Total Life Cycle Cost				24,970		35,879
		PP Factor	**Per Year**		**Per Year**	
Total Life Cycle Cost (EUAC)		0.058		$1,443.28		$2,073.82

categories were considered for rating: noise reduction, appearance and space utilization, convenience for use, and HVAC efficiency.

Survey results showed that all categories scored higher than the neutral value 3 on the average. The noise reduction scored 4.6, the appearance and space utilization scored 3.4, the convenience for use scored 4.5, and the HVAC efficiency scored 4. This result emphasized all residents experienced problems with the existing HVAC units and thought the renovation to the new centralized system was valuable.

The second part of the questionnaire asked how much money the residents were willing to pay for the renovation in terms of monthly rental rate increment. 35% of the residents were willing to spend $0-20 per month for the renovation, 50% said $20-40, and remaining 15% answered $40-60. Nobody wanted to pay more than $60 additional payment per month. This result indicated that the residents were willing to pay $26 for the HVAC renovation.

3. Conclusions

As discussed in the previous section, the

Table 6 Owner's Benefits vs. Monthly Rental Cost Increment

Monthly Rental Increment Due to Renovation	Total LCC (PV)	Total LCC (EUAC)		Owner's Benefits for the Renovation
	Centralized System	Centralized System	Window Unit System	
$0	$35,978	$2,080	$1,443	-$636
$10	$33,684	$1,947	$1,443	-$504
$20	$31,489	$1,820	$1,443	-$377
$30	$29,294	$1,693	$1,443	-$250
$40	$27,099	$1,566	$1,443	-$123
$50	$24,904	$1,439	$1,443	$4
$60	$22,709	$1,313	$1,443	$131
$70	$20,514	$1,186	$1,443	$258
$80	$18,319	$1,059	$1,443	$384
$90	$16,124	$932	$1,443	$511
$100	$13,929	$805	$1,443	$638

appropriate rental rate increment is determined by the balance point where the rental rate increment that residents are willing to pay for the renovation offsets the difference of the equivalent uniform annual cost (EUAC) for the renovated systems based on the life-cycle cost analysis. However, owners should take some of the risks if the difference of EUAC is larger than the extra money that the residents are willing to pay; while, the difference of EUAC between the alternatives will be the appropriate rental rate increment if the expected amount of money that the residents are willing to pay is more than the difference of EUAC.

Based on the results, the residents are expected to pay approximately $26 which is less than the difference in EUAC between the two systems. Therefore, owners need to bear some of the renovation costs if they do not want the vacancy rate to be significantly increased. While, owners will not avoid the increased vacancy rate if the rent rate is increased by $50. In conclusion, this method ultimately provides a threshold value so that the owners are able to a reasonable decision on the HVAC system renovation. However, future studies are recommended to compare our estimations with real data after 2010.

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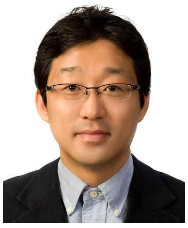

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