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Calculation of Annual Maintenance and Replacement Cost of Water Supply System through LCC Analysis

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Abstract

The yearly rehabilitation quantities of water supply systems were calculated through LCC analysis. The year of 2016 was assumed to be the base year, the discount rate, 4%, and the calculation period, 30 years. The maintenance costs that would occur annually from 2016 to 2045 was estimated to be 4.5 billion won. Future replacement costs converted to present values were 51.7 billion won. The budget required annually was calculated to be 9 billion won on the maximum value, and the minimum value, 270 million won.

Keywords: LCC Analysis, Water supply system, Water supply system Rehabilitation, Annual Rehabilitation Quantity of Water supply system

INTRODUCTION

The purpose of water supply systems is to provide water to consumers in a stable way while satisfying both the demand of consumers and the goals of the supplier. To accomplish the purpose, it is necessary to operate and maintain water supply facilities in a systematic way. Studies on the introduction of maintenance and management system with the life cycle cost (LCC) analysis technique applied have been continuously conducted in an effort to efficiently utilize the limited amount of budget and prevent costs for maintenance and management from rapidly rising. With the technique, however, it is impossible to consider the technical and economic circumstances of different regions, and thus the demand for developing measures to improve the practical applicability of the system is growing.

LCC analysis is a widely-used technique to analyze the economic valuation of an object, especially facilities or structures. Construction projects conducted in Korea are legally required to complete economic valuation analysis, but detailed analysis methods for each structure are not presented. Nevertheless, studies on water supply systems still focus on water treatment methods. Recently, some studies started to focus on costs such as effects of water supply services on production costs and water prices, but still there have been only few studies on field-oriented analysis methods of the LCC of structures.

Thus, this study aimed to compensate the limits of existing asset management practices and calculate the rehabilitation quantities of water supply systems using a LCC analysis method that could be applied in fields. First of all, a LCC analysis model was constructed for the facilities classified based on the inventory system. Yearly rehabilitation quantities were calculated by utilizing a cost integration method with analyzed data

MATERIALS AND METHODS

Current Status of TB Facility

The water supply system of the Test Bed (TB) section with the Yeong-Wol (YW) pipeline systems and its main facilities are as follows:

- YW water intake facility: 13,500 m3/day

- YW water treatment facility: 13,500 m3/day, rapid filtration method

- Pump Stations (4 sites): YH, DP, PG, JR

- Distribution facilities(5 sites): YW, YH, DP, PG & SN

Establishment of the LCC analysis the procedure

For the efficient management of the assets of the YW pipeline facilities, costs that occur throughout the life of the facilities need to be analyzed, and in this sense, LCC analysis is found to be useful. The processes of LCC analysis are summarized in the following table.

Table 1. Outline of LCC analysis procedure

Establish the LCC analysis procedure	LCCM(Life Cycle Costing Manage) about initial plan is more proper than LCCP(Life Cycle Costing Plan) about maintenance aspect to adjust the LCC analysis procedure
Formulation for the LCC analysis model	Overall analysis model is composed of maintenance costs and replace costs
Construction of cost breakdown structure	Construct the cost breakdown structure based on the set of LCC analysis object inventory
Main factor of LCC analysis	Use a literature/survey for maintenance about the ratio of the rehabilitation,
Way to verify economical efficiency	Mechanical, electronic asset appropriate to verify economical efficiency using the depreciation and structure, pump(like instrument) and pipeline appropriate to use LCC analysis model
Definition of lifespan	Lifespan has various meaning that functional, economical, social-plan, physical lifespan can be define in terms of lifespan of water supply system

For LCC analysis, clear standards on analysis processes should be established. As shown in the following figure, life cycle costing (LCC) can be divided into 6 steps, and the first 4 steps can be grouped as life cycle cost planning (LCCP), and the rest 2 steps, as life cycle cost managing (LCCM). LCCM technique is used at the maintenance and management stages, and thus the technique was adopted for LCC analysis for the management of the assets of water supply systems.

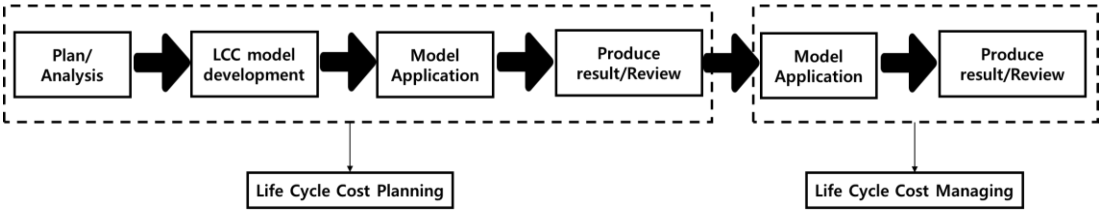

Figure 1. Procedure of LCC analysis model

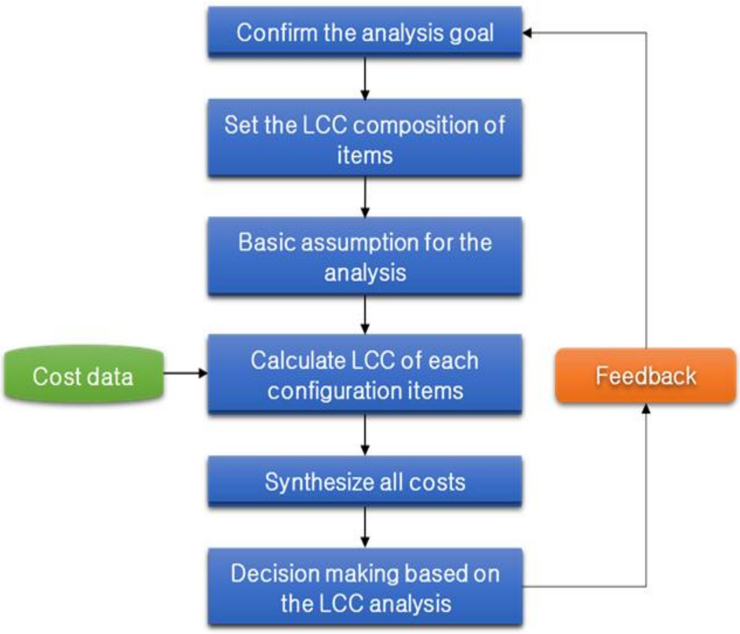

Figure 2. LCC analysis procedure

Costs calculation of each facility following the procedure of LCC

The rehabilitation quantities of water supply systems are quantitatively calculated according to the LCC analysis processes. The summary of LCC analysis processes is as follows.

- Confirm the analysis goal : Once the goal of LCC analysis is set, the total future costs of water supply systems are estimated using the total cost calculation method and LCC values are calculated accordingly.

Goal: Calculation of yearly rehabilitation quantities

- Set the LCC composition of items : Items of LCC analysis need to be selected by step. First, initial installation costs can be divided into planning & design costs, construction supervision costs, and construction costs. Maintenance costs can include direct & indirect management costs, diagnosis costs, rehabilitation costs, and emergency recovery costs. Last, disposal & replacement costs can be divided into disposal costs and replacement costs. The structure of LCC analysis items is shown in the following table.

Table 2. Composition of LCC items

Initial installation costs	Planning & design costs Construction supervision costs Construction costs
Maintenance costs	Direct & indirect management costs Diagnosis costs Rehabilitation costs Emergency recovery costs
Disposal & replacement costs	Disposal costs Replacement costs

- Basic assumption for the analysis : To estimate each cost, it is required to set certain basic assumptions. Service periods and discount rates are usually assumed to estimate future and past costs. The service periods of structures of water supply systems should be set 30 years for stainless pipe, cast iron pipe and steel pipe, 20 years for PVC pipe and PE pipe, 10 years for zinc-coated steel pipe and 20~30 years for other pipes and accessories of water pipe depending on their materials. The life of each pipeline can change depending on surrounding soils, electrical conductivity, surcharge load, etc., and thus it is difficult to predict the remaining life of various types of pipelines with a single equation. For this reason, the life of pipes stipulated by law was used to conduct LCC analysis. Next, to assume the discount rate of structures considering annual inflation rates, the Economic Statistics Yearbook 2016 published by the Bank of Korea was referred to. A real discount rate can be set by considering a nominal discount rate and consumer price index, and the equation to calculate a real discount rate is as follows:

$$ir = \frac{(1+in)}{(1+f)} - 1 \qquad (2.1)$$

Where, ir=Real Discount Rate, in=Nominal(Market) Discount Rate, f=Inflation

Given the fact that the recommended discount rate of structures in Korea is 3～5%, the real discount rate used in this study was assumed to be 4%. Costs that are annually used to urgently repair or rehabilitate water supply systems are predicted based on field data. The annual fixed expense for the urgent repair and rehabilitation of the YW pipeline systems was assumed to be 100 million won on average. Considering the 30 years of the legal durable life of general water supply systems, the periodic rehabilitation of the facilities was set to be conducted every 10 years, and the percentage was set to be 5%. Assumptions can be set differently depending on regional and financial circumstances.

- Calculate LCC of each configuration items : The next step is to predict the future costs of LCC analysis items. To predict costs that may occur in the future, it is very important to collect field data measured in the past, and thus it is necessary to integrate all the relevant information that were obtained in the process of managing water supply systems. The more information, the more reliable the data can be, and the accuracy of estimated future costs can be increased.

- Synthesize all costs : The costs of individual items that were estimated in the previous step are integrated to calculate the total LCC value of water supply systems. There are two types of total costs: unchangeable total cost that is calculated by simply adding costs; and discount total cost that is calculated by adding the costs after converting them to present values. Unchangeable total cost can be used for the purpose of simply comparing initial installation costs, maintenance costs and disposal & replacement costs. The discount total cost is calculated by adding costs that occur in each step after converting them to present values, and this can be used as a tool to make future decisions on budgets and policies.

- Decision making based on the LCC analysis : The last step is to support the decision making process based on LCC analysis. In this study, steps from establishing an LCC analysis model, to integrating costs, to calculating the rehabilitation quantities of water supply systems were conducted.

Quantity estimation for the rehabilitation

To calculate yearly rehabilitation quantities, a table for each year needs to be formed, and costs by step and purpose should be estimated. Steps are divided into initial installation costs, maintenance costs, and disposal & replacement costs, and purposes are divided into conveyance facility, transmission facility, distribution facility, and supply facility. The initial installation costs of the YW pipeline systems that had been built between 1967 (the first installation) to 2015 (the last installation) are combined. If additional pipelines are built, their cost should be included within the initial installation costs.

Maintenance costs should be suggested based on the year of 2016 with future costs and discount rates applied. This calculation should follow the LCC analysis process by step shown in Section 3.3.1, and for sensitivity analysis later on, this practice should be repeated. Replacement costs should be calculated based on the year when the legal durable years of each pipeline are expected to expire. Since pipelines are assumed to be replaced, disposal costs do not occur herein.

RESULTS AND DISCUSSION

Water Conveyance Facility

There were 5 asset items under the conveyance facility category of the YW pipeline systems. The future replacement quantity of the existing pipelines that would occur since 2016 was calculated, and the following figure shows the quantity required for conveyance facilities for 30 years since 2016.

For the next 30 years, conveyance facilities were assumed to be rehabilitated 3 times, and the average quantity of each year was estimated to be 13 million won. The total quantity of conveyance facilities was 380 million won, and the maximum value was calculated to be 290 million won in 2037.

Water Transmission Facility

There were 74 asset items under the transmission facility category of the YW pipeline systems. The future replacement quantity of the existing pipelines that would occur since 2016 was calculated, and the following figure shows the quantity required for transmission facilities for 30 years since 2016.

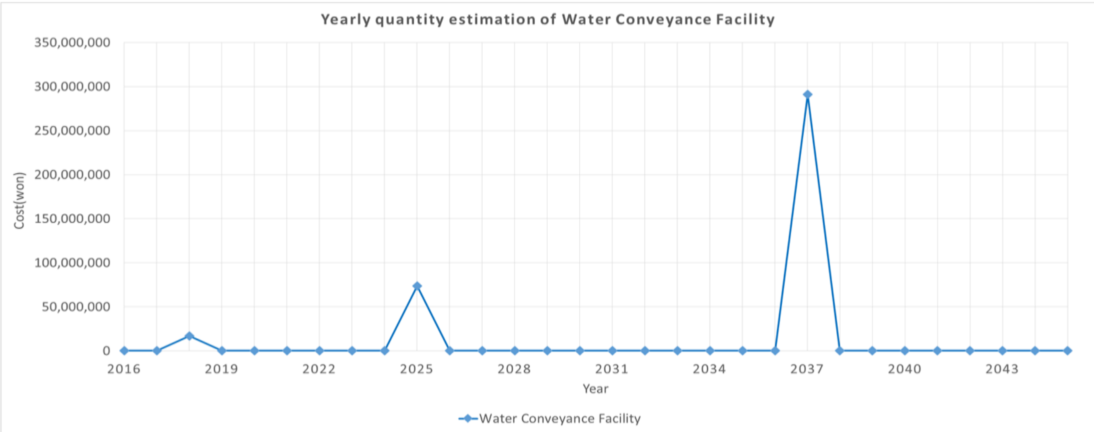

Figure 3. Yearly quantity estimation of Water Conveyance Facility

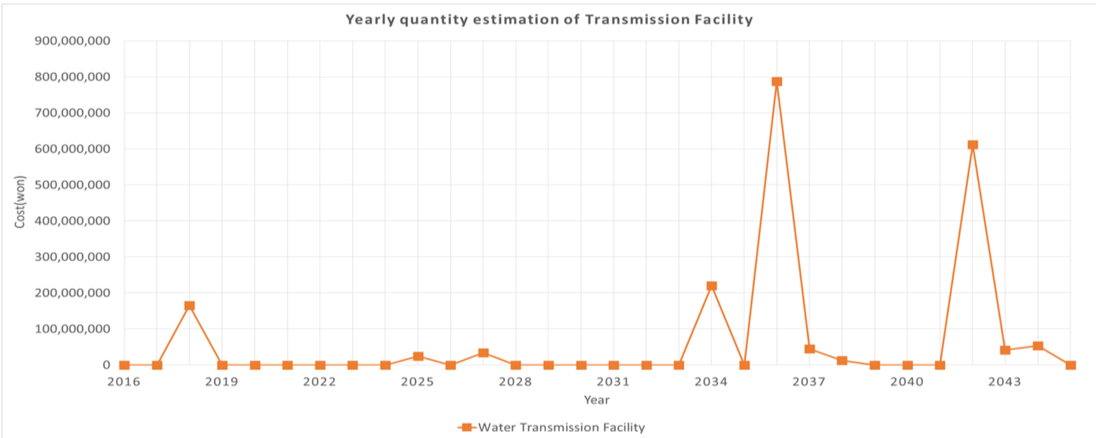

Figure 4. Yearly quantity estimation of Water Transmission Facility

For the next 30 years, transmission facilities were assumed to be rehabilitated 10 times, and the average quantity of each year was estimated to be 64 million won. The total quantity of transmission facilities was 2 billion won, and the maximum value was calculated to be 0.79 billion won in 2036.

Water Distribution Facility

There were 1,721 asset items under the distribution facility category of the YW pipeline systems. The future replacement quantity of the existing pipelines that would occur since 2016 was calculated, and the following figure shows the quantity required for distribution facilities for 30 years since 2016.

For the next 30 years, distribution facilities were assumed to be rehabilitated 26 times, and the average quantity of each year was estimated to be 1.3 billion won. The total quantity of distribution facilities was 37 billion won, and the maximum value was calculated to be 7.7 billion won in 2042.

Water Supply Facility

There were 7,703 asset items under the supply facility category of the YW pipeline systems. The future replacement quantity of the existing pipelines that would occur since 2016 was calculated, and the following figure shows the quantity required for supply facilities for 30 years since 2016.

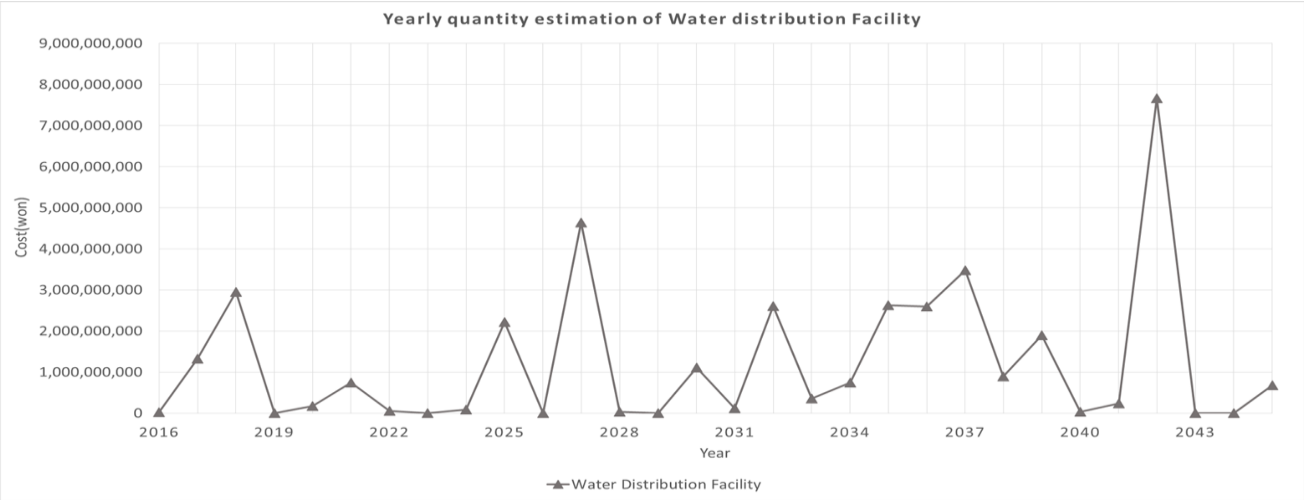

Figure 5. Yearly quantity estimation of Water Distribution Facility

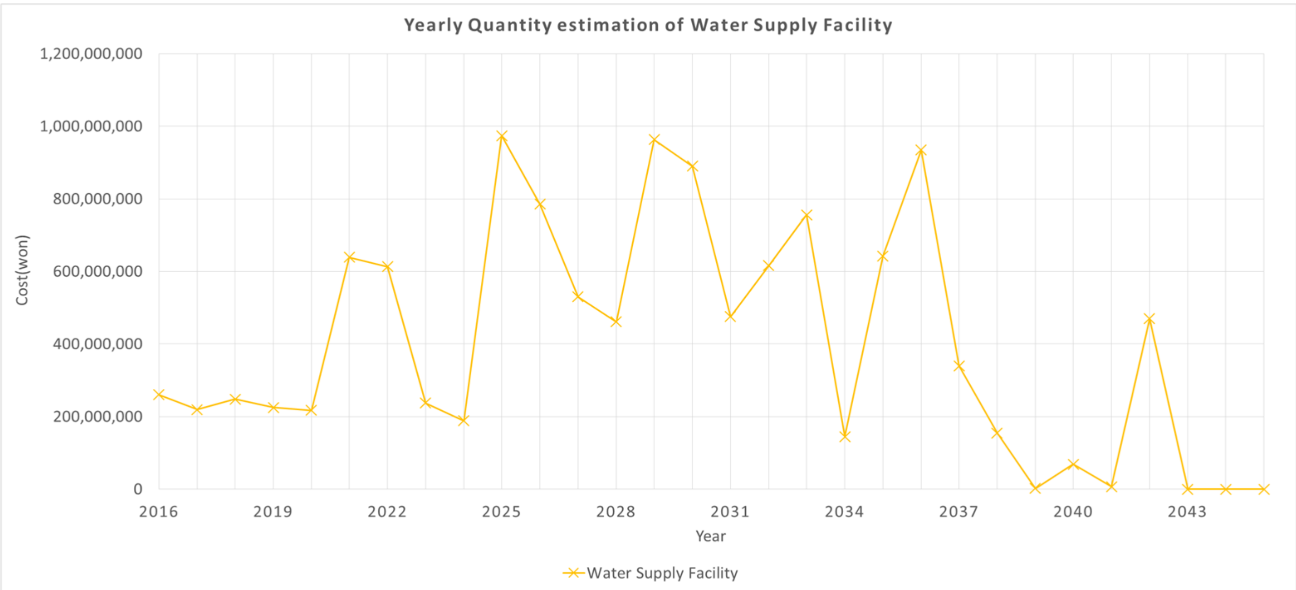

Figure 6. Yearly quantity estimation of Water Supply Facility

For the next 30 years, supply facilities were assumed to be rehabilitated 27 times, and the average quantity of each year was estimated to be 0.4 billion won. The total quantity of supply facilities was 12 billion won, and the maximum value was calculated to be a billion won in 2025.

CONCLUSION

If the YW pipeline systems are assumed to be rehabilitated and replaced for the 30 years, the future quantity that would occur after 2016 was calculated. The replacement costs and maintenance costs that were calculated by facility type earlier were combined. The maintenance costs were 80 million won in 2016 and the value is the average value of the budget that was allocated between 2013 and 2015 in the pipeline optimization project conducted in YW, in Korea. The total maintenance and replacement quantities that would occur annually since 2016 can be estimated using the following graph, and the values can be utilized as supporting data when yearly rehabilitation quantities need to be set.

Water supply systems were set to be rehabilitated, 30 times throughout the planned period of 30 years, and the average annual rehabilitation quantity was estimated to be 1.9 billion won. The total rehabilitation quantity of water supply systems was calculated to be 56.2 billion won, and the maximum value was 9 billion won in 2042, and the minimum value, 270 million won in 2043. The period of which rehabilitation quantity was expected to be largest on the 10-year basis was found to be between 2033 and 2043, 27.9 billion won in total. The average rehabilitation quantity of the period was expected to be 2.8 billion won — approximately 900 million won higher than the average rehabilitation quantity of the planned period of 30 years (1.9 billion won).

Based on the results above, water supply systems should be rehabilitated within the allocated budget by rehabilitating part of the planned quantity in advance or delaying it.

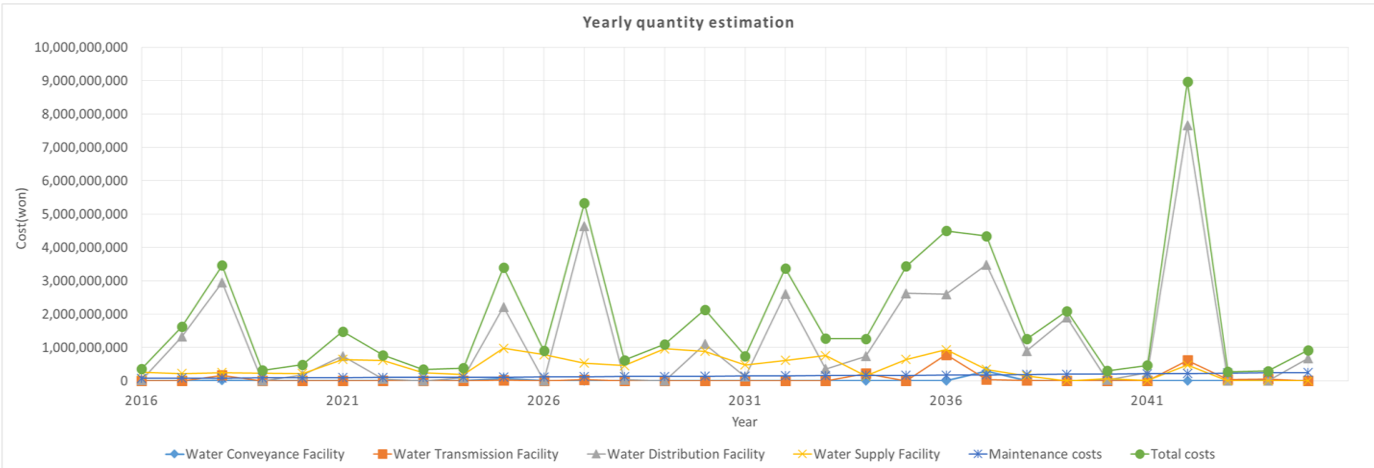

Figure 7. Yearly Quantity estimation of Water Supply System

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