SOUTH KOREA'S EXPERIENCE WITH SMART INFRASTRUCTURE SERVICES

SMART WATER MANAGEMENT

Ho-Young KIM
Dong-Won KANG

KDI
IDB Inter-American Development Bank

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library
Kim, Ho-Young.
South Korea's experience with smart infrastructure services: smart water management / Ho-Young Kim, Dong-Wo Kang.
p. cm. — (IDB Monograph ; 852)
Includes bibliographic references.
1. Infrastructure (Economics)-Government policy-Korea (South). 2. Disruptive technologies-Korea (South). 3. Water-supply-Korea (South). 4. Water-supply-Latin America. 5. Water-supply-Caribbean Area. 6. Public investments-Latin America. 7. Public investments-Caribbean Area. I. Kang, Dong-Won. II. Inter-American Development Bank. Infrastructure and Energy Sector. III. Title. IV. Series.
IDB-MG-852

JEL codes: L95, N7, O3, O18, Q25.
Key words: Technology, Smart Infrastructure, Water Management, Infrastructure Services.
Graphic design: Valeria Bernal Carvajal

This document is a product of the research program developed for the preparation of the Inter-American Development Bank 2020 flagship report: Infrastructure Services in Latin America. To know all the documents from the research program, see: www.iadb.org/infrastructureservice

CONTENTS

1. EXECUTIVE SUMMARY

The water policy of the Republic of Korea (hereinafter South Korea) has changed in line with its economic development. In the early stages of development, dams and regional waterworks were constructed to supply water to cities and industrial complexes under the water quantity augmentation policy. Since then, as the public interest in health and hygiene increased, the regulations for water quality improvement were strengthened, and the Ministry of Environment took over the responsibility of enhancing the quality of water in South Korea. Integrated water resources management (IWRM) has emerged since 2000 to use limited water resources efficiently. IWRM is an approach that efficiently distributes water to meet demands by taking into account the entire process of the water cycle.
It was quickly accomplished by adopting innovative information and communications technology (ICT) in water management. The smart water management (SWM), which is a new water management system that employs ICT technology, was commenced. The SWM is a technology platform that combines a variety of technologies, and not just a single one, to provide solutions tailored to the issue at hand.

The SWM project was introduced in Seosan, South Chungcheong Province, as a response to the long-term drought caused by climate change and to prevent leakage in its deteriorated existing water facilities to cope with the lack of water resources. The SWM allows water resources to be secured by reducing water leakage in pipelines and without having to construct large infrastructures such as dams and reservoirs. The Seosan city SWM project enabled the collection of real-time flow, water pressure, and other water data by installing smart meters at each point and establishing a network that connects the data with a central monitoring system. Constructing the system made it possible to narrow down the potential leakage points, thereby facilitating leakage detection and enabling rapid restoration. Also, by analyzing customer usage patterns, water leakage was reduced in the pipelines through customized water pressure management.

Although it had incurred costs in its initial stages, the Seosan SWM project has financial viability as it has created benefits in the long run by decreasing leakage. Moreover, the policy goal of drought response enabled the project to receive disaster-response subsidies from the local government. Thus, the project could be carried out without having to raise the water tariff.

The Seosan SWM approach would be effective if applied to an area where there is difficulty in securing water resources; water leakage is severe in its existing facilities due to deterioration; and especially, the revenue water ratio is low. The cost of introducing SWM has also significantly reduced with the ongoing development of smart devices. Therefore, when government policy support and adequate ICTs are efficiently combined, SWM will contribute to achieving water management for sustainable development.

2. INTRODUCTION

2.1 WATER MANAGEMENT CIRCUMSTANCE IN KOREA

The Republic of Korea (hereinafter South Korea), which was one of the world's poorest countries following the Korean War in 1950, has now grown into the 11th largest economy in the world. The GDP per capita was only USD 1,000 in 1960, but in 2019, it increased to USD 30,000, which is a 30-fold increase over 60 years. Also, it has been providing approximately USD 3,000 billions of international aid per year as an OECD member country since 1996. In terms of official development assistance (ODA), South Korea is the only country that has transformed from a recipient country to a donor country. There are many factors for South Korea's successful economic growth. However, it is clear that the government-led active and planned infrastructure construction policies notably played a significant role. South Korea established the "Five-Year Economic Development Plan" led by the central government from 1962 and carried out four sets of planned economic growth policies until 1982, which included fostering the heavy chemical industries and increasing exports. In particular, it promoted key sectors such as the electric power, steel, gas, and oil industries. It also established as its top priority the expansion of indirect capital, such as roads, ports, railways, and telecommunications. Continuous investment in the construction, maintenance, and management of these infrastructures drove economic growth. At the same time, it also had the ripple effect of external expansion. The same applies to water resource infrastructure policies that manage water resources, such as dams or water and sewer pipelines. Water resource infrastructures are essential for promoting economic development policies because they can secure water resources for agricultural, industrial, and household water use; prevent water-related disasters such as floods and droughts; and generate electricity through hydropower generation. However, especially in South Korea, it is climatically challenging to manage water as 70 to 80% of annual precipitation is concentrated in summer from June to August due to the monsoon season, and there is almost no rain in the winter. The highly curved surface of the country, as a result of its mountainous topography, also makes it more challenging to secure water. It is not easy to collect water as it penetrates directly into the groundwater or flows into the sea.

Due to these social and geographical factors, South Korea's water management policy has changed several times over the years, focusing on various objectives. In South Korea, the central and local governments have taken charge of water management task, including water resource management (such as building dams and reservoirs), water distribution management (such as maintaining multi regional water works and local water works across the country), water quality management for social hygiene in the process of tap water production, and bio-diversity in the rivers and lakes. Local governments have responsibilities to provide their local residents with clean tap water and collect usage fee from the consumers based on the amount of water used. The central government has to supervise local governments to ensure that they are in good compliance with the water service regulations in the way of budget allocation. Basically, the water tariff system in South Korea would charge all cost to end users as much as local governments invested into tap water production process, and the national average of coverage ratio is 80.5% in 2018, according to water statistics. The expenses not covered by tariff may be covered by the central government's subsidies.

Water is an essential commodity that is directly connected to life and a finite economic good. Therefore, it is only natural to set national objectives to efficiently manage water and revise water management policies to meet these objectives. This paper will take a closer look at the transformation of South Korea's water policies, the principal causes that brought about the transformation, and their characteristics.

2.2 PARADIGM SHIFT IN SOUTH KOREA'S WATER MANAGEMENT POLICY

The transformation of South Korea's water management policy can be divided into three main phases by the purpose of water policy over a period of economic growth.

The first phase was from the 1960s to 1990, during which South Korea embarked on economic development in earnest following the Korean War in 1950. During this period, the central government's "Five-Year Economic Development Plan" was launched and carried out actively. All national capacities were mobilized for the single purpose of economic development, and water management policies were also used primarily as a means for it. The growth of cities to supply labor and the availability of industrial water to operate factories were essential for the economy to grow, implying that the policy needed to secure water resources to deal with the explosive growth in urban population and demand for industrial water. Therefore, during this period, several multi-purpose dams were built around the Han River, which flows through Seoul, the capital of South Korea, and the Nakdong River passing through Busan and Daegu, the second and third major cities, respectively. Many of these dams were constructed because they could secure water resources and generate electricity for economic development. The dams built during this period not only supplied household water for people living in the cities and provided water for agriculture to support the increased population but also secured water for industries centered around heavy chemicals. However, as the economy grew, demand for water escalated, and the need arose for the construction of new water storage facilities.

The need to build these new facilities inevitably entailed the establishment of a piped water supply network that connected water sources to water demands. Therefore, several vein-like piped water supply networks were constructed. The facilities enabled the provision of clean water from secured resources for household, industrial, and agriculture water use through the connected pipe networks even if the location is not in close proximity of the cities. During the first phase, the piped water supply system mainly served to supply water from remote water sources to large cities for economic development. The Korean government constructed a "multi-regional water supply" network from 1962 to 1982 to improve piped water supply rate from 22% to 57%, allowing the movement of water resources. The construction of these multi-purpose dams and multi-regional water supply systems has played a significant role in helping cities like Seoul, Busan, and Daegu to grow into large cities and drive economic development.

In addition, the construction of multi-purpose dams aided South Korea to prevent and become more resilient to natural disasters such as floods and droughts. South Korea is vulnerable to water-related disasters due to the heavy rainfall in the summer, little precipitation in the winter, severe fluctuations in elevation geographically, and steep terrains. Heavy rains during the rainy and typhoon seasons often cause casualties and severe property damages, which contribute to a challenge in the economy growth. For the same reason, when droughts occur, tremendous national energy should be spent to overcome such obstacles. As such, the occurrence of chronic water disasters obstructs national capacities from being used for the country's economic development. Therefore, the Korean government have tried to build multi-purpose dams not only to secure water resources and distribute stored water to all over the country, but also to prevent water related natural disasters such as floods, droughts, and thereby contribute to economic development.

In summary, the water policy that deals with the construction of the multi-purpose dams and the multi-regional water supply system is a type of "water quantity augmentation" policy.

During the period of the water quantity augmentation policy, the South Korean economy grew by about 20 times in terms of GDP per capita, from only USD 500 in 1960 to USD 10,000 in 1990. The government was putting all its energy into implementing industrialization policies focused on exports

and heavy chemical industries, transforming the industrial structure of the country from agriculture to manufacturing. The overflow of cheap labor in the cities was a good resource to back up the factory operation, and the government required more water resources to provide the city's exploding workforce and factories. Five multipurpose dams, including Soyang River Dam (1973) and Choong-ju Dam (1986), which are first and second largest dams in Korea, had been built during this period. Accordingly, the use of 51.2 billion tons of water resources in 1960 tripled to 15.3 billion tons in 1980, and the water power generation of 580 GWh, which accounted for 34.2% of the total power generation in 1960, increased about four-fold to 1,984 GWh in 1980, to meet the demand for industrial electricity.

However, the "water quantity augmentation" policy, which focused solely on supporting economic development, caused many adverse side effects and severe problems in water quality. Industrial waste, sewage polluted rivers and lakes destroyed the ecosystem, posing a threat to human health as well.
The second phase was from 1990 to 2000. With respect to water management policies, this was the period of increased interest in the quality of water. In 1990, a serious case of water pollution took place in South Korea. Phenol, a poisonous substance, was discharged into the Nakdong River, which flows across the southeastern cities, such as Daegu and Busan. These cities in the vicinity of the Nakdong River were the main sites where the heavy chemical and electronics industries have developed in South Korea. The large numbers of factories and urban population in these cities have greatly contributed to South Korea's economic growth. Subsequently, Daegu and Busan have grown into the country's second and third largest cities with a population of about 2.4 million and 3.4 million, respectively.

Environmental pollution was relatively not an important issue when the industrial complexes were formed along the Nakdong River. The easy withdrawal of water from the river for industrial use led to the construction of large-scale factories and cities in the environs. However, the problem was that the Nakdong River was not only a source of industrial water but also a major source of drinking water for people living in these cities. Toxic substances that were secretly leaked into the river by an electronics company had a huge social impact and served as an impetus that changed the focus of national water management policies from water quantity to water quality.

When a nation experiences an increase in economic activities, it is usually followed by a rise in consumption and population, which results in increased emissions of pollutants in urban areas and industrial facilities. It will also lead to decreased amount of available lad with ecosystems that can act as natural purifiers, which puts even more pressure to the environment. On the other hand, industrial development and technological advancement also allow the development of products that create less environmental damages and technologies that reduce damages to the environment. In the early stages of economic development, industries only focused on exploiting natural resources directly while citizens encouraged to achieve the basic needs for life such as food and housings. By enduring and overcoming the initial damages to the environment, the economic structure will transform into high value-added industries such as service industries, which will, in turn, put less burden on the environment. Along with economy growth, citizens often become more interested in health and environmental issues for the future.

A similar phenomenon was observed in South Korea. Along with the achievement of significant economic growth by 1990, with the GDP per capita reaching USD 6,505, an increased public interest in the environment, health, and sanitation followed. The "phenol discharge" incident further augmented these concerns and incited the change in the national water policy from "securing water quantity" to "improving water quality." Subsequently, the government enacted laws on water quality safety to strengthen environmental standards when constructing factories. An environmental management committee was also founded for each watershed to manage the four major rivers in South Korea, namely the Han, Nakdong, Geum, and Yeongsan Rivers, to improve problems in the water quality management by city according to the administrative area.

In addition, the role of water quality management began to play an important role by upgrading the environmental department, which was previously responsible for water quality, to the Ministry of Environment. The shift in the focus of water quality management policies had changed not only the legal system and governmental organizations but also the entities that devise the water policies. In the past, the central government alone established and enforced water management policies, and the public merely followed these policies passively. In the second phase, the public began to take an interest and participate in water policies. However, the participation was limited to monitoring government policies and other passive areas in the entire process of establishing and enforcing water management policies, which remained the government's responsibility largely. Moreover, there are limitations in the second phase of the water quality management policy as the main focus was only on the water quality values directly related to human life and health. The policy failed to change its focus to the "water environment" that deals with the entire environmental value of water.

The third phase was implemented in 2000 and is still in progress to the present. During this period, South Korea's growth rate has slowed with the advancement of its economy, and civic consciousness has dramatically improved. South Korea has entered the era of integrated water resources management, which goes beyond the "water quantity augmentation" policy of the first phase—where the authority for water management was concentrated on the central government with the focus on economic development, and the "water quality improvement" policy of the second phase—where civic groups acted as surveillance to ensure water quality for human life and health. Under the integrated water resources management approach, the central government and citizens establish and enforce water policies together to improve the efficiency of water resources and the health of humans as well as natural ecosystems through the integrated management of both water quantity and quality. When the government decided to build dams, it had established a system to reflect public opinions by organizing a preliminary review council involving stakeholders such as the public officers and citizens, and disclosed the progress to public transparently. Integrated water resources management has the following characteristics. First, the values of water management policies go beyond that of economic growth or securing human health and safety. The policies consider economic growth, social equity, and environmental preservation. Second, the right to water management policies is no longer concentrated on the central government, which delivers policies downward to lower bodies. Instead, power is distributed among various stakeholders, such as local governments and civic groups, so that these policies are established and implemented through interactive governance. Third, the implementation of water management policies is not fragmented and fixed, such as the supply augmentation or water quality improvement policies. It is driven by a flexible demand customization that changes according to the customer and situational needs. Based on these characteristics, the integrated water resources management policies aim to make use of limited water resources as efficiently as possible and to achieve sustainable growth by increasing the resilience to disasters through safe water management. However, the continuous growth in population and the rise in demand for water prevent the realization of integrated water resources management. The construction of water storage facilities such as dams has become difficult due to concerns about environmental degradation. At the same time, however, extreme floods and droughts due to climate change have occurred frequently, further aggravating the water crisis.

The smart water management (SWM) is considered to be one of the most effective ways to respond to the water crises and achieve the goals of integrated water resources management. The SWM basically refers to the technology that collects data on various water demands, such as agricultural, industrial, household, and other people-related water demands, and the demand for water to maintain the environment, responds to disasters and optimally allocates limited water resources to meet these demands. Therefore, for the SWM to work, it is necessary to collect data on demand basis and to predict the demand trend in order to properly allocate existing water

resources and develop future volume as required. The SWM introduces advanced technologies such as information and communications technology (ICT) into water management. The SWM has been in operation in Korea since the 7th World Water Forum was held in Daegu in 2015. Since then, the SWM technology, which had been previously applied case by case, became integrated into SWM platform. However, adoption of the SWM is not limited to South Korea. Water crises, in varying degree, due to explosive population growths and unpredictable climatic changes are common issues around the world. In South Korea, the SWM could be further developed for the following two reasons. First, a public consensus on the need for an "integrated water resources management" was found in the process of water policy changes from "water quantity augmentation" to "water quality augmentation."

Second, South Korea is an advanced country in information technology (IT) and possesses various innovative technologies that enable the SWM. The following chapter will examine the SWM and discuss the basic concepts and the representative SWM (elements and) technologies that are generally addressed around the world.

TABLE 1. HISTORY OF WATER POLICY CHANGES IN SOUTH KOREA

PHASE	PERIOD	WATER POLICY TREND		EXECUTION	NATIONAL WATER POLICY MAKER
1	1960-1990	Quantity Management	Supply policy	Construction of dams and multi-regional waterworks	Government
2	1990-2000	Quality Management		Improvement of water quality preservation systems	Government and civil society surveillance
3	2000-present	Integrated Water Resources Management	Demand policy	Introduction of IWRM and SWM system	Water management Committee composed of public and civil experts

Source: Author

3. KOREA'S EXPERIENCES

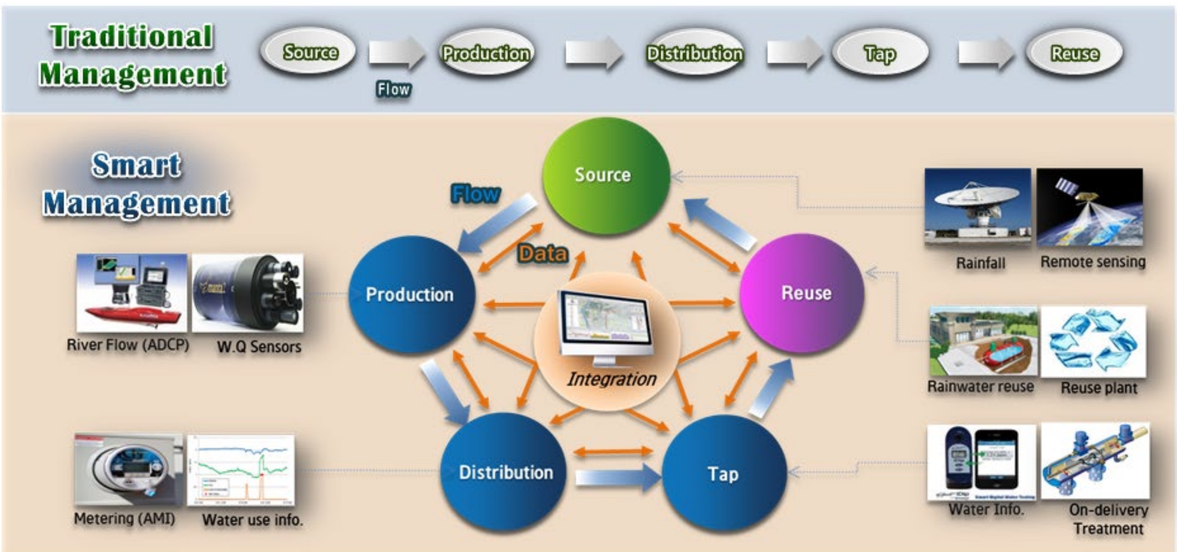
3.1 DEFINITION OF SWM

In 2009, Water Innovation Alliance (WIA), an association of water-related private companies in USA established "Smart Water Grid Initiative" as an early form of the SWM. At first, the SWM was launched in search of advanced ITs for water management to encourage further collaboration and better management decision. Since then, the concept of smart water management (SWM) varies globally. In the 2012 Smart Water Grid White Paper, the United States defined the SWM as an information network that intelligently manages water resources by integrating various technologies such as smart meters, state-of-the-art modeling, water mapping, smart irrigation agriculture, and automation robots (WIA, 2012). From a similar perspective, the Korea Water Resources Cooperation (K-water) and the

International Water Resources Association (IWRA) defined the SWM in a joint study as "the use of information and communication technologies (ICTs) to provide real-time, automated data to resolve water-related challenges through integrated water resources management" (IWRA & K-water, 2018). The paper further specified SWM as "the use of integrated, real-time ICT solutions, such as sensors, monitors, geographic information systems (GIS), satellite mapping, and other data sharing tools to realize IWRM" (IWRA & K-water, 2018).
The SWM can be applied to water resources, water supply, and sewerage to improve the operational efficiency of water management by combining various ICT-based SWM technologies within existing water management facilities and systems. It can also be applied to a wide range of fields, including general households, industries such as manufacturing, agricultural sectors such as irrigation agriculture, and environmental sectors for preserving the ecological environment. The wide application of the SWM is possible as it is not a single fixed technology but a technology platform system that can combine a variety of technologies.

With regard to the SWM, IBM (2012) purported the concept of "smarter water management," where smart means 1) instrumented "automated acquisition of information," 2) "interconnected" based on participation in information sharing, and 3) "intelligent" information analysis (Keeling, 2012). "Automated acquisition of information" refers to the ability to collect information from varied sources to increase situational awareness in a fast and automated manner. The various collected information becomes the material for the integrated management of water resources. "Interconnected" means the delivery of information about the real-time operating situation. The primary purpose of traditional water management was to collect and deliver information at each stage of water: water resources (hydrology and water utilization), waterworks (water withdrawal, piped water transfer, water purification and treatment, and water delivery), and sewerage (sewage collection, sewage treatment, and recycling). On the other hand, in smart water management, multi-directional information sharing and feedback from various sources are possible. It enables water management based on the usage patterns and demand of water users, resulting in collaboration between water use stakeholders and the implementation of effective water policies. Finally, "intelligent" means the analysis of collected data to improve water management planning and policy-making capabilities based on cooperation among stakeholders. That is, it is possible to go beyond the traditional descriptive and diagnostic analysis and perform predictive and prescriptive analysis in real-time (Hong, 2019).

FIGURE 1. DATA FLOW IN TRADITIONAL WATER MANAGEMENT AND SMART WATER MANAGEMENT



Source: K-water.

3.2 POLICY BACKGROUND OF SWM

The SWM is popularly adopted around the world because it provides solutions to global water problems. In particular, SWM attempts to solve water problems from the perspective of an integrated water resources management, which aims to manage water quality and quantity, the ecosystem, disaster prevention, and the environment in an integrated manner, taking into account all factors that affect water management in the region for the sustainable use of water. The acceleration of climate change that is occurring all around the world is expected to worsen the conditions of water management. Therefore, the introduction and advancement of the integrated water resources management based on the SWM in order to adapt to climate change is not a choice but a water management requirement.

The policy background behind the SWM is the increased need for efficient water use and effective response in water quantity management. The frequency of droughts and floods is increasing, and the intensity of server weather conditions is getting severe due to global climate change. The occurrence of severe droughts and the surge in water demand as a result of the increase in population and industrial development worsens the problem of water shortages more challenging. Consequently, the efficient distribution of water has become an important issue. In this case, the SWM enables the efficient allocation of water according to temporal and spatial water consumption, and the prediction of future demands for the reasonable use of water. Moreover, if there is a concentration of water in a specific area due to a flood or typhoon, the SWM can be used to minimize the fl ood damage by allocating appropriate quantities of water, taking into consideration the flood adjustment capacity of all water storage facilities in the watershed. As such, the SWM is an efficient way to respond to water utilization and water control. Second, there is an increased interest in the conservation and health of the water ecosystem, including water itself and the environment, and water and sanitation. Since humans are also part of the ecosystem, it is common sense that humans cannot lead a healthy life if the ecosystem is destroyed. Climate changes due to carbon emissions and the destruction of the ecosystem due to water pollution are not only harmful to water-based living organisms but are also directly related to human health. As mentioned earlier, the SMW is a technology that maximizes the efficiency of water management. Therefore, it is possible to reduce energy waste through the effective use of existing facilities and to refrain from constructing additional facilities, thereby reducing carbon emissions. Also, an effective wastewater treatment helps improve purification capacity while a real-time sewage monitoring can prevent highly contaminated substances from directly entering rivers or seas. The SWM can ameliorate human health and sanitation through the management of clean water and enhance the quality of human life and water welfare through the preservation of the ecosystem.

Third, the technological advancement in the fields of sensors, communication, computation, and data management have increased the data that can be acquired in water management, making it possible for such data to be shared and analyzed. The SWM-related technology is rapidly evolving, resulting in a decrease in hardware price for measuring data; lowered data maintenance costs due to enhancement in network and cloud technologies; diversification of data that can be measured as a result of advances in sensor technology; development and evolution of central processing unit (CPU) and general-purpose computing on graphics processing units (GPGPU) technologies; the emergence of distributed processing support frameworks represented by Hadoop[1]; and the creation of open-source statistical analysis tools represented by a statistical program called R. As a result, it is both economical and easier to produce and manage l arge volumes of data in the current information age than it was in

1. **Hadoop** is an open-source software framework for storing data and running applications on clusters of commodity hardware. It provides massive storage for any kind of data, enormous processing power and the ability to handle virtually limitless concurrent tasks or jobs (https://www.sas.com/nl_nl/insights/big-data/hadoop)

the past. Similarly, it is also possible to obtain diverse water data (data required for integrated water resources management such as the ecologic, land use, and agriculture monitoring rural data, in addition to traditional measurement data such as river flow rate, precipitation, pipe pressure, and more.)

3.3 METHOD OF OPERATION AND REPRESENTATIVE TECHNOLOGY

The SWM can be realized by integrating devices, solution, and services. Intelligent sensors continuously transmit data through wide wireless network and big data will be accumulated in the monitoring server. Integrated information analyzed in the acquisition system provides smart solution, such as forecasting system to decision makers and smart service to consumers based on consumer-oriented data.

The technical application of the SWM can be summarized in the following three steps: 1) an integrated "real-time data acquisition" through the sensing devices such as smart-sensors or smart-meters; 2) a "network construction" for the transmission, storage, and integration of collected data; and 3) a "data analysis" through the modeling and visualization of aggregated data. The final data generated through these processes are used as a scientific and reliable material needed for making water management decisions. The related representative technologies of each step are as follows.

The main technologies for real-time data collection in the first stage are remote sensing technology and real-time monitoring technology. The sensing technology is evolving toward the development of new sensors and measuring equipment, falling prices of equipment, and miniaturization of sensors. Through this, various smart meters at competitive prices are developed and applied to measure the flow rate, pressure, stage, and quality of water. The decision on which data to collect at what resolution and at which point in time for the purpose of the analysis is also an important part of the first step. In addition, with the development of smart sensors and the Internet of Things (IoT) technology, more sensors are installed to measure the water quality of rivers, lakes, waterworks and sewage pipelines, and the ocean in real-time. Therefore, it has become possible to present a proactive and creative control method through real-time monitoring from the previous reactive control method.

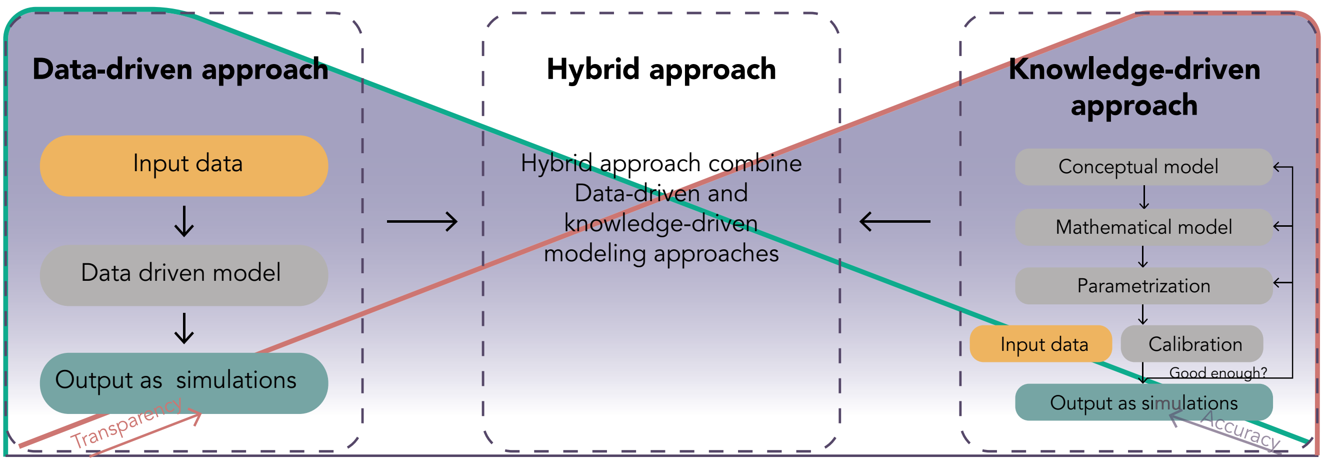
In the second stage, the core technology is the network construction technology for transmitting and receiving data. The SWM often uses a wireless network method, including a two-way radio paging network (such as a pager) or digital mobile telecommunications (such as a cellular phone), to build a network. In a two-way radio paging network method, a remote transmitter connected to a smart meter transmits data to the base station through a direct radio path, which is a pager frequency, and the base station transmits the collected data to the monitoring system through a wireless paging network. The wireless network construction enables a stable transmission of data and secures low communication costs. The remote transmitter is relatively simple in structure and, thus, require low installation costs. However, there is one limitation in that simple information, such as the quantity of household water consumption, cannot be transmitted. On the other hand, the digital mobile telecommunications method uses cellular phone frequencies such as 2G, 3G, or 4G (LTE). Unlike the radio paging network method that requires the installation of a base station between the remote transmitter and the monitoring system, the digital mobile telecommunications is a method of transmitting data directly from the remote transmitter to the monitoring system by installing a radio frequency (RF) modem in the remote transmitter that is connected to the smart meter. It has the advantage of transmitting a large volume of information and controlling or remotely adjusting equipment through Tele-Metering/Tele-Control (TM/TC). However, the disadvantages are that the costs of communication and installation are quite costly, and it can be installed only when a telecommunication infrastructure,

such as 2G, 3G, or LTE, is provided in the area. At the center of the third stage is the technology of aggregating, modeling, and analyzing through visualization of the measured data. The process aims to support the analysis, diagnosis, and decision-making for integrated water resources management of basins, reservoirs, rivers, estuaries, groundwater, water treatment, sewage treatment, and pipelines. To this end, in addition to the technical review of simple items, the trend is that capacity is required for the complex analysis of various water utilization, water quality, and ecological themes across the watershed.

Priority resolution of issues related to input data (such as pre-processing, quality control, availability, and costs) is required for successful and efficient data-based analysis. General pre-processing is performed through data cleaning, integration, transformation, reduction, discretization, and expression feature extraction to utilize actual data, which is by itself inconvenient to use as it is incomplete, noisy, and inconsistent during data pre-processing. This process is the most time-consuming step in data analysis. Issues related to device integration, battery issues, sensor communication, and others affect the accuracy of the measured data and make data quality control necessary to process it. In addition, various technologies are applied for data availability, which is making useful data available to users or related organizations for use, and low costs of the operation and maintenance of sensors and measurement equipment.

In addition, the analysis techniques are expanding from the traditional physical model (a model that represents the relationship between input and output as a mathematical relationship by applying physical, chemical, or biological theories and laws) to the data-based model (a model that finds patterns between input and output data based on large amounts of data obtained) or the hybrid model. The constraint in applying a data-based or hybrid model is that both require a massive amount of data than the physical model. However, the adoption of the SWM has expanded the scope of application as it allows the acquisition of increased amounts of data. The physical model provides a clearer understanding of the causal relationship between phenomena, and the data-based model enables accurate estimations at high speed. Therefore, the hybrid model that takes into account the advantages and disadvantages of both approaches can become an efficient analytical model.

FIGURE 2. COMPARISON AMONG DATA-BASED MODEL, HYBRID MODEL, AND PHYSICAL MODEL

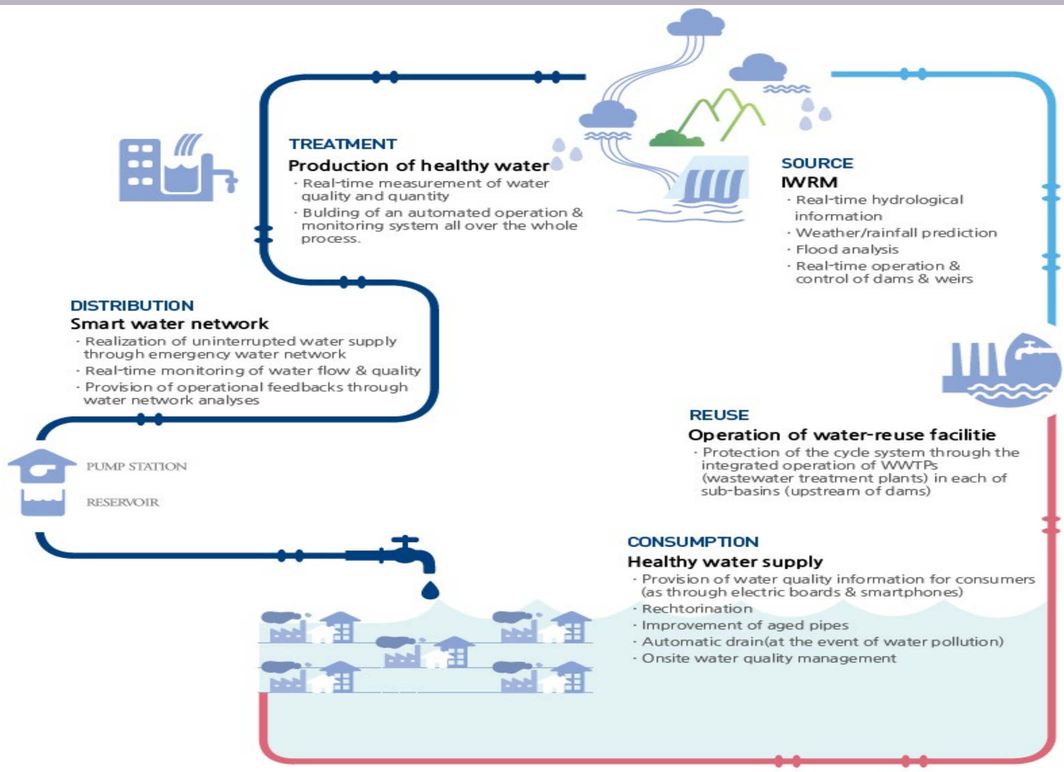


Source: Radhouan Ben-Hamadou et al. (2011).

The concept to be noted concerning its representative technology is that the SWM refers to a platform for open technology applications rather than a single, standardized technology. It should be clearly recognized that the SWM is a procedural tool that provides customized solutions to a variety of

problems, primarily in the operation and maintenance (O&M) of water management. Therefore, the SWM project is not about newly building massive infrastructure for water management but about increasing efficiency by introducing the necessary innovations at the O&M stage. As a result, the applied technologies and their combinations may vary depending on the purpose.

FIGURE 3. CONCEPT OF SMART WATER MANAGEMENT (SWM)



Source: K-water

3.4 SWM IMPLEMENTATION

As mentioned above, the SWM offers tailored solutions to solve the water crisis by applying various ICT technologies. Therefore, the first thing to consider for the implementation of SWM is a clear recognition of the purpose to be achieved. Since the SWM is a management technique that guarantees efficiency, a project should be pursued in a purpose-oriented manner to achieve maximum effect at minimum cost. The next step is to establish the scope of the business. The business size and target area of the SWM project must be carefully reviewed in advance to ensure that the maximum effect can be derived within the given time and budget. As the SWM proposes a solution in response to the water issue, there may be differences in the planning stage of a project and its actual performance. Technical diagnosis and financial analysis should be conducted in advance to reduce risks in the course of a project. A technical diagnosis is a process of deriving new technology by identifying the technology needed to troubleshoot and combining the applicable technologies. Diagnosis can be made based on the data available if the amount of existing water data is sufficient, and its contents are correct. However, in most water-crisis areas, water-related data is poorly managed and is often insufficient, missing, or inaccurate. In such cases, it is also a good idea first to conduct a pilot project in a small target area and collect, analyze, and diagnose relevant data before expanding the solution to the entire region. Even though a pilot project may entail time and money, this process helps reduce major SWM risks.

Financial analysis checks whether a project can be carried out within a limited budget. Since SWM often entails projects with long durations, financial feasibility is crucial for a business to be sustainable. Generally, the government grants subsidies for water management projects, and, therefore, a long-term plan on costs and benefits should be thoroughly reviewed. It is not easy for the SWM business by itself to secure financial feasibility where the benefits outweigh the costs, as is the case with most public infrastructure businesses. Therefore, it is necessary to discover new benefits or simultaneously review policy support measures, such as government subsidies, to supplement the benefits for the project to be carried out efficiently.

Finally, once the actual project is started, a specific and long-term assessment system must be established to increase the efficiency of project implementation. Even with thorough review and diagnosis of the project in advance, unexpected variables and additional costs may arise, and the expected benefits may not take place in the course of the project. Therefore, it is essential to check the project achievements on a monthly or annual basis in order to efficiently solve the water issues at hand through continuous assessments and supplementation.

TABLE 2. IMPLEMENTATION PROCESS OF THE SWM PROJECT

	PROCESS	MAIN TASK
1	Clarify the goal	- Identify the policy issues
2	Decide the scope	- Select the target area - Adjust the range of project according to budget constraints
3	Establish SWM objectives	- Search for the technical solution suitable for issues
4	B/C analysis	- Secure social benefits
5	Design and install the equipment	- Arrange facilities and install the devices in the field
6	Assessment	- Evaluate performance and achievement

Source: Author

3.5 CHANGES THAT SWM BRINGS

Previous attempts of water management were segmented into the following processes: withdrawal of water resources, production of water at purification plants, distribution of water through pipelines, water usage by customers, and discharge of used water as wastewater. Each of these processes was unrelated to the other. Unexpected problems materialized as a result including the construction of water purification plants with water treatment capabilities that are not in line with the water quality of the source; insufficient or over-invested water purification plants and pipeline facilities that are not in line with customer demands; and the discharge of sewage without being reused despite the lack of water resources in the region. The Integrated water resources management (IWRM) can resolve such water management problems as it aims to efficiently and effectively manage water through interaction of the above water management processes without tackling them independently.

The SWM is the one of the best ways to achieve the IWRM. The changes arising from the adoption of SWM are as follows. First, the SWM has increased the efficiency of water supply (water supply efficiency) and provides an optimal utilization system by combining all available water resources, including underground water, seawater, and rainwater, without having to depend on the supply capacity of water sources. Therefore, water can be provided and reused wherever necessary without having to construct additional large-scale infrastructures such as dams. Second, SWM has enhanced the ability to respond to water-related disasters (water disaster mitigation). Today, it is possible to predict accurate weather forecasts by collecting and analyzing information in real-time not only from rain gauges installed on the ground but also from precipitation data and satellites. Information sharing among different water management facilities and systemized operations will minimize damages caused by natural disasters, leading to advanced flood and drought control. Third, SWM has saved water resources by supplying demand-matched water services (customer-oriented service, appropriate production based on accurate prediction, and water-saving). Water quality and quantity can be ensured, and water-savings can be promoted by accurately predicting the needs and through the appropriate coordination of the production and supply processes, using ICT-based analyses of consumption patterns. Fourth, the SWM ensures rapid leakage prevention and management (identifying leakage incidents). It is capable of identifying leakage incidents through automated information analyses without having to dispatch a worker to check on-site. Real-time analysis of information collected from smart devices ensures an improved response time to any incident, subsequently reducing the risk of accidents and the waste of human resources and time.

4. CASE STUDY: SEOSAN CITY SWM

4.1 CHARACTERISTICS OF THE SEOSAN CITY SWM PROJECT

Since the introduction of SWM in South Korea, various projects related to smart water have been advocated. In addition to the Seosan SWM project, the smart water city (SWC) project, an extension of the SWM project, was implemented in the city of Paju. Moreover, the Busan Eco-delta City (EDC) project, which is currently under construction, promotes the idea of a smart city (SC) equipped with various smart infrastructure technologies including the SWM, smart transportation, smart building, and more.

As mentioned above, SWM is not a single fixed technology but a platform that fuses innovative ICTs. Different technologies are applied to each project according to their differing purposes through various execution methods.

Among the numerous SWM cases, the Seosan city case has remarkable adequate-technology implications. Water management technology is as diverse as the history of water management and ranges from low-level to high-level innovative technology. Despite a popular belief, high-level technologies are not always the best option as it often requires high expertise and entails high costs of operation. On the other hand, if the low-level technology can respond to local circumstances effectively, it would be a more effective and efficient option over the expensive high-level technologies. In this sense, it is essential to introduce technologies of adequate level that suit the region-specific water management.

Therefore, the Seosan SWM project's adoption of various technologies in tackling the water supply challenges can be applicable for many countries, especially the developing countries. The new approach has a wide scalability to deteriorated water infrastructures and leakage problem as well.

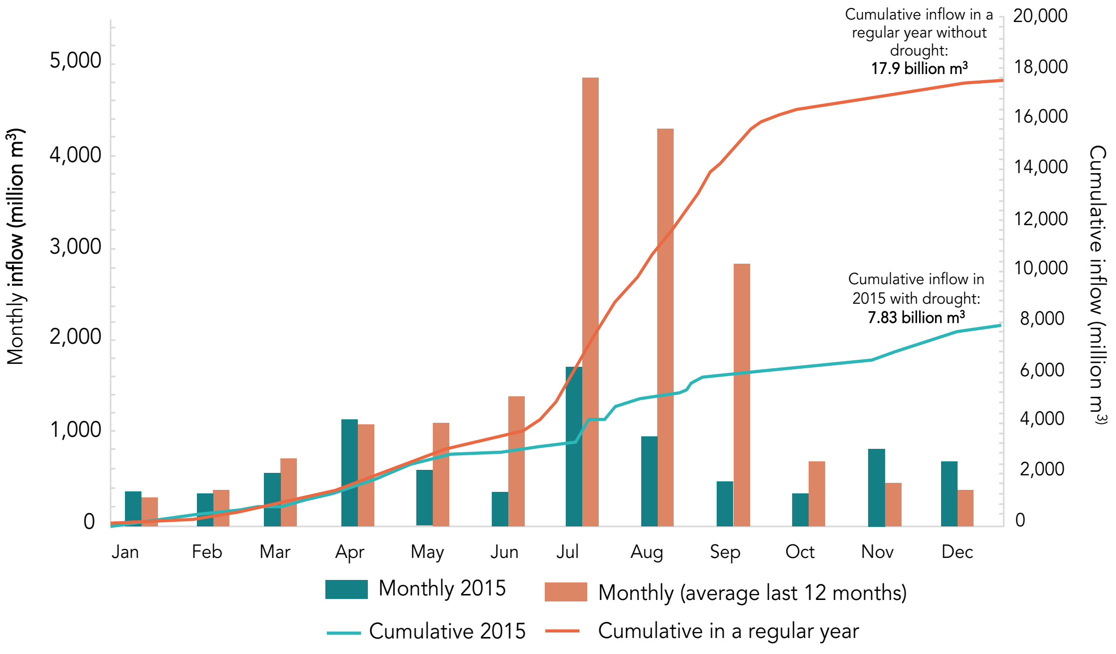
4.2 ON-SITE BACKGROUND

4.2.1 SEVERE DROUGHT DUE TO CLIMATE CHANGE

Seosan uses Boryeong Dam as its main water source. The dam supplies about 240,000 m^3 of water per day to eight neighboring cities, including Seosan city, and five thermoelectric power plants in the Chungcheongnam-do Province. Boryeong Dam has a relatively small basin area of 163.6km^2 but provides a relatively large quantity of water that equals to 84 percent of its supply capacity.

Drought conditions in South Korea began to worsen from 2013. Of the country's annual average precipitation of 1,342 mm, only 89% was recorded in 2013 and 90% in 2014. The average rainfall in 2015 was 965mm, which was merely 72% of that of an average year and the third lowest record of precipitation ever in history. The damage was bound to be greater as the city experienced unexpected droughts for three consecutive years.

FIGURE 4. INFLOW RATE OF SOUTH KOREA'S MULTI-PURPOSE DAM IN 2015



Source: K-water.

In summer 2015, the inflow rate from June to September was a mere 3 billion m^3 as shown in Figure 4, which was just 25% of the annual average inflow during the same period. As a result, the total amount of cumulative inflow in the Boryeong dam in 2015 was 7.83 billion m^3, which was only 43.7% of the annual cumulative average inflow,17.93 billion m^3.

In the same year, as the drought that started in 2014 continued, the dam recorded its lowest water level ever in history. On October 30, 2015, the dam recorded 22 million m^3, which is only 19.7% of its total storage capacity and 33% of the annual average record low at 70.2 million m^3.

The water shortage caused by the drought caused an even bigger problem in connection with the increasing water demand from Boryeong Dam since 2005. The water supplied by Boryeong Dam had continuously increased as it also began to provide water to cities, newly-built industrial complexes, and thermoelectric power plants in its vicinity. However, its storage volume had also continued to decrease. In 2015, the dam's annual water supply contract amounted to 38.25 million m^3, an increase of 1.87 times compared to 2005.

In response to the severe drought, an emergency water restriction was implemented for Boryeong Dam from August 2015 to February 2016, lasting a total of 127 days. Emergency water restriction entailed three stages:

- **Stage 1** (Urgency Level 1): 91% of dam supply and 9% of water distribution system adjustment; Supply 100% of domestic and industrial water.

- **Stage 2** (Urgency Level 2): 71% of dam supply and 9% of water distribution system adjustment; supply 80% of domestic and industrial water.

- **Stage 3** (when a low level of water is reached): 66% of dam supply and 9% of water distribution system adjustment; supply 75% of domestic and industrial water.

In addition to the emergency water restrictions, various measures were discussed to secure additional water resources, and it was also at this point that SWM was introduced for leakage reduction in areas with leaking water pipelines.

4.2.2 LOW REVENUE WATER RATIO IN PALBONG, SEOSAN

The Seosan SWM project was conducted in Palbong area, one of the small administrative area located in Seosan city, covering an area of 57 km^2 with mountainous terrain. In 2014, Palbong had a population of 3,444 people and 2,099 hydrants supplying water to households. About 97% of all water supply pipelines consist of small-caliber conduits under 15 mm in diameter, most of which were installed between 2009 and 2011. About 218 km of the total pipeline were non-metallic polyethylene (PE) conduits, making it difficult to detect leakage.

TABLE 3. PIPE CONDUIT AND HYDRANT IN PALBONG-MYEON IN SEOSAN CITY

MM	13	15	2	25	32	40	50	TOTAL
Hydrant	2,006	23	47	13	7	2	1	2,099
%	96%	1%	2%	1%				100%

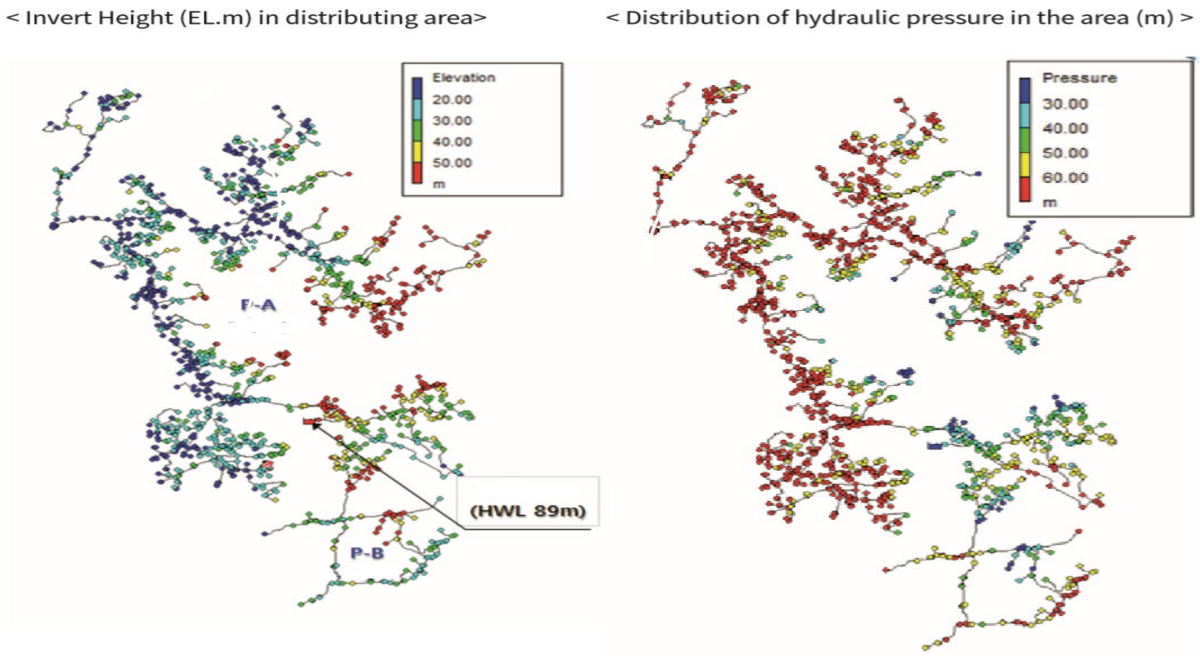
Source: K-water.

At the time, the scope of water management of Palbong was divided into two district metered areas (DMAs): P-A and P-B. The DMA P-A is mainly a mountainous area inhabited by a population that uses water on a small scale. On the other hand, the DMA P-B is a water-intensive area, consisting of apartment blocks, shopping malls, and military units. Even though the minimum night flow (MNF), which is measured at night when there is no water use, was relatively high at approximately 47 m^3/hour, pinpointing the leakage point was difficult.

Also, the entire region, including DMA P-A, has a mountainous terrain that creates a highly fluctuating landscape for the pipelines as shown in the Figure 5 below, resulting in high water pressure in the pipes at 6.1kgf/cm^2, and consequently, more leakages in the pipelines.

As a result, the revenue water ratio of Palbong-myeon in Seosan city was only 60% in 2015, which meant that about 40% of tap water was leaking from the pipelines and into the ground.

FIGURE 5. HYDRAULIC PRESSURE AND INVERT HEIGHT IN DISTRIBUTING AREA



Source: K-water

4.3 LEAKAGE REDUCTION THROUGH SWM SOLUTION

4.3.1 INTRODUCTION OF THE SEOSAN CITY SWM PROJECT

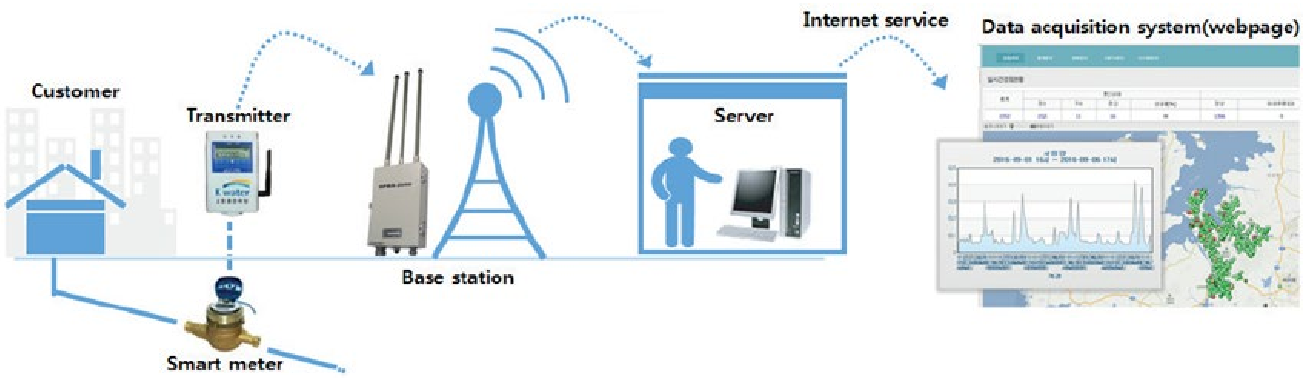
The Seosan SMW project was launched in April 2016, constructed over approximately five months, and carried out with a set project cycle of eight years, which is the service lifespan of the smart meters. The project launched when the municipality of Seosan city asked K-water, a specialized water agency to whom Seosan City consigned its water facility since 2006, to reduce leakage in the local waterworks system to respond to the severe droughts it was experiencing.

Boryeong Dam, which serves as the water source for Seosan, had reached water storage of less than 21%, resulting in urgent measures to be taken against droughts. The Seosan SWM project is a type of project that aims to improve the O&M efficiency by streamlining the operation and maintenance of water supply pipelines. The costs entailed in improving the O&M efficiency of waterworks facilities are generally born by the end-user of tap water in the form of a water tariff. Because the water bill in South Korea is subject to all expenses for the user except where subsidies are provided for special public interest purposes.

However, the Seosan SWM project had an additional objective of coping with drought. Therefore, the municipality of Seosan invested approximately $400 thousand in the form of disaster response funds in this project. The project was able to secure financial viability due to the budget support in the form of a subsidy. It could be carried out without burdening the residents of Seosan with an increase in the water rate.

The Seosan SWM project was implemented with the objective to reduce water leakage and secure water resources. In general, the aim of project to reduce water leakage is carried out to prevent a decrease in revenue from water tariffs as a result of leaks. However, the Seosan SWM project had an additional goal that had to do with responding to droughts. Therefore, various ICTs were introduced to improve the traditional leakage detection method to urgently and efficiently secure water resources. The existing two DMAs were divided into eight sub-DMAs (SDMAs) to identify suspicious leakage areas quickly. Also, the leakage detection and restoration procedure were implemented swiftly by collecting and analyzing real-time water flow rate and usage information within a DMA. The usage pattern analysis also reduced water leakage by decompressing the water pressure in the leaking pipe to a level found when there is no abnormality in the water supply. All of these results were made possible by setting up smart meters for data collection, constructing a network for real-time data transmission, and establishing a monitoring system for monitoring and data analysis.

FIGURE 6. SMART METERING SYSTEM TO MEASURE WATER FLOW IN SEOSAN CITY



Source: K-water

4.3.2 CONSTRUCTION OF SUB-DISTRICT METERED AREAS (SDMAS) BASED ON SMART METERS

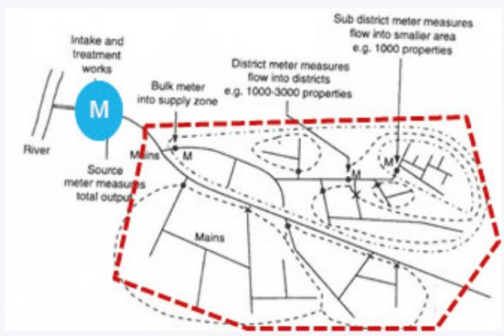
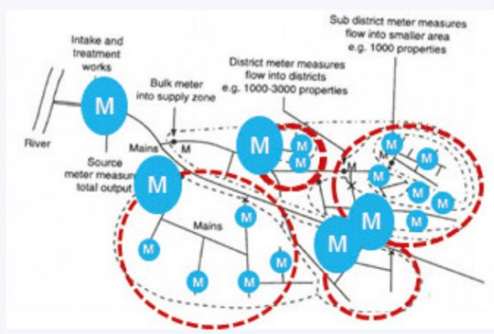
A DMA is a concept that divides water service areas into smaller unit sections for the efficient water management of flow rate, water pressure and water quality. Setting up a DMA system addresses two purposes. The first is to respond to changes in water demand relevantly and minimize the risks and damages to customers in case of facility accidents or disasters by isolating the district unit in a water supply network. The second is to improve the water management of water flow and water quality within smaller areas where a water supplier can continue to monitor and analyze leakages, water pressure, and water quality.

In general, a DMA system is built by isolating the inlet and outlet pipelines for each district unit. The critical point is to organize the intricately interconnected pipes, separate them by zones, and divide the DMAs so that they do not interfere with other district areas. Therefore, the construction of a DMA system will reduce risks as there is no external influence on the problems occurring within the

DMA and allows the performance of accurate data analysis of the cause of the problem. However, the construction of a DMA system by physically separating pipes, as in the past, has the disadvantage of being time-consuming and costly due to the underground structure of most pipelines. As an alternative to pipeline construction, the DMA can be built by installing smart meters in the major pipelines to analyze flow rates in real-time while eliminating interference between the DMAs. This approach can save money and time by allowing the DMA system to be built without additional pipeline construction.

The two DMA systems, P-A and P-B, were installed in the target area of Palbong-myeon in the city of Seosan. When the SWM project was implemented, smart flow meters were installed in the major pipelines to subdivide the two DMA systems and build a total of nine SDMA systems. If the district area of a DMA system is large, it implies a wide supply area. Therefore, even if there is a leakage within the district area, it makes it difficult to localize the leakage and, consequently, leads to the problem of delayed restoration. The most crucial point in leakage management is to recognize the existence of a leak quickly, pinpoint the leakage spot, and repair it as soon as possible, due to the direct proportionality of the loss by leakage to the leakage duration time.

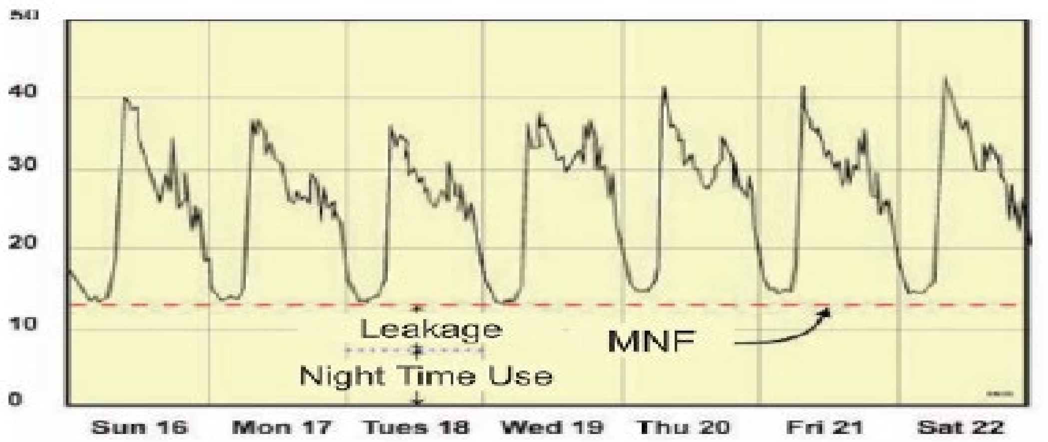
FIGURE 7. COMPARISON BETWEEN EXISTING DMA SYSTEM AND SDMA SYSTEM

	Before (DMA system)	After (SDMA)
Metering area management	1 DMA (500 ~ 1500 meters/BL)	1 DMA + SDMA Subdivision (About 200~300 meters/SDMA)
Quantity management (leakage restoration)	• 1 inflowTM minimum flow during night monitoring • Monthly revenue water ratio management • Difficulty in quantity management including leakage detection	• Monitor not only DMA inflow, but also numerous SDMA minimum flow during night • Daily revenue water ratio management • Effective and quick control on leakage
Concept map		

Source: K-water

Leakage detection starts with the recognition of the leak, which begins with the minimum night flow (MNF) analysis. The premise is that there is almost no water consumption during the night except for menial household water use, such as toilet flushing and the use of washing machines or dishwashers, and non-household consumption from entities such as factories, hospitals, or public institutes. Therefore, a high minimum night flow suggests that there is water leakage

FIGURE 8. FORMULA TO CALCULATE LEAKAGE USING MNF



Source: K-water

The minimum night flow analysis is usually performed for each DMA. Thus, the smaller the area of the DMA, the smaller the suspicious leakage area becomes, facilitating the leakage detection. It allows the leakage point to be narrowed down from the unit of space to line.

TABLE 4. COMPARISON BETWEEN DMA AND SDMA OPERATIONS

CLASSIFICATION	PRESENT (DMA SYSTEM)	IMPROVEMENT (SDMA SYSTEM)
Metering Area	2 DMAs (2 Flows™)	2 DMAs + 9 SDMAs (3 Flows™+around6SM)
Analysis of Revenue Water Ratio	Monthly analysis of revenue water ratio	Daily analysis of revenue water ratio
Minimum Night Flow (MNF)	Monitor a total of 3 MNFs	Monitor a total of 12 MNFs

Source: K-water

For around two months, from April 20, 2016 to July 20, 2016, this project set up 1,550 units of smart meters, built 30 base stations, and established 9 SDMAs from A1 to A9. The DMA sub-division enables water information data taken by the smart meter to find leakage points easily and investigates abnormal data by analyzing user consumption patterns in real-time to detect water leakage. This smart technology enables the development of revenue water ratio analysis from a monthly to a daily basis. It extends the minimum flow during the night point from 3 points to 12 points. As a result, the existing two units were subdivided into nine units, creating high data accuracy. The SDMAs monitor not only the DMA inflow but also numerous minimum flows during the night and manage the daily revenue water ratio to ensure an effective and quick response to leakage.

4.3.3 PROMPT LEAKAGE DETECTION AND RESTORATION

The leakage detection began when the 1,550 smart meters installed in Pabong-myeon in the city of Seosan started to measure the real-time flow information. The smart meters converted the measured flow data into electrical signals and transmit them on a timely basis (hourly, daily, and monthly), performing precise flow measurements by sensing the impeller pump rotation. Smart meters installed at the household level transmitted data to the waterworks server through a wireless communication network and monitoring system, automatically transmitting metering information such as hourly, daily, and monthly water consumption.

The data-transfer procedure of a smart metering system consists of digital meters installed at the end-user sites. These digital meters are connected to the remote transmitter through direct wires. Remote transmitters send the collected data to the base station through wireless communication such as pagers. The base station then transmits the received data to the server and monitoring system through the Internet service.

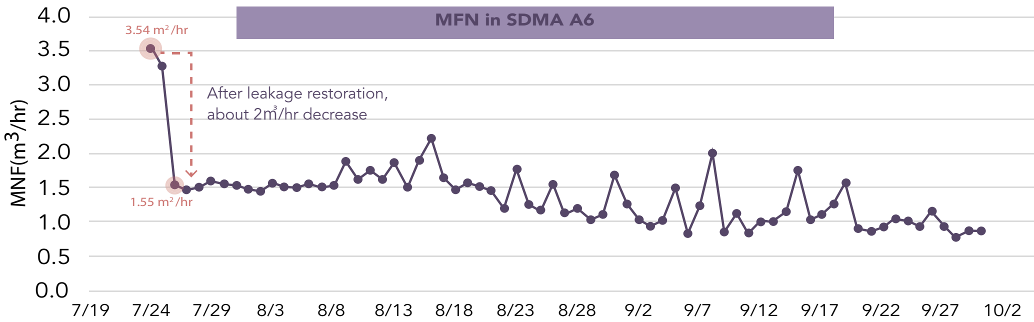
The flow meters previously installed in Palbong were human-read meters that were measured monthly. The revenue water ratio, which is an indicator of leakage, was also calculated every month. However, smart meters have less reading errors than those taken manually and provide real-time aggregated usage, enabling the analysis of the revenue water ratio on a daily basis. Therefore, when the revenue water ratio of a DMA in the target area is low, or there is an abrupt drop in the ratio, leakage detection and repair can be conducted quickly and, consequently, reduce overall leakage. In the Seosan SWM case, intensive leakage detection was conducted for about nine times in the three SDMAs that recorded low revenue water ratios, which helped localize seven leakage points and make quick restoration responses possible. After leakage repair, the minimum night flows of the A5 and A6 areas reduced by approximately 2.0m/hour each, demonstrating an effective decrease in the leakage.

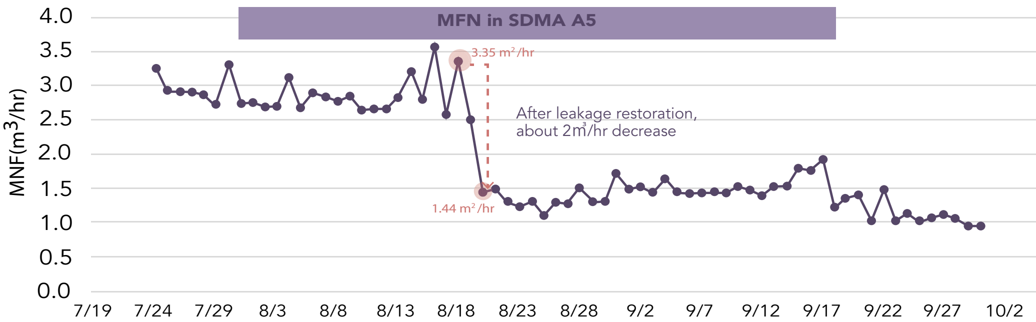
TABLE 5. REVENUE WATER RATIO BY SDMA IN JULY 2016

SDMA (AREA NUMBER)	A1	A2	A3	A4	A5	A6
Revenue water ratio (%)	87	73	92	85	59	50
Leakage Detection Priority		3			2	1
Leakage Detection and Repair		3			2	2

Source: K-water

FIGURE 9. LEAKAGE RESTORATION AND MNF DECREASE IN SDMAS





Source: K-water

4.3.4 OPTIMAL WATER PRESSURE MANAGEMENT

Water pressure management is one of the most important methods of water leakage management. Water leakage usually occurs in proportion to water pressure. Therefore, reducing water leakage through water pressure management is more cost-effective than replacing the leaking pipelines. Water pressure management is performed by installing a pressure reducing valve in the pipeline, and the most critical issue is determining the degree of decompression. If the water pressure is lowered too much, water will not flow through the pipes, resulting in water blockage. Therefore, the key point is water pressure management with an adequate amount of pressure.

FIGURE 10. RELATIONSHIP BETWEEN WATER PRESSURE AND LEAKAGE IN DETERIORATED PIPE

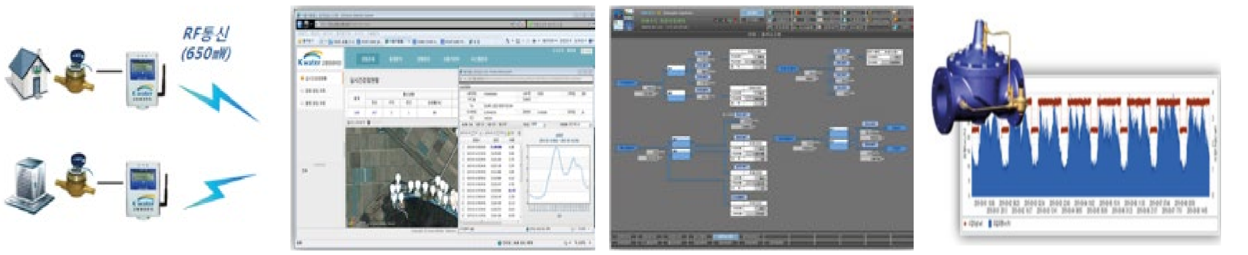
Low Pressure High Pressure

Source: Water Management and Water Loss, IWA (2014)

Optimal water pressure can be set based on the consumption patterns of water users. It is not a fixed value and can be set differently over time, even at the same location. If water usage is high at a specific time, the water pressure should be maintained high. In the Seosan SWM case, water pressure was measured for each DMA, and the four areas from PMA (Pressure Measurement Area) 1 to PMA 4 with a water pressure of over 5 kgf/cm^2 were designated as pressure management areas. By combining smart metering systems with decompression remote control technology, it enables the construction of a water pressure management system, which considers the consumption pattern of the user. In order to operate without a booster pump in some of the hillside areas, which were expected to have problems with water supply, K-water installed a pressure reducing valve (PRV) to provide a small decompression amount in every pressure management area. This enabled the control of future decompression based on the pattern analysis of the users.

The system construction consisted of three stages. In the first stage, data on water use was acquired at the critical point of the hillside, where problems with water supply were expected when decompression was operated. In the second stage, based on the data, pattern use was analyzed, and time-based decompression measures were constructed. In the third stage, the pressure was adjusted using an automatic remote control with the monitoring system in the office, according to the season, holiday period, and time of day, allowing a flexible reaction to any water supply problem in the hillside area. The pressure reducing valve is operated by the DMAs, where the water pressure is high. Water pressure is then decompressed based on each SDMA characteristic, making it possible to prevent pipe breakage due to high water pressure in advance. The amount of background leakage due to unnecessarily high pressure is also reduced, which is effective in improving the flow rate.

FIGURE 11. WATER PRESSURE MANAGEMENT BY SMART METER AND PRV REMOTE CONTROL



1. Smart meter transmission
2. Acceptance pattern analysis
3. Remote control of pressure valve
4. Optimal water pressure management

Source: K-water

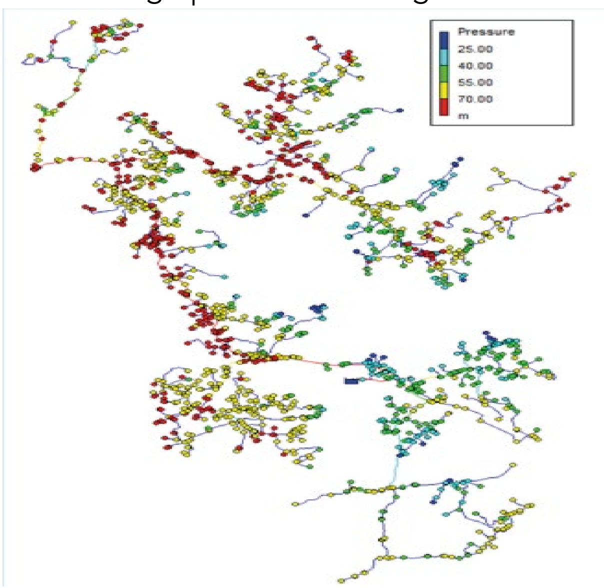
TABLE 6. DECOMPRESSION TO OPTIMAL WATER PRESSURE IN SDMA

AREA	SDMA	METHOD	INFLOW PRESSURE			DECOMPRESSION
			FIRST	SECOND (DAY 3:30~23:30, NIGHT 23:30~3:30)		
PMA 1	A1	Time control	6.5 (EL.22)	Day	5.0	↓1.5
				Night	4.0	↓2.0
PMA 2	A2, A4, A6	Remote control	6.5 (EL.30)	Day	5.5	↓1.0
				Night	5.0	↓1.5
PMA 3	A3	Remote control	6.5 (EL.20)	Day	4.0	↓2.5
				Night	3.5	↓3.0
PMA 4	A5	Time control	8.0 (EL.5)	Day	6.5	↓1.5
				Night	6.0	↓2.0

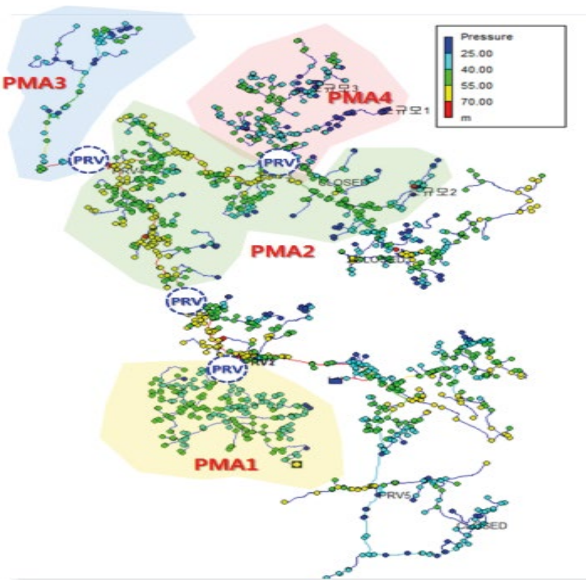
Source: K-water

FIGURE 12. WATER PRESSURE IMPROVEMENT MAP IN SDMAS

(Before) Water Pressure Management: average pressure of 6.1 kgf/cm^2



(Improved)Water Pressure Management: average pressure of 4.4kgf/cm^2



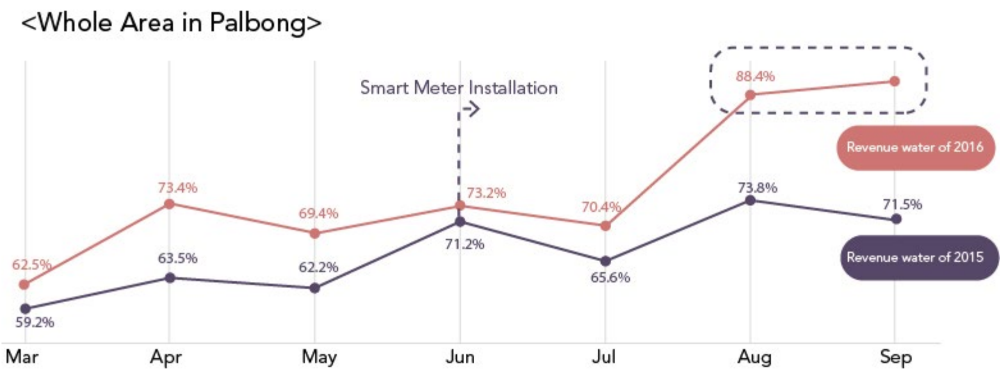
Source: K-water

4.4 OUTCOMES OF THE SEOSAN CITY SWM PROJECT

4.4.1 DECREASE IN LEAKAGE

After applying the SDMA system through smart metering, intensive detection in suspicious leakage area, and water pressure management system, the revenue water ratio reached 90%, and each SDMA improved by 15 to 40%. As compared with 2015, when severe drought broke out, the revenue water ration rose in 2016 due to increase in water use, but the increase in the ratio was only 5 to 10%. Overall, in comparison to the revenue water ratio before installing SWM, this was approximately a 20% increase from the previous year. It meant that an equivalent amount of leakage was reduced in the pipes. As a result of establishing and operating the SWM system, it was possible to reduce 19,000 m^3 of leakage annually, which is equivalent to about USD 0.1 million.

FIGURE 13.IMPROVEMENT IN THE REVENUE WATER RATIO IN 2016



< SDMA in Palbong>

	A1	A2	A3	A4	A5	A6
'16.7	87%	73%	92%	84%	58%	50%
'16.8	89%	86%	91%	87%	69%	78%
'16.9	95%	**90%**	88%	97%	**88%**	
		↑ 17%			↑ 30%	↑ 39%

4.4.2 ECONOMIC ANALYSIS

The Seosan SWM project initially entailed installation and other costs as a cost-saving project through O&M efficiency. However, it has created far more benefits in the long run.

The project invested about 611 million Korean won (USD 0.51 million) in installing SWM. Benefits from this investment include the revenue water profit as a result of decreased leakage, the reduction in the labor costs of metering personnel, and leakage detection costs. The financial analysis period for the business was set as eight years, which is the service lifespan of the smart meters. Through the implementation of this project, the revenue water ratio of Palbong-myeon reached 87.7%, which is a 20% improvement. The results of the benefit-cost (B/C) ratio analysis to calculate the benefits for each business period in terms of the net present value (NPV) are as follows.

Although the Seosan SWM project incurred 566 million won (USD 0.47 million) at present value in initial facility investment, it was estimated to generate 1,179 million won (USD 0.98 million) at present value over eight years by creating revenue water profits and reducing the labor costs of the metering personnel and leakage detection costs (Table 7). As a result, net profit at the present value was 613 million won (USD 0.51 million) and the B/C ratio is 2.1, which indicates that the project has an economic feasibility. In addition, as mentioned earlier, the Seonsan SWM project is a disaster response project to droughts. Consequently, the expenses incurred by the project are not born by the water users but paid through a separate disaster management fund managed by Seosan city, implying that the project is also a business with the benefits of drought response, making it valid project financially.

TABLE 7. ECONOMY ANALYSIS IN BUSINESS PERIOD (8 YEARS)

		TOTAL (MILLION WON)	1ST YEAR 2016	2ND YEAR 2017	3RD YEAR 2018	4TH YEAR 2019	5TH YEAR 2020	6TH YEAR 2021	7TH YEAR 2022	8TH YEAR 2023
1. INCREMENTAL COST (A)		611	497	15	15	16	16	17	17	17
FACILITY INVESTMENT	SUBTOTAL	497	497	-	-	-	-	-	-	-
	PURCHASE SMART METER	88	88							
	PURCHASE REMOTE INDICATION CENTER	154	154							
	REPLACEMENT AND INSTALLTION COST	129	129							
	SDMA CONSTRUCTION	70	70							
	MONITORING CENTER	40	40							
	PURCHASE S/W FOR MONITORING SYSTEM	16	16							
COMMUNICATION COST	660WON/UNIT/MONTH	95		12.6	12.9	13.2	13.5	13.9	14.2	14.6
REPAIR AND MAINTENANCE COST	0.5% OF INVESTMENT	19		2.5	2.6	2.7	2.7	2.8	2.9	2.9
1. INCREMENTAL COST (PRESENT PRICE) (A')		566	475	14	14	13	13	13	12	12
INSTALLATION COST		475	475							
COMMUNICATION COST		76	-	11	11	11	11	11	10	10
REPAIR AND MAINTENANCE COST		15	-	2	2	2	2	2	2	2
2. IMPROVEMENT BENEFIT (B)		1456	86	186	192	211	201	192	191	196
REVENUE WATER PROFIT	IN SALES PRICE	1212	78	157	159	160	162	164	165	167
SAVING ON METERING PERSONNEL	METERING READ (60% OF SERVICE BUDGET)	53		7.0	7.2	7.4	7.5	7.7	7.9	8.1
SAVING ON METER REPLACEMENT	EXISTING METER REPLACEMENT COST	90	2.2	9.3	13.5	29.7	17.9	6.7	4.0	6.9
SAVING ON LEAKAGE DETECTION COST	OWN OPERATING COST	102	6.2	12.7	13.0	13.3	13.6	13.9	14.3	14.6
2. IMPROVEMENT PROFIT (PRESENT PRICE) (B')		1179	82	170	168	176	160	146	139	137
REVENUE WATER PROFIT		981	74	144	139	134	129	125	120	116
SAVING ON METERING PERSONNEL		42	-	6.4	6.3	6.1	6.0	5.9	5.8	5.7
SAVING ON METER REPLACEMENT COST		74	2.1	8.5	11.8	24.8	14.3	5.1	2.9	4.8
SAVING LEAKAGE DETECTION COST		82	5.9	11.6	11.3	11.1	10.9	10.6	10.4	10.2
3. NET PROFIT (PRESENT PRICE) (B'-A')		613	-393	156	154	163	147	134	127	125

5. IMPLICATION AND RECOMMENDATION FOR LAC COUNTRIES

The demand for water is increasing with population growth and economic development. However, since water is a finite resource, water management is becoming more difficult as a result of climate changes. It means that the existing water management techniques have limitations in adapting to a changing climate and mitigating its effects. Hence, the smart water management has emerged around the world to effectively tackle the issue.

The SWM has been around for a long time but is still in the process of evolving. The changes in SWM are the responsive consequences of the water crises becoming more complex with time and the new SMW techniques through ICT development.

The SWM is not a single, fixed technology. It is a platform that provides solutions through the combination and fusion of various technologies. Therefore, the SWM can create a maximum effect at low costs by accurately recognizing the water crisis issues that each region faces and providing customized solutions to these problems. In particular, the following implications must be reviewed prior to the introduction of SWM.

First, an SWM is a long-term business project. It incurs intensive facility investment costs at the beginning phase of the project. Therefore, it must be designed as a long-term project in order to recover the expenses over time. If the business period is too short to recover the cost from tariffs, water users would have a burden of large sum payment. Thus, a thorough financial analysis should take precedence in order for the launch of the business to prevent the project from being interrupted midway due to funding issues. It is also necessary to have a written procedure for compromise with each other in the event of an important change in circumstances involving cost payment issues. Thus, it should entail a process of regular evaluations and feedback. Based on the evaluation results, the plan shall be revised to suit the situation through close consultation between the parties.

Policy support is particularly essential for the successful long-term implementation of the SWM project. As it requires a large budget for local governments take charge of local waterworks, to implement SWM projects, subsidies from the central government may be granted to local governments with poor finances. In South Korea, local watering business, including water supply improvement and water rate collection, is categorized as local government's duty. Central government is reluctant to provide subsidies for local water works rehabilitation without consensus among policymakers, stakeholders and citizens who pay taxes.

Second, the SWM is a system customized to its clients. Cost payments related to local water work projects have to be charged to user in the region in Korea. However, the Seosan SWM is not only the project of water supply improvement but also drought response measures securing more water resource by paradigm shift. The SWM project in Seosan was implemented by drought fund at no additional costs to the residents. Furthermore, the successful effectuation of the SWM project necessitates professional competency to recognize the project objectives and review the applicable technology accurately. A structure that provides water management personnel with continuous training and consultation with experts, along with technological development, must be followed. Openness to the development and introduction of new technology can enhance the efficiency of the SWM project. Efforts should be made to introduce an approach suitable for the target area by implementing, verifying, and studying various pilot cases. Finally, the SWM should be pursued within the scope of integrated water resources management and sustainable development. A method that sacrifices water quality or destroys the environment merely to secure volumes is not sustainable.

Goal 6 of the United Nations Sustainable Development Goals (SDGs) on water and sanitation also declares this point. SDGs 6 encourages UN member countries, including South Korea, to improve water quality (SDG target 6.3), increase efficiency in water use (SDG target 6.4), and realize integrated water resources management (SDG target 6.5) by 2030.

The SWM should be utilized to efficiently manage the quantity and quality of water as a public good and improve the resilience to water-related disasters to protect and recover aquatic ecosystems by applying the evolving technologies of the fourth industrial revolution.

The success of the Seosan city SWM project was attributable to the cooperation among stakeholders with a clear purpose in mind. The local government contributed disaster response funds to achieve the policy goal of countering droughts and promptly requested professional assistance from K-water, a specialized water agency. K-water organized the entire project process, from planning to implementation, and adopted adequate technologies among various ICTs to obtain efficient results. The citizens, who suffered from continuous droughts and water shortages, can get water service secured by leakage reduction at no additional costs.

The Seosan SWM case is a project that improved the operational efficiency in water. Greater results can be expected and achieved in other regions if this example is applied to those areas with insufficient water resources, deteriorated facilities, and numerous leaks.

6. REFERENCES

Choi (2016). SWMI: new paradigm of water resources management for SDGs. Smart Water

Eunkyung, Noh and Sooho, Bae (2019). The Study on Water Policy Changes: Based on the Water Law Legislation. *National Policy Management* Vol 14(2): 137-166

IBM (2009). A Vision of Smarter Cities: How Cities Can Lead the Way into a Prosperous and Sustainable Future. IBM

IEC(International Electrotechnical Commission) (2014). Orchestrating Infrastructure for Sustainable Smart Cities. IEC

IWRA and K-water (2018), Smart Water Management Case Study Report. K-water

Keeling (2012). The Economics of Smarter Water? Lecture, Innovation in Water: Dublin Study Tour Study Tour. Dublin.

K-water (2015). Center of scientific watershed integrated water management. *Water and Future* Vol.: 258-278.

K-water (2016), A Report on SWM Construction Project in Seosan, Palbong Water Supply Area Implementation and Results. K-water

K-water (2016). A Study on Water Resources Development during Korea Development Period. *The Journal of The Korea Regional Development Association:* 121-130

K-water (2016), Optimal of Water Pipe Network Operation and Management Based On Smart Meter And Sensor Network. Ministry of Environment

K-water (2016), Paju SWC Pilot Project Final Performance Report. . K-water

K-water (2016). Waterworks Leakage Management; Essential Processes and Methods. K-water

K-water (2018), Promoting Smart Drinking Water Management in South Asian Cities; Technical Diagnosis Report. K-water

Yookyung, Lee and Seungho, Lee (2018). A Case Study of Smart Water Management Technology in Korea: Based on Conceptualization of Smart City and Smart Technology, *The Study on Regional Policy* Vol 29(2): 149-182

Yoonseok, Hong (2019). Applications of Artificial Intelligence Technologies To Water Resources Systems: Water Quality Management In The Reservoirs. London South Bank University