Smart Water

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SWMI: new paradigm of water resources management for SDGs

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Abstract

The seriousness of water related issues is increasing due to regional imbalances of water use and damages from water related disasters. Various technologies are being applied to resolve water related issues. Recently, interest in SWM, water management methods converging with ICT, is increasing. K-water, as a Korean government owned corporation, suggested SWMI as a new paradigm to resolve water related issues by converging K-water's experienced water management know-how with advanced ICT. SWMI is an integrated management model covering the entire water cycle from sources to tap for securing the stability, safety and efficiency of water. At the same time, a 3-step strategy consisting of technology development, standardization and standardized frame for application of technologies was established to implement SWMI. It is expected that SWMI will enable scientific and efficient water management by interacting of technologies converged with ICT for entire water cycle from sources to tap water.

Keyword: SWMI, IWRM, SWG, Standardization

Introduction

These days, water management conditions are becoming increasingly complex because of climate change, increasing of water withdrawal, growing imbalance of water use between developed and developing countries and the increasing number of international water conflicts.

Water-related hazards account for 90 % of all natural hazards, and their frequency and intensity are generally increasing. The occurrence of floods and droughts are expected to increase with a climate change, with the IPCC predicting that water-related disasters will increase in both frequency and severity, as the whole global water cycle is affected by global warming. Since the original Rio Earth Summit in 1992, floods, droughts and storms have affected 4.2 billion people (95 % of all people affected by disasters) and caused USD 1.3 trillion in damages (63 % of all damage). So far this century, there has been USD 2.5 trillion in economic losses from disasters - 70 % relate to floods and droughts.

Currently, approximately 700 million people in 43 countries are suffering from water shortage. And it is projected that by 2025, the water withdrawals will increase by 50 % in developing countries and 18 % in developed countries because of population and industrial growth. Due to the increasing number of water scarcity regions, more than 2.8 billion people in 48 countries will face water stress or scarcity conditions by 2025 (Hameeteman, 2013).

In developing countries, poor water and sanitation facilities are the source of health problems for almost half of the population and can be linked to 80 % of all diseases. Each year, 5 million people, mainly children under 5 years of age, fall victim to illnesses directly related to polluted water - the leading cause of death in this age group (Hameeteman, 2013).

Importance of efficient water management is increasing as the topic of water cries and failure of climate change adaptation have been selected by World Economic Forum in "Global risk landscape 2015" (WEF, 2015). However, due to the complexity of water related issues, traditional water management systems have been shown their limitations and inability to solve water related issues. Therefore, there is a demand for new water management technologies to resolve current water related issues and enhance water management efficiency.

Smart water management initiative

Smart water management

Many technologies have been applied to water management for resolving various water related issues and increasing the efficiency of water management. And recently, information and communication technologies (ICT) have been applied to optimize the water production and distribution processes with maximum efficiency at each step (Byeon et al., 2015). Also, many research projects are ongoing to develop Smart Water Grid (SWG) technologies (Byeon et al., 2014) and apply the technologies to secure a sustainable water supply by connecting water sources and optimizing water treatment methods based on ICT in Korea (Choi and Lee 2013).

At the same time, interest in Integrated Water Resources Management (IWRM) is rising due to innovative technological advances which have expanded the water management scope to cover entire water basins, including the sustainability of ecosystems, economic and social welfare in equitable terms not only quantity managing focused on the river. In such an approach, ICT solutions can play a key role for implementing the concepts of IWRM and achieving water sustainability (Byeon et al., 2015). Water management technologies converging with ICT have been called Smart Water Management (SWM) distinguished from traditional water management technologies. SWM integrates ICTs to monitor water resources, diagnose problems, improve efficiency and coordinate management to help overcome the challenges to provide every citizen with sustainable water supply (ITU, 2014; Heland et al., 2015) Fig. 1.

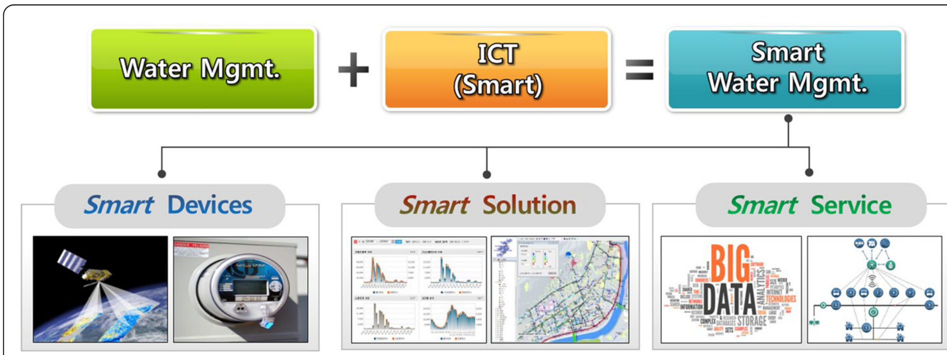

Fig. 1 Concept of SWM

SWM is a future-oriented water management strategy capable of integrating and managing the entire process of the water cycle from analysis of current situations to purification, distribution, as well as the using and recycling of water resources scientifically and systematically.

ICT utilization status of K-water

ICT application history in the water industry has changed depend on the ICT development stage of industrial control fields in Korea.

Before 1980, contact relay types such as local control panels and remote control panels were built and applied to operations. The contact relay mixed local control panel with small scale PLC (Programmable Logic Controller) after that starting small scale PCL application since 1980. Since 1990, local control panels were built at local sites and SCADA (Supervisory Control and Data Acquisition) system was built based on internal networking by DCS (Distributed Control System) installation at each local site facility due to the introduction of processing automation. The introduction of the SCADA system made it possible for local or remote supervisory control systems to be set up and integrated operation infra for each site was built. Since 2000, integrated operation systems for each local headquarters in the water supply field and a national wide integrated operation system for the water resources management field were built through rapid development of industrial networking technology. Since 2010, advances in technology have made it possible to mix DCS and PLC by introducing highly functional PLC. As well, the condition for applying systematic technologies was established through the development and in-house standardization of ICT while promoting the commercialization of relevant IT technologies. As shown in Fig. 2, K-water has applied ICT in water management fields following Korea's ICT develop status (Ryu et al., 2014).

Conceptual overview of the smart water management initiative

K-water, as a government owned corporation, is responsible for managing the whole water cycle from sources to taps, including the operation of water treatment facilities. Therefore, integrated management of water basins and water supply networks, including water treatment, is very important. As well, ICTs have been undertaking to K-water's all water management tasks to increasing efficiency through scientific water management.

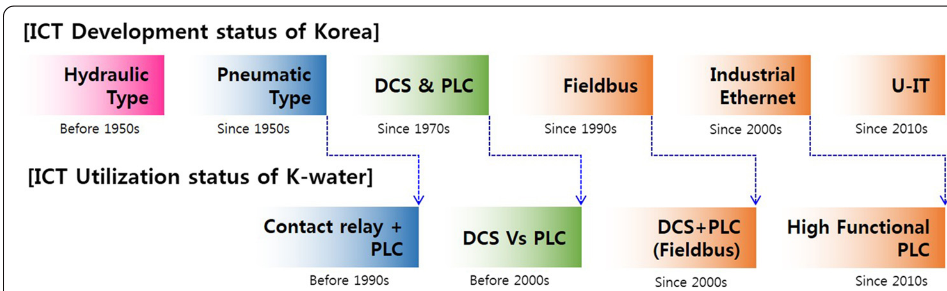

Fig. 2 K-water's ICT Application Timeline

K-water promulgated the Smart Water Management Initiative (SWMI) as a new paradigm for water management based on K-water's experienced water management know-how using Korea's global leading advanced ICT at the 7th World Water Forum which was held in 2015. SWMI is an integrated water management model which deals with the entire process of water management from planning to operations based on IWRM and SWG (K-water, 2015).

Meanwhile, there are some overlaps and confusion in terms of IWRM and SWG because the concepts and scope of IWRM and SWG are being used too widely. In order to resolve this problem, at first, the scope and meaning of IWRM and SWG were clarified in SWMI's concept. It was important to clarify the scopes of IWRM and SWG because SWMI covers the entire water cycle from sources to tap including water treatment, transmission, distribution and reuse of water. If there were any confusion and overlaps in IWRM and SWG, the technologies being used in each sector cannot be defined clearly. Once the scopes for IWRM and SWG were defined clearly, all technologies for each of the sectors were investigated and linked from sources to tap converging with ICT.

IWRM can be defined as scientific water management and includes the following characteristics: IWRM provides a comprehensive perspective of basins and regions, integrated governance of stakeholders, comprehensive consideration of the economy, society, culture and environment as well as technological aspects.

SWG can be defined as an advanced and intelligent water supply system and includes the following characteristics: ICT integration of the water supply network, including real-time information sharing through smart measurement and networking, and healthy water supply management.

Figure 3 shows major concept of SWMI including scope of IWRM and SWG in SWMI based on entire water cycle.

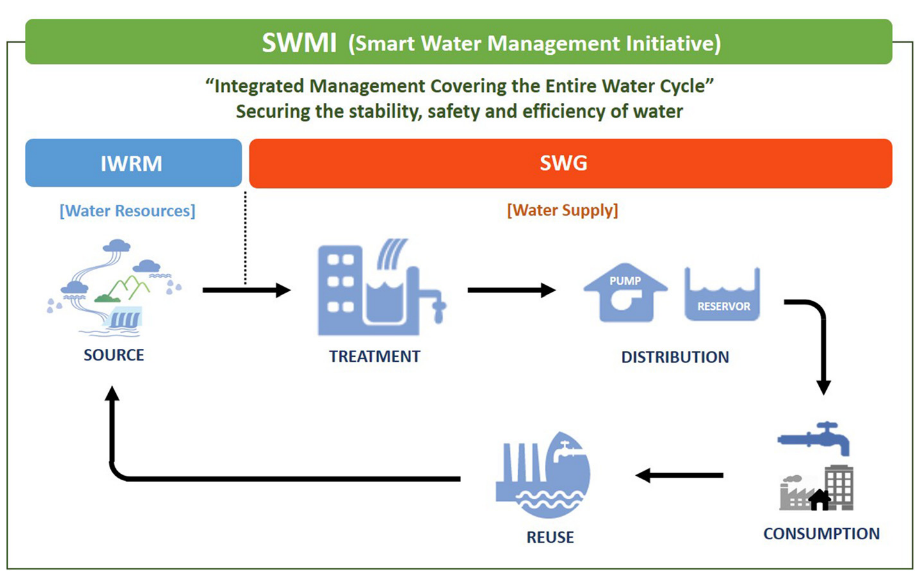

Fig. 3 SWMI Conceptual Map

SWMI can be defined as an intelligent water management model covering all aspects from water supply infrastructures to the production and distribution of water resources, digital data to manage water scientifically, ICT systems to process information in real-time and high-tech skills and equipment to use big data skillfully.

Implementation of SWMI

To implement SWMI, the development and application of various technologies is required. According to Oxford Dictionary, the definition of technology is "The application of scientific knowledge for practical purpose, especially in industry". Technology was divided into three categories - Infra & device (I), Solution & Service (S), Process & Management (P) - to establish strategies for developing, standardizing and applying technologies to implement SWMI depend on their characteristics such as types, etc., in this project.

A three-step strategy was established to implement SWMI through the development and application of technologies for the entire water cycle system. The first step, entitled K-Tech Tree, involves the development of necessary technologies for SWMI implementation based on the current state of technologies. The second step, entitled STEP-ISP, includes the standardization of developed and will be developed technologies depending on the technology types. The last step is a standardized frame for applying technologies developed by K-Tech Tree and STEP-ISP.

Technology development - K-tech tree

K-Tech Tree was established as a strategy for finding necessary technologies and developing the technologies to implement SWMI. As shown in Fig. 4, K-Tech Tree consists of three components which are technology classification, current state of technology, and technology development.

The concept of SWMI is to systemize the entire water cycle and each of the components of the systemized water cycle were divided into technology classifications. As shown in Fig. 5, classification was set up by departmentalizing in a step by step process.

Once K-water's technologies were departmentalized, they were then investigated and linked to applicable classes which are considered as a room to contain technologies. Technologies which are required to develop or improve for implementation of SWMI will be selected through this process based on the current state of technologies. Also, the plans for development required technologies were established.

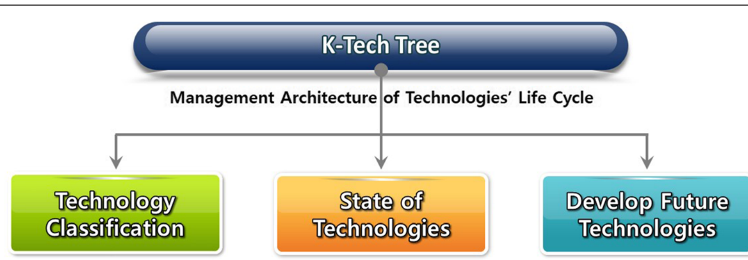

Fig. 4 Conceptual Diagram for K-Tech Tree

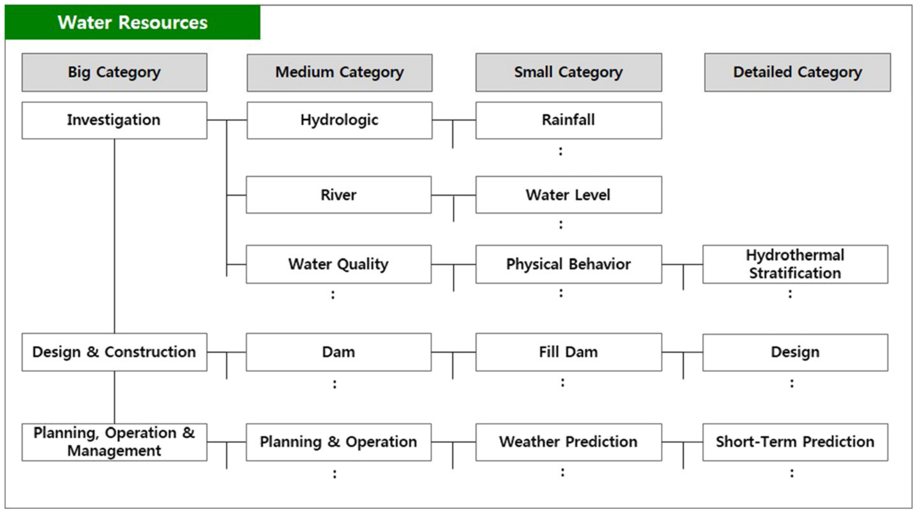

Fig. 5 Example of Technology Classification

Standardization of technologies - STEP-ISP

The importance of the standardization is increasing to get connectivity of each technologies and improve efficiency of technology application, because diverse and complex technologies are continually being applied to water management. As such, standardized technologies could be used to increase business efficiency. The STEP-ISP (Standardization Technology Enhancement Project - ISP) strategy was established to standardize technologies depending on their types related K-Tech Tree. Figure 6 shows the concept of STEP-ISP standardization strategy of K-water. All technologies have been classified based on their types and characteristics. And then, standardization strategy has been established according to the technologies' types and characteristics.

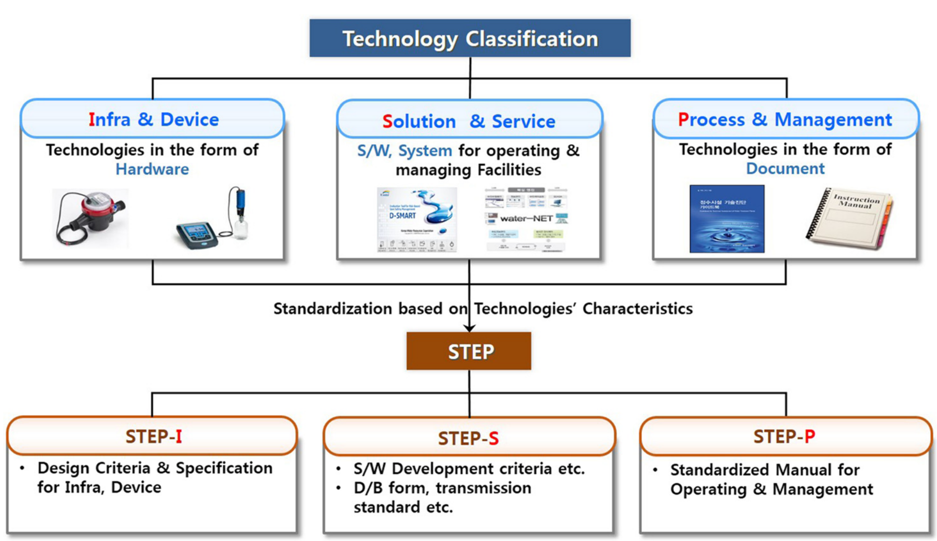

Fig. 6 Conceptual Diagram of the STEP-ISP Strategy

STEP-I is the strategy for standardizing the installation of infra and devices. K-water, as a public organization, suggests standards for the installation of infra and devices. Accordingly, private sector entities that pursue the development and production of relevant products abide by the standards. Consultation with the private sector has been undertaken to discuss and cooperate in the standardization process, because a consensus among all concerned parties is very important for establishing standards.

STEP-S is the strategy to standardize systems such as S/W and information. The strategy for standardizing each component has been established with consideration of difference characteristics between S/W development and using information. When a new S/W was needed for some task, the traditional way for a new S/W to be developed independently and linked necessary part of the S/W to existing systems or adding new functions. Therefore, securing connectivity between S/W is quite difficult because of differing developing languages, algorithms, and GUIs were applied to develop S/W depend on the person in charge. Also, efficiency for new S/W development and integrated operating is very low. In order to resolve these problems, a standard for developing S/W needs to be established with a concept of modularization and framework. The basic components commonly used in various systems will be modularized and a standard framework will be built to increase the availability of the components.

A variety of information has been using for water resources management by various organizations and the amount of information is increasing recently because water management tasks are becoming more complicated. As well, the number of ICT technologies is the field of water management is continually growing. However, limitations still exist in terms of sharing and using the information because of differences in information types and delivery systems between organizations. The types and delivery systems of information, including observation data, will be standardized in order to share and provide open access to water resources management information.

STEP-P is the standardization strategy for operating and managing processes of facilities, devices and systems. There are some limitations in achieving identical qualities and results due to differences of each individual employee's experiences and level of work performance. In order to resolve these issues, standard manuals of all K-water's technological tasks will be established through the conversion of tacit knowledge to explicit knowledge. K-water's vast pool of technological know-how will be capitalized with the creation of standard manuals. Also, optimized work processes will be built to gain identical qualities across all of K-water's technological tasks by establishing identical work methods and processes through the manuals. At the same time, a standard manual management system will be developed for the systematic management of standard manuals for the purpose of distinguishing the roles and responsibilities between headquarter and branch offices.

Application of technologies - standardized framework

The final step is the establishment of a standardized framework to apply technologies secured from K-Tech Tree and STEP-ISP. The established framework is composed of customized and modularized technologies to resolve water related issues in targeted regions of interest. The framework consists of a water management level assessment of a targeted region, result analysis, composing technologies and then applying them to improve vulnerabilities.

The composition standard for the water resources management and water supply field is established to make a criterion for water management level assessments of targeted regions. The composition standard for the water resources management field consists of four components which reflect the water cycle in a basin such as observation, dam, river and city area as shown in Fig. 7. Also, each of the components consists of technologies for smart water management including schemes and planning.

The composition standard for the water supply field consists of five components considering water treatment and distribution processes such as intake, water treatment, distribution, consumption, and reuse as shown in Fig. 8. As well, each of the components consists of technologies which are the same as water resources management field.

Approximately 100 indices have been developed to assess the smart water management level of a targeted region based on the composition standards. The level of a targeted region will be classified into Levels 1 to 5 against each assessment indicators. Vulnerabilities of the region will be definitized through analyses assessment results. Figure 9 shows the assessment process including sample indicators for the assessment to definitize vulnerabilities of a targeted region.

The last process is the application of the standardized framework to improve a targeted region's water management level by supplementation of vulnerabilities. The framework consists of modularized necessary technologies developed by K-Tech Tree and STEP-ISP to achieve the water resources management improvement goals of the targeted region. As well, the component technologies of the standardized framework

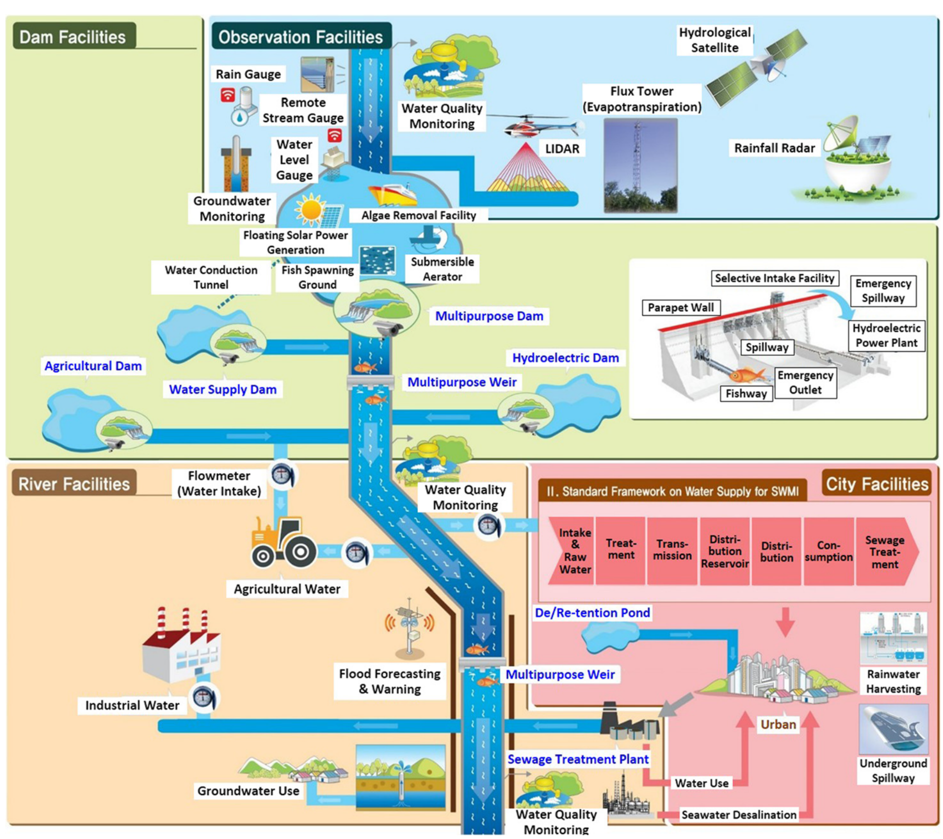

Fig. 7 Composition Standard of the Water Resources Management Field

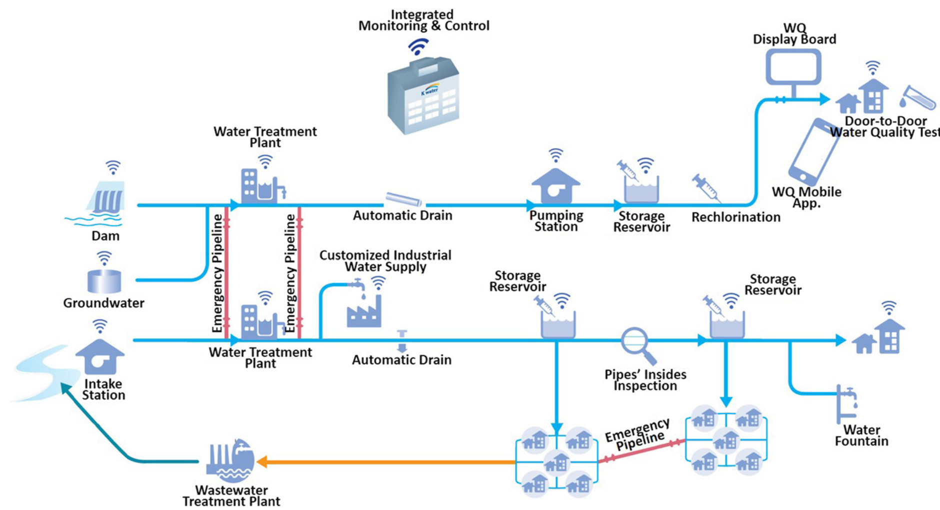

Fig. 8 Composition Standard of the Water Supply Field

can be changed by improving the goals depend on assessment results. Figure 10 shows the standard framework's concept consist business model from technologies.

It is expected that the efficiency of selecting public investment projects needing to resolve water related issues will increase as the investment direction and necessary technologies are determined by applying the standardized framework based on the water management level assessment. Time and effort for planning and launching new businesses can be reduced by establishing a standard business model using the framework with standardized and modularized technologies. Also, efficiency in terms of promoting new businesses will increase as necessary technologies and improvement goals are systematically determined based on framework assessments.

Expected effects of SWMI

SWMI can help implementing projects to resolve various water related issues through the interaction between technologies converging with ICT.

SWMI will result in more accurate weather forecasting by collecting and analyzing information in real-time not only from rain gauges installed on the ground but also from precipitation data and satellites. In addition, advanced flood and drought control can be achieved through information sharing among different water management facilities and systemized operations will minimize damages caused by natural disasters.

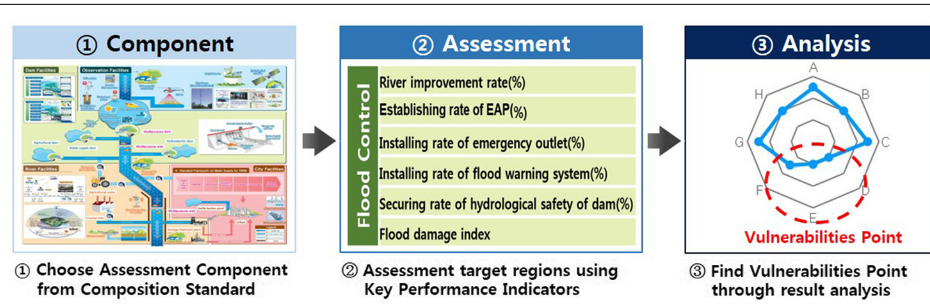

Fig. 9 Conceptual Diagram of Key Performance Indicators

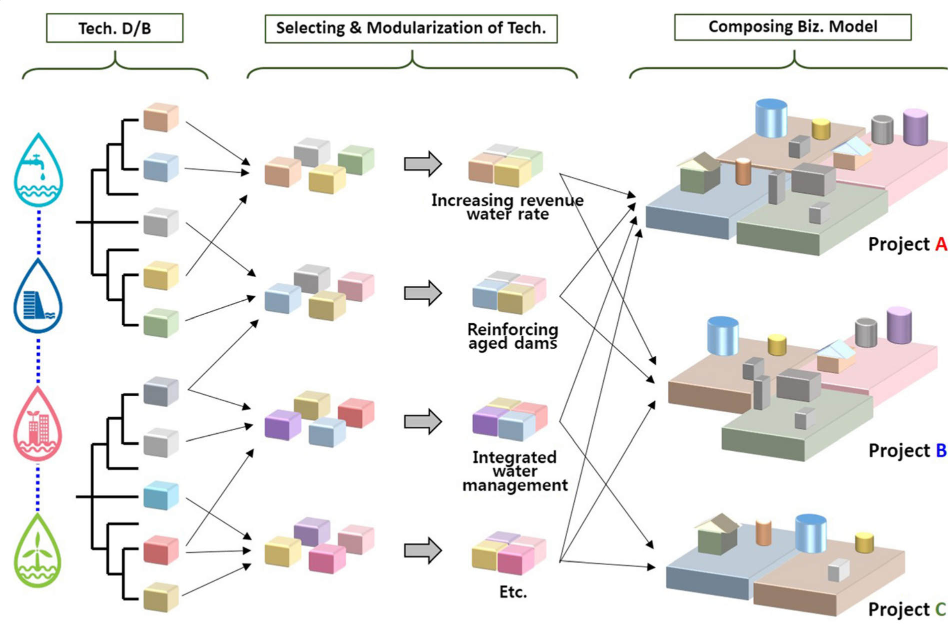

Fig. 10 Standard Framework

Also, SWMI provides the optimal utilization system by combining all available water resource including underground water, sea water and rainwater not dependent 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.

As well, water quality and quantity can be ensured and savings can be promoted by accurately predicting the needs and appropriate coordination of production and supply processes through ICT-based analyses of consumption patterns.

SWMI is also capable of identifying leakage incidents through automated information analyses without having to dispatch a worker to check onsite. Real-time analysis of information collected from smart devices ensures improved response time to any incident, subsequently reducing the risk of accidents and waste of manpower and time.

Additionally, SWMI can help in the decision process to improve the water management level through the proposal of correct and accurate directions for investment and business. Revenue can also be generated through the creation of various projects in the water industry.

Conclusion

The seriousness of water related issues is increasing all over the world and international conflicts are occurring to secure water resources. The importance of water management is rising enough that it could be said that the future of the world will depend on how water is used and managed. At the same time, the need for new technologies for water management is increasing because traditional water management technologies have limitation in terms of resolving water related issues of the present and future.

Therefore, various technologies are being applied to resolve water related issues. Recently, interest in SWM using ICT for water management is increasing. K-water proposed SWMI as an innovative water management technology to supplement traditional water management technologies at the 7th World Water Forum. SWMI is a smart water management technology that combines the accumulated advanced ICT of Korea with K-water's experienced water management know-how.

K-water has been making various efforts to implement SWMI through various strategies such as K-Tech Tree, STEP-ISP and standardized frame. K-water expect that K-water's efforts will help to resolve water related issues all around world. Cooperation to resolve complex water related issues is essential as countries and regions around the world are in need of assistance. In order to enhance cooperate, K-water will actively participate in international water associations to share and spread SWMI technologies.

First, K-water will participate in the newly formed @qua association, the world's benchmarking association in the field of smart water management that is dedicated to identifying technologies and solution. K-water will cooperate with others members to standardize and improve SWMI technologies. K-water is committed to making SWMI universally applicable so that it can be applied anywhere in the world through cooperation with @qua.

Second, K-water is committed to finding solutions for water related issues in Asia through cooperation with the Asia Water Council (AWC) which was recently established for the purpose of resolving water related issues and realizing water welfare in Asia. For this, K-water will share its expertise and SWMI technologies with Asian countries. It is expected that SWMI will help to mitigate the effects of natural disasters and many other issues such as the imbalance of water, etc.

Based on its expertise, know-how, and advanced technologies, K-water will endeavor to make the world a safer and happier place through the sharing of SWMI. As the complexity and range of issues vary from country to country, K-water has developed a comprehensive system that is flexible to meet the needs of the global community. K-water will continue to promulgate SWMI as a solution to resolve complex global water issues.

Abbreviations

AWC, Asia Water Council; DCS, Distributed Control System; GUI, graphical user interface; ICT, Information and Communication Technology; IPCC, Intergovernmental Panel on Climate Change; ISP, infra & device, solution & service, process & management; IWRM, Integrated Water Resources Management; PLC, Programmable Logic Controller; SCADA, Supervisory Control and Data Acquisition; SDGs, Sustainable Development Goals.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

GWC The author is CEO of K-water, establishes the basic concept of SWMI and has involved writing manuscript. KYC The author has involved SWMI implementation strategies. SJK The author has participated establishing SWMI implementation strategies. TSR The author has participated establishing SWMI implementation strategies as a director general and has written and proofread manuscript as a corresponding author. All authors read and approved the final manuscript.

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