Asset Management for Waterworks in South Korea: Trends and Case Study

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1. Introduction

Problems caused by aging water supply facilities are increasing worldwide. In countries that built water supply facilities relatively early, the problem was recognized, and appropriate solutions have been in place for more than 20 years. Although there have been several methods to solve the problems, the most effective of these has proved to be the application of an asset management (AM) paradigm.

Water supply facility problems became evident in Korea after year 2000. As the age of the facilities increased, the frequency of failures began to gradually increase, thus the cost of maintenance and repair also began to increase rapidly. Concurrently, consumers began to demand improvements in service quality as their income levels rose. The Korean government also has a price stabilization policy where the water rate is set lower than the production cost, resulting in Korean water service providers not having the resources to maintain water supply facilities with a large amount of non-revenue water exacerbating the situation. In other words, it can be said that the water service providers in Korea have reached their limit in maintaining water supply facilities.

Investigation into a waterworks AM were underway, considering examples from developed countries. One such country was Japan, which has a water supply system similar to that of Korea, AM started there for the purpose of giving the system a longer lifespan. New systems related to AM were also established and introduced in Australia, the United States, and the European Union, all of which were studied as a references.

This article describes the progress made in introducing AM in Korea, the mindset around AM, and the application effects of the AM system on an actual city. The object of this article is to provide a reference for other countries and industries seeking to implement an AM solution for their water supply facilities.

2. AM for waterworks in Korea

1) Definition

The definition of AM for infrastructure is widely established; using this definition, Korean researchers generated new definition specific to waterworks sector:

"A management system to identify and manage risk factors throughout the life of waterworks facility assets in order to achieve safe water quality, sufficient quantity, and appropriate water pressure, which are the original goals of waterworks, and at the same time provide the services required by consumers at the lowest cost"

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2) 7 STEP AM procedure (for Korean style waterworks)

In Korea, a 7-STEP AM execution procedure, shown in Fig. 1, was developed from a combination of the 10 STEP AM procedure suggested by U.S. Environmental Protection Agency (2012), the Macro/Micro concept of Japan Ministry of Health, Labor and Welfare (2009), and the key elements of AM discussed in the International Infrastructure Management Manual (IIMM) (2015) by the Institute of Public Works Engineering Australasia in Australia.

3) INSAM (INtegrated System for Asset Management of waterworks)

Fig. 2. shows a schematic of INSAM, an AM system developed in Korea. The word INSAM

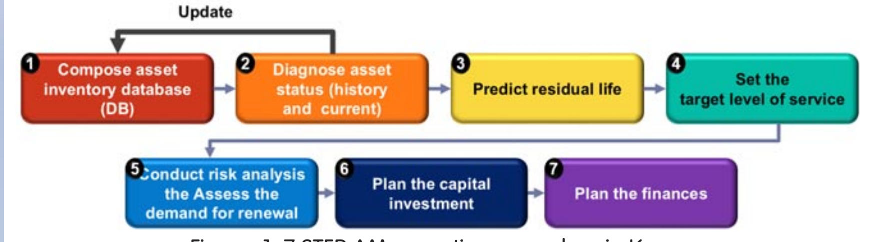


Figure. 1. 7 STEP AM execution procedure in Korea.

Figure. 2. Schematic of INSAM

in Korean has the same pronunciation as ginseng, a Korean specialty. The system was named INSAM in the hope that it would become Korea's unique AM system. The system integrates seven sub-software packages ranging from asset list management software to financial planning software, and each package aligns with the 7 steps of AM shown in Fig. 1. Meanwhile, it is also partially linked with a mobile App. that can effectively manage facilities using near field communication (NFC).

4) The introduction of AM in Korea
Fig. 3. below shows the steps of introducing AM in Korea. The direction was initiated in 2017 and is currently at step 2 of 3 in 2021. The first standard for AM in Korea was established in 2016, called the Korea standard (KS), based on international organization for standardization (ISO) standard.

The Law for life cycle management of infrastructures was enacted in 2020, thus laying the legal basis for the introduction of AM. In Korea, a large-scale aging pipe renewal project, about $ 3 billion, is currently underway called "Modernization project". The project guidelines include various regulations for the introduction of AM and are accompanied by extensive asset research so that the AM system can be easily applied. Further, a pipe inspection project, about $ 0.5 billion, is also currently underway to construct a diagnosis DB for most pipes. When the projects are completed, the AM system will be applied in earnest.

5) Empirical case study using INSAM
The system was installed on a trial basis in a small downtown in Y city, Korea, shown in Fig. 4. The water supply system in Y city is a system that supplies an average of 9,000 m3/d to approximately 22,000 customers through one water treatment facility, and the length of the transmission and distribution pipes is 61.5 km. The number of assets was 1,329 (732 pipes, 325 valves, 35 pumps, and the other machinery in purification plant). For system installation, the site was investigated for 2 years to build an asset list, and the data were entered into the software for each step.

Importantly, there is an engineering rationale for figuring out when an asset reaches the end of its useful life. Fig. 5. describes the pipe's useful life prediction procedure using safety factor based on the pipe corrosion depth prediction. Before the system was applied, the lifespan was set according to the accounting lifespan, but after the system was introduced, the lifespan of the asset could be determined using the data obtained through investigation and diagnosis. Since the derived useful life of asset is very important factor in determining the investment scale, it is expected that the accurate identification of the useful life of asset will be of great help in determining the investment time.

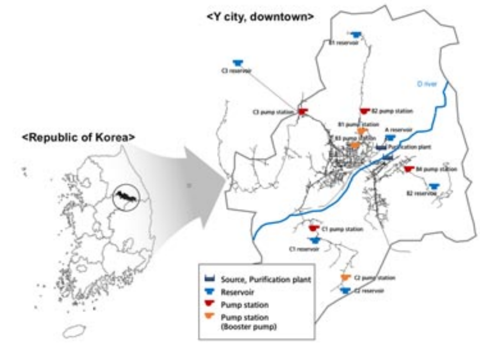


Figure 4: Case study area (Y city, in Korea)

A customer survey identified the level of service that customers evaluated as shown in Fig. 6. In the case of Y city, customer answered that a stable water supply is the most necessary, presumably because the water supply was often interrupted due to leaks caused by improper

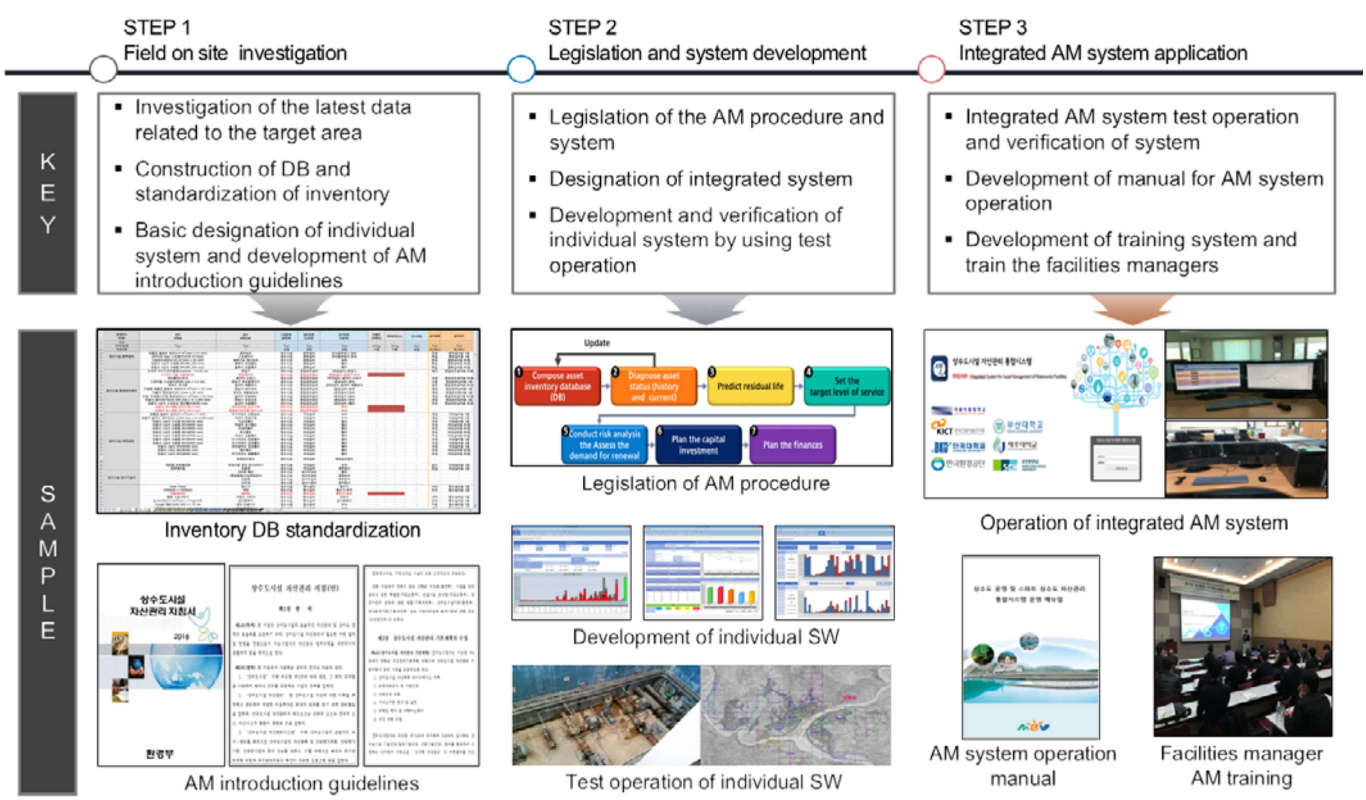


Figure 3. Direction of introducing AM in Korea.

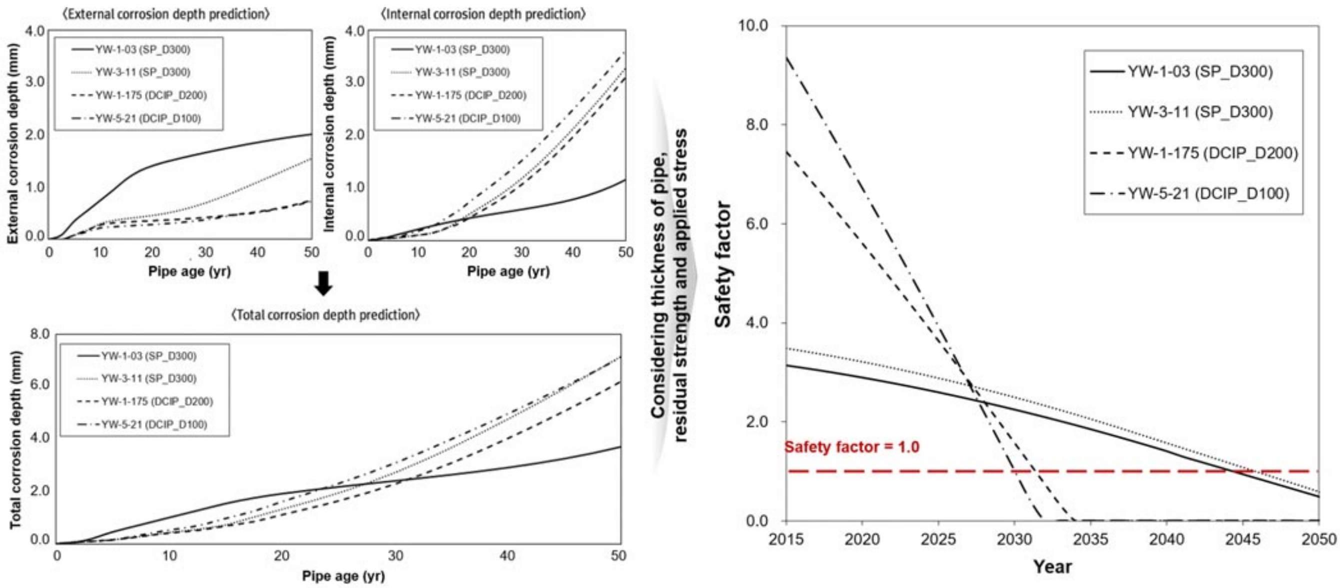


Figure 5. Useful life prediction of pipes using safety factor

management. The survey results were used for gap analysis in connection with the self-diagnosis results of water service provider.

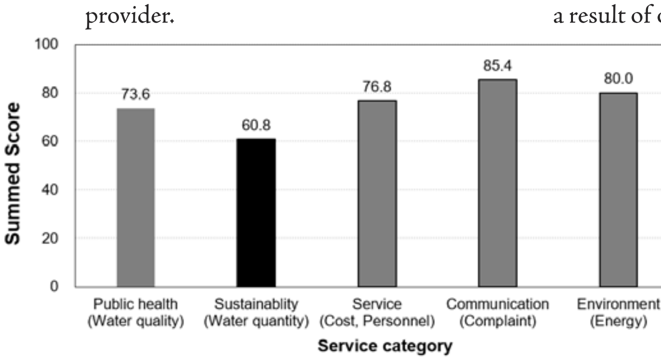


Figure 6. Level of service rated by consumers.

The existing renewal plan was a method based on the lifespan of assets from an accounting point of view. However, as a result of optimizing the renewal plan, it was confirmed that many effects occurred. It was possible to establish a long-term renewal plan for Y city, with the expected outcome of a reduction in renewal costs by more than 15 % compared to the existing renewal plan. In addition, the risks were also reduced by 28 %, resulting in an excellent plan in terms of risk management.

Lastly, an appropriate water rate for water providers was determined to aid them in operating without financial loss. The current water rate (about 9.0 \$ / 10 m^3) is approximately 50 % of the production cost. It was determined that if water rate incomes are used to all assets that have reached the end of their useful life, Y city would have to raise its water rate by 1.0 \$ / 10 m^3 every 5 years. Such a water rate increase was deemed reasonable, as it was within the range of customer willingness to pay. Fig. 8. shows the

Category	Existing renewal plan	Optimal renewal plan
Residual life	Based on accounting	Based on useful life prediction
Service & Risk	Not considered; Avg. Suspension risk (25.44 m^3/yr, 27 h/yr)	Considered; Avg. suspension risk (18.22 m^3/yr, 19 h/yr) ▼ 28.4 %
Budget	Not considered	Considered; \$ 1.0 million constraints
Renewal costs 1)	\$ 34.2 million	\$ 28.9 million; ▼ 15.5 %
Lifecycle costs 2)	\$ 67.7 million	\$ 63.3 million; ▼ 6.5 %

1) Considering inflation rate: 2.0 %
2) Considering inflation rate: 2.0 %, Social discount rate: 4.5 %

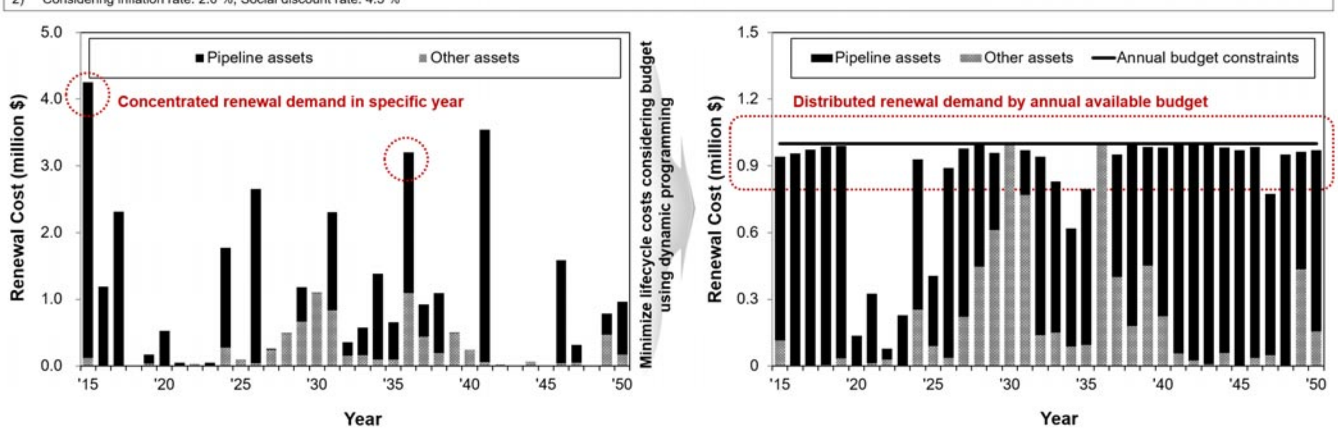


Figure 7. Comparison of renewal plan (Left: Existing renewal plan, Right: Optimal renewal plan)

Category	Existing financial plan	Optimal financial plan
Capital investment	Based on existing renewal plan	Based on optimal renewal plan
Water rate [1)]	Same as 2015 (9.0 \$ / 10 m^3) (In 2050, 18.0 \$ / 10 m^3)	Raise by 1.0 \$ / 10 m^3 / 5 yr (In 2050, 25.0 \$ / 10 m^3) ▲ 38.9 %
Net fiscal balance	- \$ 27.9 million during analysis period	\$ 0.0 million during analysis period; Securing financial soundness

1) Considering inflation rate: 2.0 %

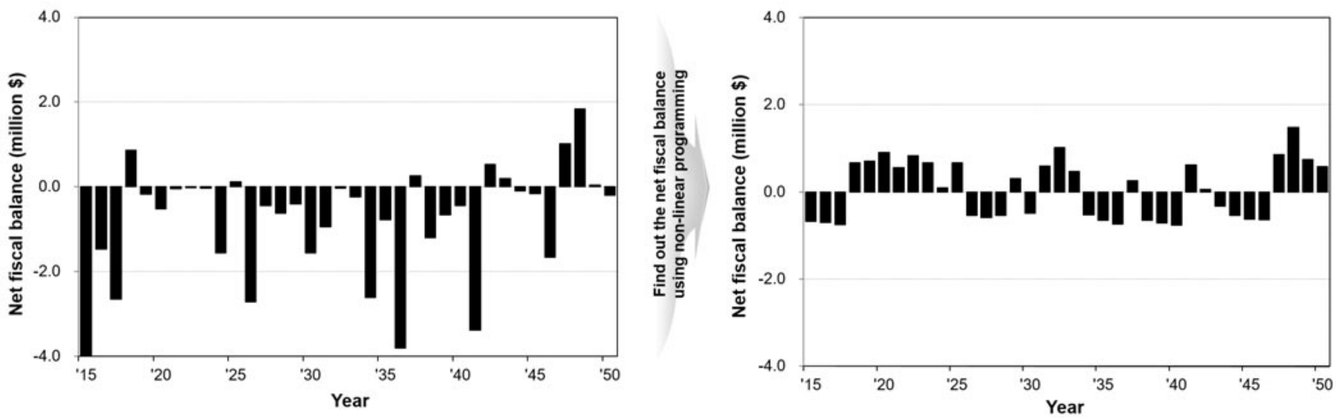


Figure 8. Comparison of net fiscal balance (Left: Existing financial plan, Right: Optimal financial plan)

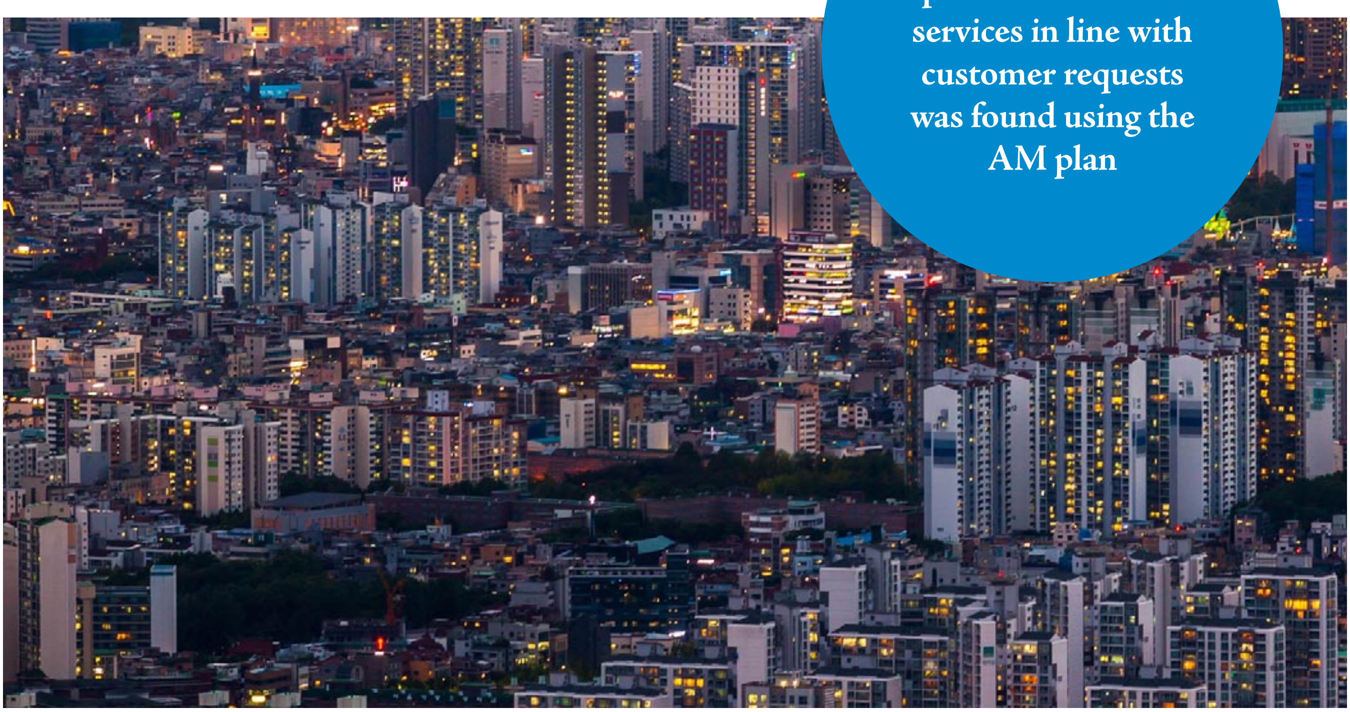
results of optimizing the fiscal balance in consideration of the water rate increase, and represents that financial soundness is secured.

In conclusion, a solution to the provision of water services in line with customer requests was found using the AM plan. Based on this case, Korea is gradually increasing the number of cases of application of AM system. In addition, R&D projects are continuously being carried out, and education program is being developed.

3. Conclusion

Water supply facilities need to be recognized as assets for society and as assets whose value depends on their functional integrity. Proper AM will answer the previously unanswerable questions such as, "How much does each water supply facilities?", "When should partial or complete replacements be accomplished?", "What are the costs involved?", "What finances must be peremptorily allocated?" etc. As mentioned in the introduction, AM can solve many of our problems. It should continue to evolve with more detailed investigations and sophisticated modeling techniques. It is believed that the case study in Korea will be a good reference for water service providers in countries or industries in a similar position to Korea wishing to develop a similar solution.

A solution to the provision of water services in line with customer requests was found using the AM plan



Key task of each step of AM

The objectives and key tasks of each step are shown in Table, which summarizes the ideal AM tasks proposed by Korean government (Ministry of Environment) and researchers. AM is still being gradually introduced in Korea, so each water provider is implementing the key tasks within the scope of their ability, albeit that the government recommends that all steps be performed.

Step	Objective and key task
Compose asset inventory DB	• Classify assets into "managed" and "not managed" (In Korea, assets worth more than 5,000 $ are managed).Standardize and systematize asset lists and identify items to be contained in the lists (In Korea, 5 levels of asset classification exist based on the water supply process). • Standardization enables anyone to investigate data according to the same procedures and standards. • If the geographical information system (GIS) is established in target facilities, link all assets with GIS to capture the basic status of assets and to output data analysis results.

Diagnosis asset status (history and current)	• Build the 3 DBs that can be used in subsequent steps and analyze the results.
	  • Current status DB: This consists of data when the asset is first investigated. (in case of pipes: installation year, material, diameter, length, etc.)
	  • History DB : This consists of data that identify asset history (renewal, rehabilitation, repair, leak recovery, etc.). (in case of pipes: time of breakage, consequence of breakage (suspension time and population, economic damage), renewal method, etc.)
	  • Diagnosis DB : This consists of data containing the results of all the past visual inspection and specimen detailed inspection (in case of pipes: time of inspection, corrosion area and depth, soil corrosiveness, results of stress test, ovality, etc.)
	• Various methods can be used for diagnosis. Recently, technologies that can evaluate and record conditions in real time using information and communication technology (ICT) are in the spotlight.

Predict residual life	• If no data to predict the residual life of an asset are available, it is based on accounting standards. (In Korea, the lifespan of metal pipes is 30 years and that of plastic pipes is 20 30 years.). If a more accurate lifespan can be determined using the 3 DBs built, it will aid decision-making.
	• Define the residual life in one of the following ways:
	  • Physical life: based on the structural safety factor considered external and internal stresses and residual strength
	  • Service life: based on the historical customer complaints and functional aspect of asset (for example, water quality problems and malfunctions)
	  • Economical life; based on the lifecycle cost of assets (installation cost, maintenance cost, renewal cost, etc.)
	  • Guaranteed life: based on the suggestion of manufacturer

Set the target level of service	• Define the service items and evaluate the level of service currently provided to customers. (In Korea, 33 service items are being evaluated.)
	• Use a survey to identify the gap between the perspective of the water service provider and the customer to set the target level of service.
	• Consider factors that may change in the future:
	  • Water demand: A function of natural or anthropogenic changes in population or changes in living conditions resulting in the rebuilding of the district metered area (DMA) and reservoir.
	  • Water quality regulations: A function of customer demand for higher quality tap water or discovery of new contaminants that may add more water treatment process such as membrane treatment.
	  • Water pressure: If the water pressure is lowered for leakage management, the water system may be adjusted to have an appropriate range of water pressure by including pump station or pressure reducing valves.
	  • Calculate the cost once the target service level has established.

Conduct risk analysis and Assess the demand for renewal	• Calculate the risks in accordance with an accepted model:
	  • Risks can be defined in various ways but are commonly calculated using the probability of failure (POF) and the consequence of failure (COF)
	  • For the risks associated with suspension in water distribution networks, for example, the POF is a function of the failure rate based on the diagnosis DB and history DB, the COF is a function of the hydraulic analysis or cost analysis.
	  • Use the risk model functions to identify criticality in the system and prioritize asset renewal.
	  • Evaluate the residual life prediction result and the level of service result; predict renewal timing and costs along with the necessity for the reduction or expansion of facilities in the future.

Plan the capital investment	• If the renewal is concentrated in a specific year, the annual budget may be exceeded (In Korea, the water supply system is financed by the government, so a certain level of budget is allocated every year.). Distribute the concentrated demand for renewal properly using optimization algorithm or various scenario analysis. • Establish a long-term optimal renewal plan that minimize risk and lifecycle costs within a limited budget and calculate the necessary investment costs. When optimizing, risks or goals and will of water provider can be thought as a priority.
Plan the finances	• Simplifying the complex financial structure and formulate the trends of each financial items. • Based on the water service business management performance recorded in the past financial statements (balance sheet, profit and loss statement, cash flow statement), a revenue and expenditure forecast can be made for the water service provider, and resources can be allocated. • Readjust the capital investment plan and resources to make rational fiscal balance by comprehensively considering the depreciation of assets, liabilities (loan, borrowings), equity, government subsidy, etc. • Use the consumer's willingness to pay for readjustment of the water rate, which accounts for a large portion of the revenue.