ARCHITECTURAL RESEARCH, Vol. 14, No. 2(June 2012). pp. 75-83 ISSN 1229-6163

Development of Repair and Replacement Cost Management System for Public Buildings to Establish Accurate Facility Management Budgets

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http://dx.doi.org/10.5659/AIKAR.2012.14.2.75

Abstract Buildings that are more than 10 years old generally have considerable repair and replacement costs due to the rapid deterioration of their systems. For public buildings in particular, which have national and social significance, considerable effort is required not only to ensure a long life cycle and safety but also to minimize the overall public expense. Along with increasing repair and replacement requirements, however, there have been problems related to the establishment of an accurate facility management budget. To address these concerns, a repair and replacement cost management system was constructed. This system manages both invested maintenance and forecast costs to establish a reasonable repair and replacement planning process and budget. The effectiveness of the system was verified through a pilot test targeting one of public Corporation (K).

Keywords : Repair and Replacement Cost Management System, Repair and Replacement, Facility Management Budget, Public Buildings

1. INTRODUCTION

1.1 Background and objectives

From a life cycle management perspective, buildings over 10 years old have considerable repair and replacement costs due to rapid deterioration of the building's systems. For public buildings, which have national and social significance, ensuring a longer life cycle and safety are key objectives. Considerable efforts are made to maintain the property value (i.e., avoid deterioration) of these buildings, while reducing the related public expenditure. Preventive maintenance is performed, which reduces the repair and replacement cost by more than 15%–30%[1], but the allocated budget is frequently insufficient even for corrective maintenance[2].

The solution to these problems such as insufficient budget and the rapid deterioration requires the establishment of a practice-oriented maintenance system, rather than a perfunctory preventive maintenance system. Moreover, such a system should actively make use of widely scattered maintenance data and sources.

To achieve these goals, this study investigates a Web-based repair and replacement system for efficiently managing the increasing repair and replacement requirements for public buildings in light of limited facility management budgets. This system forecasts the future cost of investment in facility maintenance based on a life cycle cost (LCC) analysis. In addition, it manages the actual repair and replacement cost, allowing managers to avoid duplicate spending and more efficiently manage budgets.

1.2 Study components

This study first reviews the building maintenance and budget management situation for public Corporation in light of recent developments in maintenance systems, both in Korea and abroad. The study then establishes facility repair and replacement items and a cost classification scheme, followed by a detailed system design.

Next, a prototype is developed for a repair and replacement cost management system that can provide source data for the establishment of an accurate facility management budget.

[1] Frenando et al., 1980

[2] Tae-Keun Park, Development of maintenance history management system for Buildings, The final Report, Korea Science and Engineering Foundation (Current, Korea Research Foundation), 2004

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This research was supported by Researcher Program through the National Research Foundation (NRF) of Korea (2011-0000101) funded by the Ministry of Education, Science and Technology and Joint Research Project funded by K-WATER.

- Development trend of maintenance system in Korea and abroad
- Maintenance and budget situation analysis of test-bed building
- Classification establishment of facility, repair and replacement items and cost
- Basic design and prototype design

2. FACILITY MAINTENANCE SYSTEMS IN KOREA AND ABROAD[3]

2.1 Domestic maintenance systems

The Facility Management System (FMS) in Korea Infrastructure Safety and Technology Corporation is the most commonly used system in building maintenance industry, from an inspection and safety management perspective; it includes a huge database of maintenance information. In particular, interest in building maintenance systems with energy management has increased in the last five years in Korea because of issues reduced energy consumption. Table 1 below contains representative examples of domestic maintenance systems.

Table 1. Domestic maintenance systems

System Name	Type	Description
S city facility management corporation	Target	Consigned operation of public facilities within S city
	Functions	Repair defects on owned facilities, conduct maintenance and operation activities
Korea Infrastructure Safety and Technology Corporation	Target	Facilities regulated in Article 17 of special urban regulations
	Functions	Search and query facility information, document and monitor maintenance and repair work, manage facility lists and costs as only detailed inspection.
PM highway building management system	Target	Commercial buildings (department stores, shopping centers, etc.)
	Functions	Safety inspection of buildings, drive and maintain electric/plant equipment Firefighting emergency action Self inspection and safety management for elevators
Visual CAFM	Target	Educational Facilities, offices, Airports, hospitals, exhibition halls, shopping centers(Multi-purpose buildings)
	Functions	Automatic connection with map, picture, drawing, text information Provide data in block link function and environment
ARCHI BUS/ FM	Target	Private multipurpose buildings
	Function	Search and query facility information, document and monitor maintenance and repair schedules to process works Analyze past maintenance details and costs Provide preventive repair function Compatible with CAD package, ERP, IT-based solutions, GIS system

[3] Tae-Keun Park, The Computed aided Facility Management system, Result report of the first year, K-water, 2010

2.2 Foreign maintenance systems

In the United States, Japan, and Europe, maintenance systems have been developed and used to manage social overhead capital (SOC) facilities such as roads, bridges, etc.. In particular, bridge maintenance systems are easy to organize systematically. Their development has frequently been carried out in accordance with government regulations. In addition, active systems have been constructed and utilized that deal with accident analysis, residual life cycle, and repair prioritization. Table 2 below gives some examples of foreign maintenance systems.

Table 2. Foreign maintenance management systems

Country (system name)	System	Description
China (BGI)	Target	• tunnel construction and measurement
	Function	• simulation system
UK (MAEPAS)	Target	• railroad line
	Function	• rail track repair, replacement projects, • preparation of activities accompanying • time and space plan
France (Target GOP)	Target	• road
	Function	• improvement analysis function for ballast
US (Pontis)	Target	• buildings
	Function	• record preservation • damage trend analysis, damage level determination, residual life evaluation, • economic feasibility analysis and repair priority determination
Japan Safety management support system	Target	• buildings
	Function	• manage and analysis accidents • safety information and support decision-making for safety diagnosis

2.3 Current status of maintenance systems

Although facility maintenance methods and system development have proceeded actively in Korea since 2000, consideration of database (DB) setup and utilization are insufficient. In particular, existing maintenance systems manage only information related to maintenance and safety management; there is no connection with or utilization of important budget information relating to the maintenance of public building.

On the other hand, in many overseas systems, maintenance was implemented from a facility management perspective. Many such systems have been developed and have now reached the commercialization stage.

Domestically, the introduction of several systems was attempted, but this is considered to have failed because of a lot of different activities.

3. MAINTENANCE SITUATION ANALYSIS OF TEST BED FACILITIES

3.1 Maintenance situation

K Public Corporation, the subject of the test bed, owns 1,203 buildings across the country (as of 2009). It has rapidly increased its repair and replacement activities which building manager and user required due to deteriorating facilities, so priority consideration is required to handle such requirements. In addition, the number of people in charge of maintenance is considerably lower than the huge number of facilities, which makes it difficult for them to process similar type projects or refer to existing data when planning repair and replacement activities. Nevertheless, maintaining optimal performance is necessary for basic infrastructure such as electric, network, and communication equipment. Due to the introduction and development of diverse systems that are suitable for facilities, no complaints are found from the investigation of new system application.

3.2 Process of planning facility management budget of K

To set up a facility management budget, local conservancies prepare a budget compilation, which is confirmed by the planning and coordination office. Although this procedure is similar to that typically used by public facilities, it also sets up a separate procedure for budget changes, depending on the features of the facility. The budget is implemented systematically. However, this investigation showed that the basis for decisions in this process is insufficient. The current budget compilation procedure of public Corporation is shown in Figure 1.

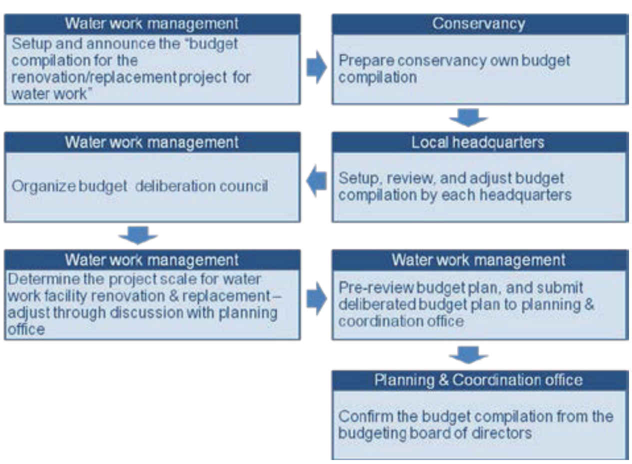

Figure 1. Process of planning Repair and replacement budget

4. CLASSIFICATION OF SYSTEM COMPONENTS

The basic components of the maintenance management system were classified as part of structuring the overall design of the system for the K facilities and the target test bed facility. The major categories of components that were classified were for facilities, renovation and replacement items, and cost.

4.1 Facility classification scheme

The facility classification scheme has three steps. In step 1, facilities are classified based on whether they are the Head Office or one of the eight local headquarters. In step 2, the classification is by local area, so the facilities are further organized in the Head Office and operation conservancy groups in the local headquarters offices. Finally, in step 3, further divisions are made based on functional buildings or rooms.

Basic facility information refers to basic information data for the facility classification scheme. Information about all facilities in the test bed target business site is organized in order to input the information of the test bed business site in advance.

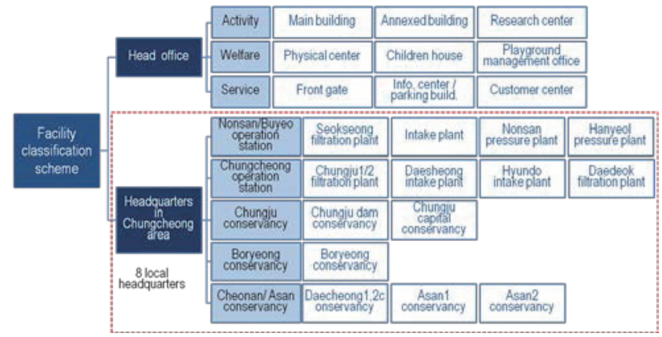

Figure 2. Facility classification scheme of K

4.2 Repair and replacement item classification scheme

A DB was made with K's optimal repair and replacement cycle to be used in the LCC analysis. The data in this DB was used as source data in forecasting and establishing this cost to be invested into repair and replacement activities. The repair and replacement cycle was prepared based on the existing repair and replacement standards of the Korea Water Resources Corporation, housing laws, CBR facilities, and notifications issued by the Public Procurement Service. The items utilized as basic data in this system were classified using four steps. Titles for each step are shown in Figure 3 below.

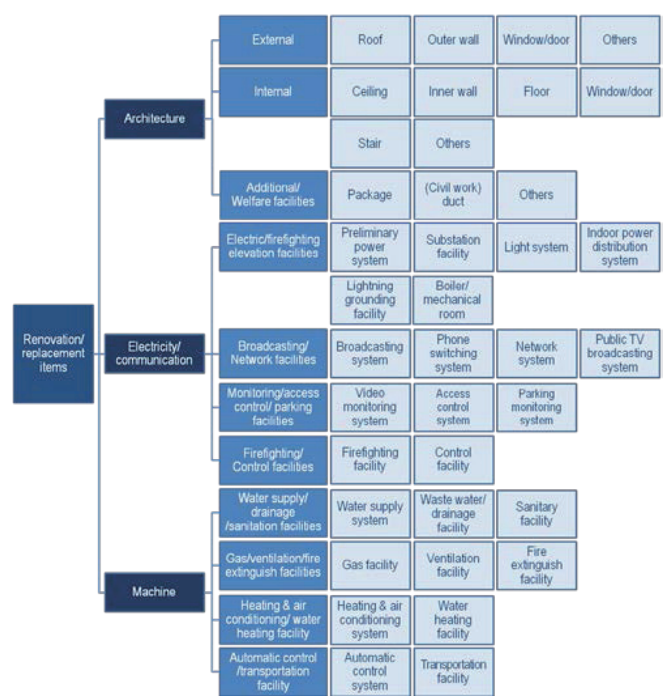

Figure 3. Repair and replacement classification scheme of K

4.3 Cost classification scheme

Cost items to be used in the actual maintenance cost-based building maintenance system are divided into four types: initial cost, actual cost (which includes repair and replacement cost), facility management cost, and energy cost. The forecasting system for life cycle cost includes this classification.

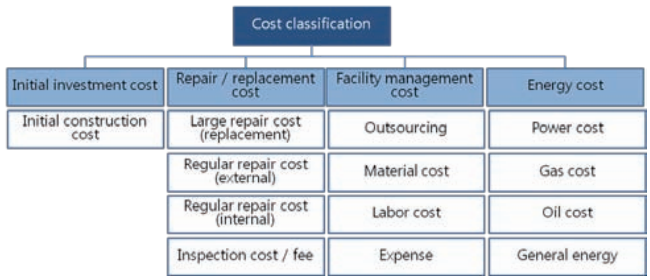

Figure 4. Cost classification scheme

5. SYSTEM PROTOTYPE DESIGN

5.1 Prototype overview

Both user convenience and system expandability were considered in setting up the repair and replacement cost management system web-based for public buildings. In addition, the system tracks the detailed occurred work data for repair and replacement maintenance activities. It also increases efficiency in maintenance works through both a repair and replacement items analysis and a comparative analysis of alternative plans.

As shown in Figure 5, the repair and replacement cost management system developed in this study consists of two modules: the basic maintenance system (Maintenance Information System, or MIS) and the life cycle cost forecasting system (Life Cycle Cost System, or LCCS). This study managed records on repair and replacement work and added a composite analysis function in LCC analysis. In addition, the system allowed for use by two distinct groups: a manager group and a general user group.

Table 3. Environment for system development

Development base	System	Language	DBMS
.NET Framework	Windows (Web)	C#	Oracle 10g

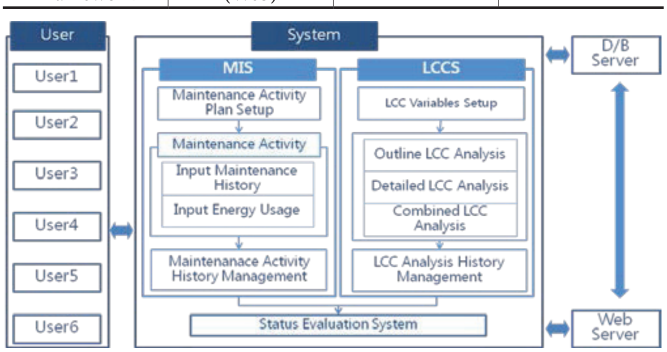

Figure 5. Overview of repair and replacement cost management system

5.2 Basic maintenance system

The basic maintenance information system (hereafter, it is called MIS) is a module that records and manages information on actual repair and replacement activities and maintenance. The MIS includes data related to the repair and replacement plan, maintenance, and energy management, as well as the repair and replacement histories.

The system collects and manages the history of actual activities conducted for repair replacement operation and maintenance, and uses activity-related information, activity-related material information, energy usage information, and operation and maintenance-related key architectural facility information for the building as a source data for repair and replacement items. The variables in MIS are composed of repair and replacement history and costs, as shown in Table 4 below.

Table 4. MIS variables

Type		Detail items		
Cost variable	Cost	Repair and replacement cost	Energy cost	Facility management cost
	Task promotion	Large repair	General repair (external)	General repair (internal)
	Cost item	Labor cost/ material cost	Expense	Inspection/fee
Energy variable		Power usage volume	Gas usage volume	Oil usage volume
		Power unit price	Gas unit price	Oil unit price

5.3 Life cycle cost forecasting system

The life cycle cost system (hereafter, it is called LCCS) is based on variable factors including the LCC analysis period and interest. Outline analysis and detailed analysis are available in the preliminary plan setup stage. In outline analysis, once the project information is entered and the analysis variables are set up, an analysis is performed of various alternative plans. A comparative analysis of those plans is then performed. The detailed analysis is composed of the same processes as the outline analysis, but the actual interest rate is set up prior to the cost analysis. For the four types of costs, an analysis of each facility is conducted through the analysis and combination of repair and replacement items. In addition, a comparative analysis is conducted through sensitivity analysis.

The price variable, outline analysis variable, and detailed analysis variable are the basis of the LCCS variables. The actual interest rate is assigned based on the inflation rate and index interest with the price variable. For the price basis, in general, the 10-year-average value calculated from LCC using the currently valued, ending, and invariable prices is applied, but only the values after 1999[4] are appropriated.

The outline analysis variable is composed of core variables and cost variables. The core variables include durable years, gross area, total construction cost, and interest rate. Four kinds of rough calculations are performed based on the core variables and appropriated for the construction cost unit price, repair cost ratio, replacement cost ratio, and operation cost ratio.

Table 5. LCC outline analysis - variables

Type	Detail items			
Core variable	Durable years	Gross area	Total construction cost	Interest rate
Cost/ratio variable	Construction cost unit price	Repair cost ratio	Replacement cost ratio	Operation cost ratio

[4] The inflation ratio after 1999 is used because applying the actual interest ratio for 1997 ~1998 would not be acceptable due to the decline sharply in inflation rate. However, the inflation ratios and market interests of respective years are entered, so that the 10-year-average value can be applied, if necessary.

The variables in the detailed analysis are composed of base time variables and cost variables. The cost variables are required in the calculation of the invariable, annual, and ending prices for each appropriated cost. The current price is appropriated for the initial investment cost, and the unchanged cost is appropriated for the operation and maintenance cost, as they are costs that are changeable in their course.

Table 6. LCC detailed analysis - variables

Base time variable			Cost variable		
Analysis base date	Analysis period	Construction period	Inflation rate	Actual discount rate	Deposit interest

6. REPAIR & REPLACEMENT COST MANAGEMENT SYSTEM FOR PUBLIC BUILDINGS[5]

A pilot test was conducted on K facilities using the repair and replacement cost management system for public buildings developed in this study. The objectives of this test were to manage this cost and to verify the calculated formulas and processes.

6.1 Basic maintenance information system

The MIS handles basic building information. If a building type from the tree-structured facility list on the left side of the screen is selected, a screen is displayed (Figure 6), through which detailed building information can be managed and queried.

Figure 6. Screen of basic building information

The contents and progress status of repair and replacement activities conducted on the building are displayed in calendar form, and the progress status can be displayed in one of three icons. In addition, a manager of that building can make inputs and change progress status, whereas a high-ranking manager or a manager of other buildings can only inquire regarding repair and replacement activities, without the ability to use the edit or delete functions. Based on the daily work log of K-public Corporation, input, edit, and deletion of the details of actual repair and replacement activities can be performed (by managers with access).

The activity type can be selected and the reason for the activity manually entered along with an activity description. For repair and replacement cost information, a unit price can be taken from the repair and replacement item DB or can be manually input in consideration of deduction ratio. Through these processes, the overall repair and replacement activity records can be managed for each building.

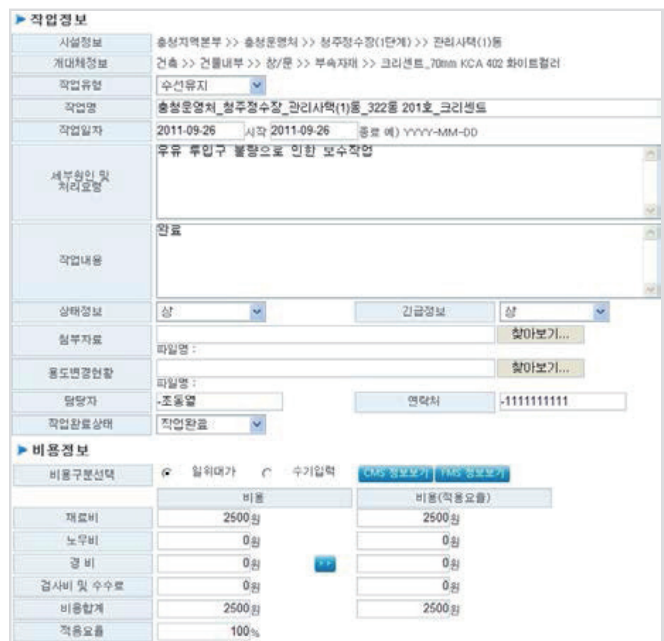

Figure 7. Repair and replacement activity input screen

In addition, energy usage volumes and costs can be managed for each building. Once power, gas, oil usage volume by period, and unit price for each energy type are entered, the total energy usage volume and energy cost are displayed automatically.

Figure 8. Energy cost input screen

Once the entry of repair and replacement activities history is completed for the building concerned, a result screen will be displayed as shown in Figure 9. This screen shows repair and replacement costs, energy costs, facility management costs, and the sum of repair and replacement costs for the building. It also uses graphs to identify the ratio of costs used for the facility.

[5] Min-chan Choi, etc., Development of the repair and replacement cost management system for planning budget of facility management in public buildings, 2011, annual conference of AIK, p. 421~422

Figure 9. Repair and replacement activity history result

In addition, the input data can be searched by building, facility, and repair and replacement item, allowing for up to three different comparative analyses of historical data by setting the variables for analysis period and activity type (see Figure 10).

Figure 10. Comparative analysis results by facility

The variables building repair and replacement item, repair and replacement cost invested in a given variable period, energy cost, and facility management cost can be analyzed comparatively. Moreover, search results can be represented in bar and pie graph form, to allow checking of proportions.

6.2 Life cycle cost forecasting system

Using LCCS, the deposit interest, inflation rate, and actual interest rate information required for the LCC analysis can be reviewed. In addition, the actual interest rate required for analysis can be appropriated, and outline, detailed, and combination analysis performed.

First, to get the outline analysis, select a facility from the facility classification tree on the left side of the screen as shown in Figure 11. The selected facility will be then be automatically entered in the target field at the top of the screen. After selecting the outline analysis, the durable years and price basis can be selected, and the construction unit price entered.

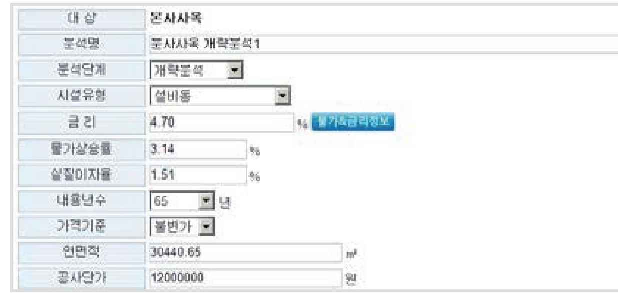

Figure 11. Outline analysis variable setting screen

The result screen shows the details of analysis setting and its results, and displays setting variables and result values by cost item as both amounts and graphs. In addition, it is possible to view a comparative analysis of the existing and alternative plans according to changes in critical variables, through sensitivity analysis.

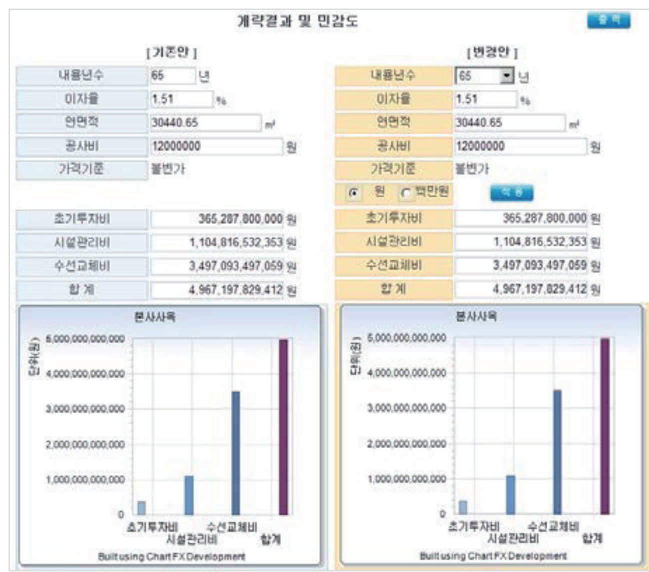

Figure 12. Outline analysis result and sensitivity setting screen

As in the outline analysis, the detailed analysis is started by selecting a facility from the facility classification tree on the left side of screen, then the detailed analysis on the analysis setting, followed by the durable years and price basis to be used, and then clicking the add button. The screen shown in Figure 13 below will then be displayed.

Unlike the outline analysis, the detailed analysis requires entering the initial construction cost, repair and replacement cost, and energy cost of repair and replacement items. For the initial construction cost, a repair and replacement item can be selected by using a search for that item, and also entering target name of the analysis. The item quantity, material cost, labor cost, expense, inspection cost, and fees, as well as the total cost of the repair and replacement item, are previously entered in the database and are automatically appropriated.

Figure 13. Initial investment cost setting screen

In the repair and replacement cost tab, the initial construction cost entered in Figure 13 is brought up along with a check button. Then the Standard of the repair and replacement items are retrieved from the database, the repair and replacement amounts are calculated, and the total sum of repair and replacement costs is displayed.

Figure 14. Repair and replacement cost setting screen

In the energy cost tab, one of three calculation methods can be selected. The option of calculating the energy cost for machines and electric communication can be made, and items that need to be calculated can be marked in the database. For energy cost input, the sum of the energy costs can be calculated and displayed if manual data entry is done for fuel consumption, power usage volume, number of days, number of pieces of equipment, and individual consumption charge of the repair/ replacement items.

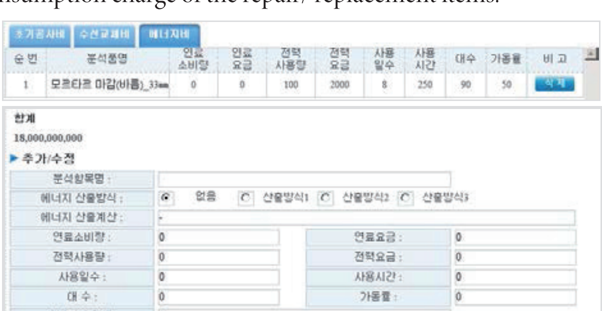

Figure 15. Energy cost setting screen

Figure 16 below is the result screen for a LCC detailed analysis, in which the initial investment, repair and replacement, and energy costs of this item for which the analysis was carried out are displayed in graph form. As in the LCC outline analysis, a comparative analysis between the existing and alternative plans is available to reflect changes in the critical variables.

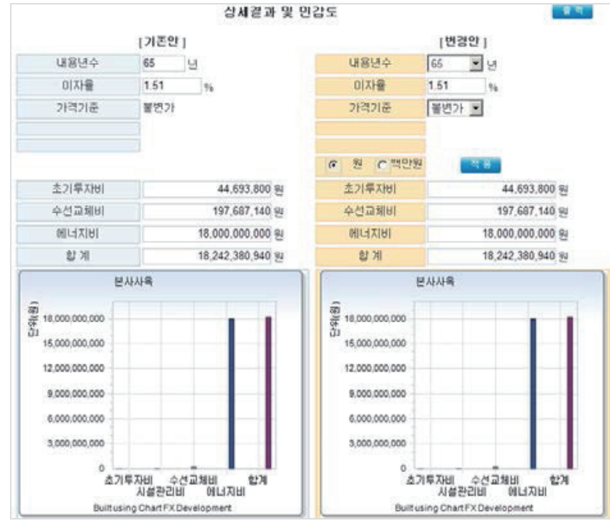

Figure 16. Detailed analysis result and sensitivity setting screen

In addition to the above functions, the life cycle cost forecasting system can provide two types of comparative analysis between the results of the outline and detailed analyses, through a combination of comparative analysis and comparative analysis based on an alternative plan. The comparative analysis based on the alternative plan is further divided into single and combination comparative analyses.

First, for the combination analysis, the facility inquiry feature can be used to search for and select lists of facilities to be included in the comparison. This gives the screen shown in Figure 17 below, where the upper left-hand area shows the combination analysis results based on initial investment, repair and replacement, facility management, and energy costs and the upper right-hand area shows the results using bar and pie graphs. The bottom of the screen shows the result for the period selected in the analysis to show detailed costs. Using this procedure, both the costs of one building and the sum of multiple buildings can be found. In addition, the detailed costs by period can be displayed on a linear graph in a pop-up window when the graph button is clicked, as shown in Figure 18. In this window, only large life cycle amounts for the respective buildings are displayed.

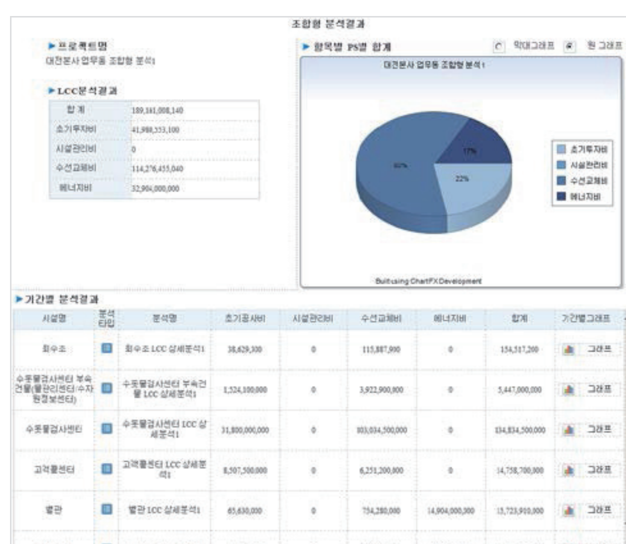

Figure 17. Combination comparative analysis result

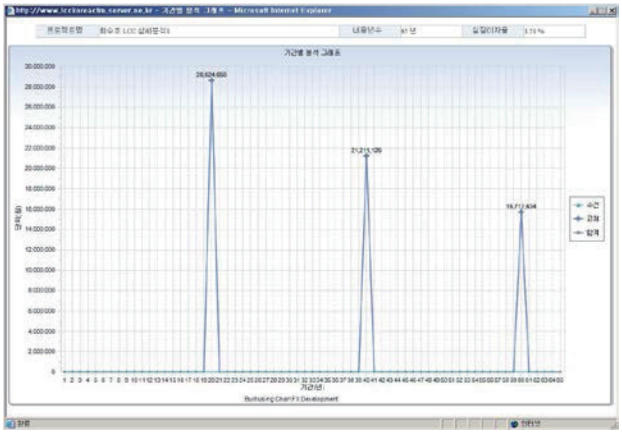

Figure 18. Analysis graph by period

Second, the single comparative analysis allows a comparison of LCC analysis results for one building based on the total amount of initial investment, facility management, repair/replacement, and energy costs for each item. The single comparative analysis can also provide results in bar and pie graph form, so that proportions can be checked, as shown in Figure 19. In addition, as shown in Figure 20, the annual LCC analysis result of the building can be displayed in the form of a linear graph, and the durable years, actual interest rate, and price basis for the building can be found.

Figure 19. Single comparative analysis result screen

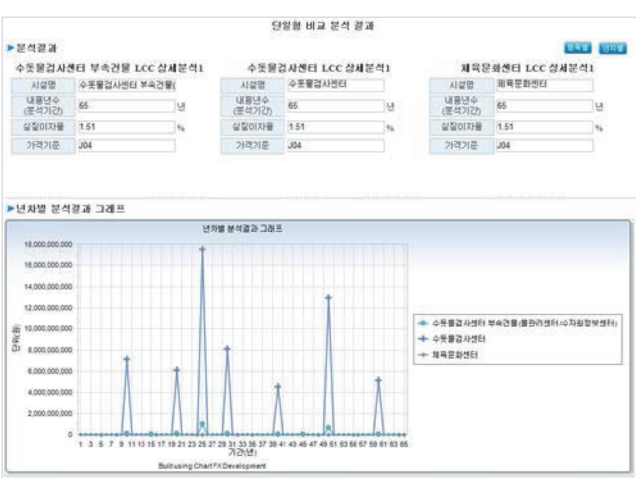

Figure 20. Annual single analysis result screen

Finally, the combination comparative analysis, which is similar to the single comparative analysis, is essentially a comparative analysis of the three pre-entered types of LCC combination analysis results. This allows the total amount of initial investment, repair and replacement, facility management, and energy costs for each item to be compared. The results are given in a bar graph and pie graph to check proportions. In addition, each annual analysis result in the combination LCC analysis result is represented in a linear graph, and the building name, durable years, actual interest rate, and price type from each combination LCC analysis result can be displayed.

6.3 Verification of the repair and replacement cost management system for public buildings

This study included a pilot test for K facility, which is a test-bed object, to verify the cost management system for public building repair and replacement. First, the basic maintenance information system enabled system intranet users to leave records and to check repair and replacement work carried out at the same time at many business locations. The collected data were used to compare the energy cost to the previous month. In addition, records on repair and replacement work could be compared. Second, both a facility manager and a headquarters employee calculated life cycle costs for the relevant repair and replacement items. When they used these costs from the preplanning stage through the life cycle prediction system, costs were reduced by about 10%–35% as compared with the costs before the system was introduced.

Table 7. Comparison with existing system

type	Existing system	Verification
MIS	- Short consideration for the maintenance environment in Korea - Improper management for detailed records - Impossible data application	- Management of maintenance work and projected cost (record management) - Possibility of search for necessary data and of real-time monitoring - Possibility of energy cost management when establishing a mid and long term maintenance plan
LCCS	- LCC analysis result management by excel-based project - Impossible analysis in case of non-specialists - Inadequate result application	- Sharing of real-time analysis results - Application possibility for quantitative and qualitative assessment - Possibility of plan establishment by LCC analysis (alarm function)

7. CONCLUSION

In order to develop a repair and replacement cost management system for public buildings that will enable the establishment of an accurate facility management cost budget, this study (1) verified repair and replacement cost management, calculation formulas, and processes through an analysis of domestic and overseas maintenance system trends; (2) analyzed a test bed facility maintenance and budget management application; (3) established cost, facility, and repair and replacement classification schemes; (4) developed a system prototype design; and (5) conducted a pilot test on the test bed.

The facility classification scheme and repair and replacement item classification scheme of K facility which is one of public Corporation were reclassified to be applicable to the system through preliminary study. In addition, the actual investment and forecasting costs were divided through the classification of cost items used in the MIS and LCCS. This was followed by an analysis of the actual maintenance situation and budget management situation of K facility. The next step was to develop a Web-based program, taking into consideration the need for user convenience and system usage. Implementation of this repair and replacement cost management system for public buildings will allow future costs to be forecast based on the actual history of repair and replacement activities, the invested cost, and LCC analysis. This forecast can be utilized to determine the priority of repair and replacement activities as part of conducting repair and replacement work at K facility. It can also provide a qualitative and quantitative source for the establishment of an accurate facility management budget.

Additional studies of forecasted and actual invested costs based on the quantitative evaluation of facility status should be carried out in future. In addition, a budget establishment management system should be developed based on the repair and replacement cost management system proposed in this study.

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(Received September 20, 2011 / Accepted March 28, 2012)