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Knowledge Sharing Program

2022/23 KSP Policy Consultation Report

Ghana

Establishing Data-driven Comprehensive Water and Sanitation System in Ghana

Ministry of Economy and Finance

KDI Korea Development Institute

FRI 미래자원연구원 Future Resources Institute

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Establishing Data-driven Comprehensive Water and Sanitation System in Ghana

Preface

In the world of development, some projects really stand out for their teamwork and smart solutions. This Knowledge Sharing Program (KSP) through Korea Development Institute (KDI) was initiated by Ghana's Ministry of Sanitation and Water Resources (MSWR) to address the technical and institutional barriers for establishing an integrated water and sanitation management system.

By bringing together experts from both South Korea and Ghana for a collaborative effort for knowledge sharing and capacity building, the diverse expertise unraveled the technical challenges and institutional intricacies in order to come up with ideal solutions to the issues facing the Ghana water management.

This KSP project also serves as a testament to the prowess of collaboration, innovative thought, and unswerving commitment. Its implications extend beyond the present, promising a substantial impact on Ghana's water and sanitation domain in the future. With the forthcoming establishment of Ghana's water and sanitation information system through the Korea ODA project, facilitated by policy advisors, the nation's water and sanitation management is poised for a new level of systematic efficiency. The ripple effects will enhance the quality of life for Ghana's citizens.

Central to this achievement is the facet of policy advice in water and sanitation. The successful establishment of this policy advice framework sets a formidable precedent. This success story is not an isolated incident, but a harbinger of more to come as it lays the groundwork for continued implementation of policy advice for analogous projects in diverse domains. This trajectory foretells a future wherein policy advice becomes a cornerstone of developmental projects, catalyzing progress and innovation.

This project's resounding success owes a debt of gratitude to the steadfast commitment of various stakeholders. The Government of Ghana and the MSWR were very dedicated to making this project work. Other groups, like the Ghana Water Company Limited, the Community Water and Sanitation Agency, and the Water Research Institute, also supported the efforts by sharing their knowledge about water and sanitation in Ghana. In particular, Mr. Noah Tumfo (Chief Director of MSWR), Mr. Anthony Dzadzra (Director of Policy Planning, Budget Monitoring and Evaluation of MSWR), Ms. Jennifer Buabeng (Human Resources Director of MSWR), and Sethina Okornoe (Deputy Director of MSWR) ensured the project maintained its course amid the complexities and challenges.

The team of experts was vital to the project's success, offering a multi-dimensional perspective. Thanks go to Mr. Jaeyou Choi (Senior Advisor), Dr. Gwangman Lee (Principal Investigator), Dr. Youngho Park (Researcher), Mr. Sooyoung Eo (Researcher), alongside local consultants Ms. E. A. Tsagbey and Mr. Ibrahim Musah, for their outstanding shared and contributed insights that fortified the strategic evolution of the project.

Behind the scenes, KDI's Center for International Development played a pivotal role in orchestrating and coordinating the project objectives. Particular acknowledgments go to Dr. Jungwook Kim (Project Director), Dr. Ho Kyoung Bang (Project Manager), and Ms. Sehee Jeon (Project Officer).

The collaboration between KDI, FRI and Ghana's MSWR has birthed a pioneering project that encapsulates the essence of cooperation, forward-thinking, and unwavering dedication. As Ghana's water and sanitation sector stands on the cusp of transformation, the echoes of this partnership are set to reverberate through time, offering a guiding roadmap for global cooperation.

Sisaeng Ryu
President
Future Resources Institute

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2022/23 KSP with Ghana

Sung Je Park (Future Resources Institute)

2022/23 KSP with Ghana

Sung Je Park (Future Resources Institute)

The Republic of Ghana (hereinafter Ghana), is an emerging power in West Africa with high economic growth and a democratic political system. Ghana is plagued by water leakage rates and bad sanitation. Amidst the COVID-19 pandemic, the Ghanaian government has focused on solving drinking water shortages and bad sanitation.

In this rapidly changing external environment, the theme of the 2022/23 Knowledge Sharing Program (KSP) with Ghana, 'Establishing Data-driven Comprehensive Water and Sanitation System,' is timely. Ghana has a national medium-term development policy framework (MTNDPF. 2022-2025). The plan points to inadequate access to water services and poor hygiene and waste management as important matters to be addressed at the national level.

The Knowledge Sharing Program (KSP) with Ghana was launched in this context. In Ghana, the Ministry of Sanitation and Water Resources (MSWR) explained to Korea the need for an integrated system to solve water and sanitation problems. To make informed decisions, MSWR asked for policy suggestions for establishing ICT-based water and sanitation information management system for effective data collection. The following table summarizes the general information about the project, including the consultation topics and project organization:

Sub-topics	Researchers	Local Consultants
I. Korea's Experience with Establishing ICT-based Information System in Water & Sanitation Sector and Its Implication for Ghana	Youngho Park, Senior Research Fellow, Korea Institute for International Economic Policy	-
II. Technical Solution for Establishing ICT-based Water and Sanitation Information Management System in Ghana	Gwangman Lee, Director, Future Research Institute	Esinu Ama Tsagbey, Chief IT Specialist, Community Water and Sanitation Agency
III. Policy Suggestions for the Introduction of ICT-based Water and Sanitation Information Management System in Ghana: Focusing on Accra City	Sooyoung Eo, CTO, GWORLD Company Limited	Ibrahim Musah, Community-based Grants Technical Advisor, Safe Water Network
• **Senior Advisor:** Jae-you Choi, Former 2nd Vice-Minister of the Ministry of Science and ICT, Republic of Korea • **Project Manager:** Ho Kyoung Bang (Specialist, Center for International Development, Korea Development Institute) Sung Je Park (General Director, Future Resources Institute) • **Principal Investigator:** Gwangman Lee (Director, Future Resources Institute)		

Before the official launch of the 2022/23 KSP with Ghana, the KDI project management team and the Ministry of Sanitation and Water Resources (MSWR) agreed on the detailed subjects. In particular, the KSP team from both sides had discussions for communication and cooperation.

As the first official stage of the project, the Launching Seminar was held on 15 December at MSWR. The Korean and Ghanaian side officially announced the start of the research and discussed the sub-topics and research plans. As part of the in-depth study, Korean researchers visited Weija Plant in Ghana Water Company Limited (GWCL), Lavender Hill Plant in Sewerage Systems Ghana Limited (SSGL), Integrated Recycling and Compost Plant Limited (IRECoP), and Greater Accra Metropolitan Area (GAMA) Sanitation and Water Project Office.

Through these visits, the delegation from Korea learned that Ghana's water and waste disposal technologies were quite systematic and advanced. The basic data-driven information management systems were somewhat already built by international organizations or NGOs. However, the fundamental functionalities of the integrated system had inadequacies, such as with data not being delivered automatically and having to go through manual work in the middle stage.

Subsequently, Policy Seminar and In-depth Study was held in Ghana from 19 to 26 February to share the progress of the study conducted since the Launching Seminar and get a deeper look at the local status by detailed topic. At a policy seminar held at MSWR in Ghana on February 23, 2023, Principal Investigator, Gwang Man Lee, Chief Director, Noah Tumfo, Deputy Director, Sethina Okornoe, and local experts attended.

As part of the in-depth study, Korean researchers visited Waste Disposal Agencies (J. Stanley-Owusu & Company Limited, Zoompak Ghana Limited), Sewerage Systems Ghana Limited (SSGL), ATMA Production in Ghana Water Company Limited (GWCL). After the visits, the Korean experts felt that Ghana's level of data-driven system construction was higher than that diagnosed in its previous business trip. In addition, it was diagnosed that it is urgent to establish governance for an integrated system in terms of water and sanitation in Ghana.

For the next stage of the project, from 15 to 22 April, the policy practitioners from Ghana were invited to Korea for the 'Interim Reporting and Policy Practitioners' Workshop.' KSP delegation from MSWR and Ghana Water Company Limited visited relevant institutions and had lectures to have first-hand experiences and insights regarding Korea's experience of establishing and managing adequate ICT-based water and sanitation system.

Ghanaian delegations listened to lectures on Korea's water supply and sewage development process from Korean water and hygiene-related institutions. They visited institutions such as Jungnang Water Recycling Center and Ttukdo Arisu Water Purification Center where Korea's water supply and sewage systems work to acquire knowledge about building water and sanitation systems.

Korean experts delivered interim research results and policy recommendations to receive feedback and opinions from Ghanaians. In addition, in the Interim Reporting Workshop, Korean experts introduced a case of using a standard data model as a suggestion for Ghana's situation in which the tools for managing data are different for each data.

For the final stage of the 2022/23 KSP with Ghana, the Korean delegation, including Mr. Jae-you Choi, the Senior Advisor, attended the 'Final Reporting and Senior Policy Dialogue' in Ghana from 17 to 22 July. In the Final Reporting Workshop, the KSP team presented the final research findings and policy recommendations and received feedback from policy practitioners and other stakeholders in Ghana.

The KSP team also had a Senior Policy Dialogue with Mr. Anthony Dzadzra, the Director of Policy Planning, Budget Monitoring and Evaluation and delivered summarized policy recommendations for this project. Through this, both sides could share a common understanding of the importance of ICT-based integrated water and sanitation information management system.

Executive Summary

Gwangman Lee (Future Resources Institute)

Executive Summary

Gwangman Lee (Future Resources Institute)

1. Background and Objective

Inadequate WASH services impact the health, livelihoods, and wellbeing of many countries around the world. It has been sought a new leap forward by improving the public health environment that has worsened due to COVID-19. The Ghanaian Government also hopes to enhance its socio-economic ecosystem by developing an ICT-based infrastructure for water and sanitation management. It aims to establish a robust "water and sanitation data management" system, serving as a pivotal foundation for diagnosing, monitoring, and optimizing water resources, as well as for the informatization of water and sanitation markets and services.

ICT initiatives are proving how ICT can promote Water and Sanitation goals, including growing access, improving service delivery and enriching governance. The Ghanaian Government wishes to benchmark the “Digital New Deal” policy rolled out by the Korean Government. In response to these ICT initiatives, “Establishing Data-driven Comprehensive Water and Sanitation System” was selected as the 22/23 KSP project. The project consists of three sub-topics as below:

- Korea’s Experience with Establishing ICT-based Information System in Water & Sanitation Sector and Its Implication for Ghana
- Technical Solution for Establishing ICT-based Water and Sanitation Information Management System in Ghana
- Policy Suggestions for the Introduction of ICT-based Water and Sanitation Information Management System in Ghana: Focusing on Accra City

The specified objectives of the research were to:

- identify challenges and development needs in Ghana's WASH sector in terms of country contexts including policy and social aspects;
- analyze the ICT-based WASH Information Management System (IMS) in Ghana with the focus on evaluating the existing WASH data collection system, as well as identifying its limitations in terms of system functions including social, institutional and financial factor, among others;
- find Korea's policy efforts for Establishing ICT-based Water & Sanitation Information System IMS, and derive relevant lessons that help Ghana address the challenges in the WASH sector;
- provide policy implications, technical solutions and implementation strategies for ICT-based WASH in Accra, which are basically based on Korea's experience as well as Ghana's country contexts including especially its absorption capacity among others.

2. Methodology, Input and Process

In order to achieve the above objectives, the methods, inputs and processes of the research were broken down into four key activities that generated analyses, outputs and reports, as follows:

- Lessons Learned from Other Studies: ICT has seen remarkable development in developing countries over the last decade. Its applications in the WASH sector have proved the benefits such as data collection, information sharing and service improvement. It was carried out by reviewing a great number of research papers (over 200 documents and materials). The current SIS system developed by the Ghanaian Government was deeply analyzed in order to address the key objectives of the research, especially Ghana's experiences with key ICT applications in the WASH sector.
- Studies of Experiences of ICT Use in the Water and Sanitation Sector in Korea: In order to find implications from Korea's experiences, the characteristics of the existing water and sanitation sector information system were analyzed, and laws and

development guidelines relevant to the system implementation were reviewed in line with technical features.

- Field Surveys and Interviews, and Local Consultants: Two on-site surveys and face to face interviews were conducted with related organizations and experts. Two local experts who had participated in the Smarter WASH project were involved to ensure the project's tangible results. Field surveys were prepared based on consultations, interviews and focus group discussions with key water and sanitation sector stakeholders including field facility operators. Ghana's feedback was collected by holding three local meetings (Launching Seminar, Policy Seminar, and Final Reporting Seminar).

- Expert Consultation and Evaluation Meeting in Korea: Two expert consultation and evaluation meeting organized by KDI were held in Korea to solidify the substance of the project. Experts who attended presented in-depth opinions centered on Korean cases so that the sub-topics covered in each topic could be realized in Ghana, and these opinions were appropriately reflected in each sub-topic.

3. Analysis and Findings

3.1. Sub-Topic 1: Korea's Experience with Establishing ICT-based Information System in Water & Sanitation Sector and Its Implication for Ghana

The resulting recommendations included a comprehensive approach as follows:

- A system solution tailored to the country context and absorption capacity of Ghana, which includes social, technical, and program designs, is an important policy challenge in the country. The choice of technology is a critical issue directly related to the usability and scalability of the system, so a tailored approach that considers the overall technological environment and appropriateness of the technology is important. The Smart Water System case in Seosan City, Korea, is analyzed as a noteworthy example of how appropriate technology can be applied in Ghana.

- It is important to secure financing for ICT-based information systems and infrastructure development, including communication networks, water supply, and sewerage networks. To implement an ICT-based information system, funding

is necessary for both system development and maintenance. Although ICT-based information systems are currently established and operational in Accra, limitations in system expansion and maintenance exist due to insufficient funding. In this study, we presented how Ghana strategically utilizes Korea's ODA and Development Financing Instructions (DFIs) funds.

- The utilization of Cost-Benefit Analysis is recommended. Ghana's government needs to use CBA as leverage to mobilize funds into ICT-based WASH IMS. Considering the significance of the WASH sector in the health and welfare of the population, developing a cost-benefit analysis methodology is highly recommended. CBA is widely used in Korea to assess the feasibility of system establishment across the WASH sector.

- Lastly, strengthening political commitment and legal institutions, and establishing an education system to train experts are important policy recommendations. As is well-known, political commitment, institutions, and education play a crucial role in the establishment and effective operation of information systems in the WASH sector in Ghana.

3.2. Sub-Topic 2: Technical Solution for Establishing ICT-based Water and Sanitation Information Management System in Ghana

Key highlights from the analysis of the technical solutions into recommendations applicable to the Water and Sanitation IMS in Ghana include the following:

- From a technological perspective in Ghana, infrastructure shortages, siloed systems and inadequate services are prevalent all around the industry. The waste treatment sector, including fecal and stock manure, is managed by individual businesses, but it is small and inefficient. The service capability is evaluated at a low level overall. Information sharing between the central and local governments is not smooth, resulting in a lack of vitality throughout the nation. The functionality of the existing sector information system (SIS) is not enough to support the government's policy making and initiating governance. The informatization is one of the main challenges that the Ghanaian government should resolve for restructuring the data management chain and service delivery in the water and sanitation sectors.

- The implications and insights learned from the National Waterworks Information

System and the Allbaro System (Total Waste Management System) operated in Korea are presented to apply their merits to Ghana's Water and Sanitation IMS. It is assured that the concepts of the systems can be benchmarked for Ghana's Integrated ICT-based Water and Sanitation IMS, because the systems have many similar parts envisioned with Ghana's situations, such as basic structure, application of ICT technology and its key functions as well as the policy will of the state. The specific informatization-related regulations stipulated in the relevant laws and regulations have also proved that they have played an important role in water and sanitation sectors.

- For the basic strategies of the technical solutions for Ghana's Water and Sanitation IMS, a feasible design of the system is schematized to meet the specific needs required by all actors. A general mapping of a data networking system for system integration is presented for each sector. Key thematic components of ICT technologies to integrate all sectors are proposed on how to organize servers and mobile data services. The methodology how to develop an information system and how to manage a desired data set in an appropriate place and time is designed in respect to various utilizable technics.

3.3. Sub-Topic 3: Policy Suggestions for the Introduction of ICT-based WASH Management Information System in Ghana: focusing on the Accra Metropolitan Area

Key outputs on the policy suggestions for Ghana's ICT-based WASH MIS are as follows.

- GWCL is now promoting a plan to introduce a smart metering system in the waterworks networks as part of the future management scheme of NRW. Infrastructures for inducing an information system in Ghana are in relatively good conditions compared to other African countries. However, it is necessary to further strengthening the capacity in implementing data collection management and the WASH IMS.

- Given the situations and need of an information system, the drinking water sector should be prioritized while considering the integration process of the existing WASH systems (SIS). The main components to be included in the system are water source management, block monitoring of the distribution system and e-billing based on the GIS system. The effectiveness of the system should be maximized through the operational improvement of water supply facilities for the specified pilot area.

- MSWR should promote administrative enforcement of the waste field, which includes solid, liquid, and fecal treatment. Along with the system development, data collecting process for informatization should be rearranged in consideration of data generators and users. The assessment accuracy of the golden indicators that measure the progress level of SDG 6 can be improved through the planned system. However, the system alone is not enough to support WASH goals because of lack of the general ICT infrastructure.

- ICT initiative in water quality field should be promoted and expanded to an integrated WASH center. The water quality sector could range from domestic sewage to industrial wastewater, because all wastes are discharged without any appropriate treatment. Because the water quality sector in Ghana is not fully managed, it imposes a great burden on the purification cost in the drinking water supply system. In addition, illegal discharge of wastewater impacts the national economy not only undermining citizens' right to health and wellbeing but also various critical standard issues to Ghanaian exporters.

- Finally, this project has already been the motivation for "Smart Water Management System Project in the Western Part of Accra" that the Korea Environmental Industry & Technology Institute is planning to pursue in Ghana.

01

CHAPTER

Korea's Experience with Establishing ICT-based Information System in Water & Sanitation Sector and Its Implication for Ghana

Youngho Park (Korea Institute for International Economic Policy)

Keywords
Water, Sanitation, Information System, Smart Water Management, Cost-benefit Analysis

Korea's Experience with Establishing ICT-based Information System in Water & Sanitation Sector and Its Implication for Ghana

Youngho Park (Korea Institute for International Economic Policy)

Summary

Ghana has experienced rapid economic growth based on its political stability and has been upgraded from a low-income country to a low-middle-income country. It is classified as a group of high-growth countries in Africa, and the inflow of foreign direct investment is steadily increasing. However, there have been insufficient improvements in the water, sanitation, and hygiene (WASH) sector. Ghana has poor access to safe and clean drinking water, with only 41% of the population having access to it, and only 13% of the population having access to sanitation. Ghana ranks low in the "clean water score" evaluated by the international community. Most Ghanaians purchase sachet water or use contaminated water due to insufficient supply of drinking water in the water supply. The sanitation situation is also poor, with only 20% of the population using basic sanitation facilities. Sewage treatment is not carried out properly, with only 2% going through sewage treatment. Only a small number of households rely on the sewerage system to dispose of their wastewater. Ghana is lagging far behind in all areas of WASH performance assessment in Sustainable Development Goals (SDGs), which are essential for achieving several SDGs, particularly Goals 3, 6, and 14.

The development needs of Ghana's WASH sector are depicted in a schematic diagram, taking into account the policy, social, economic growth, and technical contexts. The Ghanaian government has prioritized water and sanitation as a key development area in its national development policies, and the United Nations' Sustainable Development Goals include "clean water and sanitation" as a top priority. The social context reveals that demand for basic social services, including water and hygiene, is increasing due to population growth and urbanization, while environmental pollution caused by poor sanitation is a major issue. The economic growth context highlights that economic development has increased demand for improved WASH services, particularly for sanitation facilities and hygiene products, and has

led to increased urbanization and demand for WASH services. The technical context shows that the development of information and communication technology (ICT) has increased access to information and enabled the use of digital technologies to provide WASH services, leading to new business models and improved data collection and analysis. These contexts are interconnected, and addressing the development needs of Ghana's WASH sector requires a multifaceted approach that leverages policy, social, economic, and technical initiatives to ensure that clean drinking water and sanitation are available to all.

ICT-based information systems have the potential to improve WASH-related activities in Ghana, but the current reality is that these systems are not functioning effectively. The DiMES system, installed in 2007 with the support of the Danish Aid Agency, is not fully operationalized, and there is no coordination between monitoring systems due to the absence of standardized monitoring procedures. The Ministry of Sanitation and Water Resources has developed 14 key indicators for measuring progress in the WASH sector, but the Sector Information System (SIS), which is supposed to aggregate data from regional monitoring systems, has been neglected due to inadequate capacity, insufficient data collection, and limited data sharing. The lack of integration between systems has resulted in poor performance of the SIS, and it is essential that these issues are addressed to ensure effective monitoring and decision-making in the WASH sector.

The success of Korea's ICT-based WASH information system offers valuable lessons for Ghana, particularly in the areas of policy, institution, ICT development, economy, social factors, infrastructure, financing, and technical factors. Korea's success in utilizing ICT technology to remotely monitor leakage point detection, water pressure changes, and other aspects of WASH management has led to improvements in water quality, leak management, and sewage treatment, as well as cost savings and budget reductions. The implementation of smart water management (SWM) in Korea has also been successful in addressing water challenges in the face of rapid urbanization and climate change.

Before implementing an SWM project, there are several implications to consider, including initial investment costs, financial sustainability, policy support, customization, continuous training and consultation, and integrated water resources management. To ensure success, SWM projects should be customized to meet the specific needs of the region, and policymakers, stakeholders, and citizens should reach a consensus before implementation. Pilot cases should also be implemented, verified, and studied to introduce an approach suitable for the target area. Finally, SWM should take into account the environmental, social, and economic impacts of the project to promote sustainable development.

Overall, the implementation of ICT-based WASH information systems and SWM has the potential to improve the efficiency and effectiveness of the WASH sector in Ghana, leading to progress toward achieving the WASH-related SDGs. However, careful consideration and planning are necessary to ensure the success and sustainability of these projects. Lessons can be learned from Korea's successful approach, and by addressing the challenges faced in Ghana, the potential benefits of ICT-based WASH information systems and SWM can be realized.

This chapter provides an in-depth analysis of Korea's ICT-based information system in the field of WASH, aiming to draw implications and policy proposals that can be presented to Ghana. Although Ghana faces challenges such as a lack of basic infrastructure, human capabilities, and investment resources, which make it challenging to implement a Korean-level ICT-based information management system, it is still possible to establish an information management system that is suitable for Ghana's specific circumstances. In fact, when examining the case of establishing ICT-based WASH systems in developing countries, it becomes evident that technology, tools, and solutions are not always required to the same extent as they are in Korea.

Drawing on the insights gained from this study, we propose the following policy recommendations for improving Ghana's WASH information system.

The resulting recommendations included a comprehensive approach as follows:

First, it is highly recommended to build a system solution tailored to the country context and absorption capacity of Ghana, which includes social design, technical design, and program design. Given that information systems are managed by individuals, technologies, and organizations within society, it is essential to develop systems that take into account this societal framework. The choice of technology is a critical issue directly related to the usability and scalability of the system, so a tailored approach that considers the overall technological environment and appropriateness of the technology is important. The case of Seosan City in Korea analyzed in this chapter is a noteworthy example of how appropriate technology can be applied in SWM.

Second, it is important to secure financing for ICT-based information systems and infrastructure development, including communication networks, water supply, and sewerage networks. These relevant infrastructure developments are prerequisites for building ICT-based information systems. To implement an ICT-based information system, funding is necessary for both system development and maintenance, which includes

purchasing devices and training staff. Although ICT-based information systems are currently established and operational in Accra, limitations in system expansion and maintenance exist due to insufficient funding. Moreover, the majority of rural areas lack information systems in the WASH sector, and the solution to this problem is to secure investment funds. In this study, we presented how Ghana strategically used Korea's official development assistance (ODA) and Development Financial Institutions (DFI) Fund.

Third, the use of cost-benefit analysis (CBA) is recommended. Ghana's government needs to use CBA as leverage to mobilize funds into ICT-based WASH information systems. Considering the significance of the WASH sector in the health and welfare of the population, developing a cost-benefit analysis methodology is highly recommended, which is expected to be used effectively and convincingly for widely publicizing its social benefits domestically, as well as attracting foreign aid. CBA is widely used in Korea to assess the feasibility of system establishment across various sectors, including data management systems in the WASH sector.

Lastly, strengthening political commitment and legal institutions, and establishing an education system to train experts are important policy recommendations. As is well known, political commitment, institutions, and education play a crucial role in the establishment and effective operation of information systems in the WASH sector in Ghana.

Overall, establishing and operating an ICT-based information system requires a comprehensive approach that takes into account investment financing, technology, and human capabilities. It is essential to have a long-term vision to ensure the sustainability and effectiveness of the system.

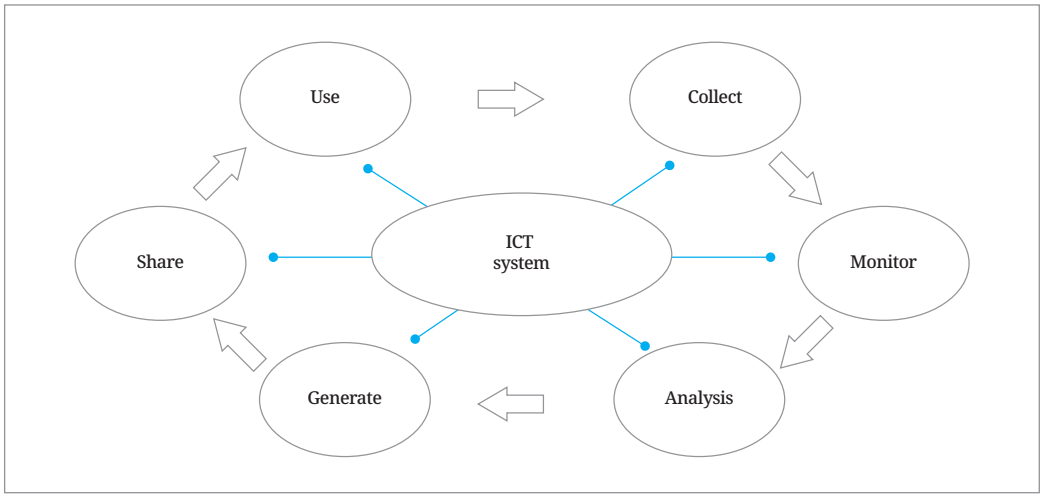
1. Introduction

1.1. Background and Objectives of the Study

In this research, the term "ICT-based information system" refers to the utilization of ICT tools and solutions for improving the delivery and management of water and sanitation services. ICT comprises hardware, software, networks, and media devices that facilitate data collection, transmission, storage, monitoring, analysis, and the production and sharing of information. The ICT-based information system is becoming increasingly important in the WASH sector.

Robust ICT systems are crucial to the "data value chain" approaches, as they offer a useful framework for transforming data into actionable information. [Figure 1-1] below illustrates the concept of the data value chain, which encompasses the processes of collecting, processing, and utilizing data to generate valuable information.

[Figure 1-1] Data Value Chain: Evolving from Collection to Decision-Making



Source: Author.

The potential of ICT has largely remained untapped in Ghana's WASH sector, while ICT, as a key instrument for data-driven management, offers enormous opportunities to address the challenging task of managing WASH services in Ghana. Data-driven management, as widely understood, greatly depends on an ICT-based robust foundation that systematically collects data, monitors, and, based on this, produces meaningful information for decision-making, leading to an efficient WASH management system.

Clearly, an ICT-based information system is a necessary precondition for addressing daunting challenges in Ghana's WASH service management, whether by enhancing efficiency or enabling intelligent approaches. ICT-based information systems offer various benefits, including 1) improving data and information accuracy, 2) increasing the frequency of data collection and monitoring, 3) reducing time and cost while improving data quality, 4) decreasing manual data errors, 5) enabling scientific data analysis, thereby producing reliable information, 6) improving the collection of charges for service provision through e-billing systems, 7) promoting public participation and creating a system of transparency and accountability, and more.

The ICT-based information systems in Korea's WASH sector have led to multiple benefits, including enhanced water supply efficiency, improved water quality, leak detection

and prevention, data-driven decision-making, and better customer service. As such, implementing an ICT-based information system in Ghana's WASH sector can also bring various potential benefits.

The purpose of this chapter is to provide policy implications for establishing an ICT-based WASH information system in Ghana, based on Korea's experience and technologies, thereby contributing to the transformation of the WASH sector and the improvement of the health and welfare of the Ghanaian people. To achieve this objective, this chapter will prioritize the following topics.

1.2. Major Topics of the Study

The major contents of this study are summarized as follows:

(1) Identifying challenges and development needs in Ghana's WASH sector in terms of country context including policy and social aspects.

(2) Unlocking the potential of ICT to improve the WASH information system in Ghana

(3) Analysis of the ICT-based WASH information system in Ghana with a focus on evaluating the existing WASH monitoring system, as well as identifying its constraints in terms of system factors, social and institutional factors, financing factors, among others.

(4) Identify and document Korea's experiences/efforts in improving its WASH information system through adoption of ICT. This includes an analysis of the success factors behind the establishment of an ICT-based WASH information system, from the perspectives of technological advancement, political commitment and legal institution, and the like.

(5) Provide policy implications/recommendations for and ICT-based WASH information system in Ghana, which are, though not all, based on Korea's experience as well as Ghana's country context, particularly including its absorption capacity, among others. To be more specific, this study will identify Korea's policy efforts to establish an ICT-based WASH information system, and draw relevant lessons that can help Ghana address the challenges in establishing a WASH information system. The policy recommendations of this study will be categorized into four dimensions, which include 1) a comprehensive approach, 2) building system solutions tailored to the country's context and absorption capacity, 3) securing financing, and 4) using cost-benefit analysis. These policy recommendations have been developed with an emphasis on the pivotal roles of the MSWR (Ministry of Sanitation and Water Resources).

1.3. Structure of the Study

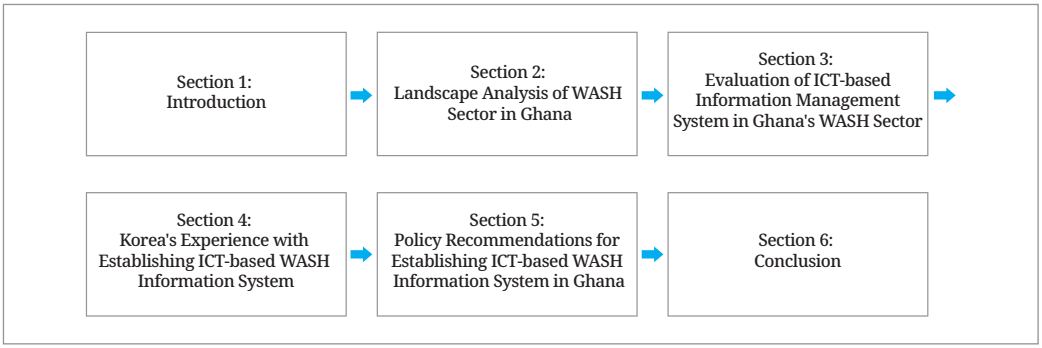
The mission of this study is to determine the best answers to the following questions:

- What are the daunting challenges facing Ghana's WASH sector?
- How can an ICT-based information system contribute to addressing these challenges?
- Are the ICT-based information systems implemented in Ghana's WASH sector working effectively? If not, what are the underlying obstacles?
- What should the Ghanaian government do to address these challenges?
- What are Korea's experiences in establishing ICT-based information systems in the WASH sector?
- Based on Korea's experiences, what policy recommendations or implications can be shared with Ghana?

The structure of this study is summarized as follows: In the introduction of Section 1, the main topics along with the background and purpose of this study are presented. Additionally, the concept of the data value chain is introduced, which is a fundamental process to understand this study. Section 2 identifies challenges and development needs in Ghana's WASH sector in terms of the country context, including policy and social aspects, while unlocking the potential of ICT to improve the WASH information management system in Ghana. Section 3 analyzes the ICT-based WASH information management system in Ghana, focusing on evaluating the existing WASH monitoring system and identifying its constraints in terms of system factors, social and institutional factors, financing factors, among others. Section 4 details how Korea successfully established an ICT-based WASH information system and provides a case study with implications for Ghana.

In this section, the key factors for success are analyzed, including policy and institutional factors, ICT development, economic and social considerations, infrastructure, financing, and technical considerations. Section 5 provides policy implications/recommendations for the ICT-based WASH information management system in Ghana, which are based on Korea's experience and Ghana's country context, including its absorption capacity, among others. These policy recommendations are developed with an emphasis on the pivotal roles of the MSWR of Ghana.

[Figure 1-2] Structure of the Paper



Source: Author.

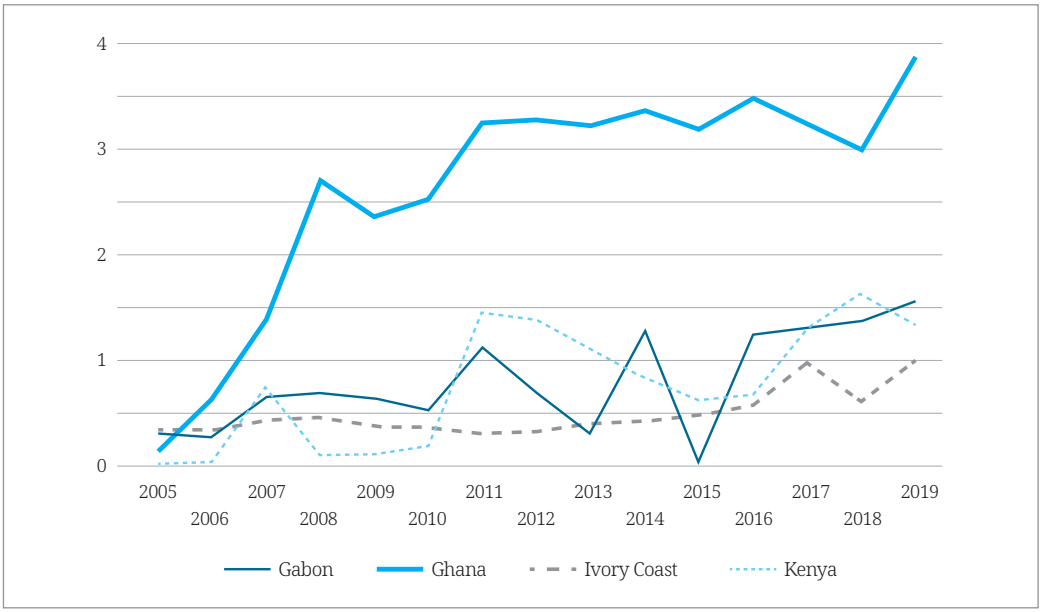
2. Landscape Analysis of the WASH Sector in Ghana

2.1. WASH Profile in Ghana

Ghana is showing rapid economic growth based on political stability, and in 2010, it was upgraded from a low-income country to a low-middle-income country. Ghana is classified as a group of high-growth countries in Africa, and as shown in [Figure 1-3] below, the inflow of foreign direct investment (FDI) is steadily expanding.

[Figure 1-3] Foreign Direct Investment in Ghana

(Unit: billion USD)



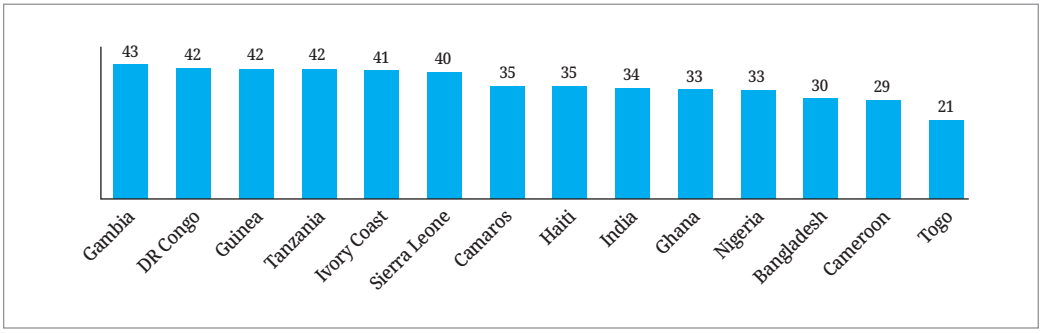
Source: The Statista Database (https://www.statista.com, accessed on July. 10, 2023).

However, as shown in the table below, improvements have not been made properly in the WASH sector. As of 2020, only 41% of the population was supplied with safe and clean drinking water in Ghana, and only 13% of the population is using sanitation. Only 42% of the population had a hand-washing facility equipped with water and soap at home, and only 12% of wastewater was safely treated.

Ghana's drinking water supply is poor among underdeveloped countries, including those in Africa. Ghana also ranks among the lowest in the world with 33 out of 100 points in the "clean water score" evaluated by the international community.

[Figure 1-4] Lowest Clean Waters Scores Worldwide as of 2021, by Country

(Unit: 100 p)

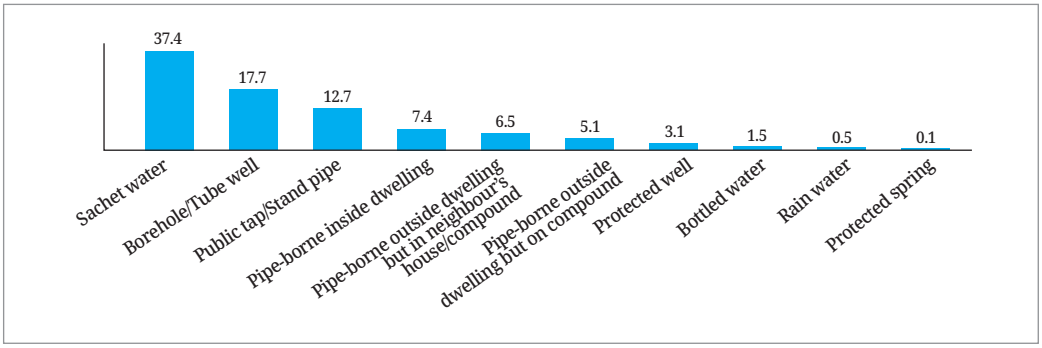


Source: The Statista Database (https://www.statista.com, accessed on July. 10, 2023).

As the supply of drinking water from water supply is not keeping up with demand, most Ghanaians purchase sachet water or use contaminated water as it is. Sachet water is sold in popularity because it is cheaper and easier to transport than plastic bottles, and nearly 40% of Ghanaians currently use sachet water as drinking water.

[Figure 1-5] Share of People Using Improved Drinking Water by Source as of 2021

(Unit: %)

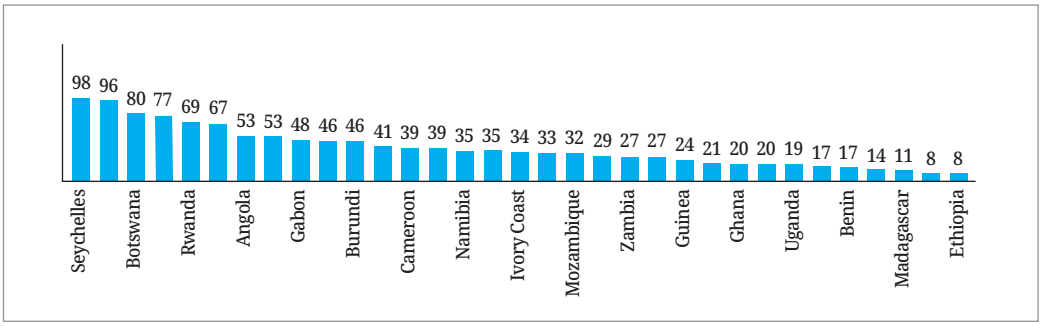


Source: The Statista Database (https://www.statista.com, accessed on July. 10, 2023).

In the sanitation sector, Ghana is also in a poor situation within Africa. As shown in [Figure 1-6], the proportion of the population using basic sanitation facilities in Ghana is 20%, showing a wide gap with Seychelles, Botswana, and Rwanda.

[Figure 1-6] Population Share Having Access to Basic Sanitation as of 2020

(Unit: penetration rate in %)



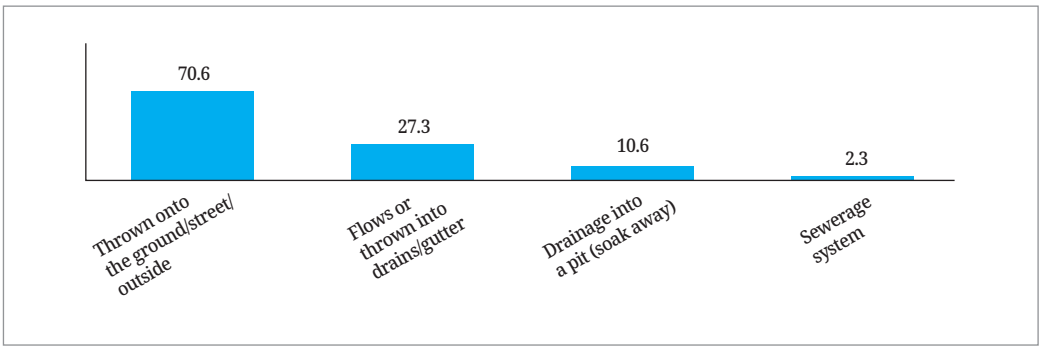
Source: The Statista Database (https://www.statista.com, accessed on July. 10, 2023).

Sewage treatment is also not carried out properly, with only 2% of the portion going through the sewage treatment process, with most of what remains being dumped on the streets and down drainage pipes.

In Ghana, the majority of households (over 70%) dispose of their wastewater by dumping it on the ground, street, or outside their homes. Additionally, approximately 27% of households dispose of wastewater by throwing it into drains and gutters, while around 10% drain wastewater into pits. Overall, only a small number of households in the country rely on the sewerage system to dispose of their wastewater.

[Figure 1-7] Most Used Methods of Household Wastewater Disposal in Ghana as of 2021

(Unit: share of households, %)



Source: The Statista Database (https://www.statista.com, accessed on July. 10, 2023).

<Table 1-1> illustrates the assessment of Ghana's WASH performance in SDGs, and it can be seen that they are lagging far behind in all areas. The SDGs are a set of 17 global goals established by the United Nations in 2015 to address global challenges such as good health and well-being, and clean water and sanitation. The WASH sector is a crucial sector that underpins the achievement of several SDGs, particularly Goals 3, 6, and 14.

<Table 1-1> Overview of the Performance of Ghana in SDG Targets

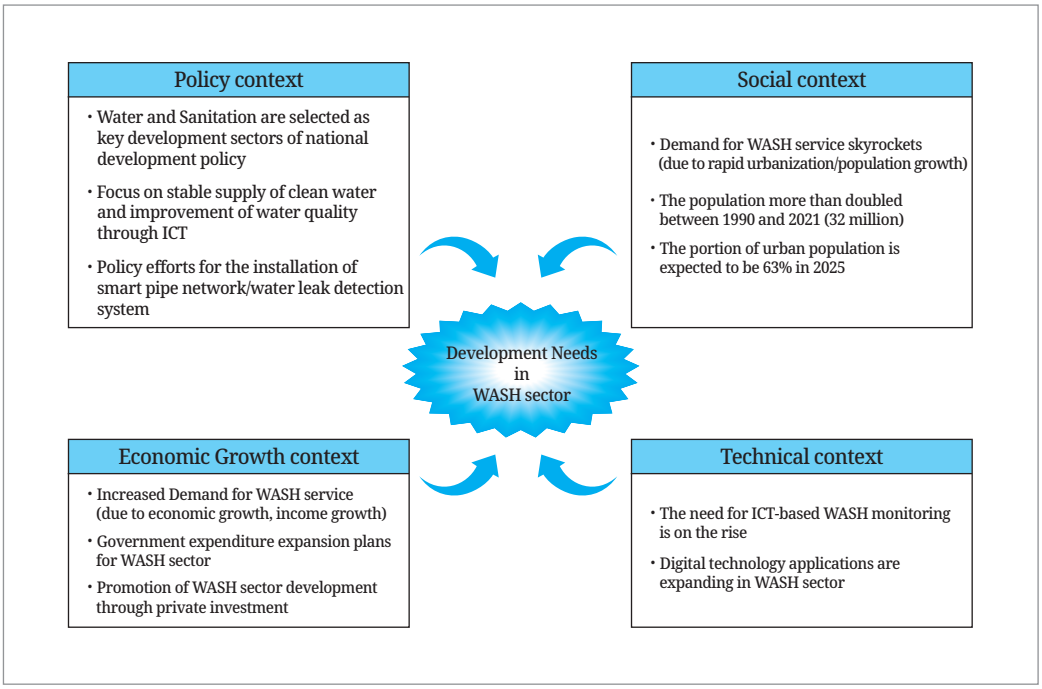
SDG	Detailed Indicators	Performance in Ghana's WASH Sector
SDG 3 (Healthy lives and well-being)	(Target 3.9) Reduce the number of deaths and illness from water pollution and contamination	- Significant challenges remain - Water pollution and inadequate waste management practices are major contributors to health risks in Ghana
SDG 6 (Management of water and sanitation)	(Target 6.1) Increase access to safe and affordable drinking water	- Water quality remains a significant challenge
	(Target 6.2) Achieve access to adequate sanitation and hygiene, and end open defecation	- Significant challenges remain - Open defecation, inadequate access to sanitation facilities, and poor hygiene practices remain major contributors to environmental and health risks in Ghana
	(Target 6.3) Improve water quality by reducing pollution and untreated wastewater	- Significant challenges remain - Inadequate wastewater management exacerbates water pollution
	(Target 6.4) Increase water-use efficiency and address water scarcity	- Significant challenges remain - Ghana's water resources are under significant stress
	(Target 6.6) Protect and restore water-related ecosystem including rivers and lakes	- Significant challenges remain - Many water-related ecosystems are under threat from human activities
	(Target 6b) Strengthen the participation of local communities in improving WASH management	- Significant challenges remain - Low participation of local residents in WASH programs
SDG 14 (Conserve oceans, seas, and marine resources)	(Target 14.1) Reduce marine pollution of all kinds	- Significant challenges remain - Ghana's marine environment is highly vulnerable to pollution from land-based activities, including urbanization

Source: Author.

2.2. Development Needs in Ghana's WASH Sector

A schematic diagram of the development needs in Ghana's WASH sector is shown in [Figure 1-8].

[Figure 1-8] Development Needs in Ghana's WASH Sector



Source: Author.

1) Policy context

Access to clean drinking water and sanitation is crucial for human well-being and is becoming an important focus area in Ghana's national development policies. The Ghanaian government has identified water and sanitation as a key development priority in its Medium-Term Development Policy Framework for 2018–2021 and 2022–2025.

Recently, the government has been leveraging digital technologies to ensure stable water supply and improve water quality. In November 2020, the government instructed the Ghana Water Company Limited (GWCL) to install a water leak detection system across the country to address chronic water leakage issues. Although the government had previously attempted to install smart pipelines with leak detection sensors, this effort did not yield significant results due to budget and capacity constraints. Currently, about half of the water produced by GWCL is lost due to leaks, which are attributable to aging pipelines and illegal connections (theft).

While Ghana has managed to reduce its non-revenue water (water loss) from 50% in 2013 to 47% as of 2023, this is still a high rate and remains a top priority in the government's water management policy. The high leakage rate is a major factor contributing to the lack of access to clean drinking water in Ghana, and the government is working on solving the leakage problem in addition to expanding the water pipeline network. Non-revenue water refers to the water that is introduced into the pipeline system but is lost before reaching the consumer.

Water and sanitation are also key development issues for international aid organizations. The United Nations SDGs include "clean water and sanitation" as Goal 6, which includes specific targets such as reducing water pollution, managing water quality, and ensuring access to safe drinking water and sanitation for all.

2) Social context

The demand for basic social services such as water and hygiene is rapidly increasing in Ghana due to the growing population and urbanization. However, the lack of infrastructure, such as water and sewage systems, sanitary facilities, and environmental management systems, is a major challenge to supporting this expansion. Although urbanization is increasing, Ghana's infrastructure has not kept up with the pace of growth.

Ghana's population has more than doubled from 15 million in 1990 to 32 million in 2021, and the proportion of the urban population is expected to rise from 58% to 63% by 2025. As urbanization continues to progress, the demand for water supply network expansion is increasing, and the capacity to provide clean water must be dramatically increased. Environmental pollution caused by wastewater, sewage, and solid waste dumping in rivers and on land is a major problem in Ghana, and public health services are extremely poor. This pollution leads to the deterioration of water quality and poses a threat to people's health and lives.

Access to clean water is the top social concern for Ghanaians, especially for urban residents. The majority of Ghanaians are highly concerned about drinking water problems caused by water shortages and pollution. Although Ghana has abundant water resources, it is classified as a "water-stressed" country due to the limited availability of water. Over 60% of the population is unable to access clean water, and many use contaminated water for drinking or must travel long distances to collect water. Although access to drinking water improved somewhat in the 2000s, the proportion of the population using piped water remains low. The sales of sachet water have increased as Ghanaians seek safe drinking water amid a lack of supply.

Water and sanitation are fundamental human rights and critical elements of human capital development. They are core agendas of the Sustainable Development Goals, Ghana's national development policy, and development projects of the international community. Insufficient access to clean drinking water can lead to disease outbreaks and a higher mortality rate. On the other hand, when clean and safe water is readily available, the incidence of disease decreases, leading to improved health and quality of life and decreased poverty. Human capital development, which includes education, knowledge, technology, and health, ultimately leads to increased economic and social competitiveness. SDG Goal 6 deals directly with water and sanitation and is one of the 17 SDGs. Access to clean drinking water is also linked with education, malnutrition, and economic development, making it a crucial cross-cutting issue with enormous socioeconomic value.

3) Economic Growth Context

Ghana's national income has been increasing at a rapid rate since the 2000s, which has been leading to increased demand for improved WASH services in several ways. This is summarized as follows:

First, economic development has increased awareness of the importance of safe and clean drinking water. As incomes rise, people become more aware of the health risks associated with unsafe water, such as waterborne diseases. This awareness has created demand for high-quality drinking water that is safe and clean. As a result, the private sector has invested in water treatment plants and distribution networks, leading to increased access to safe and clean drinking water for households and businesses. Additionally, government agencies have also invested in improving water infrastructure to ensure safe water supply.

Second, economic development has increased demand for improved sanitation facilities. As incomes rise, people become more aware of the health risks associated with poor sanitation and are more willing to invest in improved sanitation facilities. This has created opportunities for private sector investment in the sanitation sector, leading to the construction of more public and private toilets and the development of innovative sanitation solutions. The government of Ghana has also invested in improving sanitation infrastructure to provide access to basic sanitation facilities to the population.

Third, economic development has increased demand for hygiene services. As incomes rise, people become more aware of the importance of personal hygiene in preventing the spread of disease. This has created opportunities for private sector investment in hygiene products and services, such as soap and hand sanitizer. The government has also invested in hygiene promotion programs to increase awareness of the importance of hygiene practices.

Furthermore, economic development has also led to increased urbanization in Ghana. As more people move into urban areas, demand for WASH services has increased, particularly for improved water supply and sanitation services. To meet this demand, the government has invested in the expansion of water and sanitation infrastructure in urban areas, and the private sector has also invested in providing WASH services to urban populations.

In conclusion, economic development in Ghana has led to increased demand for improved WASH services due to increased awareness of the importance of safe and clean water, sanitation, and hygiene practices. This has created opportunities for private sector investment in the WASH sector and for government agencies to invest in improving WASH infrastructure. As economic development continues, demand for WASH services is likely to continue to increase, creating further opportunities for investment and innovation in the sector.

4) Technical Context: ICT Development

ICT development in Ghana has been leading to an increase in demand for improved WASH services in several ways. This is summarized as follows:

First, ICT development has increased access to information about WASH services and their importance. As more Ghanaians gain access to mobile phones and the internet, they are able to access information about WASH services, such as the benefits of clean drinking water, improved sanitation, and good hygiene practices. This has raised awareness of the importance of WASH services and increased demand for them, particularly among rural communities and low-income households who may have had limited access to information about these services in the past.

Second, ICT development has enabled the use of digital technologies in the provision of WASH services. For example, mobile-based payment systems can be used to make it easier and more affordable for households to access safe drinking water and sanitation services. Digital mapping tools can also be used to identify areas where WASH services are lacking and prioritize service delivery. This has led to increased demand for innovative WASH solutions that leverage ICT, which can improve service quality, increase efficiency, and reduce the cost-of-service delivery.

Third, ICT development has led to the emergence of new business models in the WASH sector. For example, mobile-based platforms can be used to connect households with WASH service providers, creating new opportunities for entrepreneurs to enter the WASH market.

This has led to increased demand for WASH services as more households gain access to affordable and convenient WASH services.

In addition, the use of ICT in the WASH sector can improve data collection and analysis, enabling better monitoring and evaluation of WASH programs and services. This can help to identify gaps in service provision and inform policy decisions to improve access to WASH services. For example, data on water quality can be collected and analyzed in real time, enabling rapid identification of water quality issues and timely response.

Overall, ICT development in Ghana has contributed to an increase in demand for improved WASH services by raising awareness, enabling the use of digital technologies, creating new business models, and improving data collection and analysis. As the use of ICT continues to grow in Ghana, it is likely that demand for innovative WASH solutions will continue to increase, leading to further improvements in service provision and delivery. This has the potential to improve health outcomes, increase productivity, and support economic development in the country.

3. Evaluation of the ICT-based Information System in Ghana's WASH Sector

3.1. Overview of the ICT-based WASH Information System in Ghana

As is well known, the use of ICT has the potential to improve the delivery of WASH services significantly and to increase access to safe water and sanitation. ICT has been increasingly used in Ghana's WASH sector in recent years to improve access to safe water and sanitation and to enhance the delivery of WASH services. <Table 1-2> gives some examples of the use of ICT in Ghana's WASH sector.

<Table 1-2> Examples of the Use of ICT in Ghana's WASH Sector

District Monitoring and Evaluation System (DiMES)	- DiMES is a web-based platform that enables district-level monitoring and evaluation of water and sanitation services in Ghana. - DiMES was developed by the Community Water and Sanitation Agency (CWSA) with support from the SMARTerWASH project, funded by the Dutch government
Basic Sanitation Information System (BaSIS)	- This system, launched in 2012, uses mobile phones and web-based tools to collect data on sanitation facilities, including toilets, septic tanks, and wastewater treatment plants. - The system is designed to be a participatory tool that involves multiple stakeholders, including community members, civil society organizations, and government agencies in the data collection and management process.
Sector Information System (SIS)	- SIS is an ICT-based platform developed by the Ministry of Sanitation and Water Resources to monitor and measure the progress of the 14 WASH key indicators. - Not fully operationalized. - Integrating different information systems into an SIS is a challenge.
SCADA	- SCADA is a system that monitors and controls the operation of water and sanitation infrastructure, such as pumps, valves, meters, sensors. - SCADA can help improve the efficiency, reliability, and quality of water and sanitation services by providing real-time data and remote control of the facilities. - Facing challenges such as the lack of budget and trained personnel to operate and maintain.

Source: Author.

These examples demonstrate the potential that an ICT-based information system has to improve WASH-related activities in Ghana. These systems enable real-time data collection, analysis, and dissemination, which can improve decision-making and resource allocation to ensure that WASH-related SDGs are achieved in a timely and sustainable manner.

3.2. Challenges of the ICT-based WASH Information Systems in Ghana

Contrary to initial expectations, these information systems based on ICT are not functioning properly. These systems do not even perform basic functions such as data collection, and there are various reasons why coordination and integration between these systems cannot be achieved.

ICT-based WASH systems require significant capital investment, as well as operational and maintenance costs, and skilled personnel to function properly. However, the WASH sector in Ghana is facing serious constraints, including a lack of financing, particularly from the government budget, which falls well below the required amount to support these ICT-based information systems. Additionally, the WASH sector heavily relies on donor funding, which poses a risk of unsustainability and uncertainty.

Another challenge in the ICT-based WASH information systems in Ghana is the lack of standardization, integration, and interoperability. These information systems were often implemented as pilot projects in an ad hoc manner to meet immediate needs, rather than using a comprehensive approach. As a result, these systems lack standardization, which makes system integration, interoperability, and sustainability difficult. The design, configuration, communication protocols, and data formats of these systems vary depending on the service provider or project. This variability can create integration challenges for different ICT systems or components within or across facilities or regions, affecting the quality and reliability of data collection and analysis.

ICT-based information systems require trained personnel to operate and maintain them, but there is often a shortage of trained personnel in rural areas where WASH services are most needed, resulting in a lack of technical support and inadequate maintenance of the systems, which can lead to their failure.

DiMES is an ICT-based information system installed in 2007 with the support of the Danish Aid Agency (DANIDA), which currently remains underused with its data collection not fully operationalized.

Although the Flow Monitoring System (mobile data collection) is a powerful tool for data collection and analysis in the WASH sector in Ghana, there are also several challenges that the system faces. Some of the key challenges include connectivity, technical capacity, restricted access to technology, data quality, sustainability, and limited stakeholder engagement. In addition, data collection using this app requires travel to all communities, which can be time consuming and costly.

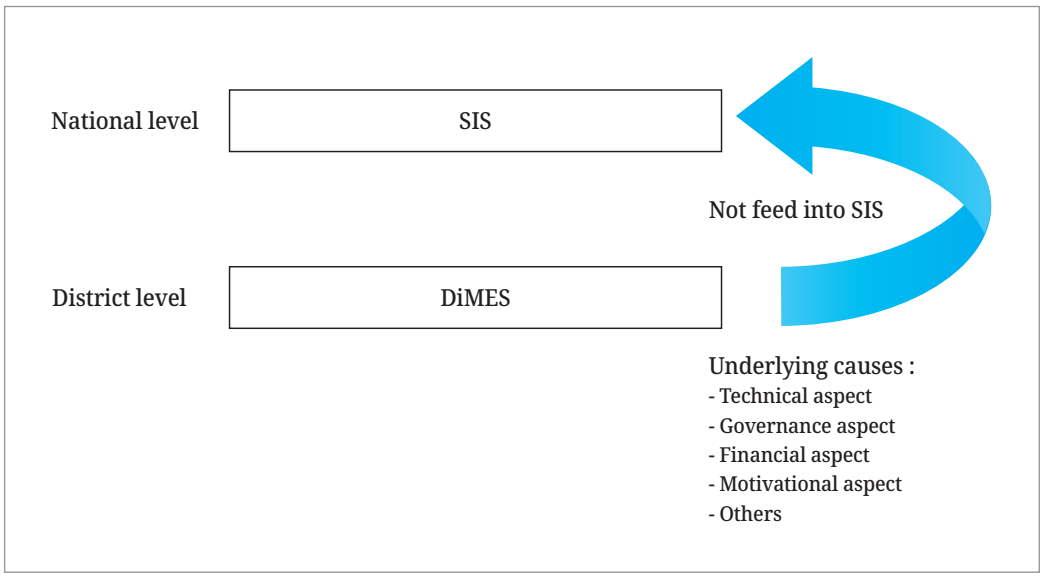
SCADA systems also face several challenges that impact their effectiveness. One major challenge is the high cost of implementing and maintaining a SCADA system. This can be a significant barrier for smaller communities or organizations with limited budgets. Another constraint facing SCADA systems is the lack of trained personnel to operate and maintain them. The maintenance and repair of SCADA systems is also challenging, especially in remote or hard-to-reach areas. Regular maintenance is essential to ensure the system's effectiveness and reliability. However, this can be difficult and expensive to carry out, particularly in areas with limited resources and infrastructure.

Finally, there is the challenge of infrastructure. Many of Ghana's SCADA systems rely on a robust and reliable telecommunications infrastructure to function effectively. However, Ghana's telecommunications infrastructure is often unreliable and inadequate, which can

cause problems with SCADA systems. As such, SCADA systems in Ghana's WASH sector face diverse challenges, including a lack of infrastructure, high costs, personnel training, and maintenance and repair challenges.

The MSWR in Ghana has developed 14 key indicators, which are commonly known as the "14 WASH Golden Indicators."[1] These indicators were developed as part of the country's efforts to improve access to safe water, improved sanitation, and hygiene services. These indicators serve as important benchmarks for measuring the progress of the WASH sector in Ghana, and they help to guide the development of policies and strategies to improve access to safe water, improved sanitation, and hygiene services. In order to monitor these indicators, an SIS, which is a national-level WASH monitoring system, was established, and guidelines for standardized data collection and reporting procedures were prepared. However, the SIS has been neglected for various reasons. While the SIS has the potential to provide valuable information for policy and decision-making, it faces several challenges, which include inadequate capacity, inadequate data quality, insufficient data collection, limited data sharing, and the like. Apparently, the SIS is described as aggregating data/information collected from regional monitoring systems (DiMES, BaSIS, etc.), but in reality, the integration between systems is poor and fragmented; thus it does not work properly.

[Figure 1-9] Fragmentation of Ghana's WASH Information Systems



Source: Author.

1 It includes the percentage of households using improved water sources, percentage of households with access to improved sanitation facilities, percentage of the population with access to basic handwashing facilities, and the like.

As such, ICT-based information systems in Ghana's WASH sector are not functioning properly for a variety of reasons. Moreover, the measuring instruments installed in the water supply pipe network, which are used to measure flow rate, water quality, and water pressure, are often old and may not function effectively.

Overall, these challenges highlight the importance of designing and implementing ICT-based information systems that are sustainable, context specific, and inclusive of stakeholders.

The successful integration of ICT into the WASH sector requires careful planning, stakeholder engagement, and continuous improvement, to ensure that the technology solutions are effective, sustainable, and aligned with the goals and priorities of the WASH sector.

3.3. Uncovering the Root Cause of the Inadequate WASH Information System in Ghana

In Ghana, the implementation and operation of ICT-based WASH information systems faces a variety of fundamental constraints, which can affect the overall performance, adoption, and sustainability of the system.

Addressing these constraints is essential for the successful implementation and operation of ICT-based WASH information systems in Ghana. This may involve improving infrastructure, securing funding, building technical capacity, enhancing data management, developing supportive policies, promoting interoperability, and fostering user acceptance and training. These are summarized in <Table 1-3>.

<Table 1-3> Key Constraints of Ghana's Inadequate WASH Information System

Financial Constraints	- Financing from the government budget falls well below the required amount to support an ICT-based system, including maintenance and repair of systems. - Relying on donor funding poses a risk of unsustainability and uncertainty.
Standardization, Integration, and Interoperability	- Many ICT-based information systems in Ghana's WASH sector are pilot projects based on an ad hoc approach to meet the immediate needs of the time, rather than a comprehensive approach. - As a result, these systems have not been standardized, which makes system integration, interoperability, and sustainability difficult. - In fact, these systems vary in design, configuration, communication protocols, data formats, and other factors, depending on the service provider or project.

<Table 1-3> Continued

Infrastructure Limitations	- Inadequate communication system, unreliable electricity supply, and limited access to ICT hardware/software hinder the performance and adoption of ICT-based WASH systems.
Policy and Regulatory Framework	- The research team examined the Ghanaian government's WASH-related policies, but it was difficult to find any content anywhere to improve water quality and solve the leak problem using ICT. - This may be due to a lack of awareness regarding the importance of ICT-based information systems. - The absence of clear policies, guidelines, and regulatory frameworks relating to the implementation of ICT in the WASH sector hinder the successful adoption and integration of ICT-based WASH systems in Ghana.
Technical Capacity	- ICT-based information systems require trained personnel to operate and maintain them, but there is often a shortage of trained personnel, especially in rural areas where WASH services are most needed.
Data Quality	- The efficiency of ICT-based WASH systems relies on accurate, up-to-date, and comprehensive data. - In Ghana, there are issues with data collection, validation, and management, which can negatively impact the effectiveness of the system.
Maintenance and Sustainability	- Maintaining and updating ICT-based WASH systems is challenging due to a lack of financial resources, and technical capacity. - Ensuring sustainability of these systems requires ongoing maintenance and repairs.

Source: Author.

3.3.1. Infrastructure Limitations

One of the most fundamental challenges in establishing an ICT-based information system in Ghana's WASH sector is the inadequate communication infrastructure. Since a robust communication network is crucial for an effective information system, the state of Ghana's communication network is deemed inadequate.

Ghana's communication networks, including internet and mobile networks, as well as national infrastructure networks, are inadequate, making it difficult to transmit data in a timely manner. To produce useful information, various data, such as facts or values collected through observation or measurement, need to be transmitted promptly, stored in a database, and processed to make them useful. However, due to the poor communication networks, the system is not functioning properly. Because of the significant investment required to expand the network, rapid improvement is unlikely to occur.

On the positive side, Ghana has made significant investments in its telecommunications infrastructure over the past decade. The country has a relatively high mobile penetration rate, with over 40 million mobile subscriptions as of 2021. Additionally, the country has made strides in expanding its broadband infrastructure, with over 40% of Ghanaians having

access to the internet as of 2021. As such, Ghana's telecommunications infrastructure has made significant progress in recent years; however, there are still several challenges that need to be addressed.

To elaborate further on the challenges facing Ghana's telecommunications infrastructure, it can be summarized as follows: One of the most significant challenges is the limited coverage of network infrastructure in rural areas. While Ghana's urban areas have relatively good telecommunications coverage, the same cannot be said for rural areas. The lack of network infrastructure in these areas makes it difficult for people in rural areas to access telecommunications services, including the internet. This digital divide creates significant disparities in access to information and opportunities between urban and rural communities.

The second challenge is the high cost of services. Despite the increase in the number of telecommunications providers in Ghana, competition has not led to lower prices for consumers, resulting in the cost of data and voice services remaining high. This high cost of services limits access to telecommunications services for many Ghanaians, particularly those living in rural areas. The high cost of telecommunication services can lead to stifling the expansion of ICT-based information system in Ghana's WASH sector by limiting access to digital services and hindering the ability of businesses and consumers to communicate and transact online.

The third challenge is poor network quality. Many Ghanaians have reported poor network quality, including frequent disruptions and slow internet speeds. Poor network quality can significantly impact the whole economic activity including ICT-based information system in the WASH sector.

Addressing these challenges requires significant investment in infrastructure and regulatory reform. The government of Ghana has taken steps to address some of these challenges, including the development of a national broadband plan and the establishment of a universal access fund to promote telecommunications infrastructure development in underserved areas. However, much more needs to be done to ensure that all Ghanaians have access to affordable, high-quality telecommunications services.

Overall, while Ghana's telecommunications infrastructure has made significant strides in recent years, there are still several challenges that need to be addressed to ensure universal access and high-quality services for all Ghanaians.

A weak power system is another obstacle. Ghana has been facing a poor power situation for many years, characterized by frequent power outages and unreliable electricity supply. Ghana's electricity generation capacity is not sufficient to meet the growing demand for power. The country relies heavily on hydroelectric power, which is subject to seasonal changes and droughts. The hydroelectric power stations are dependent on the water levels of the Volta River, and when the levels are low, the electricity output is reduced. Additionally, the thermal plants in the country are old and inefficient, leading to frequent breakdowns and maintenance issues. This results in a situation where the power supply is inadequate, and power outages are frequent.

Ghana's power infrastructure is old and inadequate. The transmission and distribution networks are insufficient, leading to losses and inefficiencies in the system. Additionally, the existing infrastructure is often poorly maintained, resulting in frequent breakdowns and power outages. Many of the power stations are located far away from the major population centers, which leads to transmission losses and increased costs.

As such, in many areas of Ghana, the lack of reliable electricity and connectivity hinders the effectiveness of ICT-based information systems. Without access to electricity or internet, it can be difficult to collect and transmit data, making it challenging to operate ICT-based information systems effectively.

The electricity sector in Ghana has been struggling with financial challenges for many years. The high cost of fuel, coupled with low tariffs, has resulted in a situation where the power companies cannot generate enough revenue to cover their costs. This has led to a situation where the power companies are unable to invest in new generation capacity or maintain existing infrastructure.

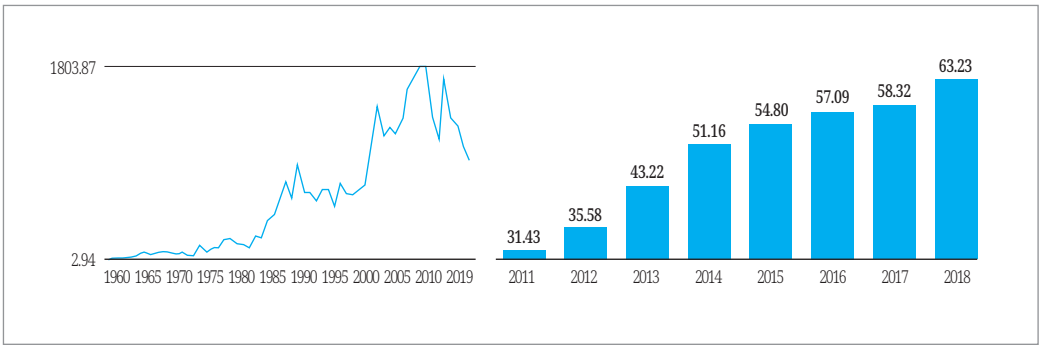
3.3.2. Financial Constraints

Establishing information systems requires a robust infrastructure. In the WASH sector, building infrastructure is a capital-intensive project, and funding is crucial. However, Ghana's government finances are weak, which limits its ability to provide financial support. To achieve the Ghanaian government's targets in the water and sanitation sector, significant investment funds are needed, but the funding gap is as high as 75% due to the limited fiscal spending capacity of only 25%. In contrast, Korea's local governments have funded and executed projects, with the central government offering budget support based on the financial conditions of local governments and project needs. However, in Ghana, the national financial situation is weak, and economic growth has recently slowed, leading to concerns about a decline in tax revenue.

FDI flowing into Ghana mostly focuses on resource development (oil), infrastructure, and agriculture. It is challenging to attract foreign investment in the WASH sector due to the difficulty in creating a profitable business model. Additionally, development assistance from the international community has been decreasing in recent years, as shown in [Figure 1-10], making it challenging to raise funds. The top five development aid donors to Ghana's WASH sector are the World Bank, the Netherlands, Canada, the European Union, and the United Kingdom. They mainly support water resource development and hygiene projects in rural areas, as well as COVID-19 response programs.

[Figure 1-10] Ghana's Fiscal Deficit and ODA Inflow Trend

(Unit: million of USD, % of GDP)



Source: The Statista Database (https://www.statista.com, accessed on July. 10, 2023).

Although financial resources could be raised by restructuring the water bill system, it may not be realistic due to the lack of basic infrastructure conditions, such as the absence of water meters and the political/social sensitivity to payments. As water meters are not installed in many parts of Ghana, water bills cannot be determined based on usage as in Korea.

<Table 1-4> shows the source of finance in Ghana's WASH sector. Water bills account for 76% of the WASH investment resources, which is the most stable long-term funding source. However, it is challenging to expand them in a short period. Although there are proposals to establish a digitalized water bill payment system to expand financial resources,[2] it is a long-term task and difficult to achieve quickly.

2 The absence of water meters is considered a contributing factor to excessive water consumption (waste), and some advocate for establishing an operational system that determines water bills based on usage through the installation of water meters.

<Table 1-4> Sources of Finance in Ghana's WASH Sector

(Unit: %)

Households (76%)	Tariffs, which are payments made by households to service providers for access to and use of their services, constitute 76% of the total WASH expenditures.
Government (4%)	The government contributes 4% of the total WASH expenditures through its WASH budget, which is generated by domestic taxes.
External Sources (6%)	External sources, such as international donors, foundations, NGOs, and remittances, contribute 6% of the total WASH expenditures through transfers.
Repayable Finance (14%)	14% of the total WASH expenditures are represented by repayable finance, which includes concessional loans classified as ODA and non-concessional loans from bilateral donors and multilateral development banks.

Source: USAID, Sanitation Profile: Ghana (2020).

3.3.3. Technical Constraints

Ghana has made significant progress in improving access to WASH services in recent years. However, challenges still remain, particularly in rural areas and among low-income populations. The adoption of ICT-based WASH information management systems can play a vital role in addressing these challenges, but Ghana faces several technical constraints that need to be overcome.

Addressing these technical constraints will involve concerted efforts from all stakeholders, including government agencies, NGOs, the private sector, and international partners. Collaborative approaches that promote local capacity building and improve access to technology will be critical to the successful implementation and impact of ICT-based WASH information management systems in Ghana.

Here is a detailed analysis of the current situation.

Limited access to technology: Although mobile phone usage has increased rapidly in Ghana, with penetration rates reaching over 140% in 2021, not everyone has access to smartphones or computers, especially in rural areas. The high cost of devices, coupled with limited access to electricity, can hinder the effective implementation of ICT-based WASH systems.

Unreliable internet connectivity: While internet penetration has improved, reaching around 67% of the population in 2021, it remains uneven across the country, with rural areas having significantly less access than urban centers. The national broadband policy aims to address this gap, but achieving universal access remains a challenge. The lack of reliable connectivity can hamper the effectiveness of ICT-based WASH systems, particularly when it comes to real-time data collection and sharing.

Insufficient software solutions: Existing WASH software solutions might not be tailored to the local context, considering factors such as language, culture, and varying levels of technical literacy among the population. Developing customized, user-friendly solutions that cater to the specific needs of Ghana's WASH sector is essential for the successful implementation of ICT-based systems.

Limited technical capacity: Ghana may face a shortage of skilled professionals capable of designing, developing, and maintaining ICT-based WASH systems, particularly in rural areas. Building local capacity through targeted training programs, partnerships with educational institutions, and collaborations with international organizations can help address this constraint.

Lack of integration and interoperability: Fragmented data collection and management systems can hinder the effective use of WASH data in Ghana. Standardizing data formats and developing integration protocols can facilitate data sharing and analysis across various initiatives, promoting evidence-based decision-making in the WASH sector.

Scalability and sustainability: The long-term success of ICT-based WASH systems in Ghana depends on their ability to scale up and sustain operations. This requires ongoing investment in infrastructure, technical capacity, and support from government agencies, and development partners.

4. Korea's Experience in Establishing an ICT-based WASH Information Management System

This section details how Korea successfully established an ICT-based WASH information system and provides a case study with implications for Ghana. The success factors are identified across various areas including policy, institution, ICT development, economy, social factors, infrastructure, financing, and technical factors.

The success of Korea's data-based WASH information system was not solely due to technical factors, but also due to a range of environmental factors. This underscores the need for a comprehensive approach, which can offer valuable lessons for Ghana. The current malfunctioning of the ICT-based information system in Ghana's WASH sector is largely due to a lack of political will, weak governance, poor financing, social capacity, and technical factors.

The Ghanaian government has been exerting great effort to enhance water quality, reduce water loss, and properly manage sewage through the establishment of an ICT-based information management system. However, progress has been sluggish.

4.1. Overview of the ICT-based WASH Information System in Korea

4.1.1. History of Adoption of the ICT-based Information System in Korea's WASH Sector

The adoption of an ICT-based information system in Korea's WASH sector has a long history, dating back to the 1990s when a computerized billing system for water customers was introduced. Since then, Korea has developed various ICT applications for the WASH sector, including smart meters, leak detection sensors, water quality monitoring devices, mobile payment platforms, graphic information system (GIS)-based mapping systems, customer feedback mechanisms, and online education programs.

The Korean government recognized the importance of ICT in improving the efficiency and effectiveness of the WASH sector, and it has since invested heavily in the development of various ICT-based information systems.

The adoption of ICT-based information system in Korea's WASH sector has been driven by several factors, including government leadership and policy support, public-private partnerships, R&D investment, standardization efforts, human resources development and educational information services.

The history of ICT-based information systems in Korea's WASH sector can be traced back to the early 1990s. In 1992, the Korea Ministry of Environment (MOE) launched the National Water Quality Information System (NWQIS) to provide real-time water quality data to the public. The NWQIS was one of the first ICT-based information systems in the WASH sector in Korea.

In the following years, the MOE and other government agencies implemented several other ICT-based information systems in the WASH sector. These systems included the Water Resources Information System (WRIS) launched in 1996, the Water Supply Information System (WSIS) launched in 2000, the Sewage Treatment Information System (STIS) launched in 2004, the Water Supply and Sanitation Information System (WASIS) launched in 2010, and the Water and Sanitation Management Information System (WAMIS) launched in 2015.

The Korean government has continued to invest in the development of innovative ICT-based information systems for the WASH sector. For instance, the SWM system was launched to improve water management from water supply to wastewater treatment. The SWM system employs digital sensors and real-time data to monitor water flow and pressure in the distribution network, enabling prompt repairs and maintenance.

Another recent advancement is the development of the internet of things (IoT) for the WASH sector, which allows for real-time monitoring and management of water and sanitation infrastructure.

Overall, the history of adopting ICT-based information systems in Korea's WASH sector has been characterized by strong government commitment to developing and implementing innovative technologies to improve the efficiency and effectiveness of water and sanitation services. The continuous investment in these systems has positioned Korea as a leader in the use of ICT in the WASH sector.

4.1.2. Profile of ICT-based Information Systems in Korea's WASH Sector

Korea has achieved success in enhancing water quality, preventing water leakage, and ensuring safe sewage treatment by implementing an ICT-based information system in the WASH sector. By smartly managing the entire WASH sector, including water supply and sewage systems, with ICT technology, Korea has fostered innovation. Utilizing ICT technology, Korea remotely monitors leakage point detection and water pressure changes in real time, enabling prompt responses to leakage and water pollution. This ICT-based WASH management not only increases confidence in tap water but also facilitates systematic leak management, leading to a reduction in production costs and budget. Korea also operates an integrated water information system that combines ICT technology with advanced digital devices, providing advanced solutions such as monitoring and scientific predictive management. Many developing countries, including Ghana, are looking to Korea's innovative approach in the WASH sector as a benchmark.

As such, the ICT-based information system in the WASH sector in Korea plays a crucial role in supporting data-driven decision-making and planning. The system includes a range of processes and tools for data collection, transfer, analysis, and information production, and is supported by advanced data analysis techniques and visualization tools. Through these systems, the WASH sector in Korea is able to manage and use data effectively to promote water, sanitation, and hygiene for the benefit of all.

The WASH sector in Korea has implemented several ICT-based data management systems to improve the monitoring, evaluation, and management of water and sanitation services. These systems have helped to streamline data collection, analysis, and reporting, leading to more efficient and effective service delivery.

Overall, these ICT-based data management systems have helped to transform the WASH sector in Korea by improving data collection, analysis, and management. The systems have enabled water and sanitation managers to make informed decisions about resource allocation, management, and service delivery, leading to more efficient and effective service delivery.

1) Water Resources Information System

The WRIS is a web-based platform that provides access to water resources data and information. It was developed by the MOE and the Korea Water Resources Corporation (K-water) to improve water resource management.

The WRIS includes a wide range of data, including

- Surface water data: This includes data on river flows, lake levels, and reservoir storage.
- Groundwater data: This includes data on groundwater levels, aquifer properties, and well yields.
- Meteorological data: This includes data on rainfall, temperature, and evaporation.
- Water quality data: This includes data on water quality parameters such as *p*H, conductivity, and turbidity.

The WRIS also provides a variety of tools and services for water resource management, including

- Data visualization tools: These tools allow users to visualize water resources data in a variety of ways, such as maps, charts, and tables.
- Water modeling tools: These tools allow users to simulate the behavior of water resources systems.
- Decision support tools: These tools help users make decisions about water resource management.

2) Water Supply Information System

The WSIS is a web-based platform that provides access to water supply data and information. It was developed by K-water to improve water supply management.

The WSIS includes a wide range of data, including

- Water supply data: This includes data on water sources, water treatment plants, and water distribution networks.
- Water quality data: This includes data on water quality parameters such as *p*H, conductivity, and turbidity.
- Customer data: This includes data on water customers, water consumption, and water bills.

The WSIS also provides a variety of tools and services for water supply management, including

- Data visualization tools: These tools allow users to visualize water supply data in a variety of ways, such as maps, charts, and tables.
- Water modeling tools: These tools allow users to simulate the behavior of water supply systems.
- Decision support tools: These tools help users make decisions about water supply management.

3) Sewage Treatment Information System

The STIS is a web-based platform that provides access to sewage treatment data and information. It was developed by the Korea Environment Corporation (KECO) to improve sewage treatment management in the country.

The STIS includes a wide range of data, including

- Sewage treatment data: This includes data on sewage treatment plants, sewage collection systems, and sewage treatment efficiency.
- Water quality data: This includes data on water quality parameters in rivers and streams affected by sewage treatment plants.

- Environmental impact data: This includes data on the environmental impact of sewage treatment plants.

The STIS also provides a variety of tools and services for sewage treatment management, including

- Data visualization tools: These tools allow users to visualize sewage treatment data in a variety of ways, such as maps, charts, and tables.
- Sewage modeling tools: These tools allow users to simulate the behavior of sewage treatment systems.
- Decision support tools: These tools help users make decisions about sewage treatment management.

4) Water Supply and Sanitation Information System

The WASIS is a web-based platform that provides access to water supply and sanitation data and information. It was developed by the MOE to improve water supply and sanitation management.

The WASIS includes a wide range of data, including

- Water supply data: This includes data on water sources, water treatment plants, and water distribution networks.
- Sewage treatment data: This includes data on sewage treatment plants, sewage collection systems, and sewage treatment efficiency.
- Water quality data: This includes data on water quality parameters in rivers and streams, as well as in drinking water.
- Sanitation data: This includes data on sanitation facilities, sanitation practices, and sanitation-related diseases.

The WASIS also provides a variety of tools and services for water supply and sanitation management, including

- Data visualization tools: These tools allow users to visualize water supply and sanitation data in a variety of ways, such as maps, charts, and tables.

- Modeling tools: These tools allow users to simulate the behavior of water supply and sanitation systems.
- Decision support tools: These tools help users make decisions about water supply and sanitation management.

5) Water Resource Management Information System

The WAMIS is a web-based platform that provides access to water resources data and information. It was developed by K-water to improve water resource management in the country.

The WAMIS includes a wide range of data, including

- Surface water data: This includes data on river flows, lake levels, and reservoir storage.
- Groundwater data: This includes data on groundwater levels, aquifer properties, and well yields.
- Meteorological data: This includes data on rainfall, temperature, and evaporation.
- Water quality data: This includes data on water quality parameters such as pH, conductivity, and turbidity.
- Water management data: This includes data on water allocation, water use, and water conservation.

The WAMIS also provides a variety of tools and services for water resource management, including

- Data visualization tools: These tools allow users to visualize water resources data in a variety of ways, such as maps, charts, and tables.
- Water modeling tools: These tools allow users to simulate the behavior of water resources systems.
- Decision support tools: These tools help users make decisions about water resource management.

6) Smart Water Management System

SWM is a system that uses ICT to improve the efficiency, effectiveness, and sustainability of water management. SWM can be applied to all aspects of water management, from water

supply to wastewater treatment.

Here are some of the technologies that are used in SWM systems:

- Sensors: Sensors are used to collect data on water usage, water quality, and other water-related parameters.
- Communication networks: Communication networks are used to transmit data from sensors to a central data repository.
- Data analytics: Data analytics is used to analyze data from sensors and communication networks to identify patterns and trends.
- Decision support tools: Decision support tools are used to help water managers make informed decisions about water management.

SWM systems can be used to improve water management in a variety of ways, including

- Reducing water loss: SWM systems can help identify and repair leaks in water distribution networks, which can reduce water loss.
- Improving water quality: SWM systems can help monitor water quality and identify problems early on, which can help improve water quality.
- Promoting water conservation: SWM systems can help track water usage and provide feedback to water consumers, which can help promote water conservation.
- Managing demand: SWM systems can help manage water demand by providing information to water consumers about their water usage and by offering incentives to reduce water usage.
- Disaster management: SWM systems can help manage water resources during disasters by providing information about water availability and by coordinating water distribution.

<Table 1-5> Summarized Characteristics of Korea's ICT-based WASH Information Management System

Digital Devices	Establishment of real-time automatic monitoring and control system through various digital measuring devices	- Real-time monitoring of the flow of water supply through various digital measuring devices (water pressure/ flow/water quality/leakage detection sensors) and communication devices - Construction of a control system through the automatic drainage system
Digital Solutions	Providing state-of-the-art solutions for efficient water management systems	- Processes and analyzes data collected by digital devices, thereby providing state-of-the-art solutions for scientific and efficient water management systems
Digital Services	Consumer-centered services	- Provide customized water information in real time to meet consumer demand - Water quality information provision system, digital metering system

Source: Author.

SWM systems are a promising technology that has the potential to improve water management in a variety of ways. However, there are still some challenges that need to be addressed, such as the cost of SWM systems.

7) Arisu Combined Info System in Seoul City

The Seoul Metropolitan Government is known for its strict management of water quality, and they use the Arisu Combined Info System (CIS) to achieve this. The Arisu Combined Info System is an advanced water supply management system that was developed by the Seoul Metropolitan Government to ensure safe and reliable water supply to its citizens. The system combines various technologies and techniques to monitor water quality, detect leaks, and control the water supply network in real time.

One of the key features of the system is its water quality monitoring network. The network consists of over 200 monitoring stations located throughout the city. These stations collect data on various water quality parameters, such as *p*H, turbidity, and chlorine levels. The data are transmitted in real time to a central control center where they are analyzed by water quality experts. If any issues are detected, the system can automatically adjust the water treatment process to ensure that the water is safe for consumption.

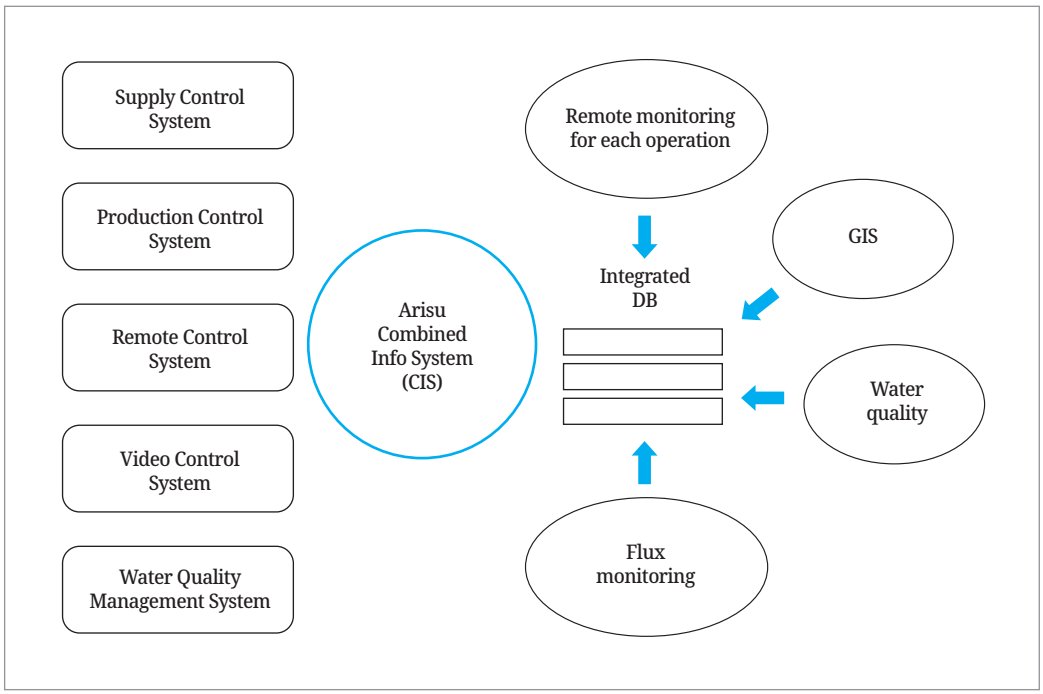
Another important aspect of the Arisu Combined Info System is its leak detection system. The system uses various technologies, such as acoustic sensors, to detect leaks in the water supply network. The sensors can detect even the smallest leaks and alert operators in real time. This allows for quick response times and helps reduce water loss, which is a major problem in many cities around the world.

The system also includes a centralized control center that allows operators to monitor and control the water supply network in real time. The control center is equipped with advanced technologies, such as GIS mapping and hydraulic modeling, that provide operators with detailed information about the water supply network. Operators can adjust the water supply pressure, control water flow, and detect any abnormal conditions in the network.

In addition to its technical features, the Arisu Combined Info System also includes a customer management system. The system allows customers to access their water usage data, pay their bills online, and report any issues they encounter with their water supply. This improves customer service and makes it easier for customers to access information about their water supply.

This system incorporates various technologies such as GIS, remote monitoring, weather information, leakage information, real-time operation, and CCTV monitoring. Arisu is the name given to tap water in Seoul, which is considered Korea's representative drinking water. Currently, the Seoul Metropolitan Government conducts water quality tests on 163 parameters, which include residual chlorine, turbidity, hydrogen ion concentration, iron, and copper. To cater to the water needs of 10 million citizens in Seoul, they operate a total of six water purification plants and five water intake plants.

[Figure 1-11] Operating System of the Arisu Combined Info System



Source: Seoul Metropolitan Government (https://english.seoul.go.kr, accessed on July. 20, 2023).

Here are some of the key features of the Arisu Combined Info System.

Water quality monitoring: The system has an extensive water quality monitoring network that collects data from over 200 monitoring stations across the city. The data are collected in real time and analyzed to detect any changes in water quality. If any issues are detected, the system can automatically adjust the water treatment process to ensure the safety of the water supply.

Leak detection: The Arisu Combined Info System also includes a leak detection system that monitors the water supply network for leaks. The system uses various technologies, such as acoustic sensors, to detect leaks and alert operators in real time. This allows for quick response times and helps reduce water loss.

Water supply control: The system has a centralized control center that allows operators to monitor and control the water supply network in real time. The operators can adjust the water supply pressure, control water flow, and detect any abnormal conditions in the network.

Customer management: The Arisu Combined Info System also includes a customer management system that allows customers to access their water usage data, pay their bills online, and report any issues they encounter with their water supply. This improves customer service and makes it easier for customers to access information about their water supply.

Overall, the Arisu Combined Info System is an advanced water supply management system that combines various technologies and techniques to ensure safe and reliable water supply to the citizens of Seoul. The system has helped reduce water loss, improve water quality, and enhance customer service, making it a model for other cities around the world.

4.2. Case Study of Smart Water Management in Seosan City

SWM refers to the use of integrated, real-time ICT solutions, such as sensors, monitors, GIS, and satellite mapping, as well as other data sharing tools in water management.

In recent years, there has been a trend toward real-time data collection and use to optimize operations and knowledge, and SWM offers integrated water management solutions for all scales and contexts to address water challenges in both developed and developing countries.

The integration of devices, solutions, and services is essential in realizing SWM. The technical application of SWM can be broken down into three main steps. First, integrated real-time data acquisition is achieved through the use of sensing devices such as smart sensors or smart meters. Second, a network is constructed to facilitate the transmission, storage, and integration of the collected data. Lastly, data analysis is conducted through modeling and visualization of the aggregated data.

SWM technologies can be used to enhance the efficiency of water management operations in areas such as water resources, water supply, and sewerage. These technologies can be integrated with existing water management facilities and systems to achieve greater operational efficiency. As SWM is not a single, fixed technology but rather a platform system that can combine a variety of technologies, it has broad applications across the water management sector. The potential benefits of SWM in water management are vast, including solutions for water quality and quantity, sewage management, flood and drought management, and much more. Moreover, SWM can address water infrastructure by integrating it into broader networks, reducing water and energy consumption, and improving the efficiency of wastewater treatment.

With its advanced information technology infrastructure and innovative technologies, Korea is well equipped for implementing an SWM system. Korea has implemented an SWM system known as the “smart water grid,” which utilizes sensors and real-time data to monitor water quality, consumption patterns, and pipeline conditions. The system uses advanced analytics to predict water demand, optimize distribution, and identify leaks or other anomalies in the water supply system. The smart water grid also enables consumers to track their water usage in real time through a mobile app and receive alerts for abnormal usage patterns, which helps promote conservation and reduce waste. Additionally, the system incorporates renewable energy sources such as solar power and wind turbines to power water treatment and distribution facilities, reducing the carbon footprint of water management operations. Overall, Korea’s smart water management system has been successful in improving the efficiency and sustainability of water management, reducing costs, and improving water quality.

This research conducts a case study of Korea’s smart water management system, demonstrating the potential benefits of SWM implementation. This paper emphasizes that, unlike the case of Korea, establishing an ICT-based information system in Ghana’s WASH sector does not necessitate the use of all smart tools.

Korea has developed a smart water management system that utilizes advanced

technologies to manage its water resources effectively. The country has successfully implemented this system in several cities and provinces, resulting in significant improvements in water quality, efficiency, and conservation. This study conducts a case study of the SWM system in Seosan City among others in Korea.

Overall, the smart water management system in Seosan City is a great example of how technology can be used to improve the efficiency and sustainability of water management. By leveraging sensors, data analytics, and smart meters, the city has been able to reduce water waste, conserve resources, and provide a more reliable water supply to its residents.

4.2.1. Background of SWM System Adoption

Seosan is a city located in the western part of Korea, with a population of approximately 170,000 people. The city is situated near the coast and experiences a subtropical climate with hot summers and cool winters. The area has a limited water supply due to its geographic location, and water scarcity has been a persistent issue for the city. The city faced several challenges in managing its water supply, including high water loss due to leaks and bursts in the aging infrastructure, inefficient use of water resources, and an increase in water demand due to population growth and economic development.

The challenges before the installation of the SWM system in the city are summarized as follows:

High water loss: Seosan City was experiencing high water loss due to leaks in the aging water supply network. The leaks were difficult to detect because they occurred underground, and the city was losing a significant amount of water due to the inefficient infrastructure. The high water loss was not only leading to water scarcity but also causing financial loss to the city. The city needed to find ways to detect and repair leaks efficiently in the water supply network. Furthermore, the Boryeong Dam, which provides water to Seosan city, had reached a minimum water storage level of 21% since 2015 due to drought, necessitating immediate action.

Inefficient use of water resources: Seosan City was facing challenges in efficiently using its water resources. The city had an increasing demand for water due to population growth and economic development, which was putting pressure on the existing water supply network. The city needed to find ways to use its water resources efficiently to meet the growing demand. The city also faced challenges in managing water demand during peak hours, which put further stress on the water supply network.

Limited data: Seosan City faced challenges in accessing and using data to manage its water supply network. The city did not have a comprehensive system to monitor and manage the water supply network, which made it difficult to detect leaks, monitor water usage, and make data-driven decisions. The lack of data made it challenging for the city to optimize its water supply network, resulting in inefficient use of water resources and high water loss.

Aging infrastructure: Seosan City's water supply network was aging, with many pipelines and other infrastructure components reaching the end of their useful life. The aging infrastructure posed a risk of failure, which could have led to water scarcity and damage to the environment and the city's infrastructure. The city needed to find ways to extend the lifespan of its aging infrastructure while ensuring a reliable and sustainable water supply.

To address these challenges, Seosan City decided to implement SWM systems. The smart water management systems installed in Seosan City helped the city detect leaks in real time, monitor water usage, and efficiently manage its water resources, while also helping the city extend the lifespan of its aging infrastructure and reduce water loss due to leaks. By implementing smart water management systems, Seosan City was able to ensure a sustainable and reliable water supply for its citizens. The city also improved its ability to manage water demand during peak hours, resulting in better water usage optimization.

4.2.2. SWM Solution

To address the aforementioned challenges, Seosan City introduced smart water management solutions in 2016 through a consignment contract with K-water, Korea's governmental agency for comprehensive water resource development.

The SWM system in Seosan City involved the installation of smart water meters such as digital devices and sensors, the implementation of a robust network system, the use of SDMAs, and the installation of data analytics and decision support tools. The system is designed to improve the efficiency of the water distribution network, reduce water loss, and support sustainable water management practices.

Among them, the most important goal of this project in particular was to build a SWM system that would enhance the revenue water ratio by minimizing water leakage, thus increasing the water supply available to the city. Water leakage is also a significant problem faced by Ghana today. As mentioned previously, Ghana's non-revenue water (NRW) is currently almost 50%.

1) Installing Smart Water Meters

The core part of the SWM solution was the implementation of a smart water meter system that is designed to monitor water consumption and provide real-time data to the user or utility company. A smart water meter system uses a network of sensors and communication devices to collect and transmit data about water usage to a central database, which can be accessed by the user or the utility company. Smart water meters are different from traditional water meters in that they are equipped with advanced sensors that can monitor water consumption in real time. These sensors can track the flow of water in and out of a property, as well as monitor the pressure of the water. The data collected by these sensors are transmitted wirelessly to a central database, where they can be analyzed and used to improve water conservation efforts and detect leaks.

The installation of smart water meters in Seosan City involved replacing traditional water meters with advanced meters that use smart technology to measure water consumption accurately. Smart meters are equipped with advanced sensors that can transmit real-time data on water usage to the network system. Digital sensors are installed throughout the water distribution network to measure various parameters such as pressure, flow rate, and water quality, as well as detect water leakage.

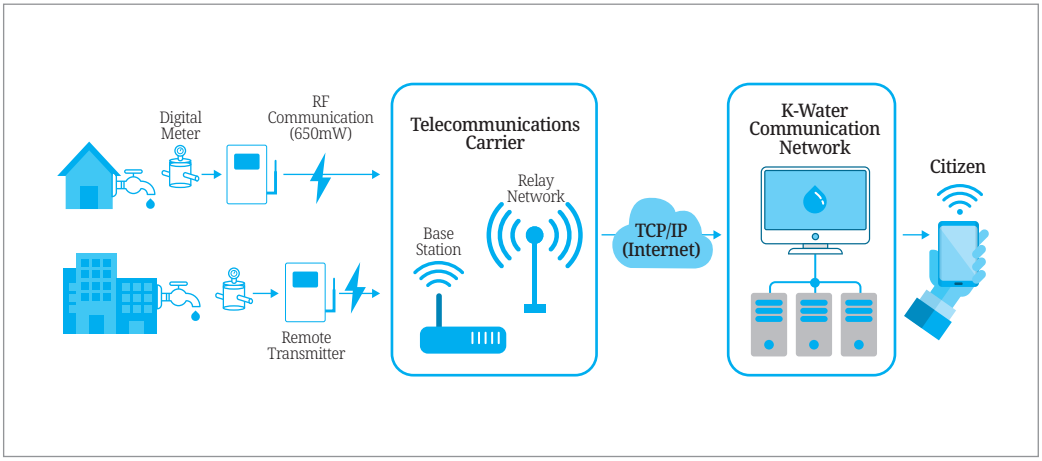
The sensors are connected to the network system and transmit data in real time. These sensors are typically pressure sensors and flow meters that are placed at key points in the network, such as at the intake points, pump stations, and at critical points along the distribution network. The sensors are capable of detecting changes in pressure and flow rates, which can indicate a leak in the system. Some sensors can also detect changes in temperature, which can indicate that a leak is occurring in a specific area of the network. The installation of sensors allows operators to monitor the health of the water distribution network and identify potential issues quickly.

The base station in the smart water management system is a centralized device that collects and manages data transmitted by digital meters and remote transmitters installed throughout the water network. It serves as a hub for data processing, analysis, and storage, enabling real-time monitoring and control of the water system.

The network system is also the backbone of the SWM system, transmitting data from smart water meters and sensors, and providing operators with real-time insights into the water distribution network. The network system consists of a combination of wired and wireless communication technologies, including fiber-optic cables and wireless networks. The network system is designed to be robust and reliable, ensuring that data can be transmitted quickly and accurately.

The sensors in Seosan City are monitored in real time, providing a continuous stream of data that can be used to detect leaks as soon as they occur. The monitoring system is automated, and alerts are sent to the relevant authorities when a leak is detected. By monitoring water usage, the city can identify abnormal usage patterns that may indicate a leak. For example, if a household's water usage suddenly increases without explanation, it may indicate that a leak has occurred on the property. This allows officials to investigate and repair the leak quickly, reducing the amount of water lost and minimizing the potential for damage to the infrastructure or the environment.

[Figure 1-12] Outline of the Smart Metering System



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

<Table 1-6> Smart Devices of Seosan City's SWM

Digital Meter	- The water flow data that are measured are converted into electrical signals by the digital meter, and these signals are transmitted periodically. - The digital meter measures both the accumulated flow rate and the current flow rate. - The detection function of the digital meter includes identifying overload, backflow, leakage, and any unused flow. - The digital meter is equipped with data communication capabilities to transmit and receive information.	
Remote Transmitter	- The remote transmitter retrieves data from the meter every hour and transmits the accumulated data every four hours. - The remote transmitter utilizes a direct radio path to communicate with the base station, using a high-power transmission of 1 watt. - The remote transmitter's 19Ah capacity battery allows it to operate for eight years, given its power consumption of 2Ah per year. - The digital meter features an LCD display that shows the current reading.	

<Table 1-6> Continued

Base Station	- The wireless transmission capability of the remote transmitter allows for wide coverage over a large area, with a transmission distance of approximately 1.5 kilometers. - The base station is designed to have a low operational cost, requiring minimal maintenance and upkeep expenses. - The base station has low power consumption, and its ultracompact design makes it easy to apply in IoT/M2M applications.	
Monitoring System	- The monitoring system provides real-time updates on the connection status and meter readings of end users. - The system can collect and analyze gauge reading data on an hourly, daily, and monthly basis. - Additionally, the monitoring system calculates the volume of supplied water and detects any leakage within the water supply network.	

Source: K-water and IWRA, Smart Water Management: Case Study Report, 2018.

2) Subdistrict Metering Area System

The SWM system in Seosan City utilizes subdistrict metering areas (SDMAs). SDMAs are geographic regions within the water distribution network that are isolated by valves and equipped with smart water meters. SDMAs allow operators to identify and address water loss issues quickly by isolating the affected area and minimizing the impact on the entire network. The installation of SDMAs allows for more effective water management practices, reducing water loss and improving the efficiency of the water distribution network.

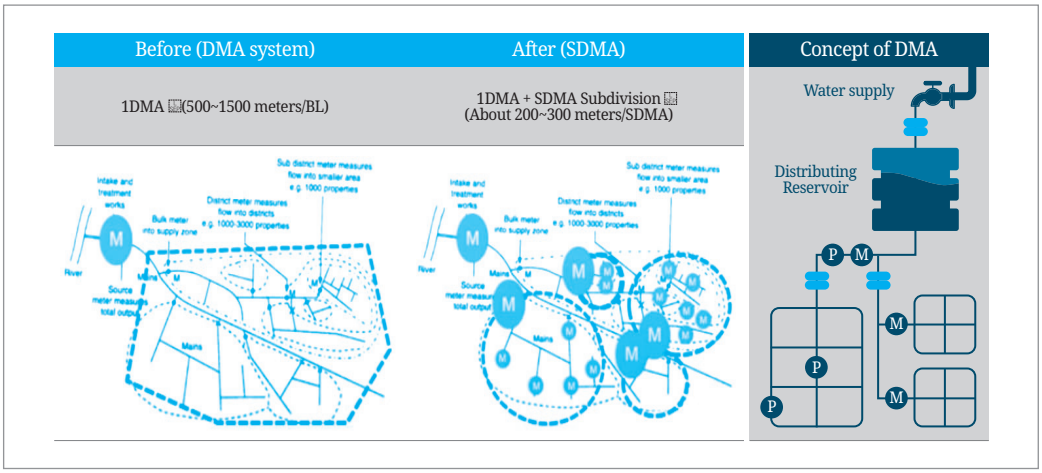
A DMA, or district metering area, is a water management concept that divides larger water service areas into smaller units for more efficient management of flow rate, water pressure, and water quality. The primary purpose of a DMA system is twofold: first, to respond to changes in water demand and minimize the risks and damages to customers in case of facility accidents or disasters by isolating the district unit in a water supply network, and second, to improve the management of water flow and quality within smaller areas where a water supplier can continue to monitor and analyze leakages, water pressure, and water quality.

The construction of a DMA system involves isolating the inlet and outlet pipelines for each district unit and organizing the intricately interconnected pipes by separating them into zones and dividing the DMAs so that they do not interfere with other district areas. This allows for accurate data analysis of the cause of any problems that occur within the DMA and reduces risks by eliminating external influence. However, physically separating pipes to build a DMA system can be time consuming and costly due to the underground structure of most pipelines. A cost-effective alternative is to install smart meters in the major pipelines to analyze flow rates in real time and eliminate interference between the DMAs. In a Seosan

City project, two DMA systems were installed, and nine SDMA systems were built using smart flow meters installed in major pipelines.

Leakage management is crucial in DMA systems, and it starts with recognizing the existence of a leak, which can be achieved through minimum night flow (MNF) analysis. A high MNF suggests water leakage, and the analysis is typically performed for each DMA. The smaller the area of the DMA, the smaller the suspicious leakage area becomes, making it easier to detect and narrow down the leakage point from the unit of space to line. Therefore, the smaller the DMA, the more effective the leakage detection, and the quicker the repair can be made to reduce the loss caused by the leakage duration time.

[Figure 1-13] Comparison of Quantity Management in DMA and SDMA



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

3) Data Analytics and Decision Support

The data collected by smart water meters, sensors, and the network system are analyzed to generate insights and support decision-making on water management. The installation of data analytics capabilities allows operators to predict future water demand, optimize water distribution, and identify areas where water conservation measures are needed. The use of data analytics and decision support tools allows for more effective and sustainable water management practices.

The data collected in the city are analyzed using advanced analytics software: The software can detect patterns and trends in the data that may indicate the presence of a leak. For example, the software can detect sudden drops in pressure or flow rates, which may indicate that water is leaking from the system. The software can also detect changes in temperature that may indicate the presence of a leak.

Seosan City uses predictive maintenance techniques to prevent leaks from occurring in the first place. The city uses data from the sensors to predict when maintenance is required, such as when a pipe is likely to fail due to corrosion or other issues. By conducting preventative maintenance, the city can reduce the likelihood of leaks occurring. This can also help extend the lifespan of the infrastructure, reducing the need for costly repairs and replacements.

In addition, Seosan City uses pressure management techniques to reduce the likelihood of leaks occurring. The city uses pressure sensors to monitor water pressure in the system and adjusts the pressure as required to reduce the likelihood of leaks occurring due to excessive pressure. This can also help reduce the amount of water lost due to leaks, as excessive pressure can cause pipes to rupture or joints to fail.

Overall, smart water management in Seosan is focused on detecting and preventing water leaks through the use of advanced sensors, real-time monitoring, data analytics, predictive maintenance, smart metering, and pressure management techniques. By implementing these strategies, the city can reduce the amount of water lost to leaks, conserve water resources, and ensure that the water supply is sustainable and reliable.

4.2.3. The Outcomes of the SWM Project

The SWM system in Seosan City has had a significant impact on reducing water leakage and improving water quality through a range of technologies. <Table 1-7> shows some of the key benefits derived from the implementation of an SWM system in Seosan City.

One of the most significant contributors to water loss in Seosan City was water leakage. Since the SWM system was implemented, the city has reported a 20% reduction in water leakage, contributing to reducing costs for the city. By implementing the SDMA system through smart metering, conducting thorough detection in areas with suspicious leaks, and managing water pressure, the revenue water ratio was boosted to 90%, resulting in a 15%–40% improvement in each SDMA, indicating a substantial reduction in pipe leakage. The establishment and operation of the SWM system led to an annual reduction of 19,000 m^3 of water leakage, which translates to approximately USD 0.1 million in savings.

The installation of smart water meters in households and businesses has been instrumental in reducing water leakage in the city. Smart water meters are equipped with sensors that detect water flow rates and can detect leaks or abnormal usage patterns. In addition, the smart water meters provide real-time data on water consumption, which can

help users identify leaks and take corrective measures. This has resulted in a reduction in water loss due to leaks and an increase in the efficiency of water use.

The SWM system in Seosan City also focused on improving water quality. The water quality monitoring system in the city is a comprehensive system that uses sensors to collect real-time data on the water distribution network's quality. The sensors measure factors such as chlorine levels, temperature, and *p*H levels. The data are then analyzed using advanced algorithms to identify any abnormalities or contaminants that could affect the water quality. The system allows for early detection of any water quality issues, which can help prevent health hazards and ensure safe drinking water. The water quality monitoring system in the city is also connected to an automatic control system that can respond immediately to any abnormalities detected in the water quality. For example, if the system detects a drop in chlorine levels or an increase in turbidity, the system will automatically adjust the treatment process to ensure the water quality remains within the acceptable range.

Overall, the results from the SWM system in Seosan City have been positive, with significant improvements in water leakage reduction and water quality.

<Table 1-7> Key Benefits of SWM in Seosan City

Leak Detection	Smart systems can quickly identify leaks in the water infrastructure, allowing for faster repairs and minimizing water loss. This leads to significant cost savings for the city and reduces the risk of property damage due to leaks.
Enhanced Water Efficiency	Smart water management systems help optimize water usage by monitoring and controlling water distribution, reducing leaks, and improving overall system efficiency. This leads to decreased water wastage and ensures a more sustainable use of water resources.
Improved Water Quality	Advanced sensors and monitoring technologies in the smart water management system enable real-time assessment of water quality. This allows for rapid response to any water contamination events, ensuring that water supplied to the residents remains safe and clean.
Data-Driven Decision-Making	The collection and analysis of data from various sensors provide valuable insights into water usage patterns, infrastructure issues, and other critical factors. This information enables city authorities to make more informed decisions about water management and prioritize resources effectively.
Better Customer Service	With the help of smart water management systems, consumers can monitor their water consumption in real time and receive notifications about potential leaks or abnormal usage patterns. This empowers users to take control of their water usage and conserve resources.
Energy Savings	By optimizing water distribution and reducing water loss, smart water management systems can also reduce the energy needed to pump and treat water, leading to significant energy savings and lower greenhouse gas emissions.
Cost Savings	The overall improvements in efficiency, leak detection, and reduced water loss translate into significant cost savings for the city. These savings can be reinvested into other critical infrastructure projects, benefiting the community as a whole.

Source: Author.

In addition to Seosan City, Korea has established SWM systems in several other cities, yielding several positive results.

Reduced water loss: The SWM system's leak detection system has been highly effective in reducing water loss. According to reports, the SWM system can detect leaks as small as 0.5 liters per minute, allowing for quick repairs before significant water loss occurs. As a result, the SWM system has reduced the amount of water wasted due to leaks, resulting in more sustainable use of water resources.

Improved water quality: The SWM's real-time monitoring system has significantly improved water quality by providing early detection of contaminants, leaks, and other issues in the water supply system. By detecting and responding to issues quickly, the SWM system has reduced the risk of waterborne illnesses and other health hazards associated with contaminated water.

Increased efficiency: The SWM system's real-time data analytics has optimized water distribution, leading to increased efficiency in the water supply system. The system can predict water demand, optimize water distribution, and identify leaks or other anomalies in the system, reducing downtime for repairs and improving overall system efficiency. This has resulted in significant cost savings for water management operations.

Cost savings: The SWM system has significantly reduced operational costs for water management operations. For example, the system uses renewable energy sources such as solar power and wind turbines to power water treatment and distribution facilities, reducing the carbon footprint of water management operations and cutting energy costs. Additionally, the system's predictive analytics and real-time monitoring capabilities have reduced the need for manual inspections, saving time and resources.

Enhanced consumer engagement: The SWM system's mobile app enables consumers track their water usage in real time and receive alerts for abnormal usage patterns, promoting conservation and reducing waste. This has enhanced consumer engagement with water management and encouraged more sustainable water use practices.

In summary, the smart water management system in Korea has yielded several positive results, including improved water quality, reduced water loss, increased efficiency, cost savings, and enhanced consumer engagement. These results demonstrate the potential benefits of smart water management and highlight the importance of utilizing technology and data analytics to promote sustainable water management practices.

4.2.4. Sharing Korea's SWM Experience through International Cooperation

Korea, a technologically advanced nation, has made significant strides in leveraging ICT to improve its WASH sector. By incorporating ICT-based information systems, Korea has ensured efficient management, monitoring, and distribution of resources in the WASH sector.

Entering the 21st century, Korea has developed and implemented various smart water management solutions to improve the efficiency and sustainability of water supply and sanitation services, such as the following.

Smart metering: A system that measures and transmits water consumption data in real time, enabling accurate billing, leakage detection, and demand management.

Smart leakage detection: A system that monitors the pressure and flow of water pipes and detects leaks using sensors, acoustic devices, or drones.

Smart water quality management: A system that monitors and analyzes water quality parameters using sensors, online analyzers, or artificial intelligence.

Smart flood control: A system that predicts and prevents urban flooding using rainfall data, hydrological models, and flood warning systems.

Korea has shared its experience and expertise in smart water management with other countries through international cooperation programs, demonstrating how it leverages ICT-based WASH information systems or smart water management to achieve mutual benefits and common goals.

Korea has developed and implemented various digital solutions to improve the efficiency, reliability, and sustainability of water supply and sanitation services, such as smart meters, leak detection sensors, water quality monitoring devices, and mobile applications.

Korea also supports other countries to adopt and adapt these technologies through international cooperation programs, such as the Korea International Cooperation Agency (KOICA) and K-water.

Some examples of these programs include

The Smart Water Management Project in Cambodia: This project aims to improve water

supply and sanitation services in rural areas by installing smart meters, solar pumps, and water quality sensors.

The Smart Water Grid Project in Uzbekistan: This project aims to reduce water loss and improve water quality by installing smart meters, leak detection sensors, and water quality monitoring devices.

The Smart Water Management Project in Peru: This project aims to enhance water resource management and disaster prevention by installing hydrological stations, flood warning systems, and drought monitoring systems.

These projects exemplify Korea's commitment to sharing its knowledge and experience in smart water management with other nations.

Korea's SWM policy includes a goal to lead the way in smart technologies for water management and share its expertise with developing countries through international cooperation. Having experienced rapid urbanization and economic growth, Korea understands the challenges faced by developing countries and the potential benefits of smart technologies. Introducing technological advancements is crucial to address the complex water challenges faced by Ghana.

Korea's smart water management system is widely recognized as a successful model for sustainable water management and has been shared with developing countries through various projects and initiatives. Sharing Korea's smart water management system experience is one of the ways that Korea contributes to the global efforts to achieve the SDGs, especially Goal 6, on clean water and sanitation.

4.3. Key Success Factors of Korea's ICT-based WASH Information Management System

The success of Korea's ICT-based WASH information system can be attributed to a combination of advancement in ICT, strong ICT infrastructure, increased social demand for access to improved water and sanitation, political commitments, supportive policy and regulatory framework, public participation, and collaboration. These factors have enabled Korea to manage its water resources efficiently and ensure sustainable development.

<Table 1-8> shows the major success factors in building information systems in Korea's WASH sector.

<Table 1-8> Key Success Factors of Korea's ICT-based WASH Information System

Advancement in Information Technology	Technological advancement in the field of mobile communication networks, internet services, computation, digital devices including sensors, and data analysis software Application of cloud computing technologies
Use of Advanced Technology	Korea has adopted and implemented advanced technology, such as GIS, remote sensing, and IoT, to collect, store, and analyze data on water and sanitation services.
Decrease in H/W Prices Used for Data Management	Decrease in H/W prices used for managing data value chains especially including data measurement, monitoring, and data analysis
Increased Social Demand for Access to Improved Water and Sanitation	Rapid economic development and urbanization increased social demand for WASH accessibility
Political Commitments	Strong government support: The Korean government has provided strong support for the development of ICT-based information systems in the water and sanitation sector, including investment in technology and infrastructure.
Government's Open Data Policy	The Korean government has been actively promoting its open data policy since 2013, with the perception that the increased data availability using open data can improve the transparency and quality of public services, which obviously include water and sanitation.
Focus on Data Quality	Korea places strong emphasis on the quality of data collected and processed in its ICT-based information systems, which helps ensure that the information is reliable and accurate.
User-Friendly Interfaces	The systems have user-friendly interfaces, which makes it easy for stakeholders, including government agencies, service providers, and the public, to access and use the information.
Partnership and Collaboration	Korea has established partnerships and collaborations with international organizations, other countries, and the private sector, to share knowledge and best practices, and to support the development and implementation of ICT-based information systems.
Continuous Improvement	Korea continuously assesses and improves its ICT-based information systems to ensure that they remain relevant and effective in meeting the changing needs of the water and sanitation sector.

Source: Author.

1) Advanced ICT Infrastructure

Korea has one of the most advanced ICT infrastructures in the world, which has provided a strong foundation for its economic/social development as well as the adoption of ICT in the WASH sector. Korea has consistently ranked high in various global indices for its cutting-edge ICT environment. For example, as of 2022, Korea's internet penetration rate was approximately 98% and the smartphone penetration rate as share of the population in Korea was around 97%. Korea has one of the highest rates of broadband penetration in the world, with almost 99% of households having access to high-speed internet. The government's efforts to promote the widespread adoption of broadband internet have been critical to the development of the country's ICT infrastructure.

Korea has consistently ranked high in the United Nations E-Government Survey, which evaluates countries' efforts to provide public services online and foster digital governance. In the 2020 survey, Korea ranked second out of 193 countries, showcasing its commitment to leveraging ICT for efficient and transparent governance.

Korea's strong ICT infrastructure and successful ICT-based information system can be attributed to a combination of government and private sector investment, a highly skilled workforce, and a culture of innovation.

Government investment: The Korean government has been actively investing in the development of its ICT infrastructure for several decades. The government has implemented various policies and initiatives to encourage innovation, research, and development in the ICT sector. For example, the government's Digital Korea 2010 initiative aimed to establish a comprehensive digital network infrastructure throughout the country, which included the construction of high-speed internet networks and the development of digital content and services. The Korean government has provided strong support for the development of ICT-based information systems in the water and sanitation sector, including investment in technology and infrastructure.

Private sector investment: Korea's private sector has also played a significant role in the development of its ICT infrastructure. The country's large technology companies, such as Samsung and LG, have invested heavily in research and development and have contributed to the growth of the country's ICT industry. These companies have been successful in developing and commercializing new technologies, such as semiconductors, smartphones, and displays. The private sector has also played a significant role in the growth of Korea's startup ecosystem, which has produced many successful technology startups.

Skilled workforce: Korea has a highly educated and skilled workforce in the ICT sector. The country has a strong emphasis on education and has a high proportion of graduates in science, technology, engineering, and mathematics (STEM) fields. Korea's universities are renowned for their excellence in science and technology education, and the country has produced many highly skilled ICT professionals.

Innovation culture: Korea is known for its innovative culture and has a vibrant startup ecosystem. The country has produced many successful technology startups, which have contributed to the growth of its ICT industry. The government's efforts to promote innovation, such as through funding programs and tax incentives, have been critical to the growth of the country's ICT industry.

These factors have enabled Korea to develop a thriving ICT industry, which has been a significant contributor to the country's successful ICT-based WASH information system.

2) Increased Social Demand for Access to Improved Water and Sanitation

Korea is a developed country with a high standard of living, and its social demands for improved access to WASH sector have continued to grow. Increased social demand for access to improved water and sanitation in Korea can be attributed to several factors, including

Urbanization: Korea has experienced rapid urbanization over the past few decades, with the majority of the population now living in urban areas. As urban areas continue to grow, the demand for water and sanitation services has also increased, leading to a greater social demand for improved services.

Public health concerns: Access to safe and clean water and sanitation is essential for maintaining public health. Inadequate access to water and sanitation can lead to the spread of waterborne diseases, such as cholera and typhoid fever. As people become more aware of the importance of clean water and sanitation for public health, there has been a greater social demand for improved services.

Environmental concerns: The pollution of water sources and the degradation of natural ecosystems have become increasingly important issues in Korea. The public has become more aware of the negative impact that pollution and environmental degradation can have on water quality and availability, leading to a greater social demand for improved water and sanitation services.

In response to these social demands, the Korean government has implemented policies and initiatives to improve access to water and sanitation. The government has invested in the construction of water treatment facilities, sewer systems, and sanitation infrastructure, and has implemented regulations to protect water sources and improve water quality. These efforts have led to significant improvements in access to improved water and sanitation services in Korea, although there are still some areas that require further improvement.

3) Use of Advanced Technology

The use of advanced technology has been a critical factor in Korea's successful ICT-based information system in the WASH sector. Korea has adopted and implemented advanced technology, such as GIS, remote sensing, and Io), to collect, store, and analyze data on water and sanitation services. GIS is one of the advanced technologies that has played a critical role

in Korea's successful ICT-based information system. GIS technology enables the collection, storage, analysis, and visualization of geospatial data, such as maps, aerial images, and satellite imagery.

In the WASH sector, advanced technologies used in ICT-based information systems in Korea including

Smart water management systems: These systems use sensors and data analytics to monitor water usage, detect leaks, and optimize water distribution networks. For example, the Seoul Metropolitan Government's smart water management system uses IoT sensors and data analytics to monitor and control the water supply network in real time.

Water quality monitoring systems: These systems use sensors and remote sensing technologies to monitor water quality parameters such as *p*H, turbidity, and dissolved oxygen. K-water has developed a water quality monitoring system that integrates data from remote sensing, water quality sensors, and weather stations to provide real-time information on water quality.

Mobile applications: Several mobile applications have been developed in Korea to improve WASH service delivery. For example, the "Clean Water" app developed by K-water provides information on water quality, water usage, and water conservation tips to consumers.

Overall, these advanced technologies used in ICT-based information systems in Korea's WASH sector aim to improve service delivery, enhance efficiency, and ensure sustainable management of water resources.

4) Supportive Policy and Regulatory Framework

Korea's supportive policy and regulatory framework has been critical to the development and implementation of an ICT-based WASH information system. The government has implemented a national ICT strategy, established a legal and regulatory framework, invested in research and development, established public-private partnerships, and implemented e-government services. These efforts have enabled South Korea to develop innovative solutions to address the challenges in the WASH sector and provide improved water and sanitation services to its citizens.

Here are some examples of how policy and regulatory framework have contributed to Korea's successful ICT-based WASH information system.

National ICT strategy: The Korean government has implemented a national ICT strategy that aims to promote the development of ICT-based solutions for various sectors, including the WASH sector. The strategy provides a framework for the development and implementation of ICT-based WASH solutions, including the use of digital technologies such as GIS and remote sensing.

Legal and regulatory framework: The Korean government has implemented a legal and regulatory framework that supports the development and implementation of ICT-based WASH solutions. For example, the government has implemented regulations to protect water sources and improve water quality, and it has established standards for the construction and operation of water treatment facilities and sewer systems.

Investment in research and development: The Korean government has invested in research and development in the WASH sector, including the development of ICT-based solutions. The government has established research institutes and provided funding for research projects to support the development of innovative solutions, such as the use of IoT and AI technologies to improve water management and sanitation.

Public-private partnerships: Korea has established public-private partnerships to promote the development and implementation of ICT-based WASH solutions. For example, the government has collaborated with private companies to develop mobile applications for water quality monitoring and to implement smart water management systems.

E-government services: Korea has implemented e-government services for the WASH sector, which use ICT technology to provide public services online. The government has implemented various e-government services, such as online registration for water and sanitation services and online payment of water bills.

5) Government's Open Data Policy

Next is the government's open data policy. The Korean government has been actively promoting its open data policy since 2013, with the perception that the increased data availability using open data can improve the transparency and quality of public services, which obviously includes water and sanitation. The Korean government deployed proactive approaches regarding the open data policy. Among others, the government has strengthened the Public Information Disclosure Act, by making government agencies open public information preemptively, while simplifying administrative procedures for citizen's public information claims.

Real-time WASH information is vividly disclosed to the public through the government's water portal service network, which allows citizens to check water quality and hygiene information every day. Information on water and sanitation is captured in real time through digital devices including sensors installed in the source points and water facilities, which eventually contribute to improving an access to clean water and sanitation. The open data contain multiple items such as water quality, water quantity, water flow and pressure, and the like, which leads to enhancing citizens' trust in tap water, and even the government.

In Ghana, the government is not willing to open its agencies' data to the public, because it has a low understanding of the open data policy. Ghana's government needs to recognize that establishing a public information system and opening it is essential, as public goods, for improving public service and the standard of living, as well as increasing citizens' trust in the government.

6) Other Success Factors

In addition, the key success factors of Korea's ICT-based WASH information management system are summarized as follows:

First, continuous improvement should be mentioned. Korea continuously assesses and improves its ICT-based information systems to ensure they remain relevant and effective in meeting the changing needs of the water and sanitation sector.

The second is the focus on data quality. Korea places strong emphasis on the quality of data collected and processed in its ICT-based information systems, which helps ensure that the information is reliable and accurate.

The third is user-friendly interfaces. Korea's ICT-based information systems in the WASH sector have user-friendly interfaces, which makes it easy for stakeholders, including government agencies, service providers, and the public, to access and use the information.

The fifth is the integration into other systems. Korea's ICT-based information systems for water and sanitation have been integrated into other systems, such as water resource management systems and waste management systems, to provide a comprehensive and integrated approach.

Lastly, public participation can be pinpointed. The Korean government has actively engaged the public in water management through education and awareness campaigns. This has helped create a culture of water conservation and efficient water use among

residents, which has contributed to attracting residents' interest in building an ICT-based WASH information system.

These factors have played a crucial role in the successful implementation of ICT-based water and sanitation information systems in Korea, and have helped improve the efficiency and effectiveness of water and sanitation services, as well as increase public access to information.

4.4. Implications for Ghana

The ICT-based WASH information system is a crucial tool for effectively managing the growing demand for water in the face of rapid urbanization and climate change. However, before implementing the information system, there are several implications that must be considered.

First, an ICT-based information system is a long-term project that requires significant initial investment. Therefore, it is crucial to conduct a thorough financial analysis to ensure that the project is financially sustainable over time. Additionally, it is essential to have a written procedure for compromise in case of any significant changes in circumstances that involve cost issues. Regular evaluations and feedback should also be conducted to revise the plan as necessary. Policy support is also necessary for the successful implementation of an ICT-based information system. Subsidies from the central government can be granted to local governments with poor finances to implement the information system. However, policymakers, stakeholders, and citizens must reach consensus before implementing an ICT-based information system.

Second, an ICT-based WASH information system is a customized system, and the cost of local water work projects must be charged to users in the region. Therefore, it is essential to recognize the project objectives and review the applicable technology accurately to ensure that the project is customized to meet the specific needs of the region. Professional competency, continuous training, and consultation with experts are necessary to ensure the successful implementation of the information system.

Third, it is crucial to remain open to the development and introduction of new technology to enhance the efficiency of information system. Pilot cases should be implemented, verified, and studied to introduce an approach suitable for the target area.

Finally, an ICT-based WASH information system should be pursued within the scope of

integrated water resources management and sustainable development. This means that information system should not only focus on providing a sufficient amount of water but also take into account the environmental, social, and economic impacts of the project.

This research team reached the conclusion that Ghana can apply an ICT-based information system by learning from Korea's experience and adapting it to its own context and needs. Some of the possible ways that Ghana can apply an ICT-based WASH information system are as follows:

Smart metering: Ghana can install smart meters to measure and transmit water consumption data in real time, enabling accurate billing, leakage detection, and demand management. This can help reduce non-revenue water, improve customer satisfaction, and increase revenue collection.

Smart leakage detection: Ghana can monitor the pressure and flow of water pipes and detect leaks using sensors, acoustic devices, or drones. This can help reduce water loss, save energy costs, and prevent pipe bursts or collapses.

Smart water quality management: Ghana can monitor and analyze water quality parameters using sensors, online analyzers, or artificial intelligence. This can help ensure the safety and quality of drinking water, identify sources of pollution, and enforce regulations.

Of course, applying these smart water management solutions requires adequate investment, capacity building, institutional coordination, stakeholder participation, and policy support. Ghana can seek technical assistance and financial support from Korea or other international partners to implement these solutions effectively and sustainably.

5. Policy Recommendations for Establishing an ICT-based WASH Information Management System in Ghana

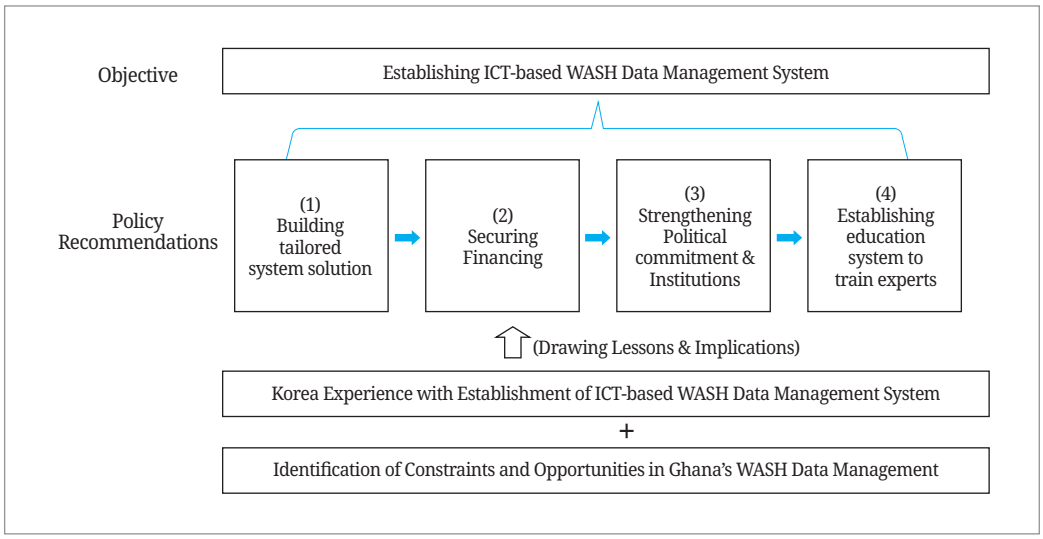
In this section, policy implications or recommendations for Ghana were developed based on the experience and know-how of Korea, as mentioned earlier. [Figure 1-14] below provides an overview of the process of generating policy proposals for Ghana. While the analysis of Ghana's WASH information management system was largely based on literature reviews, statistics, visits to relevant agencies, and in-depth interviews with local consultants, Korea's

analysis of the ICT-based WASH information system involved domestic expert meetings, literature reviews, and field visits.

The policy proposal was derived through a policy seminar that was attended by Ghanaian officials and experts, as well as in-depth interviews with experts. The resulting recommendations included a comprehensive approach that involved designing a system tailored to Ghana (including social, technical, and program design), securing investment resources, strengthening policy and institutional foundations to enhance social benefits, enhancing human capacity, and fostering trained personnel through education and training.

Although Ghana faces challenges such as a lack of basic infrastructure, human capabilities, business promotion capabilities, and investment resources, which make it challenging to implement a Korean-level ICT-based information system, it will still be possible to establish an information system that is suitable for Ghana's specific circumstances. In fact, when examining the case of establishing ICT-based WASH systems in developing countries, it is evident that technology, tools, and solutions are not always required to the same extent as they are in Korea.

[Figure 1-14] Process of Deriving Policy Recommendation for Ghana



Source: Author.

5.1. Comprehensive Approach

Section 4 detailed Korea's experience and expertise in building ICT-based WASH information systems, with a specific focus on a case study that can provide insights for Ghana's efforts in establishing such a system.

The success of Korea's WASH information system was not solely due to technical factors, but it was also due to the various environmental factors that surrounded it. This suggests that a comprehensive approach is necessary and has important implications for Ghana. Currently, the ICT-based information system in Ghana's WASH sector is not functioning properly due to a lack of political will, weak governance, poor financing, limited social capacity, and technical issues. The Ghanaian government has been working diligently to enhance water quality, minimize water leaks, and safely dispose of sewage via the creation of an ICT-based information management system. However, progress has been slow.

One should bear mind that, while technology is crucial in building successful ICT-based information systems in the WASH sector, other factors such as education, training, community engagement, and good governance hold equal importance. Technology should not be considered the end in itself, but rather a means to an end.

Establishing an ICT-based WASH information system in Ghana requires a comprehensive approach that involves strong political support, institutional capacity, secured financing, ICT technology, and relevant infrastructure such as water and sewage networks, telecommunications, education, and training. This is illustrated in [Figure 1-15].

Most importantly, the government must prioritize creating awareness of the benefits of the ICT-based WASH information system. This study shows that while the Ghanaian government recognizes the need for an information system in the WASH sector, it is difficult to say whether there is a strong commitment to promoting it. This is likely because the establishment of an information system is not a priority in the Ghanaian government's WASH sector policy. The Ghanaian government's active budget support for an ICT-based information system in the WASH sector is also a very important factor. Korea's ICT-based WASH information systems were made possible by budgetary support from both central and local governments. In the case of Seosan City's SWM project, the city invested in the project while the central government provided support through its drought fund.

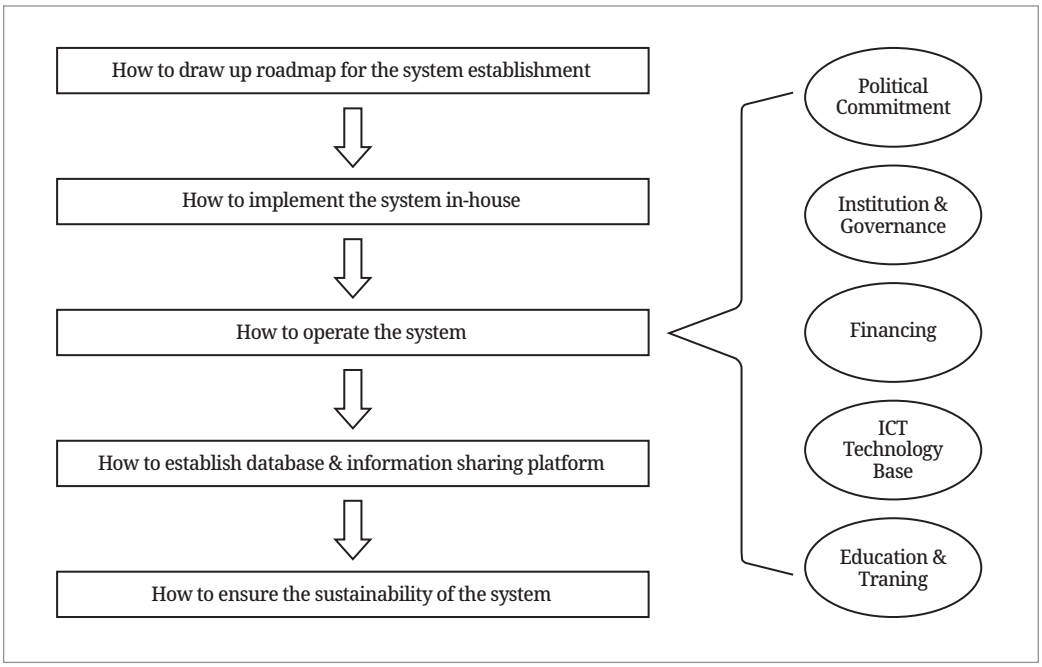
Another key factor is that the government should ensure adequate financing is available for the implementation and operation of the system. This could include leveraging funds from international organizations or donors, as well as allocating government funds to support the project. The government could also explore the potential for private sector funding or public-private partnerships. Securing financing is essential to invest in the technology and infrastructure necessary to establish an ICT-based WASH information system, including hardware, software, and communication networks.

The participation of stakeholders throughout the information system is also a very important factor. The main components of the system consist of design (roadmap), implementation, operation, maintenance, information sharing, and sustainability, which require collaboration among various stakeholders, including government, private sector, civil society, communities, and aid agencies. The government should foster collaboration and partnerships with relevant stakeholders involved in the ICT-based WASH information system. This will help ensure that data and information are accessible to all stakeholders and can be used to inform decision-making and improve WASH services.

Korea's communities have collaborated with various stakeholders such as the water supply companies, local governments, and industries to implement their ICT-based WASH information system, greatly contributing to improved water and sanitation.

In this study, among other things, the establishment of a customized information system that considers the context of Ghana, securing finance, and cost-benefit analysis are proposed as major policy recommendations, as it is believed that these play a crucial role in the establishment and effective operation of information systems in the WASH sector in Ghana.

[Figure 1-15] Framework for Establishing an ICT-based Information System in Ghana



Source: Author.

5.2. Building a System Solution Tailored to Country Context and Absorption Capacity of Ghana

5.2.1. Social Design: Designing Systems that Reflect Social Context

Given that information systems are managed by individuals, technologies, and organizations within society, it is essential to develop systems that take into account this societal framework.

In the case of Korea, securing the trust of residents through active participation, cooperation, and transparent public information is evaluated as a major factor in establishing a successful water management system.

Social design is essential in building an ICT-based information system tailored to Ghana's context and absorption capacity, as it ensures the system is culturally relevant, addresses the country's unique challenges, fosters local ownership, enhances sustainability, and strengthens local capacity. Incorporating social design ensures that the ICT-based information system is aligned with the cultural values, norms, and practices of the country. This leads to better acceptance and adoption of the system by local users, as they can easily relate to and navigate the culturally sensitive content and interface. In addition, by engaging with local stakeholders and incorporating their needs and concerns into the design process, social design helps build a sense of ownership and trust among the target audience. This fosters a more significant commitment to the success of the ICT-based information system, leading to better integration with existing structures and processes. By prioritizing social design, the ICT-based information system can have a more significant, lasting impact on the socioeconomic development of Ghana.

In order to achieve a successful social design, the following key aspects should be considered:

Needs assessment: Conduct a thorough needs assessment to identify the specific requirements of various stakeholders, such as government agencies, businesses, and citizens. This step involves analyzing existing systems, identifying gaps, and setting priorities.

Infrastructure and connectivity: Developing an ICT-based information system for Ghana must take into account the country's infrastructure limitations, such as intermittent electricity supply, low internet penetration, and limited access to digital devices. Assessing Ghana's existing ICT infrastructure, including internet connectivity, power supply, and

telecommunication networks should be carefully carried out to determine the extent to which the system can be implemented and supported. The design must be tailored to work efficiently within these constraints. While Ghana's urban centers have made strides in developing infrastructure, rural areas often lack access to reliable electricity, internet connectivity, and other essential resources. Solutions could include designing low-bandwidth applications, leveraging SMS-based services, or creating offline capabilities.

Scalability and sustainability: The ICT-based information system should be designed to adapt to the evolving needs of Ghanaian society. This means considering long-term financial sustainability, ensuring continuous improvement and updates, and planning for potential expansion to other regions or sectors. It also means designing a system that can be easily scaled up or down depending on the needs and resources of the country. It should be flexible enough to accommodate future technological advancements and changing requirements.

Affordability: Many Ghanaians, particularly in rural areas and low-income households, struggle to afford digital devices and data plans. This limits their access to ICT-based information systems and contributes to the digital divide.

User capacity: Design the system with the target users' technological literacy and absorption capacity in mind. This involves ensuring that the system is user friendly, accessible, and intuitive, and includes training and capacity-building initiatives to empower users and facilitate adoption.

Low digital literacy: Although the younger generation is more tech savvy, a large proportion of the population, particularly in rural areas and among older generations, still lacks basic digital literacy skills. This hinders the widespread adoption and effective use of ICT-based systems.

Insufficient local expertise: The lack of skilled ICT professionals within the country can be a barrier to the development, implementation, and maintenance of ICT-based information systems. This capacity gap may lead to reliance on foreign expertise, which may not always be culturally sensitive or contextually appropriate.

Stakeholder engagement: Engaging with local stakeholders, including government institutions, NGOs, community leaders, and end users, is critical to understanding their needs, expectations, and concerns. Collaboration with these stakeholders will also facilitate better integration of the ICT-based information system into existing structures and processes.

Cultural context: Designers need to understand and respect the cultural values, norms, and practices of Ghanaian society. This includes considering local languages, customs, and traditions when developing the information system. For example, stakeholders in rural areas may resist changes such as the adoption of ICT systems, preferring to continue using traditional methods of data collection and management, or be hesitant to embrace new technology. Incorporating culturally sensitive elements in the user interface and content will ensure better acceptance and adoption of the system.

5.2.2. Technical Design: Designing Systems that Reflect Technology Absorption Capabilities

Technical design in building an ICT-based information system tailored to the country context and absorption capacity of Ghana involves designing and implementing a system that effectively addresses the unique needs and constraints of the country. This process entails considering Ghana's technological landscape, as well as the capacity of its population to adopt and utilize new technology among others.

The choice of technology is a critical issue directly related to the usability and scalability of the system, so a tailored approach that considers the overall technological environment and appropriateness of the technology is important.

An ICT-based information management system has a wide range from low-level to high-level innovative technology, and it is not always the case that high-level technologies are the best option. High-level technologies often require high expertise and entail high operational costs. On the other hand, low-level technology can be effective and efficient if it can respond to local circumstances effectively. Therefore, it is crucial to introduce technologies of appropriate levels that fit the region-specific water management needs. One of the major reasons why Ghana's water management system (DiMES) based on Microsoft Access, which was established in 2007, is not being properly used and has been left neglected is due to insufficient consideration of the technological environment, as well as the basic infrastructure conditions and organizational capacity in the region.

The case of Seosan City in Korea analyzed in this chapter is a noteworthy example of how appropriate technology can be applied in SWM. The Seosan SWM project's successful adoption of various technologies to address water supply challenges can be a relevant model for developing countries, such as Ghana.

It is important to select appropriate technologies that are affordable, sustainable, and accessible within the Ghanaian context. This may involve leveraging open-source

solutions, mobile technologies, and cloud-based services that are more easily adaptable to local conditions.

The choice of technology plays a crucial role in ensuring the system's effectiveness, sustainability, and accessibility in building an ICT-based information system tailored to the country context and absorption capacity of Ghana. Choosing technologies that can easily integrate into existing systems and platforms in Ghana is also crucial to facilitate seamless data exchange and collaboration among stakeholders. By carefully considering these aspects during the technical design phase, an ICT-based information system can be tailored to Ghana's context and absorption capacity, ensuring it is relevant, effective, and sustainable.

When selecting the appropriate technologies, the factors outlined in <Table 1-9> should be considered.

<Table 1-9> Choice of Technology for Ghana's ICT-based WASH Information System

Affordability	Choose technologies that are cost effective and can be maintained within the constraints of Ghana's economic resources. This may involve adopting open-source solutions, which can significantly reduce costs compared to proprietary software.
Accessibility	Choose technologies that are accessible to the majority of the population, considering factors such as internet connectivity, mobile device penetration, and power supply. Mobile technologies are particularly relevant in Ghana, given the high mobile penetration rate and the growing adoption of smartphones.
Local Relevance	Select technologies that support local languages and are culturally appropriate, ensuring that the system is relevant and user friendly for the target audience.
User Capacity	Consider the technological literacy and absorption capacity of the target users when choosing technologies. The system should be designed with intuitive interfaces and user-friendly features that cater to varying levels of technological expertise.
Scalability and Adaptability	Choose technologies that are scalable and adaptable, allowing the system to grow and evolve with the changing needs of the country and advancements in technology.
Sustainability	Choose technologies that are energy efficient and environmentally friendly, considering the long-term impact on Ghana's environment and energy resources.
Support and Maintenance	Choose technologies that have a strong support ecosystem, with readily available technical assistance and resources to help with troubleshooting and maintenance.
Innovation and Local Capacity Building	Encourage the adoption of locally developed technologies and solutions to foster innovation and build local capacity in the ICT sector.

Source: Author.

5.2.3. Program Design: Designing a System from a Comprehensive Perspective

Establishing and operating an ICT-based information system require a comprehensive approach that takes into account investment financing, technology, and human capabilities. It is essential to have a long-term vision to ensure the sustainability and effectiveness of the system. Moreover, the establishment of an ICT-based information system involves not only initial investment costs but also continuous financial investment for equipment upgrades and system maintenance. Therefore, it is crucial to prepare a strategic blueprint for financing to ensure the availability of funds for the system's ongoing needs.

Designing a program for building an ICT-based information system in Ghana's WASH sector involves a series of steps, including planning, implementation, monitoring, and evaluation. Here is a step-by-step explanation of the program design process.

Situation analysis: Carry out a comprehensive analysis of the WASH situation in Ghana by collecting and reviewing data on water supply, sanitation coverage, and hygiene practices. This analysis should consider geographical, cultural, and socioeconomic factors to identify specific challenges and opportunities for improvement. Conduct a review of existing ICT infrastructure and digital literacy levels in the target areas to ensure the proposed system aligns with local conditions.

Stakeholder engagement: Create a stakeholder mapping to identify key actors in the WASH sector, such as government agencies, local authorities, NGOs, private sector entities, and community leaders. Organize workshops, focus group discussions, and one-on-one interviews to gather input and feedback from these stakeholders. This will help identify their needs, priorities, and expectations, ensuring the program design addresses their concerns.

Define program goals and objectives: Establish clear and measurable goals and objectives for the ICT-based information system, considering the situation analysis and stakeholder inputs. Goals should be specific, measurable, achievable, relevant, and time bound (SMART).

Develop a program strategy: Outline a comprehensive strategy that details the methods, technologies, and resources needed to build the ICT-based information system. This includes selecting appropriate hardware, software, data collection tools, and communication channels.

Hardware: Select appropriate devices and infrastructure, such as computers, mobile devices, servers, and networking equipment
Software: Choose suitable software platforms and tools for data collection, analysis, reporting, and visualization
Data collection and monitoring: Design data collection protocols and select tools (e.g., mobile-based surveys, remote sensing) to gather real-time information on WASH indicators.
Data management: Develop a data management plan to ensure data quality, privacy, and security, including data storage, backup, and access control measures.
GIS integration: Incorporate GIS technologies to map and monitor WASH infrastructure and services at different spatial scales.

Capacity building and training: Design training and capacity-building activities for stakeholders involved in the implementation and management of the ICT-based information system. This may include 1) training workshops on system operation and maintenance, 2) seminars on data analysis and interpretation, 3) hands-on training sessions on using data collection tools and software platforms, 4) train-the-trainer programs to create a network of local experts who can support ongoing capacity building, and the like.

Implementation plan: Develop a detailed implementation plan that outlines 1) the roles and responsibilities of different stakeholders in the program implementation, 2) a timeline for key activities and milestones, broken down into phases (e.g., planning, development, deployment, and evaluation), and 3) resource allocation, including human, financial, and technical resources. This plan should also include risk assessment and mitigation measures to address potential challenges, such as technical difficulties, stakeholder resistance, or funding constraints.

Monitoring and evaluation (M&E) framework: Design an M&E framework to track the progress and effectiveness of the program. This includes 1) identifying key performance indicators (KPIs) aligned with the program's goals and objectives, 2) setting up data collection and reporting mechanisms such as regular progress reports and stakeholder meetings, 3) conducting regular reviews and assessments of the program's performance, and 4) feedback loops and adaptive management strategies to incorporate lessons learned.

Budget and funding: Prepare a comprehensive budget that covers all aspects of the program, including planning, implementation, and M&E activities. Identify potential funding sources, such as government grants, international aid, private sector partnerships, or innovative financing mechanisms (e.g., social impact bonds). Develop a fundraising strategy to secure financial support and ensure the program's sustainability.

Communication and outreach: Develop a communication strategy to raise awareness of the program and its benefits among stakeholders and the public. This may include using traditional media, social media, and community engagement activities to disseminate information and gather feedback.

Continuous improvement and scaling-up: Incorporate feedback and lessons learned from the M&E process to improve the program and make any necessary adjustments. Explore opportunities to scale up the program and expand its reach, ensuring that the ICT-based information system has a broader impact on Ghana's WASH sector.

By following these steps, a comprehensive program can be designed to build an ICT-based information system effectively that addresses the needs and challenges of Ghana's WASH sector, promoting better decision-making, resource allocation, and service delivery.

5.3. Securing Financing

To implement an ICT-based information system, funding is necessary for both system development and maintenance, which includes purchasing devices and training staff. Although ICT-based information systems are currently established and operational in Accra, limitations in system expansion and maintenance exist due to insufficient funding. Moreover, the majority of rural areas lack information systems in the WASH sector, and the solution to this problem is to secure investment funds. However, Ghana lacks sustainable financing mechanisms to support the establishment of information systems, while financing for the WASH sector is critical to ensuring the provision of clean water and improved sanitation facilities for the population.

Additionally, there is a significant shortage of funds necessary to establish infrastructure, such as communication networks, water supply, and sewerage networks, which are prerequisites for building information systems. This study has shown that expanding investments in the WASH sector using national finances, water tariffs, and private sector investment is not an easy task. Although water bills are the most reliable long-term source of funding, expanding them in a short period is challenging. The cost of providing water and sanitation services is high, and the revenues generated from tariffs and user fees are often insufficient to cover the cost of operation and maintenance. Although there are proposals to establish a digitalized water bill payment system to expand financial resources, it is a long-term task and difficult to achieve quickly, considering the necessary conditions.

Moreover, the private sector's participation in the WASH sector in Ghana is limited due to the high risk associated with investing in the sector, the lack of incentives for

private sector investment, and the limited availability of long-term financing. Given these observations, it is practical for Ghana to expand its investment resources through external sources, including international development cooperation funds. To address the issue of insufficient investment funds in the WASH sector, the Ghanaian government recently established the National Sanitation Fund (NSF), which will be operated by the Ministry of Finance. However, even with the fund, achieving visible results is challenging considering the necessary conditions, and maintaining it for a long time would be difficult. Therefore, a detailed financial strategy that focuses on development cooperation funds from bilateral donor countries and DFIs is necessary.

5.3.1. Using Korea's ODA Funds

1) Korea's ODA to the WASH Sector in Ghana

The WASH sector is one of the key areas of focus for Korea's ODA to Ghana. Korea's support for Ghana's WASH sector has focused on improving access to clean water and sanitation facilities in rural and urban areas, strengthening institutional capacity and governance, and promoting hygiene and sanitation behavior change.

Korea has been Ghana's partner in providing ODA for various sectors, including water and sanitation. According to the ODA Korea website, Korea's ODA to Ghana amounted to USD 36.9 million in 2019, making it the sixth largest recipient country of Korea's bilateral ODA. Among the ODA projects that Korea has supported in Ghana, water and sanitation is one of the key areas of cooperation, as it is essential for improving the quality of life and economic activities of the people.

Some examples of ODA projects that Korea has provided for Ghana's water and sanitation sector include the following.

The Greater Accra Metropolitan Area Sanitation and Water Project (GAMA-SWP), which aims to increase access to water, sanitation and hygiene services for low-income urban communities in the Greater Accra Metropolitan Area (GAMA) and the Greater Kumasi Metropolitan Area (GKMA). The project has supported the installation of more than 27,000 household toilets and 120 km of new water pipes in these areas. The project also contributes to Ghana's COVID-19 pandemic response by strengthening key sector institutions and building resilience against future shocks and disease outbreaks.

The Water Supply Improvement Project for Tamale City and Surrounding Areas, which aims to improve the water supply system for Tamale City and its surrounding areas, where

water demand exceeds supply due to rapid population growth and urbanization. The project involves the construction of a new water treatment plant, transmission pipelines, distribution networks, reservoirs, pumping stations, and metering systems. The project is expected to benefit about 800,000 people in the project area by providing safe and reliable water services.

The Water Supply Improvement Project for Kumawu, Konongo and Kwahu Ridge Areas, which aims to improve the water supply system for the Kumawu, Konongo, and Kwahu Ridge areas, where water supply is insufficient and unreliable due to aging facilities and inadequate maintenance. The project involves the rehabilitation and expansion of existing water treatment plants, transmission pipelines, distribution networks, reservoirs, pumping stations, and metering systems. The project is expected to benefit about 260,000 people in the project area by providing safe and reliable water services.

Some of the main challenges faced by these Korea's ODA projects, among others, include the following: First, there was a lack of coordination and alignment among donors, government agencies, local authorities, civil society, and beneficiaries. This can lead to inefficiency and inconsistency in the delivery of water and sanitation services. Second, there was a lack of capacity and sustainability within the institutions and systems involved in the water and sanitation sector. This can affect the quality, reliability, and affordability of services, as well as the operation and maintenance of infrastructure.

2) Ideas on Strategic Use of Korea ODA

Ghana has been receiving grant aid and concessional loans from Korea, which can be expanded depending on the efforts of the Ghanaian government. Grant aid is managed by KOICA, while the Export-Import Bank of Korea is responsible for concessional loans (EDCF) on behalf of the Korean government. The EDCF is a concessional loan program operated by the Korean government to support the economic development of partner countries. These Korean aid agencies work closely with partner countries to identify priority areas for development assistance. The needs of the partner country are assessed, and potential projects are identified that could contribute to the partner country's development goals.

Once a project has been identified, these Korean aid agencies develop a detailed project plan that outlines the specific activities, timelines, and budget for the project. They consult with relevant stakeholders, including the partner country government, civil society organizations, and local communities, to ensure that the project is designed to meet their needs and is appropriate for the local context.

Ghana can seek various help with the ICT-based information systems in the WASH sector as follows:

Technical assistance: Korea can provide technical assistance to Ghana in the areas of data management, including the development of data collection tools, data analysis, and data visualization. This can include working with Ghanaian officials and experts to identify the most effective software and hardware solutions, and to customize them to meet Ghana's specific needs.

Training and capacity building: Korea can provide training and capacity building to stakeholders in Ghana's WASH sector to improve their technical skills in managing data and using ICT-based tools for data management. This can include developing and delivering training programs, workshops, and seminars, as well as providing mentorship and coaching to individuals and organizations.

Information sharing: Korea can share best practices and lessons learned from its own experience in using ICT-based data management systems in the WASH sector. This can include sharing case studies and examples of successful implementations of data management systems, as well as providing access to relevant research and reports.

Providing ICT infrastructure: Korea can provide ICT infrastructure such as hardware, software, and networking equipment to Ghana's WASH sector to support the development and implementation of an ICT-based data management system. This can include providing access to cloud-based data storage and analytics platforms, as well as providing funding for the purchase of hardware and software solutions.

Partnership and collaboration: Korea can partner and collaborate with Ghanaian government agencies, international organizations, and other stakeholders to develop and implement an effective data management system in the WASH sector. This can include joint research, joint capacity-building programs, and joint funding opportunities, as well as facilitating networking and knowledge-sharing opportunities among different stakeholders.

Pilot programs: Korea can support the development and implementation of pilot programs to test and evaluate the effectiveness of ICT-based data management systems in the WASH sector. This can help identify areas for improvement and develop strategies for scaling up successful programs. The pilot programs can focus on specific aspects of data management, such as data collection, analysis, and visualization, and can be implemented in specific geographic areas or among specific target populations.

Advocacy and support: Korea can advocate for increased investment and support for ICT-based data management systems in the WASH sector in Ghana. This can include advocating for policy reforms and increased funding from both domestic and international sources, as well as working with other stakeholders to raise awareness of the importance of data management for improving WASH outcomes.

Overall, by providing technical assistance, training and capacity building, sharing information, providing infrastructure, promoting partnerships and collaborations, supporting pilot programs, and advocating for increased investment and support, Korea can help to enhance Ghana's ICT-based data management system in the WASH sector and improve access to clean water, sanitation, and hygiene services for all.

There are several ways that Ghana's government can strategically mobilize Korea's ODA funds for its WASH sector development, including its relevant infrastructure and ICT-based information system. Here are a few ideas.

Develop a comprehensive plan: Developing a comprehensive plan is crucial for effective use of Korean ODA funds for WASH sector development in Ghana. The plan should identify the specific needs and priorities of the sector and outline how the Korean funds will be used to address these needs. It should also include an analysis of the current situation in the sector, including infrastructure gaps, service delivery challenges, and the status of ICT-based information systems.

Strengthen partnerships: Strengthening partnerships with relevant stakeholders is essential for mobilizing Korean ODA funds for WASH sector development in Ghana. Ghana's government can collaborate with Korean companies that specialize in WASH infrastructure development and ICT-based solutions. The government can also partner with international organizations like the World Bank and the United Nations Development Program (UNDP) to leverage their expertise and resources. Furthermore, the government can work with local civil society organizations and private sector actors to promote community participation in WASH sector development.

Prioritize sustainable solutions: Ghana's government should prioritize sustainable solutions that are environmentally sound, socially equitable, and economically viable. This can be achieved by investing in renewable energy sources to power water treatment facilities and utilizing low-cost, low-maintenance technologies for water supply and sanitation. The government can also promote the use of ecofriendly materials in WASH infrastructure development and encourage the adoption of sustainable WASH practices by local communities.

Cooperation for capacity building: Ghana's government can partner with Korean universities and training institutions to provide specialized training in WASH infrastructure development and ICT-based solutions. The government can also invest in on-the-job training and mentoring programs to help build the capacity of local professionals.

5.3.2. Bringing in DFIs for Infrastructure Development

In order to establish an ICT-based information system, infrastructure such as communication networks, power infrastructure, and water and sewage networks must be put in place as prerequisites. While Accra, the capital of Ghana, has relatively good infrastructure, the rest of the region continues to have very poor infrastructure. Construction of these infrastructures requires a significant amount of investment funds, which cannot be covered solely by the Ghanaian government's fiscal investment, domestic private investment, or aid funds from certain countries. Therefore, this study aims to explore the use of DFIs funds. DFIs can contribute to infrastructure development in several ways.

Financing: DFIs provide long-term financing options, such as loans, grants, equity investments, and guarantees, which can help attract additional private investment in infrastructure projects.

Risk mitigation: By participating in infrastructure projects, DFIs can help mitigate risks for other investors. Their presence signals confidence in the project, which can attract further investments from private investors who may have been hesitant to invest otherwise.

Mobilizing additional resources: By leveraging their financial resources and relationships, DFIs can help mobilize additional funding from other investors, such as multilateral development banks, bilateral agencies, and private sector investors.

DFIs include the World Bank's International Finance Corporation (IFC), the African Development Bank (AfDB), European Investment Bank (EIB), and European bilateral DFIs such as CDC Group (UK), FMO (Netherlands Development Finance Company), Proparco (France), and DEG (Germany).

DFIs and ODA are key external sources of funding for development projects of developing countries, including Ghana. While they share a common goal of promoting economic growth and improving living standards, they have differences in their scope, funding sources, and operational strategies, as seen in <Table 1-10>.

This comparison highlights the main differences between DFIs and ODA, though there is some overlap in their goals and activities. DFIs primarily support private sector development, while ODA focuses on public sector initiatives and humanitarian aid. DFIs offer a range of financial instruments, including loans, equity investments, and guarantees, while ODA primarily provides grants, technical assistance, and debt relief.

<Table 1-10> Comparison of DFI and ODA

	DFI	ODA
Source of Funding	Public or private sector financial institutions	Governments or their agencies
Financing Instruments	Loan (concessional or market rate) - Equity investments - Guarantees - Advisory services	- Grants - Soft loans (with grant element) - Technical assistance - Debt relief
Focus	- Long-term investments in private sector projects - Infrastructure, finance, agribusiness, manufacturing, etc.	- Development projects and programs - Humanitarian aid - Capacity building and policy support
Goals	- Sustainable economic growth - Job creation - Private sector development	- Poverty reduction - Human development (health, education) - Good governance
Examples	- International Finance Corporation (IFC) - European Investment Bank (EIB) - CDC (UK) - Proparco (France)	- Korea International Cooperation Agency (KOICA) - United States Agency for International Development (USAID) - Japan International Cooperation Agency (JICA)

Source: Author.

1) Some Examples of DFI's Investment in Ghana's WASH Sector

DFIs have played a significant role in financing and supporting development projects in Ghana's WASH sector. Here are some examples of DFI investment in Ghana's WASH sector:

World Bank: The World Bank has been a major contributor to WASH sector development in Ghana. In 2020, the World Bank approved a USD 50 million credit facility to support the Ghana Water Sector Support Project, aiming to improve access to a sustainable water supply and sanitation services in urban and rural areas. The project includes a range of activities, such as rehabilitating water supply systems, constructing new sanitation facilities, and strengthening sector governance and management. The World Bank has also provided technical assistance to support the development of ICT-based information systems for monitoring and evaluation of WASH services in Ghana.

African Development Bank: The AfDB has invested in several WASH projects in Ghana, including the Sustainable Rural Water and Sanitation Project (SRWSP). The SRWSP was designed to increase access to improved water sources and sanitation facilities in rural communities and was supported by a USD 150 million loan from the AfDB. The project included the construction of new water supply systems and sanitation facilities, as well as capacity building for local communities and service providers. The AfDB has also supported the development of ICT-based solutions for WASH sector management in Ghana.

European Investment Bank: The EIB has supported the development of the Kpong Water Supply Expansion Project in Ghana. The project aimed to increase access to safe water supply in the Greater Accra Region and was supported by a EUR 50 million loan from the EIB. The project involved the expansion of the existing Kpong water treatment plant and the construction of new water transmission and distribution pipelines. The EIB also provided technical assistance to support the project's implementation.

Proparco: Proparco, the French Development Finance Institution, has invested in the Ghanaian water and sanitation sector through its partnership with AquaVenture Holdings. In 2019, Proparco provided a USD 10 million loan to AquaVenture Holdings to support the development of the company's water treatment plant in Accra, which provides safe drinking water to over 500,000 people.

Overall, DFI investment in Ghana's WASH sector has helped improve access to safe water supply and sanitation services, promote sustainable economic growth, and reduce poverty. By providing financing, technical assistance, and capacity building, DFIs have supported the development of WASH sector infrastructure and the adoption of ICT-based solutions for WASH sector management in Ghana.

2) Use of DFI Funds

A short explanation of how Ghana can use the DFI fund is as follows: First, Ghana's government can use DFI funds to invest in critical WASH infrastructure to improve access to safe drinking water and sanitation services in underserved areas. This can include the construction and rehabilitation of water treatment plants, boreholes, wells, and sanitation facilities. The investment can target areas with the greatest need, such as rural and peri-urban communities where access to safe drinking water and sanitation is limited. The infrastructure should be designed to meet the specific needs and priorities of the communities they serve.

Second, Ghana's government can leverage DFI funds to promote the adoption of ICT-based solutions to improve WASH sector management. This can include the development of real-time monitoring and evaluation systems, digital data collection tools, and GIS mapping to support evidence-based decision-making. The use of ICT-based solutions can improve service delivery, enhance transparency and accountability, and promote sustainability in the WASH sector.

Third, Ghana's government can use DFI funds to strengthen the capacity of institutions responsible for WASH sector development and management. This can include capacity building for local government authorities, sector regulators, and service providers to improve service delivery and promote sustainability. The capacity building should focus on improving technical expertise, financial management, and governance in the WASH sector.

Fourth, Ghana's government can leverage DFI funds to promote private sector participation in the WASH sector. This can include providing credit facilities and technical assistance to private sector actors to invest in WASH infrastructure development and service delivery. The government can also promote public-private partnerships to leverage private sector expertise and resources. Private sector participation can help improve service delivery, promote innovation, and enhance sustainability in the WASH sector.

Overall, by strategically using DFI funds to invest in critical WASH infrastructure, promote the adoption of ICT-based solutions, strengthen institutional capacity, and promote private sector participation, Ghana's government can help address the most pressing challenges in the WASH sector.

5.4. Cost-Benefit Analysis of Establishing an ICT-based WASH Information System: Advocating Its Significance

5.4.1. Use CBA as Leverage to Publicize the Importance of an ICT-based WASH Information System

It is highly recommended that the MSWR use CBA as leverage to mobilize funds into an ICT-based WASH information system. Considering the significance of the WASH sector in the health and welfare of the population, developing a cost-benefit analysis methodology is highly recommended, which is expected to be used effectively and convincingly for widely publicizing its social benefits domestically, as well as attracting foreign aid. The WASH sector, which is directly associated with basic human needs, takes center stage in the international development cooperation and SDGs. In this regard, the Ghanaian government needs to analyze the economic/social benefits of ICT-based WASH data management in an in-depth manner, and use it as an appeal strategy to induce foreign aids (grants, loans).

By using CBA to prioritize potential development projects, Ghana's government can ensure that ODA funding from international partners including Korea is used effectively and efficiently to achieve development goals. Based on the cost-benefit analysis, the Ghanaian government needs to demonstrate the effectiveness of the ODA project to the donor country. Here are some ideas on how Ghana's government could strategically obtain foreign aid from international partners by using cost-benefit analysis.

<Table 1-11> Ideas on Using Cost-Benefit Analysis to Obtain Foreign Aid

Identify Potential Development Projects	Identify potential development projects that align with donors' development priorities.
Conduct CBA	Conduct a comprehensive cost-benefit analysis for each potential development project. ※ The analysis should consider the estimated costs and benefits of the project over the short and long terms, as well as the potential economic, social, and environmental impacts.
Prioritize Projects Based on the CBA	Prioritize the potential development projects based on the CBA ※ Projects that have the highest expected net benefits could be given priority for ODA funding from international partners.
Develop a Project Proposal	Develop a detailed project proposal for each prioritized project, including a detailed plan for project implementation
Engage with Donors' Government Officials	Engage with donors' government officials to discuss the project proposals and build relationships.

Source: Author.

The purpose of a CBA is to determine whether the benefits of a project outweigh its costs and to help decide if the project will be implemented. In the case of an ICT-based WASH data management system, the costs would include expenses such as the cost of hardware and software, the cost of personnel to design, implement, and maintain the system, and any additional costs associated with the development and implementation of the system. The benefits would include improved data management and analysis capabilities, improved water quality monitoring and management, and improved sustainability of water resources, among others.

To perform a CBA, the costs and benefits of the ICT-based WASH data management system would be estimated, and the benefits would be monetized and expressed in terms of financial or economic value. The costs and benefits would then be compared to determine the net benefits of the project, and the results of the CBA would be used to help decide if the project will be implemented.

Of course, it is important to note that a CBA is just one tool that can be used to evaluate the costs and benefits of a project, and that other factors, such as political, social, and

environmental considerations, should also be taken into account in deciding if the ICT-based WASH information system will be implemented.

5.4.2. An Example of CB Analysis of the Smart Water Management System in Korea

Here is an example of a cost-benefit analysis of establishing an ICT-based information system in the water and sanitation sector.

Suppose a water and sanitation department of a city is considering implementing a new ICT-based information system to manage and monitor water and sanitation infrastructure better. In this case, the estimated cost of building and operating the new system includes the cost of purchasing hardware and software, hiring staff, setting up the system, and the like.

The potential benefits of this new system can be broken down as follows:

Improved efficiency in managing and maintaining water and sanitation infrastructure: With an ICT-based information system, data can be collected, stored, and analyzed more efficiently, allowing for more effective management and maintenance of water and sanitation infrastructure. This could result in cost savings due to reduced maintenance and repair costs.

Increased transparency and accountability in the allocation of resources: An ICT-based information system can provide real-time data on resource allocation, allowing for increased transparency and accountability. This could result in improved public trust and perception of the water and sanitation department.

Improved data collection and analysis for decision-making: With an ICT-based information system, data can be collected, analyzed, and used for decision-making in real time, allowing for more effective and efficient decision-making. This could result in improved resource allocation and better decision-making overall.

Increased access to information for stakeholders, including the public: An ICT-based information system can provide stakeholders, including the public, with access to information about water and sanitation infrastructure in real time, allowing for increased engagement and participation.

In order to conduct a cost-benefit analysis, it is required to estimate the monetary value of each of these benefits. Some benefits, for example, resulting from improved data collection and analysis for decision-making, and increased access to information may be

difficult to quantify in monetary terms, and thus the cost-benefit analysis requires a process of quantifying these benefits through qualitative judgement by experts.

Once we have estimated the total benefits of the new ICT-based information system, we can compare them to the costs. If the benefits outweigh the costs, then the project is considered to have a positive net present value, and it would be recommended for implementation.

Of course, it is important to note that cost-benefit analysis is just one factor that should be taken into account when making decisions about establishing an ICT-based information system in the water and sanitation sector. Other factors such as social needs for a healthy life, investment priority, technical requirements, and stakeholder buy-in should also be considered.

CBA is widely used in Korea to assess the feasibility of system establishment across various sectors, including the data management system in the WASH sector.

[Figure 1-16] shows the results of the CB analysis of the smart water management system installed in Seosan City, Korea, which tells that the benefits are significantly above the costs.

The economic analysis of Seosan City's SWM project shows that it was a cost-effective investment. The initial investment of USD 0.51 million to install SWM resulted in a 20% improvement in the revenue water ratio, which translates into a reduction of 19,000 m^3 of water leakage annually and a financial benefit of about USD 0.1 million. The benefit-cost (BC) ratio analysis revealed a net profit at present value of USD 0.51 million and a BC ratio of 2.1, indicating that the project had economic feasibility.

Furthermore, as the project was designed as a disaster project in response to droughts, the expenses were paid through a separate disaster management fund managed by Seosan City, which also made it a valid project financially.

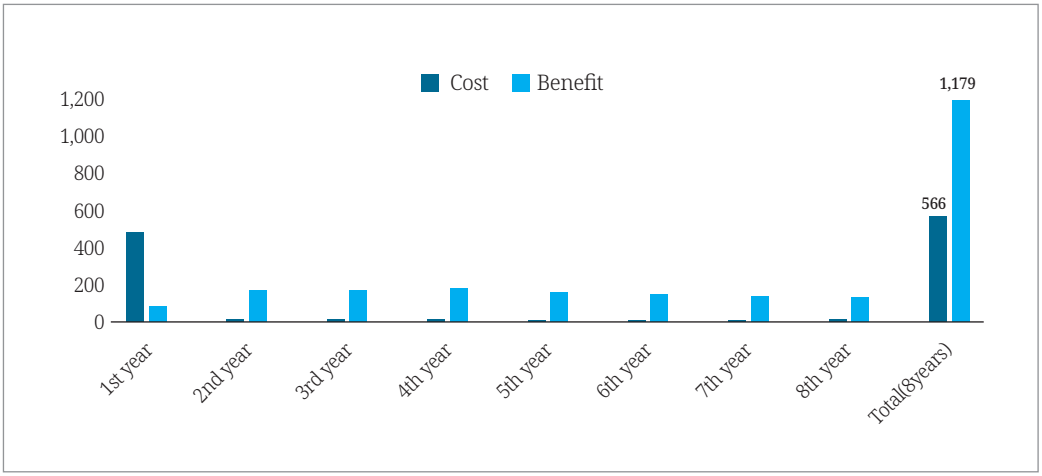
The benefits of the Seosan City SWM project included revenue water profit, reduction in labor costs of metering personnel, and leakage detection costs. The financial analysis period for the business was set as eight years, which is the service lifespan of the smart meters. The project's financial benefits were estimated to generate USD 0.98 million at present value over eight years, which more than doubled the initial investment of USD 0.51 million.

Overall, the Seosan City SWM project was not only a cost-saving project but also a financially feasible project with benefits such as decreased leakage and reduced labor costs.

Additionally, the project was designed as a disaster response project to droughts, making it a valid project financially.

[Figure 1-16] Cost-Benefit Analysis Results of the SWM Project (Seosan)

(Unit: million won)



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

In the case of Seosan City SWM, as shown in <Table 1-12>, the costs include expenses used to purchase digital devices, install the site, build the monitoring center, purchase S/W for the monitoring system, establish a remote monitoring center to track indicators, and construct sub-DMA areas, while the benefits include revenue water profit, saving on metering personnel, saving on leakage detection cost, and the like.

<Table 1-12> Cost and Benefit Items of the SWM Project (Seosan)

Cost Items		Benefit Items
Facility Investment	- Digital meter devices - Remote indicator sensors - Site installation - SDMA construction - Building monitoring center - S/W for monitoring system	- Revenue water profit (in sales price) - Saving on metering personnel (metering read, 60% of service budget) - Saving on meter replacement (existing meter replacement cost) - Saving on leakage detection cost (operating cost)
Communication Cost	KRW 660/unit/month	
Repair and Maintenance Cost	0.5% of investment	

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

6. Conclusion

The ICT-based information systems have the potential to bring significant benefits to Ghana's WASH sector. These benefits include real-time monitoring of water sources and sanitation facilities, efficient and accurate data collection and analysis, automated reports and dashboards, increased community engagement, and capacity building for WASH professionals and community members. Through the use of ICT tools such as sensors, mobile phones, GIS, and social media platforms, data can be collected, analyzed, and reported in a timely and efficient manner, which can help decision-makers plan and implement WASH interventions effectively. Furthermore, increased community participation and behavior change can be promoted through these systems, leading to more sustainable WASH interventions. It is crucial that the government prioritize the implementation of an ICT-based information system in the WASH sector and secure adequate financing for its implementation and operation. With proper implementation and stakeholder collaboration, an ICT-based information system can significantly improve WASH data management systems in Ghana and contribute to achieving sustainable development goals related to WASH.

This research examines the challenges and potential of ICT-based information systems in improving WASH-related activities in Ghana, and identifies the success factors of Korea's data-based WASH information system. It provides recommendations and policy implications for Ghana based on the experience and know-how of Korea, emphasizing the need for a comprehensive approach that includes social, technical, and program design tailored to Ghana's specific circumstances. While Ghana faces challenges in implementing a Korea-level ICT-based information system, it is still possible to establish an information system that is suitable for its specific circumstances. This highlights the importance of understanding the local context and tailoring solutions accordingly, rather than simply replicating models from other countries.

This research provides policy recommendations for Ghana based on Korea's experience in establishing an ICT-based WASH information system. The policy proposal was developed through a policy seminar attended by Ghanaian officials and experts, and recommendations included a comprehensive approach tailored to Ghana's specific circumstances, securing investment resources, strengthening policy and institutional foundations, enhancing human capacity, and fostering trained personnel through education and training. While Ghana faces challenges in implementing a Korean-level system, it is still possible to establish an information system that is suitable for its specific circumstances.

The government's prioritization of creating awareness of the benefits of the system, adequate financing, and stakeholder participation are crucial factors for the establishment and effective operation of an ICT-based WASH information system in Ghana. Additionally, the government should foster collaboration and partnerships with relevant stakeholders involved in the system. Finally, a customized information system that considers Ghana's context, secured finance, and cost-benefit analysis are proposed as major policy recommendations for the establishment and effective operation of information systems in the WASH sector in Ghana.

The MSWR in Ghana is responsible for overseeing the provision of WASH services nationwide and coordinating sector activities to maximize resource efficiency. The MSWR developed an SIS aiming to provide relevant WASH data to key sector players and the public for evidence-based decision-making. However, inadequate data collection and management, as well as disjointed data management systems that did not integrate with the SIS, undermined its effectiveness as a decision-making tool. Consequently, the MSWR struggled to identify national-level WASH service gaps and allocate resources to address them.

To address these challenges, the MSWR needs to undertake the following measures:

(1) Develop and implement standardized WASH data collection, management, and reporting procedures and protocols at all levels, and provide capacity building to WASH sector stakeholders on how to implement these procedures effectively.

(2) Collect baseline data in selected regions to facilitate effective planning and resource allocation.

(3) Establish an integrated information system for the WASH sector that ensures that data collected at the local level feeds into the SIS at the national level.
This improved system will generate sector reports and indicators that the ministry requires to target regions that lack adequate WASH services effectively.

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02

CHAPTER

Technical Solution for Establishing an ICT-based Water and Sanitation Information Management System in Ghana

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Keywords
ICT, WASH, Informatization, Information Management System, Technical Solution

Technical Solution for Establishing an ICT-based Water and Sanitation Information Management System in Ghana

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Summary

Safely managed water, sanitation, and hygiene (WASH) services are an essential part of preventing and protecting human health during infectious disease outbreaks, including the current COVID-19 pandemic. Korea has promoted the Green New Deal convergence policy for the digital-based job creation and economic innovation to overcome the epidemic disaster. Korea's digital transition policy to flexible water and sanitation management has inspired Ghana deeply. The weakness of WASH data management has become a chronic problem in Ghana. The Ghanaian government showed great interest in the ICT initiative facilitating a water and sanitation information system. By means of leveraging potential ICTs, the Ghanaian government would like to develop a robust integrated ICT-based water and sanitation information management system (IMS). This can ensure the availability of reliable sector information at all times and support the MSWR in its efforts to build resilient WASH management.

More tailored measures through systematic communication between central and local governments in Ghana are recommended for supporting reliable data-based decision-making in the drinking water system and the waste treatment network. To strengthen the WASH policy and service management at various levels, a cooperation and communication platform between authorities (central government and MMDAs) and stakeholders (service providers or users) is needed to integrate their efforts into one system. The development of digital-based water and sanitation service is an urgent task for more convenient and effective waste collection and disposal in the country.

First objectives of this research is to suggest a technical solution utilizing ICT technologies. The best practical ICT technologies currently being exploited in Korea are reviewed to initiate a technical framework for Ghana's water and sanitation IMS. Second

objective is to assess Ghana's WASH ecosystem, infrastructure, existing information systems and data, and service chains. With the view of applying the know-how from Korea's digital transformation experiences, the sectoral information management systems are excised in a technical context. Last one is to draw implications from the analysis of Korea's current ICT-based water and sanitation information systems. The implications of the lessons learned by investigating Korea's status of its digital policies and projects are applied to Ghana.

The analysis of the situation of Ghana's water and sanitation sector is as follows:

- From a technological perspective, infrastructure shortages, siloed systems, and inadequate services are prevalent all around the industry. Even though GWCL is in charge of the water supply in urban areas and CWSA is responsible for the rural water supply, there is much room for quantitative and qualitative improvement in the water sector in Ghana.
- On the other hand, the waste treatment sector, including fecal and stock manure, is mainly managed by individual businesses, but it is small and inefficient. The service capability is also evaluated at a low level overall.
- The functionality of the existing information system is not enough to support the government's policymaking and improve WASH governance. Informatization is one of the main challenges that the Ghanaian government should resolve to restructure the data management chain and service delivery in the water and sanitation sectors.
- It is also judged that the usable technics of ICTs can engineer a water and sanitation IMS facilitating the most feasible communication tools in Ghana.

The survey of the implications of Korea's information systems shows that:

- Data management systems used in the hydrologic and water resources sectors and information systems used for water and sanitation sectors are reviewed for benchmarking targets applicable to Ghana.
- Water-related information systems are largely divided into hydrologic disaster management, water and sanitation centered on urban environment and livestock manure, and water resources for domestic and industrial demands. The information systems currently in operation or under development are mostly based on ICT technologies.
- It is assured that the concepts of the systems can be benchmarked for Ghana's integrated ICT-based water and sanitation IMS, since the current WASH system

in Ghana is similar to the past cases in Korea, such as basic structure, application of ICT technology and its key functions, as well as the policy will of the state. The specific informatization-related regulations stipulated in the relevant laws and regulations have also proved that they have played an important role in the water and sanitation sectors.

- The implications and insights learned from the National Waterworks Information System and the Allbaro System (total waste management system) operated in Korea are presented to apply their merits to Ghana's water and sanitation IMS.

The basic strategies of the technical solutions for Ghana's water and sanitation IMS presented in this research are as follows:

- The technical feasibility of implementing an ICT-based water and sanitation IMS is to ensure that the system will be able to function in accordance with users' occupational requirements.
- An appropriate layout of the ICT-based water and sanitation IMS is schematized to meet the specific needs required by all actors. A customized structure of the information system is mapped with respect to eight important considerations to be examined in the water and sanitation IMS.
- For the informatization of the water supply sector, a general mapping of a data networking system is presented for GWCL. In addition, for the sanitation sector, a data networking system is presented based on the waste treatment service chain including household fecal and domestic solid waste in Accra.
- Key thematic components of ICT technologies to integrate all sectors are proposed on how to organize servers (database or Web) and mobile data service systems. The methodology of how to develop an information system and how to acquire a desired dataset in an appropriate place and time is designed with respect to various utilizable technics.
- The conceptual mapping of sector integration for the establishment of a water and sanitation IMS is suggested for Ghana. The initial version of the integrated ICT-based water and sanitation IMS and networking system including a hygiene sector is embodied and all components are systematized.

In conclusion, it is definitely believed that the implications of Korea's experiences can be successfully implemented in Ghana because the informatization strategy of the water and

sanitation sector, which is currently being promoted in Korea, is very well matched with the realistic demand of Ghana. So, it is judged to be a golden opportunity to promote common things through this project. Specifically, the proposed ICT-based water and sanitation IMS will be able to increase WASH data availability and accountability of service providers. It can also provide reliable data and information to the ministry and all stakeholders to support decision-making, policy formulation, and strategic planning. Another project achievement will be to present the MWSR with a technical concept of the WASH information management system to encourage policy development and technology promotion for efficiency enhancement. It can therefore be concluded that the ICT-based water and sanitation IMS, if put in place, will contribute immensely to the improvement in the living standards of Ghanaians through increased access to safe water and sanitation, hence, ultimately contributing to the early achievement of Ghana's Sustainable Development Goal (SDG) 6.l.

1. Introduction

1.1. Research Background

Safely managed WASH services are an essential part of preventing and protecting human health during infectious disease outbreaks, including the current COVID-19 pandemic (www.worldbank.org). Many countries are seeking to take a new leap forward by improving the public health environment that has worsened due to COVID-19. After the occurrence of COVID-19, Korea has been promoting digital-based job creation and economic innovation. As a new driving force, the digitalization of economics and promoting non-face-to-face interactions has accelerated. The Green New Deal, which seeks to promote new national vitality through digital innovation in the green sector by comprehensively adjusting the industrial system, is a symbolic policy.

A transformative digital convergence policy for a green future society has been promoted for the purpose of promoting job creation and modernization of the water industry through digital-based water management. Specifically, the transition to a digital system is intended to promote a change to a flexible water and sanitation management system suitable for various purposes through innovative digital technology (An *et al.*, 2020). Emerging digital technologies leverage a variety of water quantity/quality and service management and delivery as a tool to support the potential for integrated managements. Today, ICT can facilitate detailed measurement, real-time monitoring, and corporation and coordinating systems in water and sanitation management. Strong digital solutions have underpinned new governance and decision support systems (An *et al.*, 2020).

The definition of ICT is generally accepted to mean all devices, networking components, applications, and systems that combined allow people and organizations to interact in the digital world (www.techtarget.com, authored by Pratt). ICT is also able to facilitate a diverse set of technological tools and resources used to transmit, store, create, share, or exchange information (Karanja, 2018). These technological tools and resources include computers, internet, mobile data services, and telephony (UNESCO, 2017). ICT is an umbrella term that includes any communication device or application (IHE DELFT, www.un-ihe.org).

Like Korea's situation, Ghana's WASH sector is still interested in engaging in the efficient management of existing facilities and strengthening the system operation. Ghana is seeking breakthrough improvements in the WASH sector to maximize economic and social welfare without weakening the sustainability of the ecosystems. As pointed out in many research projects (e.g., WMO and UNICEF, 2015; Wateraid, 2016; CWSA, 2014), weak national water policy and lack of information about WASH system in Ghana are factors that make integrated management difficult.

In particular, the absolute lack of an information system necessary for policy development and strategic action plans and coordination in the WASH sector is the most difficult challenge. The lack of an information system also has an impact on the sanitation service capacity, the protection of urban rivers directly related to the urban ecosystems, the leakage management of water supply facilities, and the communication and cooperation between the government and market participants.

1.2. Research Objective

More tailored measures such as WASH information governance and its reliable data-based plan through efficient communication between the central and local governments are necessary to strengthen the WASH policy and service capacity in Ghana. In order to enhance the policy and administrative strength of the WASH system at various levels, cooperation and communication platforms between authorities and stakeholders are needed to integrate information in the WASH sector. Developing a collaborative approach among communities to provide equitable water and sanitation services is an inevitable national challenge. The cross-cutting issue to solve the problems is information sharing that articulates a common purpose and can facilitate the dialog between the roles of each sector. Eventually, informatization can play a key role in supporting dialog, cooperation, and joint decision-making among stakeholders in the WASH sector.

From the standpoint of the Ghanaian government, the primary purpose of water and sanitation informatization is to resolve a chronic issue by improving policy development and administrative work by increasing the utilization of data. Strengthening service capabilities by the appropriate arrangement of WASH service can act as a trigger to increase national green health. It is also possible to provide an enabling environment in which environmental standards for household waste management such as treatment regulations can be strictly put in. It can be a communication and outreach tool by increasing the connectiveness of market system. Informatization can also help Ghanaians carry the task of establishing a digitized tariff and fee collection system for a sustainable financing measure. Therefore, the objectives of the research on technical solutions for the establishment of an information management system in water and sanitation sectors in Ghana is as follows:

First, this research will determine the implications for Ghana by analyzing the status of Korea's digital water management project and the establishment of an information system focusing on the Korean version of the Green New Deal. The implications of the case lessons learned by investigating the status of the digital policies and projects for each water and sanitation management sector will be applied in Ghana. In addition, Korea's best practical technology in environmental sector information such as system integration, customer-oriented service, real-time tracking, and the case of its ICT-based information management system will be applied to Ghana.

Second, this research will analyze Ghana's WASH infrastructures and market systems to suggest the most appropriate information system as it pertains to Ghana's SDG 6 and provide the technical basis for the informatization project for practical improvement of water and sanitation management. We also intend to conceive and present an information system that can be practically built in the future through suggested technical solutions. Forthwith, this research presents basic technical specifications and policy directions for the development of an ICT-based water and sanitation information management system (IMS) in Ghana.

Third, this research will present a future sustainable informatization strategy through functional analysis of the existing information system. It also aims to strengthen service capabilities in related industries through information activation in line with the national goal to achieve safe water and clean sanitary environment.

Finally, this research will present the information system components and data processing structures necessary for informatization in Ghana. In considering the current water and sanitation industry characteristics, a system implementation policy will be suggested based on sectoral environmental infrastructure inventory. Based on ICT technologies, the method

that can make the most of possible communication between data and information producers and users will be recommended for Ghana's water and sanitation IMS. This research finally presents a data platform as an integrated system to maintain and utilize the existing sector information system (SIS) and to enhance the service delivery of the environmental service providers based on the water and sanitation service chain.

1.3. Needs of ICT Technology in Water and Sanitation IMS

In order to build an ICT-based water and sanitation IMS, it is necessary to apply various technologies. The interdisciplinary of water and sanitation engineering and information and communication technologies is not simply a combination of interrelated technologies, but the outputs of this research can provide more value beyond its imagination. An ICT-based information management system for the water and sanitation sector can be an interdisciplinary optimal approach among water supply, sanitation and environmental engineering, and information and communication engineering. Also, the design of an ICT-based information management system utilizing these technologies is transdisciplinary, holistic, and comprehensive, and mainly focuses on data management from water and sanitation infrastructures in urban and peri-urban areas.

The World Bank's new strategy for engagement in the ICTs sector, which came into force in 2012, is built around three strategic themes: 1) innovate, 2) ICT for innovation, and 3) and ICT-based services industries (World Bank, 2012). The strategy's innovate pillar develops competitive IT-based service industries and fosters ICT innovation across the economy, including at the grassroots technology entrepreneurship level with a focus on job creation (Trucanao, blogs.worldbank.org, 2013). The strategy's transform pillar draws on deep sector expertise and relationships with government institutions to integrate innovations into service delivery and the accountability process.

The United Nations considers one of its Sustainable Development Goals (SDGs) to "significantly increase access to information and communications technology and strive to provide universal and affordable access to the internet in least developed countries by 2020." Knowledge and information have become transformative dimensions of human existence and are key drivers behind the implementation of all SDGs. The 2030 Agenda recognizes the need to develop knowledge societies where everyone has opportunities to learn and engage with others, which starkly highlights the need for access to ICTs (www.un.org/sustainabledevelopment). Another important fact about water and sanitation is that access to water and sanitation is recognized by the United Nations as a human right that is fundamental to everyone's health, dignity, and prosperity (UN, 2010).

In order to establish an ICT-based information management system, it is important to check which ICT-related technologies can be used. In the case of Ghana, compared to Korea, there are some differences in information and communication infrastructures as well as application technologies and solutions. The basic elements that determine the success or failure of an ICT-based information management system are communication infrastructure and application software. Most of the other technologies are technics or tools that can be sufficiently procured in the market, such as computer systems, communication equipment, commercial operating software, etc. Therefore, this research will focus on the application technology among the technical components of the information system.

2. Technical Solutions for a WASH Information Management System in Ghana

2.1. Analysis of WASH Infrastructure

In order to implement an information management system for the water and sanitation sector, it is important to first understand the composition of the WASH infrastructure in the country and their status. The WASH infrastructure in Ghana comprises various components aiming to ensure access to safe water, improved sanitation facilities, and promote good practices. These components are as follows:

- Institutional Frameworks

In Ghana, WASH infrastructure is supported by institutional frameworks that oversee planning, implementation, and regulation. The Ministry of Sanitation and Water Resources is responsible for formulating policies, coordinating activities, and providing strategic direction. The Community Water and Sanitation Agency (CWSA) and Ghana Water Company Limited (GWCL) are other key agencies involved in the WASH service chain.

- Water Supply Systems

The water supply systems in Ghana include piped water systems, boreholes with hand pumps, and rainwater harvesting systems. The piped water systems are also referred to as centralized systems as they involve the construction and operation of piped water networks, treatment plants, and reservoirs to provide safe drinking water to communities. The point water systems, otherwise, are known as decentralized systems, and they provide water at a smaller scale, especially in rural areas. The water supply systems are intended to provide safe and reliable access to water for domestic, agricultural, and industrial purposes. GWCL

is the main public agency responsible for managing and distributing water to urban and peri-urban areas in Ghana. In rural areas, CWSA and other NGOs are responsible for providing water supply services. The key institutions subject to water supply and the target of informatization in Ghana are introduced in <Table 2-1>.

<Table 2-1> Water Supply Relevant Agencies and Their Missions in Ghana

Agency	Content
MMDAs (www.washghana.net)	- Facilitate collection and analysis of data on health - Promote and encourage good health and sanitation - Assist with education of residents of the district on sanitation and hygiene - Facilitate and assist with regular inspections of the district - Assist to establish, install, build, and control public latrines - Assist to establish and carry out services for liquid waste treatment - Facilitate and coordinate stakeholders for services delivery
Ghana Water Company Limited (MWRWH, 2015)	- A utility company responsible for potable water supply in Ghana - Currently operates 88 urban water supply systems nationwide - Average production is about 871,496 m^3/day - Present potable water demand is estimated at 1,131,818 m^3/day - With a staff strength of 3,476, GWCL serves 748,570 customers, 86% of which are metered and 14% unmetered
Community Water and Sanitation Agency (MWRWH, 2015)	- Responsible for the provision and management of community water and sanitation services, and coordinates all actors in the subsector - Provides support to district assemblies to promote the sustainability of safe drinking water supply and related sanitation services in rural are. - Formulate strategies for the effective mobilization of resources and encourages private sector participation in the provision safe drinking water supply and related sanitation service

Source: RCN Ghana, Drinking Water Quality Management Framework – MWRWH (www.washghana.net, accessed on May 7, 2023).

- Sanitation Facilities

Sanitation infrastructure in Ghana comprises various components that aim to safely collect and dispose of human waste and promote hygienic practices. The key elements of sanitation infrastructure in Ghana are as follows:

a) ***Toilets and latrines***: These are facilities designed to contain and isolate human waste. They can range from simple pit latrines to more advanced options like flush toilets with septic tanks. Different types of toilets and latrines are used depending on the context, availability of resources, and cultural preferences.

b) ***Septic tanks***: In areas where sewerage systems are not available, septic tanks are commonly used for safe containment and treatment of human waste from toilets and other

household sources. They are underground tanks designed to provide a means for waste to decompose and are regularly emptied or serviced to ensure proper functioning.

c) ***Sewerage systems***: In urban areas, sewerage systems are designed to collect and transport wastewater from households, commercial buildings, and industries to treatment plants. These systems involve underground pipelines, pumping stations, and treatment facilities to ensure safe disposal of wastewater without polluting water bodies.

d) ***Waste treatment plants***: These facilities receive and treat wastewater and human waste from sewerage systems or septic tanks. Treatment processes can include physical, biological, and chemical processes to remove contaminants and ensure the safe disposal or reuse of treated wastewater

e) ***Solid waste management***: Solid waste management is an integral part of WASH infrastructure. It includes the collection, transportation, treatment, and disposal of solid waste. This involves the establishment of waste collection points, waste transfer stations, recycling facilities, and landfill sites to manage the environmental impact of solid waste.

f) ***Hygiene infrastructure***: It includes facilities for handwashing, such as handwashing stations and soap dispensers and is essential for promoting good hygiene practices, which aim to prevent the spread of diseases. This includes promoting handwashing with soap, safe food handling, menstrual hygiene management, and cleanliness. Hygiene promotion programs involve educational campaigns, community engagement, and the provision of handwashing facilities in schools, healthcare facilities, and public places. The CWSA and other NGOs are responsible for providing hygiene infrastructure in rural areas.

The operation of treatment facilities in the sanitation sector in Ghana is currently mainly handled by private companies, and the data collection and sharing system is fundamentally dependent on the treatment companies. Therefore, it is reasonable to collect sanitation data and information from private companies. The companies are also taking important roles to present a service, so they need an improved information system for their business activities. In consideration of such aspects, the main companies in the environmental service providers in Ghana should be subject to informatization and they are shown in <Table 2-2> (https://espaghana.com).

<Table 2-2> Company List of Environmental Service Providers in Ghana (Accra City)

Sanitation Sector	Company
Human Waste (fecal)	- Sewerage Systems Ghana Limited - Universal Waste Concept, Zoompak Ghana Limited - J. Stanley-Owusu & Company Ltd., Erksarp Ventures - Zesta Environmental Solutions Ltd. - City Waste Management Co. Ltd., Y.N.O Enterprise - New Era Waste Management Concept - BIOLAND LTD, Keen 2 Clean Services - Golden Falcon Company Limited - Early Sunrise Trading Co Ltd, PREMKO Waste Management - Asadu Royal Seed & Waste Management
Solid Waste	- Zesta Environmental Solutions Ltd. - EPIC Window Cleaning Services, Tidyup247 Facility Management - Impact Environmental Limited, ZES Cleaning Services Office - Sewerage Systems Ghana Limited - Cleaners Ghana Safety Transport & Logistics Solution - Azisaeed Construction Travel & Tour Company Limited
Sewerage	- Sewerage Systems Ghana Limited, Checkers City
Dangerous Waste	- Zoompak Ghana Limited (medical waste)
Stakeholders	- Government, academia, development partners - Civil society organizations (CSOs), churches, schools - Imani Ghana, coalition of NGOs in water and Sanitation - Institute of Environment and Sanitation - Water and Sanitation for Urban Poor - School of Hygiene, Environmental Protection Agency - World Vision Ghana, Ghana Plastic Manufacturers Association - Sachet Water Collectors Association - The Ghana Recycling Initiative by Private Enterprises (GRIPE) - Association of Ghana Industries (AGI) - SNV, Resource Centre Network Ghana (RCN) - National Level Learning Alliance Platform - National Plastic Action Alliance - International Solid Waste Association - Sustainable Sanitation Alliance (SuSanA) - Voice for Change Partnership

Source: ESPA, ESPA Key Stakeholders and Membership (https://espaghana.com, accessed on Feb. 6, 2023).

The level of infrastructure development and access varies across different regions and between urban and rural areas. Efforts are ongoing to expand and improve WASH infrastructure to ensure universal access for all Ghanaians. Overall, the sanitation infrastructure in Ghana is still developing, and access to basic sanitation facilities remains limited in many areas, particularly in rural communities. The Ghanaian government and development partners are implementing various initiatives to improve access to basic sanitation facilities and to promote proper hygiene practices in the country.

Following the WASH infrastructural assessment, it is necessary to investigate systematically how to generate and manage data, and also how to operate and maintain facilities and service delivery. Water and sanitation infrastructures with the same function need to be grouped and organized by sector for gathering similar datasets. The water supply sector can be divided into domestic water, which collectively refers to water used at home, such as drinking or toilet water, or commercial urban and industrial water, excluding water for agricultural purposes. In general, systemic water supply facilities for the main purpose of health and firefighting are called waterworks when distinguished from sewage or industrial water (Republic of Korea, 2021).

Currently, infrastructures related to the WASH sector in Ghana can be largely divided into water and sanitation sectors, even if excepting personal hygiene. The subject of informatization for the water use sector can be divided into advanced water purification, general water purification, and simple water purification according to the degree of treatment for household or industrial water. It is also divided into water supply and recycling water according to its use purpose. In this section, the data and information collection and management targets are specified and considered as data investigation targets for the information management system.

The sanitation sector basically includes household sewage and solid waste, city waste, special waste discharged from medical facilities or any other specific waste discharger, and industrial waste. In the case of sewage, where a collection pipe is installed, it is divided into combined and separate types, and where there is no collection pipe, it is considered open sewage. There is no collection system for toilet waste, so-called fecal; it should be collected by a tank lorry and treated at the human waste treatment plant. In this case, a storage tank is installed in the house toilet, and when there is a certain amount in the tank, a tank lorry is used to collect and treat it in batches. Therefore, the component of the sanitation information management system in Ghana can be divided into sewage, domestic excreta, liquid and solid household waste, and industrial and special waste.

2.2. WASH Status and Service Elements

WASH services refer to the provision and management of services relating to water, sanitation, and hygiene. These three disciplines are interconnected and interdependent, as access to safe water is essential for maintaining good hygiene practices and effective sanitation. One cannot be fully realized without the other.

Water services are those that provide access to clean and safe water for drinking, cooking and other domestic purposes, as well as for agriculture and industrial purposes. This includes the provision of water supply infrastructure. Sanitation services are those that provide access to safe and hygienic toilets, handwashing facilities, and other sanitation infrastructure as detailed in Section 2.1. Hygiene services are those that promote good hygiene practices, such as handwashing with soap and water, and the safe disposal of human waste. This includes hygiene education and behavior change campaigns that aim to promote good hygiene practices and reduce the spread of disease.

Together, these services are essential for ensuring the health and well-being of individuals and communities, and for promoting sustainable development. Improving access to WASH services is a key priority for achieving the SDGs, particularly SDG 6, which aims to ensure availability and sustainable management of water and sanitation for all.

The status of water supply can be evaluated based on coverage, reliability, and sustainability of water sources, such as piped water systems, boreholes, or protected springs. Other factors to consider are the functionality of infrastructure, water quality testing, and equitable access across urban and rural areas.

Currently, according to the 2021 Population and Housing Census as released by the Ghana Statistical Service, 87.7% of the populace have access to basic water supply services. However, there is a disparity between urban and rural communities. About 96.4% of the urban populace have access to basic water supply services, while 74.4% of the rural populace have access to basic water supply services. About 8% of Ghanaian households continue to rely on unsafe sources (PHC, 2021). Despite the apparently high access to safe water in urban areas, sachet water dominated (51.5%), with pipe-borne water accounting for only 33.6%. The vision is to have about 70% of the populace/households in urban/peri-urban and 50% in rural areas connected to a piped water network and using safely managed water services by 2030.

In determining the status of sanitation services, the factors to analyze include the coverage and accessibility of sanitation facilities and their hygienic conditions, appropriate

waste management systems, promotion of improved practices (e.g., ending open defecation), and proper treatment and disposal of fecal waste. Progress in access to basic improved sanitation has not been as impressive as water. As of 2021, only 25.3% (PHC, 2021) of the national population had access to improved sanitation that is not shared. About 17.7% of Ghanaians still practice open defecation. Evaluating hygiene status involves assessing the availability and functionality of handwashing stations, awareness and adoption of proper hygiene practices, and integration of hygiene promotion in schools, healthcare facilities, and communities. According to MICS 2018, the proportion of people in Ghana having access to hand hygiene facilities has increased and is currently at 48.5% (MICS, 2018).

UNICEF (2016) analyzed and presented an enabling environment for monitoring and evaluation (M&E) in the WASH sector. Since the water and sanitation sector or WASH program requires regular monitoring and evaluation, relevant actors must be willing and able to use M&E information for program coordination. Effective monitoring should enable the identification of strengths and weaknesses in the implementation and cost effectiveness of program methodologies. Overall M&E responsibility in Ghana should lie with the relevant authority of the program in the central government, but data should be gathered at the local government or community level.

Informatization should focus on strengthening and maintaining connections between actors. The information generated should be used as an input to planning and decision-makings at all levels. Ewurah (2017) pointed out that policymakers need to respond appropriately since the new departure of ICT requires restructuring of management methods and is operated with a new process. It is also stressed that water management reform through ICT technologies should be built to support and manage new types of government practices. The government must follow this trend to ensure international competitiveness as ICT affects connectivity with greater impact on organizations, societies, public welfare, and collective action. Service chains should be active in strengthening coordination between all actors for the digital integration and adoption of new ICTs.

Pearce *et al*. (2015) presented research results on "harnessing ICT innovations for monitoring WASH services." In many countries facing WASH challenges like Ghana, day-to-day monitoring data are unreliable because national water supply planning inventories are not regularly updated. In this context, issues relating to WASH must be addressed in order to improve both the speed of information update and the necessary measures until water and sanitation services are accessible to all by harnessing ICT innovations. Gini-Garriga *et al*. (2013) suggested an improved approach for data collection at the local level through water-sanitation-hygiene mapping. Sdata.us (2020) suggested an idea that some

automatic technologies for data collection at the water point data transmitter, sending data periodically, are available by SMS.

For the successful development of ICT, three aspects of system design should be considered for Ghana, namely, social design, technology design, and program design. An ICT system for national WASH monitoring should include the participation of all sector stakeholders. It needs to define the target users exactly and why. At the same time, wide access to generated information and widespread dissemination of information will increase the connectivity among all actors. If the systems of the future are to incentivize the use of information to improve sustainable services, enhance learning, and support coordination among different actors, then this will require the consent of sector leaders, and ultimately monitoring systems will need easy-to-use, reliable information and provide value to various actors related to the WASH service chain.

Achieving universal and sustainable sanitation coverage will require a paradigm shift in current efforts to determine when, where, and how. While national strategies relating to waste disposal in Ghana are encouraging, the implementation of these strategies is hampered by mismatches between waste management strategies and institutional structures (Republic of Ghana, 2020). Environmental sanitation infrastructure and service practices show that the capacity of metropolitan councils remains weak.

Currently, some institutional gaps exist in the planning, design, implementation, and operational management of large-scale infrastructure activities such as wastewater treatment plants, sewers, and solid waste treatment facilities. Since MMDA's solid waste management capabilities are being complemented by the activities of private sector actors, it needs a strong leadership in the public sector to build strong solidarity with the private sectors (Zurbrügg *et al*., 2014; UKAID, 2014).

2.3. WASH Data and Information Management Status

In Ghana, several kinds of WASH sector information systems have been introduced. Most of them are supported by international organizations and global NGOs. The SMARTerWASH project collects real-time data through DiMES (District Monitoring and Evaluation System) by integrating the use of mobile and internet technologies. Three complementary smart components come into play to collect data and address facility issues discovered during the monitoring process. SkyFox SMS is a short message service (SMS) ICT platform that allows the community to report problems, order parts to fix broken facilities, and access financing using mobile phone services (Pennink, 2020).

DiMES is a global universal-level monitoring system supported by MS Access database to process, analyze, and store monitoring data. DiMES is used to capture, store, and report information on water and sanitation activities and services and includes data management tools for monitoring water and sanitation projects for rural areas and small towns. This is to inform service providers and authorities so that they can adjust their plans, funding, and policies based on data and take action to improve services. DiMES is used to generate water coverage reports for local councils, districts, and regions of the country. The national water coverage is also generated from DiMES.

Akvo FLOW is a system that allows actors to collect data using smartphone and view the data online. Together with the SkyFox SMS tool, Akvo FLOW was linked to the DiMES to support data collection even though adequate data were not available. To date, 2,000 communities have connected to the SkyFox SMS platform and have been trained to use mobile phones and special numbers to report broken facilities and order spare parts from suppliers. Community members can use their cell phone to send updates about water service during their daily activities (Pennink, 2020).

At the start of Triple-S (a multicountry learning project), IRC and CWSA were unsure of the quality of water services being provided when measured against national standards. Therefore, indicators were developed to measure and monitor water services, based on national norms and guidelines. The indicators and data collection tools were tested and refined by piloting them in three pilot districts. This resulted in CWSA publishing this indicator set as the national monitoring framework. The indicator framework and data collection tools developed under Triple-S were a good step forward in the development of the monitoring system, but work remained to be done on its ongoing application at scale and the ICT systems required for this. The ICT development under SMARTerWASH built on existing ICT systems: CWSA's DiMES, Akvo's FLOW (a smartphone platform for data collection), and SkyFox's SMS-based system for tracking functionality and ordering spare parts (Pennink, 2020). <Table 2-3> briefly describes each system's characteristics.

<Table 2-3> Analysis of Existing WASH Information Systems (MMDAs)

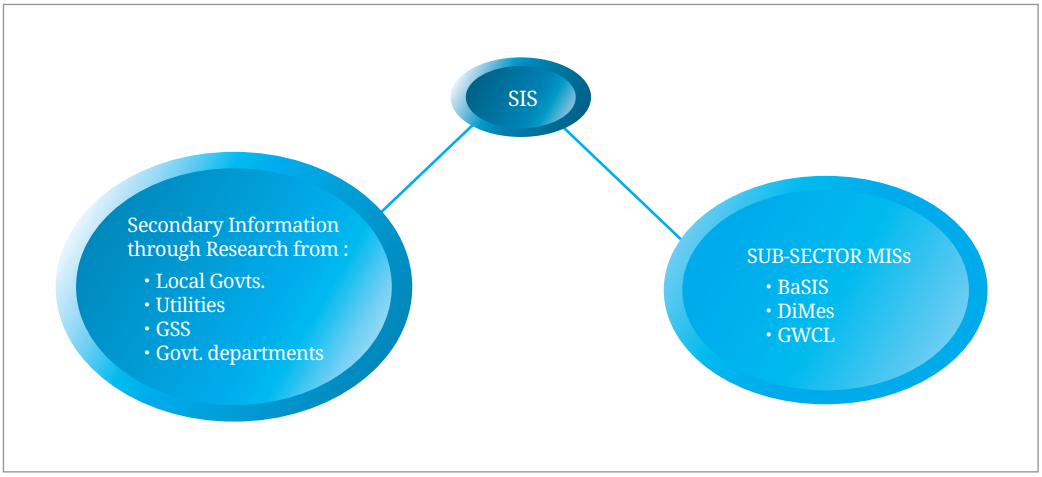
System	Description
SMARTerWASH	- SMARTerWASH is a multipartner joint initiative to ensure effective monitoring and data collecting for water and sanitation services. - Three smart components were operationalized: DiMES to analyze and collect data, Akvo FLOW to collect data using mobile phones and visualize it online, and SkyFox SMS to help users report problems, order spare parts, and access financing (www.ircwash.org).
BaSIS	Mapping capabilities - Community maps showing households and latrine types distribution with pictures of latrines District dashboard feature - Automatic SMS prompts to facilitators - Measure periodic performance with district targets - Alerts on district field facilitator trends and performance Reporting capabilities - Report filtering based on periods - Statistical summary (tabular and graphical on key indicators)
DiMES	- The District Monitoring and Evaluation System is an MS Access database application consisting of data capturing interfaces, monitoring tools, reports, and data analysis model. - The system has a link to different ICT systems (AKVO Flow and SkyFox SMS system). - Data collection at scale: data for 131 districts (out of 216) - The data are available through fact sheets and an atlas that is accessible online.

Source: Pennink (2020).

According to the analysis of the streamlining data collection and management in Ghana (Kihagi *et al.*, 2020), Ghana's MSWR oversees the delivery of WASH services across the country and coordinates sector activities to ensure efficient and productive use of resources. MSWR developed a "Sector Information System (SIS)" to provide key sector actors and the public with relevant WASH data for evidence-based decision-making. This is to address the prevailing challenge of poor data collection and management as well as fragmented data management systems that made it difficult for MSWR to identify WASH service gaps at the national level and prioritize resources for filling these gaps.

The SIS is designed to provide adequate information on access to water supply and sanitation services, the quality of those services, and their sustainability. Reporting from the system will be based on 14 WASH golden indicators. The WASH golden indicators are indicators that give a holistic overview of the status of the WASH sector in Ghana. The SIS is planned to receive data from the subsector monitoring systems as illustrated in [Figure 2-1]. It should be noted that the SIS is still in the pilot and testing stage, and it is hoped to be fully deployed by the end 2023.

[Figure 2-1] Structure of the Sector Information System in Ghana



Source: Author.

2.4. Expected Beneficiaries of WASH Data

WASH data in Ghana serve as a valuable resource for decision-makers, researchers, communities, and various stakeholders involved in improving water, sanitation, and hygiene conditions. It supports evidence-based planning, monitoring, and implementation of initiatives aiming to achieve sustainable and equitable WASH outcomes.

The beneficiaries of WASH data in Ghana include various stakeholders (who are potential information system users) involved in the WASH sector, namely,

- **Government agencies**: WASH data are crucial for government agencies responsible for planning, implementing, and monitoring WASH programs and policies. The data help them assess the status of water supply, sanitation, and hygiene practices, identify areas in need of improvement, allocate resources effectively, and measure the impact of interventions.

- **Non-governmental organizations (NGOs)**: NGOs working in the WASH sector rely on data to design targeted interventions, prioritize communities in need, and evaluate the effectiveness of their projects. WASH data enable NGOs to make informed decisions, advocate for policy changes, and secure funding for their initiatives.

- **Development partners**: Development partners and donors, such as international organizations and bilateral agencies, use WASH data to understand the WASH situation in Ghana, align their funding priorities, and monitor the progress of projects

they support. Data help them make evidence-based decisions and track the impact of investments.

- **Researchers and academia**: WASH data provide valuable insights for researchers and academia studying various aspects of water, sanitation, and hygiene. They support evidence-based research, help identify trends and challenges, and contribute to the knowledge base on effective WASH interventions and policies.

- **Communities and individuals**: WASH data directly benefit communities and individuals by driving targeted interventions and improvements in water supply, sanitation facilities, and hygiene practices. Communities can access information about the quality and availability of water sources, sanitation coverage, and hygiene education to make informed decisions and advocate for their needs.

- **Health professionals**: Health professionals, including doctors, nurses, and public health officials, use WASH data to understand the relationship between water, sanitation, and hygiene practices and public health outcomes. They help them develop strategies to prevent waterborne diseases, improve sanitation-related health issues, and promote hygiene behavior change.

- **Media and civil society organizations**: WASH data play a crucial role in raising awareness and advocacy efforts. Media outlets and civil society organizations use the data to highlight challenges, report on progress, and hold stakeholders accountable for their commitments in the WASH sector. They help drive public discourse and mobilize support for improved WASH services.

By making WASH data accessible and actionable, these beneficiaries can work together to improve WASH services, address challenges, and contribute to the overall well-being and sustainable development of Ghana.

Analyzing these issues more academically and logically, the Ghanaian government is now promoting policies to strengthen the accessibility and sustainability of water and sanitation management systems. The Ghana government established the National Mid-term Development Policy Framework (2018–2021) (Republic of Ghana, 2017). However, due to an insufficient integrated water management system and lack of development funds, chronic drinking water shortages and environmental problems persist.

A JMP report on the state of the WASH environment and industry in Ghana (WMO and UNICEF, 2017) found that the water sector achieved MDG targets for access to safe water,

but water service is perceived as insufficient even in some urban areas. The water provided by GWCL has been pointed out as having a large gap between high demand and insufficient supply. What is worse, the municipal waste disposal sector is also very underdeveloped in Ghana (Sagoe *et al*., 2019). A lot of domestic sewage discharges into city stream or rivers through open sewage systems in urban areas.

The need to meet industrial waste and wastewater treatment regulations is expected to increase the demand for related technologies and services significantly. Much has been improved since the 1990s, but many rivers in the Accra metropolitan area like the Odaw River are polluted with sewage and garbage. The inflow of pollutants into rivers causes various problems such as deterioration of ecological service functions. Ultimately, urban sanitation is threatened by insufficient garbage collection and disposal treatment capacity, insufficient landfills, and sewage systems (Appiah-Effah *et al*., 2019)

Billing *et al.* (1999) diagnosed the individual effects of Ghana's WASH sector. According to WASH Data Quality in Ghana (Republic of Ghana, 2015; Koppelaar *et al*., 2018), the quality is very low. In particular, information relating to the quality of drinking water is limited, and in the case of industrial water, the data are not sufficient. Water governance information is still lacking in terms of data quality and management issues (NORC, 2021). An integrated monitoring system in water and sanitation service can improve data quality and validation. However, the integration of decentralized monitoring and capacity development for hierarchical management need to consider the consequences of the water and sanitation services as a necessary condition (Akanbang, 2021).

According to Ntow (2019), the policies in the water and sanitation mostly rely on survey and project data rather than administrative data. The M&E component of the sanitation sector is mostly project based. Water and sanitation policies are not up to date despite significant changes. There is a weak link between policy and practice even though the establishment of the MSWR. Knowledge gaps also exist in relation to performance M&E. The lack of dedicated M&E to drive sanitation management within government agencies is draining the capacity of the government sector to generate and use evidence. This is a factor undermining the connectivity of various national-level policy frameworks (Pennink, 2019).

There are issues in monitoring after the construction phase. In most cases, there is a lack of information about the operational function of the facilities, the effectiveness of the system management, and the population size and surroundings associated with water utilities. The post-construction monitoring is not systematically carried out, despite the fact that all MMDAs and project partners have a lot of interest and enthusiasm to get normal acquisition

of data in the early stage of the project. Another weakness in the monitoring process is the speed of data sharing. Processes for data validation are also an important task of the information management system in Ghana.

2.5. Technological Level of WASH IMS

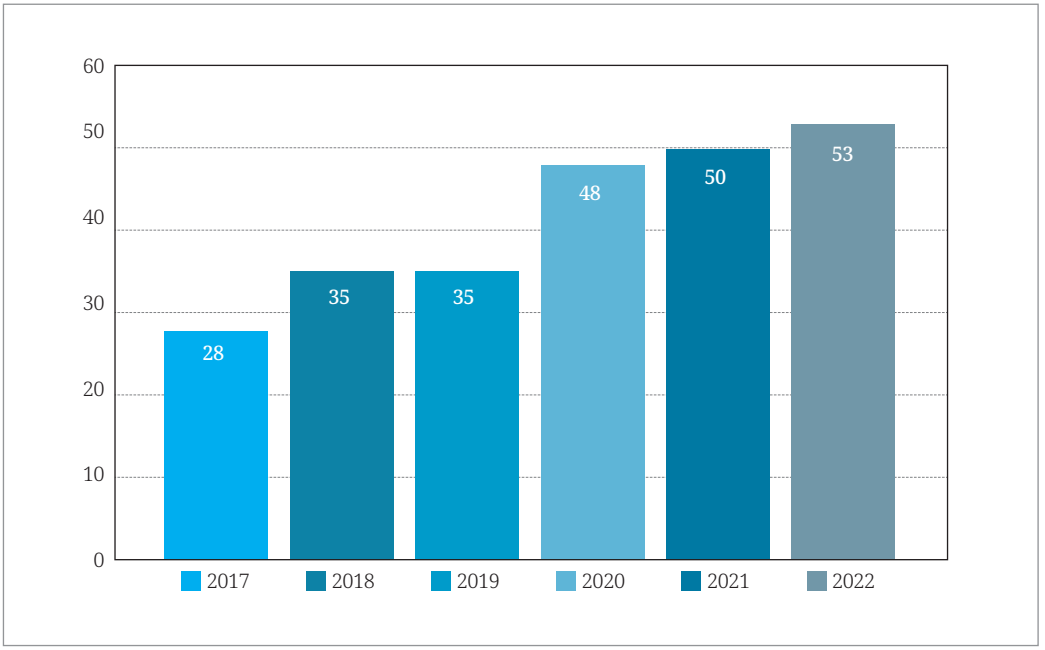
The Ghana Telecommunication Report (2020–2050) introduces market overviews including latest trends, new technologies, challenges, growth opportunities, and key emerging areas in the telecom market (www.globalmonitor.us). The report analyzed that the Ghana telecom market has witnessed strong growth in recent years and is expected to have continued growth over the forecast period to 2025. The growth in the market is mainly due to increasing urban population with rising adoption of the mobile phones that supports 3–5G services. The telecom sector is further expected to have strong growth over the forecast period with rising demand of internet that connects with wired and wireless broadband.

The major part of the market growth in Ghana is attained by premium connectivity and content services. The users in the personal communication sector, such as mobile phones and SNS, are rapidly expanding. This trend will also provide a very encouraging environment for the establishment of information systems in the water and sanitation sector in Ghana. The total number of voice subscriptions was 41,017,822 and the total penetration rate compared to the population was 134.25% at the end of January 2022. With an estimated population of 30,792,608, the total subscriptions of data in the country at the end of January 2022 was 23,682,839 (NCA, 2022).

The percentage of the population using the internet has been increasing rapidly in the West African country (www.statista.com). There were 16.99 million internet users in Ghana in January 2022. Ghana's internet penetration rate stood at 53% of the total population at the start of 2022 as shown in [Figure 2-2] (Kemp, https://datareportal.com). Kepios analysis indicates that internet users increased by 350,000 between 2021 and 2022 in Ghana (https://kepios.com). In social media statistics for Ghana in 2020, there were 8.8 million users in Ghana in January 2022. The number of social media users at the start of 2022 was equivalent to 27.4% of the total population (Kemp, https://datareportal.com).

[Figure 2-2] Internet Penetration Rate (2017–2022) in Ghana

(Unit: %)



Source: Kemp (https://datareportal.com, accessed on Feb. 15, 2023).

Telecommunication and internet connectivity are key enablers among others in technological development, and they significantly impact the technological level of WASH information management systems in Ghana. Without the internet and communication networks, it would be impossible to adopt digital solutions. The technological levels of WASH vary depending on the specific systems and implementations. However, in recent years, Ghana has made significant progress in adopting technology for data management in the WASH sector. Here are some key aspects that contribute to the technological level.

- **Mobile data collection**: Mobile data collection has gained traction in Ghana's WASH sector, leveraging the widespread availability of smartphones. Various organizations and projects have implemented mobile data collection tools and applications to gather WASH-related information in the field efficiently.

- **Geographic information systems (GISs)**: GIS technology is increasingly being integrated into WASH information management systems in Ghana. GIS enables the spatial analysis of WASH data, such as mapping water sources, sanitation facilities, and hygiene practices.

- **Remote sensing and sensor-based technologies**: Remote sensing technologies, including satellite imagery and aerial surveys, are being used to monitor water resources, identify water sources, and assess the extent of water bodies. Sensor-based technologies, such as water quality monitoring sensors, are also being deployed to gather real-time data on water quality parameters.

- **Online reporting and dashboard**s: Online reporting platforms and dashboards are being developed to provide easy access to WASH data and facilitate data visualization. These platforms allow one to view and analyze WASH data in a user-friendly and interactive manner, aiding decision-making, planning, and monitoring of WASH intervention.

- **Cloud-based storage**: Cloud-based storage solutions are increasingly being utilized in Ghana for WASH data management. Storing data in the cloud provides flexibility, scalability, and accessibility from various locations.

- **Data analytics and artificial intelligence**: Ghana is exploring the use of data analytics and artificial intelligence (AI) techniques to analyze large volumes of WASH data.

While Ghana has made progress in adopting technology for WASH data management, it is important to note that the technological level can vary across different regions and organizations. Factors such as funding, infrastructure, and institutional capacity influence the extent of technological implementation. However, there is growing recognition of the importance of technology in improving WASH outcomes, and efforts are being made to leverage technology to enhance data-driven decision-making and service delivery in the WASH sector in Ghana as evidenced with this project.

3. ICT Technology in Korea's Water and Sanitation Information Management System

3.1. ICT-based Water and Sanitation IMS in Korea

Since the 1980s, Korea has promoted policies that focused on fostering ICT as a strategic means for the national communication service. In the era of ICT convergence from analog to digital, Korea aimed to establish ICT governance beyond media governance (Kim, 2020). The strategies for e-Korea, Broadband IT Korea, and u-Korea based on the high-speed communication network and high-speed internet service were just turning points. Korea came to establish a world-top information country with a highly acknowledged e-government system and a top broadband internet subscription rate (www.mois.go.kr).

The water-related information systems are largely divided into the disaster management sector such as flood control based on weather and hydrological data, and water and sanitation centered on urban environment, and water resources for drinking water and industrial and agriculture. Most of the information systems in operation or development are based on ICT. It is probably a phenomenon that is very closely aligned with the current ICT technology in Korea. ICT investment has contributed significantly in enhancing productivity growth in water sector (Shin *et al.*, 2004).

In the weather and hydrologic sector, an ICT-based water-related data-provision system serving data collected from two central ministries, 15 government-affiliated organizations, and two local governments is open to any user, not only government levels but also public and private users through an open information system shown in <Table 2-4>. In addition, a map-based open platform system for providing probabilistic precipitation and flood volume is being developed.

On the other hand, the water and sanitation sector mainly include piped water supply, wastewater, and household waste, and any kind of city waste including special waste, etc. In Korea, the piped water supply rate is almost 100%, and the sewage supply rate is already 90%. In particular, the sewage treatment system covers domestic sewage and human waste mostly in a separate sewerage treatment system, which fundamentally reduces pollution leakage into the urban drainage or river systems.

Currently, the main concern in Korea is the disposal of household waste generated in residential areas or waste discharged from livestock cattle sheds. Therefore, the development and reinforcement of the comprehensive household waste management

information system is currently being developed. The main information systems in the water and sanitation sectors currently used in Korea are as listed in <Table 2-5>. Those systems are also an open information system for related businesses and private sectors.

<Table 2-4> Information Management Systems for Hydrology and Rivers in Korea

Name of System	Feature	Technology
Korea Water Management Information Networking System (HRFCO, www.wamis.go.kr)	Provides information on various water resources	Network and internet
Flood Forecasting System (not for the public)	Flood information for early warning service	ICT and intranet
Hydrological Data Quality Management Information System	Verification and calibration of hydrological raw data	Network and intranet
River Geographic Information System (www.river.go.kr)	Provides river geographic and embankment information	Internet
National Groundwater Information System (MoE, www.gims.go.kr)	Management of groundwater use permits and provides data for policy decision-making	ICT and internet
Rural Water Resources Information System (www.rawris.go.kr)	Provision of irrigation water and rural water information	Internet
Flood Hazard Map Information System (www.floodmap.go.kr)	Providing Flood Inundation Area and Evacuation Information	Internet and app
River Water Use Management Information System (HRFCO, https//ras.hrfco.go.kr)	Provides information on the actual status of river flow and water intake	ICT and internet

Source: Author.

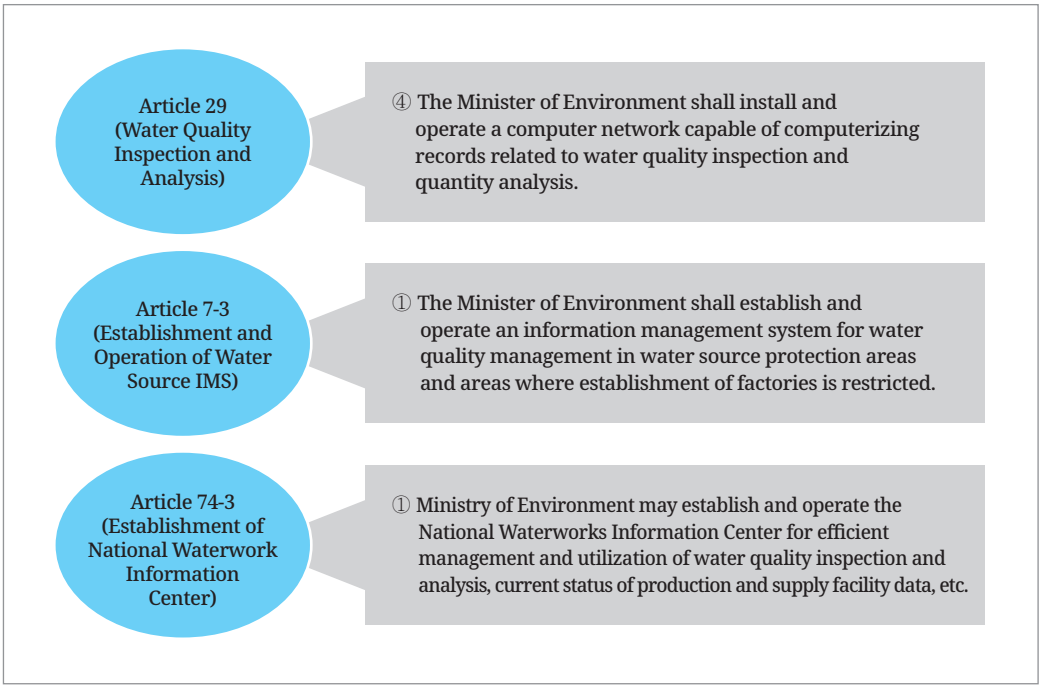
<Table 2-5> Information Management Systems for Water and Sanitation in Korea

Name of System	Feature	Technology
National Waterworks Information System (MoE, www.waternow.go.kr)	Records of water supply statistics by statistics act	ICT and internet
RFID-based Food Waste Management System (K-eco, www.citywaste.or.kr)	Statistical information on the discharge of food waste by local government	ICT, internet, mobile, and GPS
Livestock Manure Electronic Transfer Management System (K-eco, www.lsns.or.kr)	Real-time information and management system	Internet and mobile
Wastewater Treatment Electronic Handover Management System (www.keco.or.kr)	Prevents illegal disposal, such as unauthorized discharge, and induces proper disposal	ICT and app
Integrated Water and Sanitation Information Management System (https://www.kwater.or.kr)	Data Provision for Optimization of Water Resources Management and Facility Operation	Internet
National Sewerage Information System (MoE, www.hasudoinfo.or.kr)	Provides information necessary for government policy and corporate market utilization	ICT, convergence of IT and ET
Household Waste Information Management System (under development by K-eco)	Integrated household waste information and automatic site data collection	ICT and internet solution

Source: Author.

The information systems introduced in <Tables 2-4> and <Table 2-5> are basically developed and operated based on the provisions stipulated in the relevant laws of each sector in Korea. The basic clauses such as the items, methods, and responsible persons of the data investigation are clearly specified in each law. As a representative example benchmarked in this research, the main specified articles in the Waterworks Act relating to water supply are introduced in [Figure 2-3] (Republic of Korea, 2022). It also regulates that the central government should establish an information center that can develop and operate related information systems and set up its delegated organization.

[Figure 2-3] Key Provisions Concerning Informatization in the Waterworks Act



Source: Author.

In accordance with the above regulations, the Ministry of Environment has initiated the National Waterworks Information System (MoE, www.waternow.go.kr). The system is a web-based integrated system that collects and provides information relating to waterworks, such as water quality status, facility information, and technology information, and analyzes data from water intake and purification plants, raw water and purified water quality inspection results, water supply statistics, water source protection area management status, and evaluation management as detailed in <Table 2-6>. As a result, it can help users find ways to standardize and jointly use related information for data management. It can bring information together and is used for national policy and investment program developments, and operation and maintenance of related facilities.

<Table 2-6> Water Quality Survey Items Prescribed by the Waterworks Act

Classification			Items
Multiregional (large) and Local Waterworks	Purification Treatment Plant	Daily	Odor, taste, color, turbidity, *p*H, residual chlorine
		Weekly	General bacteria, total coliform, *colibacille*, ammonia nitrogen, nitrate nitrogen, potassium permanganate demand, dried residuals
		Monthly	Disinfectants, disinfection by-products
		Quarterly	7 by-products (residual chlorine, chloralhydrate, dibromoacetonitrile, dichloroacetonitrile, trichloroacetonitrile, haloacetic acid, formaldehyde)
	Tap Water	Monthly	General bacteria, total coliform, *colibacille*, residual chlorine
	Aged Pipeline Area	Monthly	General bacteria, total coliform, *colibacille*, ammonia nitrogen, total trihalomethanes, copper, *p*H, zinc, manganese, chloride ion, residual chlorine
	Supply Facility	Quarterly	General bacteria, total coliform, *colibacille*, ammonia nitrogen, total trihalomethanes, copper, *p*H, zinc, iron, turbidity, residual chlorine
Village and Small Water Supply Facility		Quarterly	Odor, taste, color, turbidity, fluoride, boron manganese, aluminum, residual chlorine, general bacteria, total coliform, *colibacille*, ammonia nitrogen, nitrate nitrogen
		Yearly	All items of drinking water quality standards (61 items)

Source: Korea Ministry of Environment, National Water Supply Information System (www.waternow.go.kr, accessed Jan. 12. 2023).

Another important national regulation is the guidelines on the information system establishment and operation for administrative agencies and public institutions (Republic of Korea, 2022). In accordance with the Article 45 of the 「Electronic Government Act」, these guidelines set criteria, standards, and procedures to be followed by heads of administrative agencies in establishing and operating information systems. The purpose is to set matters concerning interoperability technology evaluation in accordance with Article 49 of the Act.

In particular, in Article 4 (Basic Principles) of the Act, the heads of administrative agencies, etc., must observe the following matters in promoting information system projects: 1) The head of an administrative agency, etc., shall establish and operate an information system based on the agency's information technology architecture or the governmentwide information technology architecture. 2) In principle, standardized open technology is used for technology applied to information systems. However, if a non-standard, closed technology is used, the reason must be specified. 3) It should be built by considering data integrity, consistency, confidentiality, and availability. 4) The head of an administrative agency, etc., may guarantee the public's right to use public data in accordance with the

Act on the Provision and Use of Public Data (Public Data Act) when upgrading or newly establishing an information system (Republic of Korea, 2020).

3.2. Technical Solutions in ICT-based IMS

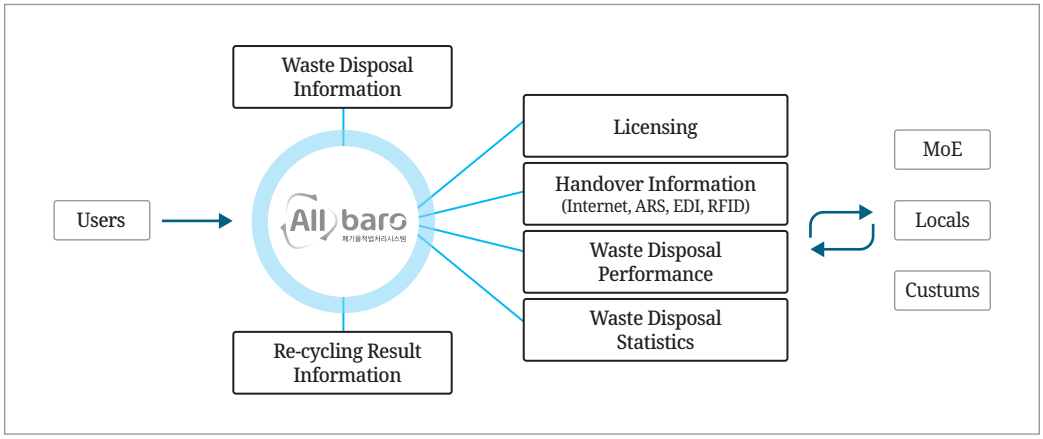
Various water- and sanitation-related information management systems have been developed and used in Korea as introduced in <Tables 2-4> and <Table 2-5>. Currently, a comprehensive management system for household waste treatment is under development, and similar systems in the same sector are being integrated. The Ministry of Environment, which oversees most of the water- and sanitation-related policies and missions, including flood control and river basin management, develops and operates information management systems through the affiliated professional organizations.

For example, the Han River Flood Control Office (HRFCO) is in charge of hydrological data surveys, river basin management, and flood forecasting and control. Korea Water Resources Corporation (K-water), a public corporation specialized in water resource development and management, is conducting multipurpose dam construction and operation for water resource development, multiregional waterworks construction and supply, hydroelectric power generation of multipurpose dams, and waterworks modernization projects with local governments. Korea Environment Corporation (K-eco)'s main tasks are environmental pollution prevention, environmental improvement, resource circulation promotion, and greenhouse-gas-related projects to respond to climate change.

K-water and K-eco are responsible for water and sanitation works in Korea and have also developed and operated a great number of water and sanitation information management systems. Among them, several typical systems are considered for a benchmarking model in Ghana's water and sanitation information system. We will now provide brief summaries of the development purposes, typical features, and ICT technologies for each information system.

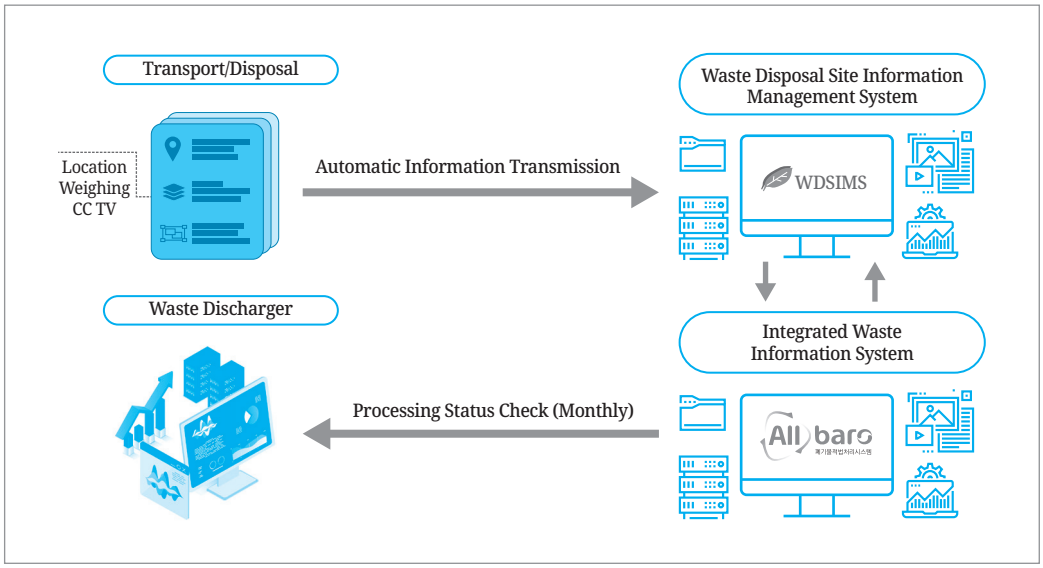
The information system that is most similar to Ghana's waste treatment sector is the Allbaro System as introduced in [Figure 2-4] (www.allbaro.or.kr). Allbaro means "always right and green." The system is designed to manage transparently the entire process from discharge of waste to transport and final treatment over the internet. The purpose of this system is to integrate all information into one total ICT-based comprehensive waste management as described in [Figure 2-5] (www.allbaro.or.kr). An important point of the system is that market operators must fill out an electronic handover form through the Allbaro System when taking over wastes that should be reported or permitted by the responsible administrative agency.

[Figure 2-4] User Networking of the Allbaro Information System



Source: K-eco, Waste Disposal Site Information Management System (www.allbaro.or.kr, accessed on Jan. 10, 2023).

[Figure 2-5] Structure of the Allbaro System and Data/Information Flow



Source: K-eco, Waste Disposal Site Information Management System (www.allbaro.or.kr, accessed on Jan. 10, 2023).

In the past, it was a structure in which dischargers, transporters, disposers, administrative agencies, etc., who manually wrote a waste handover form to check the treatment route from waste generation to final treatment, kept them separately. The problem with this manual process was that it was inefficient due to the complex administrative procedures and excessive workload and administrative costs associated with the management, verification, and review of paper handover slips. The development of a computerized system for handover information provided convenience to both operators and administrative agencies, and in particular, made it possible to manage the process automatically from waste discharge to final treatment on the internet in real time.

Securing the transparency and reliability of waste treatment certification, ensuring the appropriateness of waste treatment, and simplifying administrative work due to the reduction of waste treatment certification procedures, social and economic cost reduction and recycling of waste were promoted and environmental preservation was enhanced. In other words, waste collection and transportation or waste treatment companies with permits and reporting certificates from the government can use advanced information technologies such as RFID, ARS, internet, and EDI provided by the Allbaro system. Operators and government agencies can use the information provided by this system, such as waste handover information, annual performance report of waste discharge, transportation, and treatment, waste reduction information and reduction performance, recycled aggregate distribution support information, and waste information.

Additionally, the Allbaro System consists of several key functions such as the collected information management of the recycling waste treatment plant, the disposal import-export report information management of the compaction plant, and the disposal input-output information management of the sorting. It is also equipped with an information management function of a recycling company's carry-in/-out amount, incineration facility residues carry-in report, and landfill facility residues carry-in status information. Even though this system has many subsystems, they are operated in an integrated way to enhance synergistic effectiveness.

Another important system in the sanitation sector is the home waste treatment system. The Korean government is analyzing trends in household waste generation and treatment. The analyzed data and information are used for investigating the annual generation and treatment status of domestic and industrial waste at the local administrative district level. For this purpose, K-eco is now building an ICT-based integrated information system for household waste treatment. The concept of the system is composed of the several subsystems, and through this project, an automatic on-site information collection system is being established as a part of the domestic waste information management system.

The basic concept of these systems introduced above can be benchmarked for Ghana's ICT-based integrated WASH information management system, which will be discussed in Chapter 4, because the system has many parts envisioned in this study, such as basic structure, application of ICT technology, and its key functions.

3.3. Roles and Effectiveness of IMS

The slogan for water and sanitation management in Korea is "Always right and green." To accomplish that goal, the water management includes flood and watershed management using data on weather, floods, rivers and dams, and water supply. The major water management tasks are technically supported by information systems, including public water managements based on water quality and ecological environment information systems. Data and information collection methods for water management are mostly remote control and real-time monitoring systems. As analyzed in the previous section, it is based on ICT and expands to the smart or digital water and real-time sewage management systems centered on K-water and K-eco.

Additionally, K-water, K-eco, and HRFCO have been building a future-oriented integrated information system. This is a plan to further expand the usability of individual systems and solidifies a user-centered system. Systems currently planned or under development are mostly based on the concept of easy access to a wider range of information based on integration into existing systems. Through the so-called "one-stop information service system," it can support a batch process that enables data search, analysis, evaluation, comparison, and download.

The implementation of the smart water city, one of the hottest topics in Korea, is the establishment of a smart water supply and sewage management system to prevent water supply accidents or respond to them promptly. Along with the waterworks modernization project led by the Ministry of Environment and K-water, this project focuses on digital measurement and automatic processes through the installation of a monitoring and control system. It is also to improve the quality of local waterworks, increasing investment in the rehabilitation of outdated pipeline facilities. However, standardization of ICT solutions, business processes, and system configurations for this purpose are still insufficient. Nevertheless, there is no unsolvable issue in providing digital-based total solutions in the water and sanitation sector (An *et al*., 2020).

As pointed out above, the establishment of an integrated operating system in the same sector of water and environment provides an opportunity to reduce social and environmental costs by facilitating the monitoring system in the private sector. Additionally, the benefits of the basic functions of the information system are proved through most cases of Korea's experiences. In particular, considering the endowment and use of water resources in Korea, environmental management of public water is a very critical task. In response, related organizations operate a double- or triple-check monitoring system from the pollution source to the river outlet through real-time data so that most river systems are very clean and safe.

In Korea, water and sanitation data and information, as well as environmental information, are also surveyed, collected, managed, and provided by a number of institutions in accordance with the law. Therefore, the data processing is more complicated, and there are limitations in the usability or information sharing. However, these can be partially overcome by applying advanced ICT technology. For example, the water-related information system managed by HRFCO (www.hrfco.go.kr, 2023) provides water-related data and information collected from branch offices and assistance groups. Those systems as listed in <Table 2-4> are operated individually, but the accessibility is an open system for public and private users based on ICT technology. This means that anyone can access and get all data and modules released by the government through the Open API (Vtw, 2016).

Water and environmental information have been collected and managed by categorizing them into water resources, water quality, water supply and sewage, and solid and liquid waste. They have been assigned to the relevant institutions according to water use, public water safety, and water environment sectors. Each relevant institution has carried out data processing using the developed information systems. However, there are clear limitations in integrating and using information systems developed by individual institutions, but this has also been greatly improved through data research and informatization projects stipulated in the Official Information Disclosure Act (Republic of Korea, 2021) or each related law.

Information accessibility is being increased through the opening and integration of water and sanitation data, and real positive effects are being achieved. However, from the perspective of integrated management, it is necessary to establish mid- to long-term informatization strategies and policies to build an information platform and improve the usability of water management information. It is also necessary to modernize monitoring of the water and sanitation sector, improve analytical tools, invest in water knowledge, and build open access and real-time centralized information systems.

As has been emphasized, ICTs have various advantages in realizing information system functions well. Schaub-Jones (2013) advocated that putting in place an effective ICT system can make a visible impact on the ground, and it can pay for itself quite quickly in terms of efficiency gains and even costs saved. Opposingly, it is also important to remember that there are disadvantages to keep in mind. There are still lessons to be learned and questions that need to be further investigated and answered (Schaub-Jones and Kaliski, 2017). There is clear evidence that ICT can assist with the management functions of the WASH sector, and the literature is optimistic about the value of ICTs (Champanis *et al*., 2013).

3.4. Implications of ICT Technology and Applicability Assessment for Ghana

One of the objectives in this research is to support the Ghanaian government's integrated strategic plan for the WASH sector through the development of Ghana's ICT-based water and sanitation IMS. As the case of Korea shows, most rapidly developing ICT technologies are mainly used for water and sanitation sector information management systems. The potential of information and communication, such as mobile and the internet, which have become typical means of communication, exerts great power by integrating all sectors and areas into one. It should support the major policies and system improvements of the Ghanaian government based on the WASH-related overall development policy framework. In this context, this section analyzes the applicability of the ICT-based information system by referring to Korea's cases and international experts' remarks on Ghana's WASH.

As analyzed in Chapter 2, the demand for developing an integrated information management system in the WASH sector in Ghana can be assessed from three perspectives: 1) In terms of institutional framework, it is about institutional improvement measures for WASH facility maintenance and systematic upgrade of water resource facilities and development of field-oriented feasible policies. 2) In terms of technical instruments, it is to strengthen WASH work based on information by using advanced measurement technology through an ICT-based WASH IMS. 3) In terms of the market environment, it is to realize the diversification of service provision based on the planned WASH policy (AQUAYA, 2020).

Informatization can actively induce participation in the private sector by providing WASH market information. Services in engineering, design and construction of infrastructure, and household waste management, which are currently mainly undertaken by private actors in sanitation projects, can be further strengthened. The integrated information management system supports the development of a packaged business model such as integrated domestic-industrial wastewater, and can expand user-oriented service provision capabilities by actively utilizing ICT technology.

It is certain that the implications of Korean's experiences can help Ghana identify the success factors of information management system. The factors are a collective term for a system used for coordination, control, analysis, visualization, and use of information. In the water and sanitation sector, information management structures can offer a "systemic" approach as one of the key ways to strengthen the sector capability. There are three reasons for operating a robust information system: 1) to achieve common objectives among stakeholders on the state and issues of the sector, 2) to serve as evidence for decision-making

at all levels, and 3) to use as a means to evaluate the impact of strengthening management efforts in the sector and solving problems (Kornkaew, 2012).

The ICT-based information management system can provide the ability to combine both types of information inventory and governance link required by the sector. The simplicity of a system that allows stakeholders to operate and manage the system with minimal external support is required. An evidence-based approach (gradual development, piloting, upgrade, and implementation to allow for widespread ownership and institutionalization) is needed to ensure that clients can engage and leverage the benefits of the system. It will be able to integrate the government's own planning, budgeting, monitoring and evaluation, and reporting systems (Sugiana and Syaroni, 2019).

In other ways, Mehdi and Beikzad (2013) pointed out human-caused factors among the failure factors of information management system development, as can be seen everywhere. This is a case where the administrator lacks information and the user cannot accurately define what information they need. The lack of understanding of the community's information needs and the designer's lack of understanding of the users affect it. This is a case where the manager lacks information, and collaboration with the developer does not work properly. Lack of user participation in all stages can be a factor of failure. Lack of accurate data required for design can also be a factor of failure.

Cultural, economic, political/legal, and technological factors may influence partial key issues (Watson *et al*., 1997). Most WASH information is not generated in a format compatible with the information management system framework. When there are many stakeholders, it can be difficult to reach agreement on the information handled by the system. In particular, political interests can be dominated by an instinct to hide the dark side of WASH information. The way to ensure the continuity of system management may be insufficient due to the organization's personnel management policy or the likes and dislikes of positions.

It is necessary for all stakeholders to recognize the need and importance of an information management system. There is a need to harmonize the existing and set standards for designing the future. It should be possible to strengthen and systematize the basic capabilities required to build an information management system.

In most information systems, ICT application is conceptualized as client (local level or service user) and server (central level or service user). K-water and K-eco hold a central integrated information server and local governments and stakeholders are a client. ICT is a cooperative structure in which a specialized management agency at the central government

level (which has advantages in manpower, technology, and finance) provides a system necessary for local level agencies to collect and analyze information as prescribed by laws.

The central government also provides the necessary expertise, resources, and information to implement sector-specific information systems successfully. Therefore, most of the water and sanitation sector information systems have been currently developed and operated by the agencies affiliated with the Ministry of Environment in Korea. These systems and context are somewhat different between Ghana and Korea, but we must pay attention to the implications as they are in line with the reality facing Ghana.

4. Technical Solutions for Ghana's ICT-based Water and Sanitation IMS

4.1. Technical Feasibility of ICT-based Water and Sanitation IMS

ICTs usually use computer-based technology and the internet to make information and communication services available to a wide range of users. ICT products are helpful to store, retrieve, manipulate, and transmit information electronically, and it is generally understood to encompass both equipment and services that facilitate the electronic capture, processing, display, and transmission of information.

This section therefore ascertains the tailored technical feasibility of implementing an ICT-based water and sanitation IMS in Ghana. This is to ensure that the system will be able to function in accordance with users' occupational requirements and will also work effectively within the organizational condition. Additionally, the system will be able to provide a sufficient information management system that is needed by Ghanaians.

Water and sanitation are characterized by lots of data sourced from different locations. It is important to adopt a suitable data collection and management technology. Information management, blockchain, data security, and smart contracts are typical applications. The use of these technologies is very essential when planning an information management system (Demestichas and Daskalakis, 2020). <Table 2-7> lists the digital tools enabling ICT capabilities categorized by communication type.

<Table 2-7> ICT Technics and Tools for Information Management Systems

Communication Type	Tools and Technics
Multimedia Pcs, Laptop, Notebook	Combination of internet connectivity with PCs and laptops
Cctv, Digital Camera	Connected with PCs and laptop
Lan and Wan	Internet- and intranet-enabling networks
WWW (World Wide Web)	Internet, online databases, video conferences e-mail, discussion lists and newsgroup and chat digital libraries/e-books/e-journals/e-databases
Floppies, Cds, and Dvds, Flash Drives	Offline databases/storage devices
Cell Phones	With internet connection, digital camera and moving pictures, digital locations
Computer-Mediated Conferences	Video conferencing/telemedicine
Telecommunication Satellites	Not used much in WASH sector

Source: Demestichas and Daskalakis (2020).

Ghana has been proactive in embracing ICT solutions in various sectors, including WASH. While there may be challenges related to infrastructure and connectivity in certain areas, with careful planning and leveraging the existing resources, it is technically feasible to implement an ICT-based water and sanitation IMS in Ghana. The technical feasibility of an ICT-based water and sanitation IMS depends on various factors, such as the availability of suitable technology, the level of connectivity in the project area, and the capacity of the users to operate the system. Being an ICT-based technical solution, it is important to interrogate the ICT factors within the country context. The key factors considered to support the technical feasibility are evaluated in <Table 2-8>.

<Table 2-8> Key Factors Supporting the Technical Feasibility

Key Factors	Assessment
Internet Connectivity	Ghana has made significant progress in improving internet connectivity; however, there are still variations in coverage and speed, particularly in rural and remote areas where access may be limited or unreliable. It is important to consider the connectivity options available and to accommodate offline data collection and synchronization when internet connectivity is limited.
Mobile Penetration	Ghana has a high mobile phone penetration rate, with a significant portion of the population having access to smartphones. This provides an opportunity to leverage mobile technology for data collection, surveys, and monitoring. Developing mobile applications and SMS-based solutions can be used to gather data cost effectively.
ICT Infrastructure	Ghana has invested in ICT infrastructure development, including the establishment of data centers, internet exchange points, and fiber-optic networks. These infrastructure developments support the implementation and operation of an ICT-based water and sanitation IMS.
Government Support	The Government of Ghana has recognized the importance of ICT in development and has undertaken initiatives to promote digitalization and e-governance. This support creates an enabling environment for implementing ICT-based systems in various sectors.

<Table 2-8> Continued

Key Factors	Assessment
Existing ICT Initiatives	Ghana has already implemented various ICT initiatives in sectors such as healthcare, education, and agriculture. These initiatives have provided valuable insights and lessons learned that can be applied to the implementation of an ICT-based IMS.
Technical Expertise	Ghana has a pool of skilled IT professionals and software developers who can contribute to the implementation and customization of an ICT-based information system. This expertise can ensure that the system is appropriately designed to meet the specific requirements of the Ghanaian context. They can also provide the necessary user support and maintenance of the system.

Source: Author.

The WASH sector in Ghana has also seen an increase in ICT applications mainly for the purpose of improving data collection, information flow between decision-makers, and engagement with the wider public. An ICT-based water and sanitation IMS is basically a kind of software solution that is designed to collect, store, analyze, and distribute data relating to water, sanitation, and hygiene projects. The system can provide real-time information on the availability and accessibility of water and sanitation services, which can help stakeholders make informed decisions and ensure effective project implementation.

These technologies can be defined as a software system responsible for data storage, search, and retrieval. Some potential benefits of such a solution include more efficient information tracking and processing, improved security, and customer relationships, as well as better control of supplies (Ping, 2011). Pagoropoulos *et al.* (2017) underscore the importance of relational database management systems (RDBMS) and database handling systems. <Table 2-9> briefly describes some of ICT technical solutions.

<Table 2-9> Categorization of the ICT Solutions for Ghana's Water and Sanitation IMS

General Categorization	Subcategorization	Applicability
Communications	Adaptive links Cache-based transmission Communication infrastructure M2M, P2P communications Routing protocols Wireless transmission	 3G, 4G (LTE), 5G Internet (ADSL and VDSL) Broadband Narrowband
Computing Technologies	Cloud computing	Platform as a service
CPS	Robotics	Automation
Data Analysis and AI Algorithms	Data analytics Data and model integration Data visualization Dynamic programming Evaluation models	Data driven Statistics Analytics Decision-making Dashboard

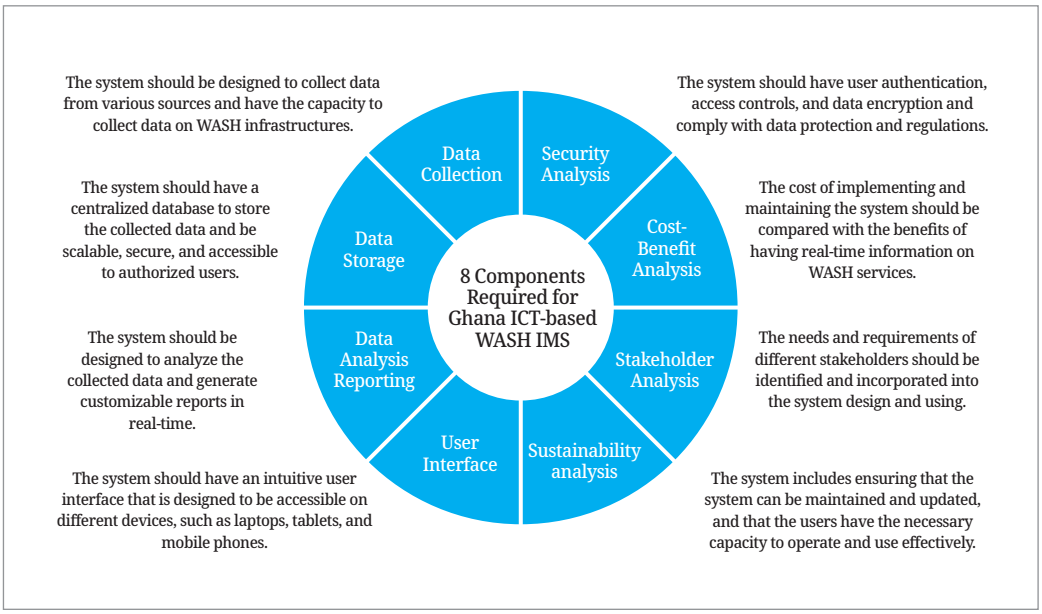
<Table 2-9> Continued

General Categorization	Subcategorization	Applicability
Data Collection and IoT	Asset tagging and RFID BIM, IoT Satellite imaging and GIS SCADA Wireless sensor networks	Tag and RFID Data sensing Satellite image GIS based Map based
Data Management and Storage	Data privacy/security Information management system, RDBMS	IMS (database server or platform type)
Software and Simulation Technologies	Digital platforms Simulation technologies Smartphone applications Software tools	Open AI Software as a service Apps SNS
Technologies	Smart grids, smart products	(Long-term vision)

Source: Author.

In analyzing the technical feasibility, it is essential to also conduct a thorough analysis of a tailored ICT-based water and sanitation IMS before implementing the system. The eight basic components of the system required for Ghana are defined in [Figure 2-6].

[Figure 2-6] Eight Basic Components of Ghana's ICT-based Water and Sanitation IMS



Source: Author.

The system should be designed to enhance the capacity of users to operate and use the system effectively. An ICT-based water and sanitation IMS has the potential to revolutionize the way the WASH sector is managed and monitored, including how WASH projects are implemented. However, it is essential to ensure that the system is technically feasible. If, as it has been argued when introducing ICTs, the best technology is "often the one you already have, know how to use, can maintain, and can afford," for most of the world, the mobile phone fits these criteria quite well (Trucanao, blogs.worldbank.org). For this argument and requirement, Ghana's current ICT infrastructures can be assessed to have matured enough to develop and operate an ICT-based water and sanitation IMS.

4.2. Technical Elements of Information Management

The technical elements of an information management system are basically the interrelated components that must work together to facilitate the collection, processing, storage, and dissemination of data and information. The role of this information management system is to enable users to create new value for the organizations such as decision-making, coordination, control, analysis, and visualization (Laudon and Laudon, 2011). Therefore, in order to design an ICT-based information management system, it is important to check the elements that make up the system and to devise the means to combine these elements for the desired system. ICT generally uses the interrelated components in an information system to allow it to collect, process, store, and disseminate information.

It is important to identify key thematic areas for the sustainable use of ICT in WASH as analyzed by Ndaw (2015). The purpose of using ICT is to strengthen monitoring and inventory of infrastructure, planning and programming initiatives, operational efficiency and service delivery improvements, strengthen the consumer voice and governance, and financing for public-private partnerships (Schaub-Jones *et al*., 2013). Users have obtained their goals through the processes that the information system has created to capture the data, process them, and present the required information for management decision-making.

Each has a specific role, and all roles must work together to have a working information system. In the stage of actual system implementation, all elements must be reviewed, but it is economically effective to build a system using essential elements. Hence, information management systems can be viewed as having six major components: 1) hardware, 2) software, 3) network communications, 4) data, 5) people, and 6) processes as listed in <Table 2-10>. The first four components among them can be grouped as technology, while people and processes are components that deliver value to organizations in how to use the technologies to meet specific organizations' goals (Laudon and Laudon, 2011).

<Table 2-10> Components of an ICT Information System and System Integration

Component	Description	Procurement in Ghana
Hardware	Computers, hard disks, keyboards, iPads, mice, pens, disk drives, printers, and flash drives	Possible for all needs
Software	System software (operating system), application software	Support necessity for application software
Data	A representation of the properties of an entity, as numerical values by numbers, letters, symbols, etc.	Ability to collaborate on data creation, collection, processing.
Networking Communication	Wired technologies Wireless technologies	Most possible, but application software supported
People	Users, technical developers, business professionals	Capacity building needed, and system maintenance planned
Process	Business process reengineering, enterprise resource planning Customer relationship management	All sectors available

Source: Prezi (https://prezi.com, accessed on Feb. 10, 2023).; EUROPEYOU, What is Information and Communication Technology? (https://europeyou.eu, accessed on Feb. 5, 2023).; TechTarget, Mobile Data (www.techtarget.com, accessed on Feb. 15, 2023).

The most important matter in developing an information management system is the technology to capture data, otherwise hardware and software are always available on the market. ICT-based data acquisition has the advantage of being able to digitize the existing paper document work completely. As can be seen in the example of GWCL, the mobile data service in SCADA system is not sufficient to collect real-time data. The data service is a structure that utilizes the internet. Since the capacity of mobile data service dominates the capacity of ICT-based data acquisition, it is very important part of the information system.

A database system is another core part of an information system. A database is a system for systematically managing the data. A database is usually a collection of interrelated data necessary to perform the tasks of a specific organization, and is composed of integrated and stored operation data with minimal duplication. It technically has several characteristics. Databases store, organize, and process information in a way that makes it easy for users to go back and find what they are looking for. It has features such as real-time accessibility, continuous evolution, concurrent sharing, content reference, and data independence.

Overviewing the modern database technology, spreadsheets process numbers and databases process information, specifically structured information. Databases can be designed to do just about anything with information such as tracking, organizing, and editing data. It also collects data and produces reports or serves as the foundation for information-rich, dynamic websites. The most common database technology is the relational database. Relational databases store data in a normalized way, which means the data are split up into

different tables to avoid redundancy. Relational databases offer a versatile tool for both data storage and data management. Both user-facing applications with high demand for performance and reporting can be backed by a relational database (www.upwork.com).

Data types are also important because they are attributes of data that tell a computer system how to interpret their value. Understanding the different data types allows users to pick the one that matches their needs and goals. When dealing with datasets, data scientists use data types to determine the statistical analysis they can apply to the data for the best results. In addition, understanding data types is critical for proper exploratory data analysis (EDA), which is one of the essential parts of a machine-learning project. This is because data types are also a way of classification that specifies what type of mathematical operations can be applied to the variable without error (www.upwork.com).

There are two main types of variables: categorical and numeric (www.upwork.com). A variable is a characteristic that can be measured and another can be classified by the level of difference in state. At higher levels, there are two kinds of data: quantitative and qualitative. These two types of data break down further into four classifications. The two subcategories of qualitative data are nominal and ordinal data. The two classifications of quantitative data are interval and ratio data. These types of classifications are important to machine learning, artificial intelligence, and market research. As identified from the previous analysis of the Ghana WASH industry, all types of data must be informatized as described in <Table 2-11>.

<Table 2-11> Data Types and Characteristics in the WASH Information System in Ghana

Data Type	Characteristics	Example
Qualitative	Qualitative data are descriptive and cannot be counted or measured using numbers. These are categorical data—information can be sorted by category, not number. They deal with characteristics and descriptors observed subjectively.	WASH service level, resident living condition, regional service grade, etc.
Quantitative	Quantitative data refer to variables with quantifiable and numerical values. They deal with numbers and information that can be structurally measured. These data are used for mathematical calculations and statistical analysis. The data can be collected through instruments, tests, experiments, surveys, reports, and metrics.	Water supply and water quality items, waste generation and throughput, beneficiaries of WASH services
Nominal	Nominal data refer to variables that name or label a category. They are data that are observed but not measured. Nominal data have no numerical value; instead, they name a variable without applying any particular order.	Areas subject to water supply services, waste disposal service areas, etc.
Ordinal	Ordinal data are statistical data with a set order or scale. This means ordinal data can be classified into different categories with a natural ranked order. However, the distances between the values are uneven or unknown.	WASH service benefit by sector or WASH infrastructure by region

<Table 2-11> Continued

Data Type	Characteristics	Example
Interval	Interval data refer to information measured along a scale with equal distances. The distances or spaces in between the adjacent values are called intervals. So, the interval scale represents information about the order, and it gives meaning to the difference between two values.	Quality inspection, waste collection, fecal treatment, transportation of collected waste
Ratio	Ratio data are quantitative data that have an equal and definitive ratio between each value. Unlike interval data, ratio data have an absolute zero. It means ratio variables cannot have negative values.	Water supply rate, waste collection rate, fecal treatment rate

Source: Upwork, Different Types of Data You Need to Know (www.upwork.com, accessed on May 10, 2023).

In ICT, the technology that should be carefully contemplated is mobile data service. Mobile data are sent from and received by a phone or a tablet using a cellular connection. They rely on mobile data anytime they connects to the internet on the phone without using a Wi-Fi network (www.whistleout.com). Generally, cellular or mobile data are technology that lets actors connect wirelessly using cell towers that transmit and receive radio signals. While the modern-day use of cellular data is starting to lean more toward connecting to the internet, cellular network technology is one that originally enables actors to have calls or send texts wirelessly (https://cellularnews.com).

Mobile data creates a wireless connection by enabling devices to communicate through radio frequencies. The data uploaded or downloaded via a mobile network are broadcasted from or to a central cellular base station or macro-cell, often housed on a cell tower. A single macro-cell can cover a broad geographical location, and multiple cells can overlap to transmit data effectively and ensure coverage across thousands of miles (www.techtarget.com). Mobile data collection originated from a need to improve on the old paper-based data collection methods. Modern technology is proven to improve the speed and accuracy of data collection, service delivery, and staff performance (Luptak, www.resco.net).

Since society relies heavily on the use of internet data, there are five reasons why an information system needs good mobile data services to support data gathering activities (https://jakartaglobe.id): 1) communication, 2) mobility, 3) download and upload, 4) smartphone, and 5) mobile data service in the future of the internet. Becoming the new currency of the digital age, the information management system in Ghana may rely on the flexibility of smartphones and mobile data just as Korea has been doing.

4.3. Technical Solutions for Water and Sanitation IMS

In Chapter 2, in order to devise the most suitable information management system for the WASH sector in Ghana, the overall status of the WASH system and market are analyzed, and the communication infrastructures that could utilize ICT are also reviewed. In Chapter 3, Korean's water and sanitation sector information management system is analyzed in depth to identify which factors of ICT contribute to the improvement of the competitiveness of the national water environment. In addition, in the previous sections of this chapter, the technical solution analysis is conducted to design the information management system for the WASH sector in Ghana. The technical analysis is not simply based on ICT technology, but a series of processes of data and information utilization are reviewed based on related basic engineering such as environment and sanitary engineering and a method of uniting them with the service chain is devised.

For the purpose of understanding the information requirements of the water supply system operated by GWCL, there is the need to be acquainted with ATMA production, which is the axil of GWCL's production, representing 78% of its total designed water supply capacity of 204.9 MGD nationwide (www.gwcl.com.gh). The ATMA region is mandated to execute three major services: 1) potable water production, 2) bulk water transmission, and 3) distribution water quality management. Therefore, informatization of the water sector can target the data generated from the components of water supply system as listed in <Table 2-12>.

<Table 2-12> Composition of the Data Structure in the Water Supply System

Element	Description	Data
Key Mandate	- Potable water production - Bulk water transmission - Distribution water quality management	Policy, profile structure, fee, employment
Weija	- First plant constructed in 1914 with an initial capacity of 1,000,000 gallons/day - Current design capacity of 54.2 MGD - Using the Densu River at Weija - Three independent treatment systems (Candy, Bamag, and Adam Clark) - Areas of supply: Western Accra and Kasoa in the Central Region	Treatment plant, water supply statistics, facility, water quality, pipe network, burst and leakage, energy consumption
Kpong	- Constructed in the 1950s consisting of Old Works (Candy, Tahal, and Siemens), New Works, and China-Gezhouba plants - The biggest treatment plant in Ghana with a collective design capacity of 101.2 MGD - Source water from the Volta Lake - Areas of supply: Tema, Accra East, and some areas around the Eastern Region	Treatment plant, water supply statistics, facility, water quality, pipe network, burst and leakage, energy consumption

<Table 2-12> Continued

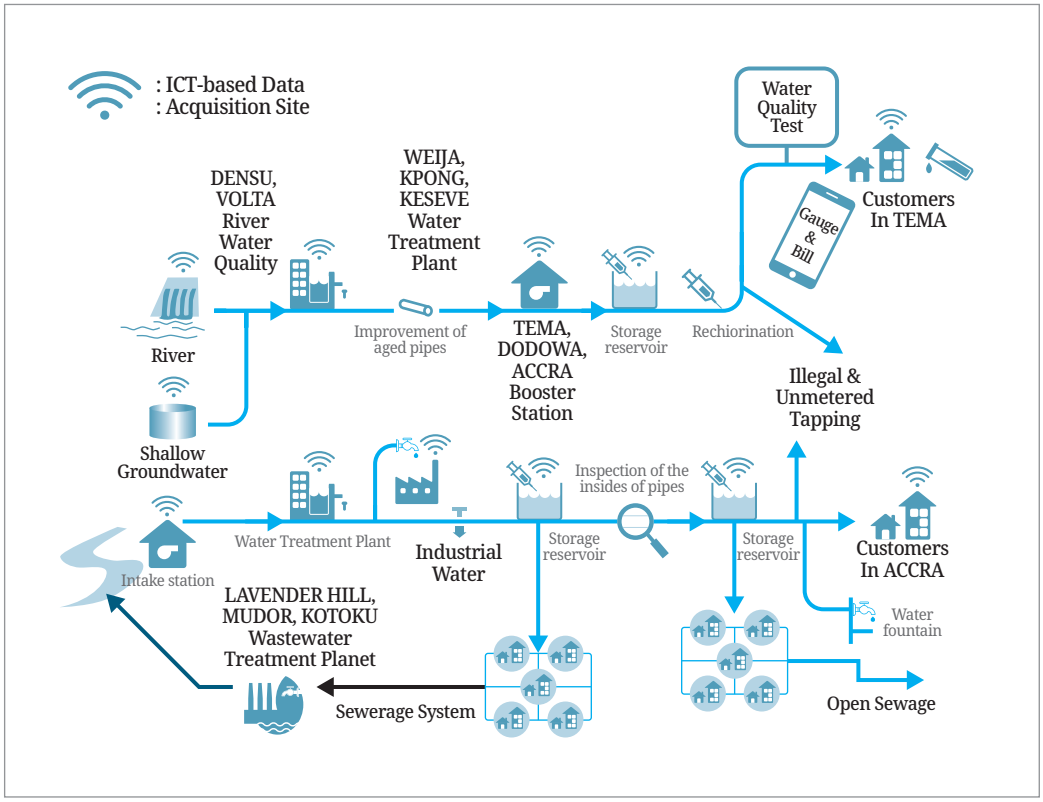
Element	Description	Data
Keseve	- Small plant with capacity of 0.3 MGD at Ada - Raw water source: Volta Lake - Areas of supply: Ada and Volta Regions	Treatment plant, water supply statistics, facility, water quality, pipe network, burst and leakage, energy consumption
Booster Stations	- Tema Booster Station is fed by high-lift pumps from the Kpong New Works via a 1,050-mm pipeline into three reservoirs. - Dodowa Booster Station receives water from the China-Gezhouba plant at Kpong via a 1,200-mm pipeline into a pond. - Accra Booster Station receives water from Tema Booster via 81-3mm pipeline and a 915-mm pipeline from Dodowa Booster station.	Pump specifications, pipe pressure, flow rate, energy consumption, storage reservoir
Pipeline	- Mobile team responsible for maintaining all bursts and leakages on major transmission mains in the region	Monitoring data

Source: GWCL, ATMA Production (www.gwcl.com.gh, accessed on Mar. 7, 2023).

The data and information to be collected at the raw water intake station are the water quantity and quality data. The water quantity can be obtained through a bulk meter installed in the water intake facility, and the water quality data can be obtained from the treatment plants, namely, Weija (which gets its water from the Densu River), Kpong (which gets its water from Lake Volta), and Keseve (sourced from Lake Volta). In the case of the Weija water intake facility, a selective water intake facility is installed, and water is taken at an appropriate water depth considering the color, turbidity, and *p*H of the water layer or water depth. In the process of supplying water that has undergone purification treatment to the Accra Region through pipelines, water quality tests are conducted at three points. The water quality test is conducted for hourly sampled water in the ATMA production laboratory.

The data chain of Ghana's water supply can be conceptualized as the process of raw water intake, purification, distribution, and tap water as depicted in [Figure 2-7] The Densu River located west of Accra and the Volta River flowing east of Accra are used as water sources. GWCL uses the Weija Dam on the Densu River for its water source so that lake water quality should be included in the water quality survey. The water treated at the Weija Treatment Plant is supplied to the central and western parts of Accra and Kasoa in the Central Region. Using the Volta River as its water source, the Kpong Treatment Plant covers the city of Tema and the eastern part of Accra. The Keseve Treatment Plant is located in the lower reaches of the Volta River and supplies mainly the eastern coastal areas. There are also three pressurization stations, booster stations, at Tema, Dodowa, and Accra.

[Figure 2-7] Water Supply and Sewerage Systems in Accra and Surrounding Areas



Source: K-water, Smart Water Management (www.kwater.or.kr, accessed on Jan. 15, 2023).

Another important part of Ghana's water and sanitation sector is the domestic sewage and wastewater treatment. Domestic waste including urban waste is largely classified into household sewage, food waste, and fecal waste. The fecal waste is classified into human waste and livestock manure. Most of the sewage is open sewage in Ghana, and the area where the collection pipe is installed is gathered and treated at the sewerage treatment plant. The biggest problem in the urban areas of Ghana is lack of a treatment facility for general sewage and fecal sewage, since sewage collection pipes are installed in only a very small area. General sewage is discharged into rainwater drainage systems in the city area or around houses. In the case of fecal waste, a septic tank is installed in a house where a toilet is installed, and when the septic tank is full, then it is collected by a fecal treatment company. In some cases, individuals directly process it at the house level. The dataset for this sector must be collected as defined in <Table 2-13>.

<Table 2-13> Dataset for the Water and Sanitation Sector

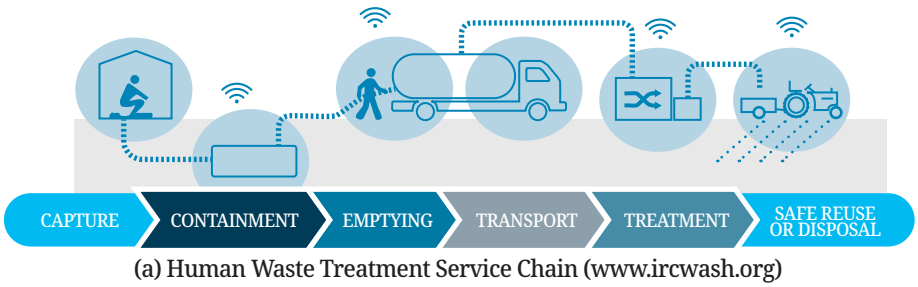
Sector	Description	Data
Wastewater	Any combination of household, industrial, commercial, or agricultural activity, surface runoff/rainstorm, sewage inflow, or sewage penetration	Sewage statistics Map (GIS) Blueprint Recycling
Solid Waste	Garbage, construction debris, commercial refuse, sludge from water supply or waste treatment plants, or air pollution control facilities, and other discarded materials	Statistics Map (GIS) Collecting system Recycling
Liquid Waste	Any waste material that passes the definition of a “liquid”	Statistics, Map (GIS) Sewage system
Human Waste	Mixture of human excreta, water and solid waste (e.g., toilet paper or other anal cleansing materials, menstrual hygiene materials)	Statistics Map (GIS) Sludge
Dangerous Waste	Waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. Hazardous waste also includes different physical forms, including solids, liquids, and gases.	Statistics Map (GIS) Collecting system
Medical Waste	Waste generated by health care activities, ranging from used needles and syringes to soiled dressings, body parts, diagnostic samples, blood, chemicals, pharmaceuticals, medical devices, and radioactive materials	Statistics Map (GIS) Collecting system

Source: Author.

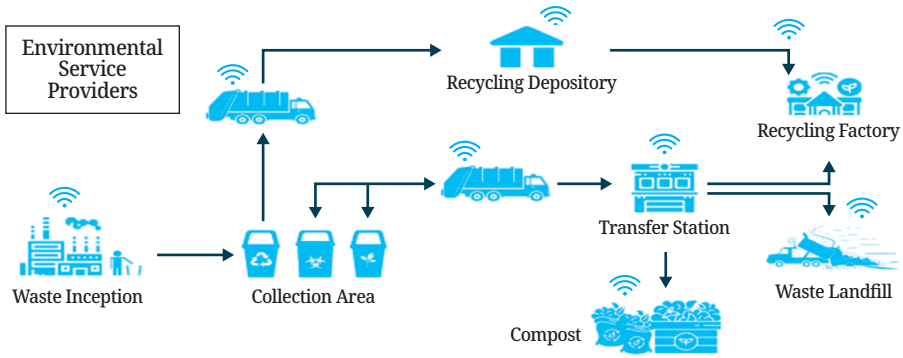
[Figure 2-8] is a more detailed mapping of the domestic waste treatment method that is currently generalized in Ghana. From the data collection point of view, the service chain of fecal and solid wastes can be reconstructed as shown in [Figure 2-8]. In the case of processing through private companies or individual operators currently in operation in the Accra region, data can be acquired through these companies and operators. However, in the case of direct treatment at home, it is impossible to measure the amount of waste, which is a task to be solved for informatization.

For processing through a service company, more accurate metering is possible because the service company meters the amount and charges a fee for the throughput. For fecal processing, emptying volume, transport distance, fees, and processing frequency, etc., can be informatized. Informatization can also serve as a catalyst to improve service delivery further.

[Figure 2-8] Household Waste Treatment System and Service Chain in Accra



(a) Human Waste Treatment Service Chain (www.ircwash.org)



(b) Household Solid Waste Treatment Service Chain (https//safeculture.com)

Source: SafetyCulture, Waste Management System: A Guide (https//safetyculture.com, accessed on Jan. 10, 2023).

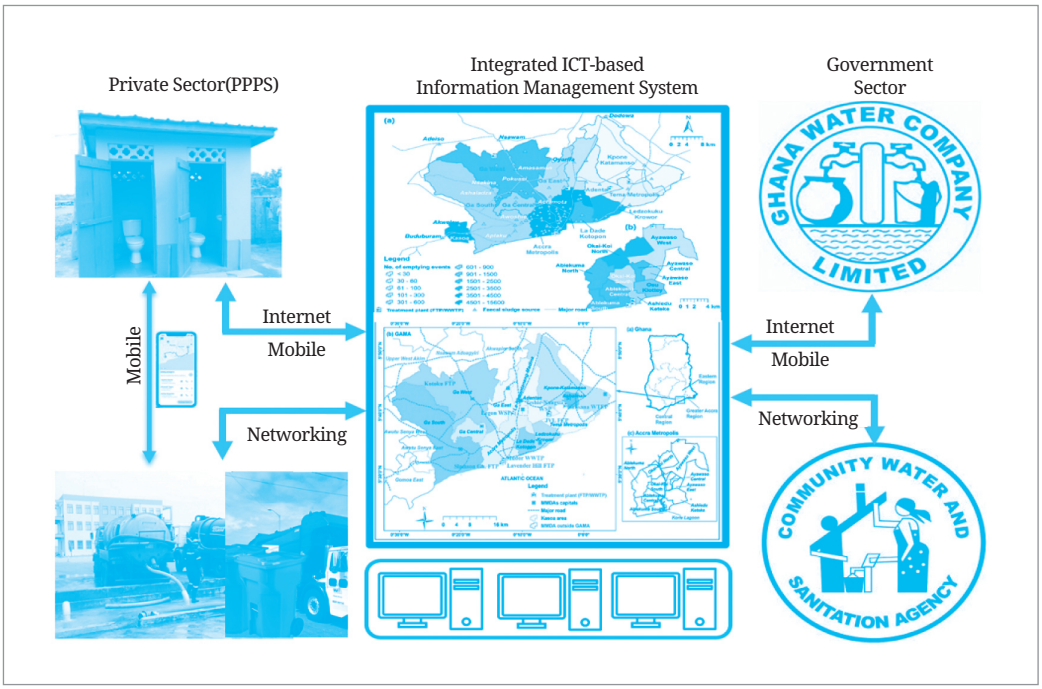
The technical analysis for establishing the information management system of the ICT-based WASH sector does not mean only the technology itself in the area of ICT. Actual ICT technology can be simple compared to the complexity of water and sanitation engineering. ICT solutions for a water and sanitation information management system are sets of water and sanitation engineering, market service, and system software and hardware that are bundled together and designed to help businesses manage complex technical operations. Because the technological elements constituting ICT can be regarded as technics or tools, they can be activated, controlled, managed, and displayed through application software.

With a focus on an informatization project, the project goal must be clear and realistic, and a concrete knowledge base for field requirements must be considered (Ball *et al.*, 2013). It is necessary to judge whether the applicable mobile solution in building an ICT-based IMS is “appropriate” for the applied technology. When implementing an information system, it is important to evaluate which technology to apply, but more emphasis should be placed on the value of the data to be acquired. It is also necessary to maintain consensus to promote

ICT-based initiatives through government policies and frameworks. In order to implement a user-centered information system, all interested parties should be able to understand the system fully and recognize what the clear incentive is through the system.

Consequently, the most important objective in developing an information system is to acquire the desired data in an appropriate place, time, and method by utilizing various technical elements. However, modern information management systems do not imply only simply acquiring data, but store, manage, and analyze it, and increase the value of data or information through sharing within the organization or with stakeholders in the concept of knowledge management. From this point of view, the conceptual mapping of sector integration for the establishment of a water and sanitation information management system in Ghana is suggested as shown in [Figure 2-9].

[Figure 2-9] Display of Water and Sanitation IMS in Ghana



Source: Author.

As implied in [Figure 2-9], networking the CWSA to the integrated system is intended to actively utilize the existing DiMES. As analyzed in <Table 2-3>, the gap between urban and rural area in water and sanitation services is very large. Many rural areas still remain underserved areas of information. Technically, there are many difficulties in linking the existing system to the new system, and it may be disadvantageous in terms of cost. Nonetheless, the integration of DiMES into a national-level integrated system is intended to

ensure that rural sanitation services are not alienated from the government's WASH policy and that rural sanitation services are not discriminated against from urban ones.

BaSIS should also be included in the suggested system for the same reason. Currently, BaSIS and DiMES are carrying out various functions, but these systems are basically used to monitor and evaluate the improvement status of WASH infrastructure rather than information management. In the long term, it will be possible to integrate or replace the existing system with the new system. However, considering the current situation in Ghana, it is necessary to actively seek ways to utilize BaSIS and DiMES while maintaining them. Ultimately, it should be taken into account that urban areas with predominant ICT infrastructure can benefit greatly from water and sanitation services compared to rural areas with internet illiteracy.

The mappings of the information management system concept for the ICT-based water and sanitation sectors in Ghana are already presented in [Figure 2-7], [Figure 2-8] and [Figure 2-9]. The technical applicability in the telecom sector is briefly analyzed in Chapter 2. The ICT-based information management system, which can be called a kind of the total solution, should fully reflect the country's technical bases to be applied and also additionally considering the implications of Korean's experiences presented in Chapter 3. Furthermore, the lessons and achievements of international organizations and expertise relating to the information management system of the water and sanitation should be referred.

The choice of technology in an ICT-based water and sanitation information management system used in developing countries is a very important aspect as Ndaw (2015) recommended. Technical design, which refers to the appropriateness of the technology platform to meet information needs, is the second key aspect to be taken into consideration. The technological appropriateness and flexibility of the ICT application should be regarded in consideration of the environments in which it is to be utilized along with the specific purpose of its application. The surroundings mean not only technological appropriateness but also sociocultural, political, legal, economic, and environmental appropriateness.

Another important consideration is the level of telecommunications service when considering the level of technology required for building an information management system in Ghana as analyzed from <Table 2-7> to <Table 2-13>. Taking into account the emphasized points in this research, ICT is a concept that emphasizes communication technology and actively utilizes it to build an information system. <Table 2-14> shows the level of telecommunications service currently available in Ghana.

<Table 2-14> Applicability of ICT Technology in Ghana

Communication	Technology	Applicability in Ghana
Multimedia PCs, Laptops, Notebooks	Internet connectivity with PCs and laptops	Highly in government and city area
CCTV, Digital Camera	Connected to PCs and laptops	Mostly possible if necessary
LAN and WAN	Internet and intranet, broadband	Mostly available
WWW/WAS (World Wide Web)	Internet, online databases Video conferences, e-mail, chat Digital libraries e-books/e-journals/e-databases	Mostly available (internet penetration rate: over 60%), will be over 65–70 in 3–5 years
Floppies, CDs, DVDs	Offline databases	Memory sticks and external drives are mostly used
Mobile Phones, Mobile Data Services	With internet connection, digital camera and moving pictures	Most possible
Computer-Mediated Conferences	Video conferencing, Tele-Zoom	Most possible, generalized
Satellite Telecom		Not prevailing

Source: Author.

Based on the literature review and the opinions of local experts, it is technically judged that there will be no major difficulties in implementing the integrated information management system for the WASH sector, which is proposed in this research. In the case of Ghana, the penetration rate of mobile users is progressing faster than the speed of infrastructure development needed in the water and sanitation sector. The informatization in modern society is not simply proportional to the economic scale of the country, but ICT can be regarded as a key facilitator as proved by Korea's cases.

4.4. Proposal for an ICT-based Water and Sanitation IMS

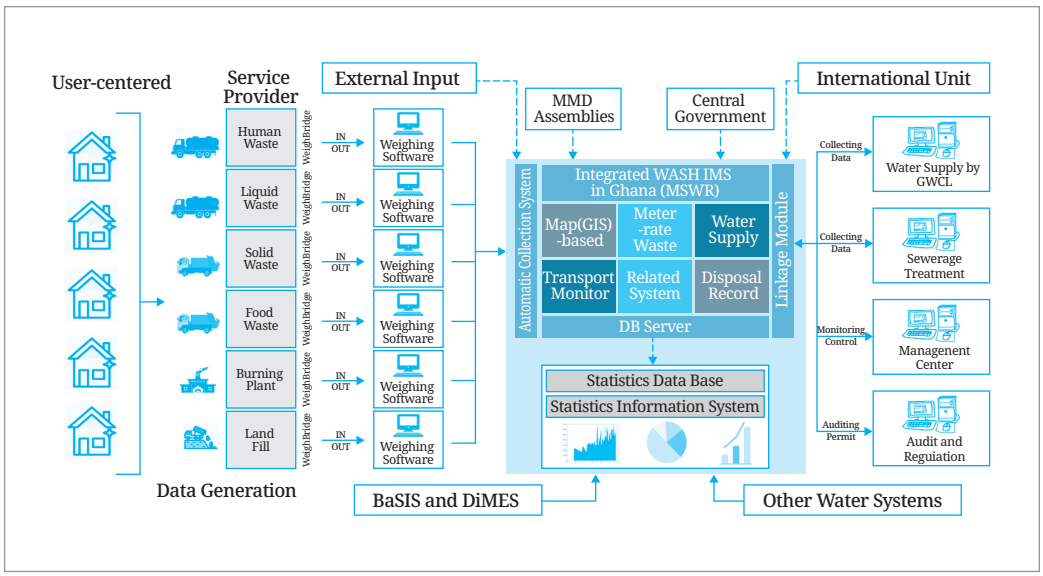
ICTs can be a key enabler for institutional transformation to address the demand for improved water and sanitation services for both rural and urban communities (Ndaw, 2015). However, as can be perceived from the cases of Korea, it is not necessary to develop ICT itself or treat it as a specific solution in order to maximize the role of ICT. ICT should be focused more on the value of data or information as a complement to national policy. In the majority of the case study countries, the national ICT policies and frameworks in place were weak, did not specifically address the key issues associated with regulating the use of ICTs in the water and sanitation sector, or did not have accompanying implementation strategies (Ndaw, 2015). These points must also be fully considered in Ghana.

Over the past decade, the WASH sector in Ghana has seen an increase in the use of ICT applications mainly for the purpose of improving data collection and information flow between central and local authorities. However, most of them were not sustainable because the ICT initiatives were funded and utilized by projects and were discontinued after the projects ended. A number of organizations in the WASH sector have information management systems in place, but they use them only for their internal operation (siloed systems).

One of the objectives in this research is to suggest an integrated concept for the WASH sector suitable for Ghana. The insights of Korea's informatization experiences are reflected to reduce trial and error that Ghana has been experiencing in the water and sanitation sector information system. Among many systems developed in Korea, the technologies used in all kinds of information systems introduced in <Table 2-4> and <Table 2-5> in Section 3.1 are incorporated into the ICT-based water and sanitation IMS to be implemented in Ghana as a benchmark.

The system's vision, process, client and server, service delivery capabilities, and governance, as with most information systems, should be considered. In this research, technical solutions are thoroughly reviewed in consideration of the information and communication infrastructures as reviewed in the previous section. The data value chain and service delivery for establishing an ICT-based water and sanitation IMS are presented in consideration of the real market conditions and the affordability of the information system. All elements of informatization are integrally mapped in [Figure 2-10].

[Figure 2-10] Integrated Water and Sanitation IMS

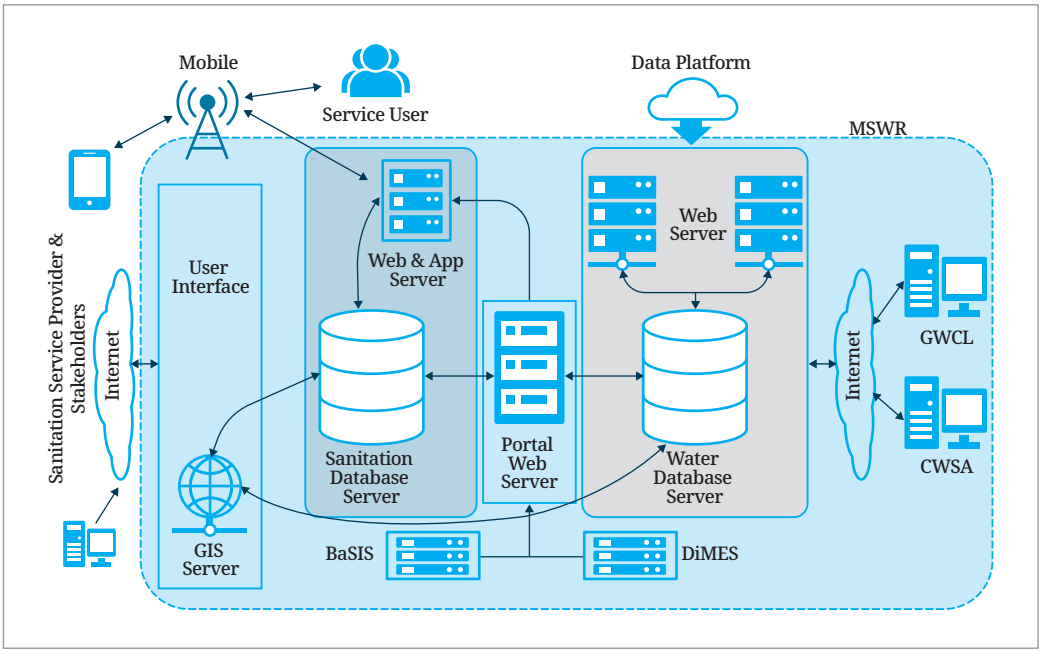


Source: Author.

Based on the key implications of the water and sanitation information systems in Korea and Ghana (refer to Chaps. 2 and 3), a basic conceptual idea of Ghana's water and sanitation sector information management system based on [Figure 2-10] is presented as shown in [Figure 2-11]. The practicality of related technologies as a top priority is basically considered for Ghana's water and sanitation sector information management system. The integrated information management system that the Ghanaian Government strongly wishes to develop is conceptualized. The monitoring and evaluation of the SDG 6 is consolidated into the system. It also attempts to find ways to address the challenges facing the Ghanaian Government while maximally reflecting the requirements of the MSWR.

Basically, considering the business capacity and the level of demand for service delivery, the database server is configured by dividing it into water and sanitation sectors. Each database server is conceived to send and receive data and information through separate web and app servers. In addition, each database server is designed to acquire various geographical data (GIS) to enhance the user-centered service and GPS by linking with the GIS server. In particular, it is conceived to enable web and mobile services for the convenience of service providers in the human waste sector and residents who are service users. The entire integrated system is designed to be managed by MSWR (or authorized subsidiaries such as GWCL and CWSA, etc.), and operators in each sanitation sector are allowed to use the server through the user interface (e.g., ESPA, etc.).

[Figure 2-11] Layout of ICT-based Integrated Water and Sanitation IMS



Source: Author.

Considering the roles of GWCL and CWSA, the two organizations can directly access the system through the internet or there will be a potential system developer and operator like K-water and K-eco that are information system developers and operators in Korea. For the data- and information-sharing network between MMDAs and MSWR in Ghana, the integrated client/server concept mostly adapted in Korea's information systems is recommended to improve the current decentralized information system. In fact, the Ministry of Environment in Korea is supporting its affiliated organizations to carry out many practical tasks because its role as an overseer and supervisory agency is more important than practical works. So, since MSWR is a policy-specialized institution for management and supervision, it will be more efficient for affiliated organizations, GWCL and CWSA, to take charge of the practical works.

To summarize, an appropriate ICT-based water and sanitation IMS for Ghana's WASH sector should be designed to collect, store, manage, analyze, and disseminate data and information relating to WASH interventions effectively. The key features that the proposed system should possess, given available technology and resources include

- **Data collection**: The system should facilitate the collection of accurate and comprehensive data on WASH indicators, such as water supply, sanitation facilities, hygiene practices, and water quality, which can be done through mobile data collection tools, online surveys, sensor-based monitoring devices, among others.

- **Data storage and management**: The system should provide a secure and reliable database to store and manage the collected data. It should have the capacity to handle large volumes of data while allowing for easy retrieval and updating of information and also allow for data backup and recovery. Additionally, it should support data sharing and collaboration among multiple stakeholders involved in WASH activities

- **Data analysis and reporting**: The system should have built-in tools for data analysis, visualization, and reporting. It should support both basic statistical analysis and advanced data modeling techniques to derive meaningful insights from the collected data. The generated reports should be customizable and easily shareable with relevant stakeholders.

- **Integration into existing systems**: The system should be able to integrate into existing WASH-related databases and management systems, such as government databases or third-party platforms to ensure interoperability and avoid duplication of efforts.

- **Real-time monitoring and alerts**: The system should support real-time monitoring of WASH indicators and provide alerts and notifications when certain thresholds are reached or anomalies or emergencies are detected. This helps in timely response and intervention, ensuring that issues are addressed promptly.

- **Mobile accessibility**: Given the widespread use of mobile devices in Ghana, the system should be accessible via mobile platforms to allow field workers to collect data directly on mobile devices, even in remote areas with limited internet connectivity. It should have offline data collection capabilities.

- **Mapping and GIS Integration**: The system should support geospatial data analysis and visualization. It should have the capability to overlay WASH-related data on maps, allowing for better planning, decision-making, and resource allocation.

- **Scalability and flexibility**: The system should be scalable to accommodate increasing data volumes and expanding WASH programs. It should also be flexible to incorporate new features or modules as needed, adapt to evolving technological advancements, and changing WASH requirements.

- **Collaboration and data sharing**: The system should facilitate collaboration and data sharing among different stakeholders, including government agencies, NGOs, and communities. It should have role-based access controls to ensure appropriate data sharing while maintaining data security.

- **Data security and privacy**: The system should have robust security measures in place to protect the confidentiality, integrity, and availability of the data. It should comply with Ghana's data protection regulations and standards.

5. Conclusion

5.1. Conclusion

Lack of timely information on water quantity and quality and other performance indicators has long since been the limitation in water management decision-making. Other challenges and vulnerabilities including the inability to measure accurately the performance benchmarks of water access and use as well as promoting accountability and transparency in the water sector are all attributable to lack of effective monitoring and availability of reliable data.

The United Nations General Assembly recognizes that access to adequate WASH embodies a fundamental human right. This importance is reinforced through the UN 2030 Agenda for Sustainable Development, SDG 6: "Ensure availability and sustainable management of water and sanitation for all." In Ghana this responsibility rests under the ambit of the MSWR, working through its sector water and sanitation agencies, departments, and private sector partners.

This project, which is a research project, seeks to assess Ghana's WASH ecosystem, structures, existing information systems and information flow, and the sector's information management in general with the view of applying the lessons learned from Korea's transformational experience in its water and environmental sanitation sector (e.g., moving from a backward and disorderly system to the standard of developed countries) to Ghana's situation where necessary.

By means of leveraging existing and potential information and communication technologies, the project's ultimate goal is to develop a robust integrated ICT-based water and sanitation IMS that will ensure the availability of quality and reliable sector information at all times to support the MSWR in its efforts in building a resilient WASH sector through effective planning and equitable allocation of WASH resources.

The proposed ICT-based water and sanitation IMS will be able to increase WASH data availability and accountability of service providers and also provide quality and reliable information and insights to the ministry and all stakeholders, to inform decision-making, policy formulation, and planning. Additionally, the project aims to support other development initiatives of the international community through the establishment of partnership and capacity building between the Korea and Ghana Governments, respectively. Another project achievement will be to present the MWSR with an information system

implementation plan to encourage policy development and technology promotion for efficiency enhancement.

It can therefore be concluded that the establishment of an appropriate ICT-based water and sanitation information management system in Ghana's WASH sector has a significant role in improving water utility management and the efficiency, effectiveness, and sustainability of wash programs by enabling evidence-based decision-making, resource optimization, and better coordination among stakeholders. This will lead to increased access to safe water and sanitation, ultimately contributing immensely to the early achievement of Ghana's SDG 6.1, hence, improving the living standards of Ghanaians.

5.2. Recommendation

ICT governance is one of the important factors in the systematic and successful promotion of national informatization policies and projects. As the SMARTerWASH project strengthened the national ICT infrastructure by linking different ICT systems for monitoring and by ensuring interoperability of the systems in Ghana (Knipschild, 2018), the outputs of this research are also expected to provide groundbreaking motivation for Ghana's water and sanitation IMS based on ICT technology.

Although this research dealt only with the ICT-based information management system as the subject, the current water management field in Korea is advancing from ICT to smart water, digital water, and digital twin. Information systems have evolved to the stages of data array, data storage system, database, and data platform and data lake or ocean. It cannot be overemphasized that ICT is the foundation of recent water-related information systems. Smart water is impossible without ICT. Digital water uses real-time data to provide recommendations to users. Digital twin means a further integration and use of multidimensional information in the complex operational system.

As can be perceived through the recent example of ChatGPT, the scalability of information technology knows no bounds. The connectivity of the latest information technology is based on ICT. The results that AI pours out look simple, but they consume enormous ICT resources at the back end. It includes an advanced computing system in charge of AI calculations, a cloud that makes it possible to store and retrieve this information anytime, anywhere, and a communication network that enables smooth communication from the cloud to users. One important thing we need to know in the field of information such as AI, big data, IoT, and virtual reality is that developed and underdeveloped countries can be regarded as equal in the space where ICT information system networks are available.

Sometimes, information system technology itself is an area where a quantum jump is possible if a communication network is possible. It is not easy to distinguish the technological development stages. Therefore, rather than specifying the technological development stage of Ghana's water and sanitation sector information management system, it is recommended that an advanced strategy riding on such a friendly environment will be more effective in Ghana. In other words, at the current stage, the best practical strategy is to build an ICT-based information system and then promote scalability based on it. In the case of urban water management, which includes sewage treatment and the drainage system in the city area or urban river management, it is a strategy to expand to the concept of digital water. And it can be developed into a digital twin if full 3D national geographic data are available. Taking a step further, those concepts can update WASH systems using real-time data throughout their lifecycle and help make decisions through simulation, machine learning, and inference in cooperation with BIM (building information management), AI, etc.

The development angle of Ghana's WASH information management can be clearly diagnosed through this research, Korea's case, and the international community's message to respond to climate change. This research has already provided motivation for Korea's KEITI (Korea Environmental Industry and Technology Institute) to start a smart water management project in the western part of Accra. It is also recommended that the proposed system can be used as a data platform for the system integration when building water and sanitation-related information systems, since the results of this research comprehensively suggest the way for the integrated national information system in Ghana's WASH sector to go.

KEITI is now dealing with the growing demands for green ODA support such as environment industries and climate change adaptations in developing countries. One of them is to build a systematic drinking water management initiative to increase water efficiency and reduce leakage loss in the western area of Accra (Weija). In order to transform the existing waterworks management system into a green system in Ghana and strengthen the scaffold for Korean companies to enter the new frontier market, it is planned to improve drastically the efficiency of water supply management by distributing ICT-based smart water management. As a result, through the establishment of a smart water management system in Accra, it is intended to contribute to increasing the quality of drinking water and improving the health of Accra's residents.

When planning an ICT-based water and sanitation IMS, it is recommended to analyze extensively the national context in which ICT will be introduced to ensure that it is relevant to ICT technologies. In modern society, information and communication are dominated by services represented by mobile communication and internet, so it is necessary to determine

whether the accessibility of mobile connectivity or mobile data service is sufficient and the network coverage is stable. Ghana's information and communication infrastructure and service quality are judged to have no unusual obstacles to developing an ICT-based water and sanitation IMS, but it is recommended that the system should be possibly developed within the national context of information and telecommunication service capability.

The ICT-based information system needs to be technically relevant to those who are managing the water and sanitation system and the individual data generation points, facilities on a day-to-day basis, if possible. This includes ensuring that water and sanitation service providers (e.g., PPPs or stakeholders) responsible for managing the water and sanitation system are not excluded within the information governance. The ICT-based WASH IMS should be designed to amplify and respond to the needs of governments, service providers, and service users. In the end, this approach can bring about job creation and revitalizing IT ventures, along with technological development in related industries, as seen in the case of Korea's Green New Deal.

The ICT technology and application method to be chosen should be appropriate for the target objects (facilities and data and service chain) and the groups expected to use it. It is recommended to adopt the best practical technology that Ghanaians are familiar with, know how to use, and can afford. The use of unaffordable technology should be avoided. Since most of generated information does not need to be used in immediate decision-making, such as waste treatment status, the short-term monitoring system should be more prudent because high cost is not always high return. Most of the information does not need to be collected in real time; it shows only a visual effect. An unfamiliar technique or device in communication tools should be excluded, but the most common information and communication technology can be a best policy.

From a detailed technical solution point of view, the water and sanitation information management system, especially in the Accra Region of Ghana, can be formulated by dividing it into two systems, namely, water and sanitation sectors. The ICT-based water IMS may be more effective if it were installed in GWCL because it deals with most of the domestic and industrial water supply systems sectors nationwide, collects all kinds of water-related data and information, and has a lot of experience in that field. In consideration of the effectiveness of the current market condition and the variety of the participants, the waste information management system should be installed in a technical institution or a professional association (e.g., ESPA or CWSA).

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03

CHAPTER

Policy Suggestions for the Introduction of an ICT-based Water and Sanitation Information Management System in Ghana: Focusing on Accra City

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Keywords
Integration, Platform, Smart WASH Center, Monitoring, Improving Non Revenue Water

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Summary

The WASH sector recognizes the importance of securing clean drinking water and a sanitary environment as crucial issues for national development and public health promotion. The significance of WASH programs utilizing information communication technology (ICT) is emphasized in Ghana as well as most African countries. Because of recent technological advances, ICT plays a an increasingly important role in the WASH field, providing various potential benefits such as information sharing, data analysis and monitoring, and sustainability enhancement.

The Ministry of Sanitation and Water Resources (MSWR), a government agency, has set 14 WASH-related indicators, with each focusing on measuring the proportion of drinking water, sanitation (handwashing facilities and toilets), solid waste, and liquid waste. While some indicators require complicated processes for measurement, others, such as "percentage of communities with access," can easily be deduced through GIS information and obtained lists from institutions.

Although various government agencies in Ghana incorporate WASH components into the information systems developed by their respective projects, they appear to fall short in effectively managing WASH objectives. Therefore, efforts are made to integrate information as comprehensively as possible, but areas of insufficiency require improvement through new development, database establishment, and process adjustments.

Among the 14 indicators, the drinking water sector is the most easily accessible for information, as the customer list is managed and supplied by GWCL. However, the biggest challenge is said to be the NRW problem. Another indicator is solid and liquid waste

information, which is difficult to integrate because information is generated by various institutions and the systems they use are not unified.

Putting together the interviews of personnel in each sector, the user information requirements include improvement of NRW, protection of water resources, and improvement of water quality. GWCL is promoting a plan to introduce smart meters in the future as part of improving NRW. In addition, infrastructure for introducing information systems in Ghana is relatively better compared to other African countries, but it is necessary to strengthen the capacity further for introducing information systems or building databases.

Given the above situation and information needs, development of the drinking water sector should be prioritized while considering the integration process of existing WASH systems. To this end, the components included in system development are water resource management, block monitoring system introduction, and e-billing system integration with GIS as the basis. The effect should be maximized through improvement of water supply facilities for some pilot areas to reduce NRW.

Second, MSWR should promote improvement in the waste field, which includes solid, liquid, and fecal. Along with system development, the process for obtaining information should be changed for waste collection companies to input directly. The indicators are the proportion of communities where services are provided, but this alone is difficult to claim that they achieved the WASH goal. All waste is discharged from the private sector to the industry, but the collected waste is collected at the collection company and transferred to the landfill. Therefore, it would be most desirable for a private collection company to be the subject of information acquisition.

Finally, ICT improvement in the water quality field will be promoted and expanded to an integrated WASH center. Water quality ranges from domestic sewage to wastewater discharged by businesses, but it is eventually discharged from workplaces using water. According to data from the Embassy of Denmark, more than 70% of companies are located around large cities, but they are discharged without permission without considering water pollution from many workplaces. Although this practice is not governed by the MSWR, the discharge of contaminated water near drinking water sources contributes to the cost of purifying water to produce drinking water. In addition, illegal discharge of wastewater is expected to have a serious impact on the national economy, as it not only considerably undermines citizens' right to health and quality of life, but the various environmental issues are critical to exporters.

Therefore, the work process should be improved to input the results of discharged water quality into a government-provided ICT system, such as in the waste sector.

Ultimately, cooperation among government departments is essential to carry out simultaneous management and monitoring to achieve the WASH goals, so an integrated WASH center for joint operation and monitoring among ministries should be established. Thus, MSWR, which is closely related to the WASH indicator, should lead the establishment of the WASH center.

The cost to establish the WASH center is estimated to be approximately USD 18 million, including the cost of integrating existing systems and the cost of improving NRW in the pilot region. It will require a considerable amount of money, will take a long time, and technology will develop in the meantime, so it will be necessary to separate the stages by sector. In addition, it is necessary to mix grants and loans for financial resources, and the construction sector should establish its own plan and carry it out in parallel to achieve its goals.

The waste sector is an open sector to the private market. However, since the Greater Accra is already serviced by domestic or multinational companies, the focus should shift towards technology development. Although the water quality field has been opened to the private sector, so far, it has been judged to be a field that requires more investment. Investment to improve the water quality of each company and wastewater treatment by an industrial complex are some of the various factors to consider. In particular, companies exporting to advanced countries such as the EU and the United States may be blocked if they do not meet Ghana's environmental standards. Therefore, more investment is required. Since it is already an open market, additional investment from abroad should be considered.

The WASH field is an area that requires reorganization or an improved legal system. In particular, improvements in the field of waste and water quality should be at the center. In the water quality field, there are relatively more intergovernmental stakeholders than in the drinking water sector. Although the law exists with various institutions, it is relatively more difficult than the drinking water sector due to the various private sector stakeholders.

It is also recommended to introduce a pay-as-you-go system for the disposal of household waste in the waste sector. The government sells standardized bags with bar codes, and waste emitters must use the standardized bags to discharge waste. However, it is believed that reflecting production and sales in the ICT system can contribute to further reduction of household waste.

1. Introduction

Represented by improved water sources, hygienic environment, and health, the WASH sector is a crucial factor for improving public health and national development. Therefore, most African countries including Ghana are putting forth their best efforts to reform the WASH sector.

MSWR, a governmental institution in Ghana, has selected 14 WASH-related indicators focused on drinking water, hygiene (handwashing facilities and washrooms), and the ratio of solid and liquid waste. Multiple government ministries and agencies are operating ICT solutions to obtain data. The measurement of indicators needs to be done quantitatively, while maintaining its accuracy and precision, since it not only decides whether goals are accomplished, but it is also a crucial factor for supporting decision-making.

In managing the indicators, the importance of a WASH program utilizing ICT is emphasized in most African countries including Ghana. Because of current technological advancements, ICT serves a more important role in the WASH sector by providing various benefits such as sharing information, analyzing and monitoring data, and improving sustainability.

Ghana is currently applying mobile technology to each field of WASH and has introduced ICT such as supervisory control and data acquisition (SCADA) and GIS systems and applications to manage water volume, maintain facilities, and manage billing. However, in order to solve various existent problems, the Ghanaian government requested policy proposals for advanced policies and ICT introduction.

MSWR hopes to integrate data from ICT systems of various institutions in order to measure the achievements of the 14 WASH indicators among other issues. Unfortunately, the integration process between systems remains a challenge.

In Ghana, problems persist with a high non-revenue-water (NRW) rate and water quality management in relation to drinking water. Moreover, public sentiment of the government's willingness to improve water quality is still not improved in relation to wastewater. Despite the introduction of the SCADA system and GIS in the drinking water sector and the management of information on the solid waste and wastewater treatment status from private companies, the pace of improvement appears slow.

When developing an information system, both top-down and bottom-up approaches can be taken. The top-down method sets the direction of the entire system and proceeds with top-down development, while the bottom-up method creates individual modules and integrates them to form the whole. Regardless of the method adopted, the project's goals and requirements must be clearly developed and shared. Since the top-down method is designed around the goals and requirements of the entire system, it can be considered a representative feature of "information engineering methodology" that development systems can maintain consistency and integration. The most crucial factor of the top-down method is the standard proposal for information integration and sharing.

On the other hand, the bottom-up method's development approach aims to achieve the final goal through feedback for integration while implementing from the lowest level of functions. This method undergoes a sustained feedback process, making cooperation among related agencies mandatory.

Another issue pertains to NRW. A workshop with Ghana Water Company Limited (GWCL) revealed that the NRW is over 45%. The cause is said to be due to aging of the water supply facilities, illegal water use, and meter reading errors. GWCL plans to introduce smart meters to eliminate the problems caused by the meters, but it will also need to improve aging water pipelines. Additionally, GWCL's ICT department announced on the organization's website that they are considering zoning measures.

From the realized WASH indices in Chapters 1 and 2, there are indicators related to solid or liquid waste. However, for the most part, only the percentage of communities providing services is considered, and the amount generated is not effectively managed. Additionally, the water quality problem, which raises many concerns, is not addressed at all. The reason is that MSWR finds it difficult to become involved in the supervision of wastewater-discharging businesses as it is managed by other government agencies.

On the other hand, it is known that most industries in Ghana require large amounts of water, and wastewater discharge is also not small, and most is illegally discharged. Additionally, in the case of exporting companies, it is difficult to overcome export barriers such as in Europe or the United States, which want to apply the RE100 or carbon border adjustment mechanism (CBAM) system without environmental improvement. Therefore, at the present time, consideration of water pollution has become a task that is difficult to delay any longer.

Therefore, the first purpose of this chapter is to seek optimal alternatives for integrating the systems of related organizations and MSWR-affiliated organizations to extract WASH indicators and to present better policy alternatives to achieve indicators in the field of water and sanitation, which are targets of the WASH indicators. As a secondary objective, wastewater discharge issues were addressed in relation to the protection of water sources in terms of reducing water treatment costs in MSWRs, and all proposals were considered only in terms of ICT.

As indicated by the title of the chapter, this study targets only the Greater Accra Region. However, it restricts only the scope to the Greater Accra Region and cannot restrict the information system by region. Regionally independent ICT solutions can create another integration problem. Moreover, solutions need to be developed and expanded as a work-dependent solution, not regionally specialized, since regionally specialized solutions require additional development or reconstruction of programs for regional integration. Nevertheless, the reason for the inclusion of regional restriction is that most WASH-related infrastructure and industry bases are concentrated in the Greater Accra Region, serving as an adequate pilot to expand the standard of Accra to the nation.

In conclusion, this study proposes the establishment of an integrated WASH center focusing on data collection and monitoring. To this end, firstly introduce an integrated solution in the drinking water sector including NRW improvement, secondly develop a waste sector solution for the purpose of automating data collection, and finally introduce a solution for water quality management and monitoring.) Improvement of NRW has been proposed to confirm the effectiveness of the project by improving the processing at the water supply facility in a few pilot areas selected from the Greater Accra Region and expanding it to the entire region.

This study conducted meetings with related personnel from the MSWR and GWCL regarding the drinking water sector, visited two private corporations in the solid waste sector, and carried out interviews by visiting a private corporation in charge of a sewage treatment plant and fecal processing. Also, by deducing precepts and the pros and cons from cases in Korea and referencing citations from international society, this study developed a policy alternative that can be applied to Ghana.

2. Assessment of ICT Infrastructure

2.1. ICT Status of a Target Organization for WASH

In Ghana, various WASH-related systems are operated in distributed forms in various organizations, including MSWR and affiliated organizations. In addition, MSWR is working to integrate the systems of various institutions successfully for effective measurement and decision-making of the 14 golden indicators selected in relation to WASH.

Therefore, in this chapter, with the goal of integrating 14 indicators, analysis of Ghana's existing ICT infrastructure was conducted to understand the existing ICT status and capabilities. First, WASH-related systems operated by various institutions, which are the basis for acquiring indicators, were investigated, and their functions, performance, and interoperability were analyzed, and through this, the strengths and weaknesses of the existing ICT infrastructure were identified. In addition, the status of the communication network currently applied in Ghana was identified, and the appropriateness of the communication network was investigated in the WASH field. Through this, a plan to increase accessibility and efficiency of the WASH service in Ghana was sought. Next, by analyzing the applicability of mobile technology, how mobile technology has been applied to the WASH field in Ghana was investigated, and effective information and data collection, sharing, and monitoring methods were studied. Finally, a stakeholder analysis and user demand analysis were also conducted to identify the WASH-related stakeholders and collect their requirements and opinions.

2.1.1. ICT Infrastructure

Currently, four systems are identified that are applied to the acquisition of WASH indicators, and survey data from the Ghana Statistics Office is being applied. In the water sector, except for the e-billing system and the SCADA system, most of them exist in the form of distributed data, and it was confirmed that development of solutions and standardization of databases are required for integration. The drinking-water-related system is currently operated independently, and information is provided in the form of an Excel spreadsheet. The SIS system is a decision-making system that integrates four systems and other information, but is not currently in operation. The current system for extracting WASH-related information is shown in <Table 3-1>.

<Table 3-1> System in Operation and Related Information Status of WASH

Sector	System	Description
Integration	SIS	• A system for integrating information from various sectors WASH-related and supporting decision-making • Currently not running
Rural Water	DiMES	See Chaps. 1 and 2
Rural Sanitation	BaSIS	See Chaps. 1 and 2
Healthcare Facilities	DHiMS	• Primarily monitors relevant WASH indicators in healthcare facilities • Tracks facilities' access to improved water supplies and sanitation, which provides information on healthcare facilities' sanitary conditions and environmental factors to support decision-making to assess and improve the health situation
Education	EMIS	• System that monitors WASH indicators related to educational institutions • Evaluate access to sanitary and handwashing facilities in schools and homes, thereby gathering information on sanitation in educational institutions and the health and well-being of students to support educational decision-making and policymaking
Urban Water	SCADA	• System for automatically identifying improved drinking water supply • Acquires the volume of drinking water supplied from the vicinity of the water purification plant with a sensor
	E-billing System	• A system for charging users based on measured usage • Identification of information such as customer usage volume and management of bill payment
	Pipeline GIS	• Location-based data to locate pipeline facilities • It is confirmed that it consists of some database tables, but it is found that there are difficulties in integrating with other systems.
Water Resource	Excel	• The status of the system is not identified and is provided as statistical data in Excel format
Others	Survey Data	• WASH-related factors are provided in the form of data from Ghana Statistics Office

Source: Author.

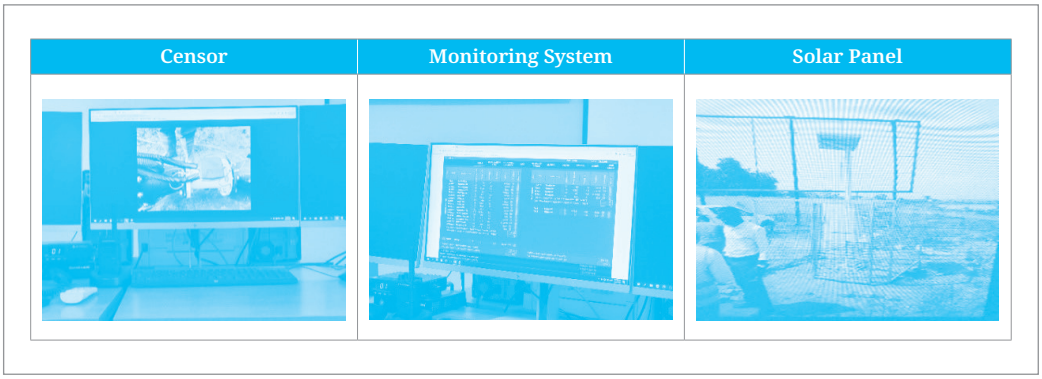
1) Details of the SCADA System in the Water Sector

In the water treatment sector, SCADA systems are commonly used for automation and monitoring of water treatment and distribution systems. These systems can be connected to various components of a water treatment and distribution system using communication links such as the internet or ethernet to monitor and control system operation. They are primarily installed to measure supply volumes automatically.

The operating status of the SCADA system managed by GWCL is as follows:

- Currently, 16 flow measurement sensors are installed in Accra and four in the Tema area.
- Measurement information is volume and pressure information, and there is a room (telemetry control room) for monitoring within the Technology and Innovation Department.
- Measurements are taken at 15-minute intervals, but information is transmitted to the system once a day due to difficulties in sustaining a power supply at all times after accumulated.
- Solar panels are installed to supplement electricity and some CCTVs are installed.
- It is hoped that communication can be improved, but specific problems have not been identified yet.

[Figure 3-1] SCADA System



Source: Author.

2) GIS for Managing Survey Data of Water Pipelines

GIS is a system for providing data and analysis results required by decision-makers or users by integrating and managing spatial data and attribute data for objects with spatial locations by object. It consists of a GIS engine, customized applications, and a database that manages data, and the hardware consists of a computer and output device as needed. GWCL is building location information on water pipelines and consumer meters.

The software in use is an ArcGIS Enterprise version, and it is understood that the software is used only for simple data input and attribute data construction; there is no customized solution.

The GIS DB for identifying the location of the installed pipeline has been established, but the ratio of the total pipeline has not been confirmed. It is claimed that over 90% of the consumer meter information is built, but it is not complete. Location information was constructed using digital surveying equipment such as GPS, but most of the pipeline information was derived from non-metallic pipelines, so location accuracy could not be confirmed. In addition, there are few valves or manholes exposed to the ground on the pipeline, so it is judged to be insufficient to estimate the location of the pipeline. It is determined that the location accuracy is low and maintenance history such as water leakage is not managed. It is judged that pipeline improvement for the reduction of the NRW ratio is urgent, and that considering it together with the smart meter project can increase the effect. Digital surveying devices are being used to measure the location of pipelines, and drones are also used to monitor areas that are difficult to access.

3) E-Billing System for Managing and Billing of Drinking Water

Drinking water consumption is measured and billed to customers based on the amount used. Depending on the country, the amount of water used is directly read and recorded from an analog meter or transmitted remotely. In Africa, in many countries, customers directly read usage and send it to their mobile devices. Customers who have not sent or customers who have found an abnormality in usage are visited by an employee entrusted with meter reading by the government to read the meter.

Customer meter information is built using a mobile app, and it is known that more than 90% of the list is secured. The billing and management system for water consumption has been established, and the electronic payment system for payment has been established and confirmed to be operating smoothly. The consumption of drinking water is input by the customer and checked by the manager. A bill is issued for normal consumers, but a bill for average usage is issued for customers who have not reported water supply volume, and households with meter abnormalities are visited to check.

Currently, GWCL is requesting a loan from the Export-Import Bank of Korea for an AID project to introduce smart meters.

[Figure 3-2] Customer List Display of Billing System and Analog Meter Test Toom

Customer List in System	Analog Meter
	

Source: Author.

4) System for Drinking Water Quality Management

Water quality management of drinking water is generally divided into information measured by sensors for turbidity and *p*H and information measured by water quality laboratories. The former is automatically measured by sensors, while the latter is acquired through periodic experiments in the laboratory.

One of the ICTs introduced for water quality management in Ghana's drinking water sector is the Water Quality Monitoring and Surveillance System (WQMSS). The system is managed by Ghana Water Company Limited and is responsible for monitoring water quality and detecting and responding to large-scale microbiological contamination events nationwide. Water quality management in drinking water treatment plants was found to have been greatly improved after the project was carried out by funding from the EU from 2011 to 2015, and ICT in the water purification plant seemed to have been improved at that time. WQMSS is used to collect and analyze water quality data from various regions in Ghana. The system utilizes a GIS and computerized database to perform water quality monitoring and provides access to the data through a web portal. This enables real-time water quality monitoring and response, leading to better water quality management and conservation. It is understood that there is no system to issue an alert or provide information if drinking water is scarce or water quality standards are not met. There are concerns about pollutants near water intake sources, but it appears that there is no ICT for control and monitoring.

Water quality monitoring in Ghana is judged mainly to evaluate safety through water quality tests after periodically taking samples from water sources or treatment plants, etc.,

and constant monitoring and control of some items may not be considered. However, the WASH sector and environmental experts are expressing concerns about the monitoring and control of contamination of rivers, lakes, or groundwater.

5) ICT for the Wastewater Sector

Domestic sewage is discharged after being treated at a sewage treatment plant through sewage pipes from households, and human waste is collected through a collection truck and treated at a treatment plant operated by the private sector before being discharged. Accra's sewage treatment plant is out of service and is currently being upgraded.

The sewage treatment plant or human excreta treatment plant has ICT facilities for managing the treatment process and water quality process by the operator.

Since wastewater that is discharged without permission without going through treatment facilities is directly discharged into a river, underground, or ocean, there is no main cause of aggravating water pollution or a means to control or suppress it. However, a mobile app called CleanApp Ghana, which is distributed by the government, is spreading. The CleanApp Ghana enables one to report on the sanitation situation in their neighborhood.

6) ICT for the Solid Waste Sector

In the private sector, solid waste is also collected after separation of recyclables, compacted in processing plants, and landfilled in more distant landfills. Private sector processing plants have and operate their own ICT, but information shared with the government appears to be limited.

To prevent unauthorized disposal of solid waste, a mobile app called CleanApp Ghana distributed by MSWR is being used. CleanApp Ghana is an application that solves local waste issues. By reporting on a phone any time waste is found where it should not be, the District Assembly and service provider are alerted and able to fix the problem.

2.1.2. Telecommunications Network

In Ghana, there are several telecommunication network providers such as MTN, Vodafone, AirtelTigo, and Glo. These providers offer various services including voice calls, SMS, mobile data, and broadband internet. The country has experienced significant growth in the telecommunication sector over the past decade, with a high mobile penetration rate and increasing internet connectivity. However, there are still some areas in the country with limited access to reliable and affordable telecommunication services.

To complement the efforts of the private sector in the extension of affordable and efficient connectivity solutions, the National Fiber Communications Backbone Infrastructure Network aiming to provide open access broadband connectivity is being developed.

GIFTEL has been set up to facilitate the extension of communications services to underserved and unserved areas through the provision of common facilities. It has thus far completed a total of 39 common telecom facilities, and this has enabled telecommunications providers to extend their services to over 273 communities. For instance, GIFTEL has undertaken the common telecom tower service facility at Nandom (in the Upper West Region), which is now offering transmission coverage to over ten towns including Lambushie, Boe, Burutu, Piiri, Basabli, Yipele, Naapal, Pofiem, Napaali, and Gengenkpe.

The government has the focus of developing e-government points of presence through the development of broadband connectivity to link all district capitals to the national high-speed broadband. Over the past two years, owing to massive investments made by major industry players, the Ministry of Communications has commissioned major submarine fiber-optic cables to increase bandwidth capacity. Ghana has, cumulatively, approximately 7,160 gigabytes (i.e., 7.16 terabytes) of bandwidth capacity available. The country is thus well positioned as the potential ICT-enabled services hub in the subregion. Thanks to the government's ICT sector policy, Ghana's internet penetration rate was about 45.9% as of 2022, showing a growth rate of 49.126% compared with 2000–2021.

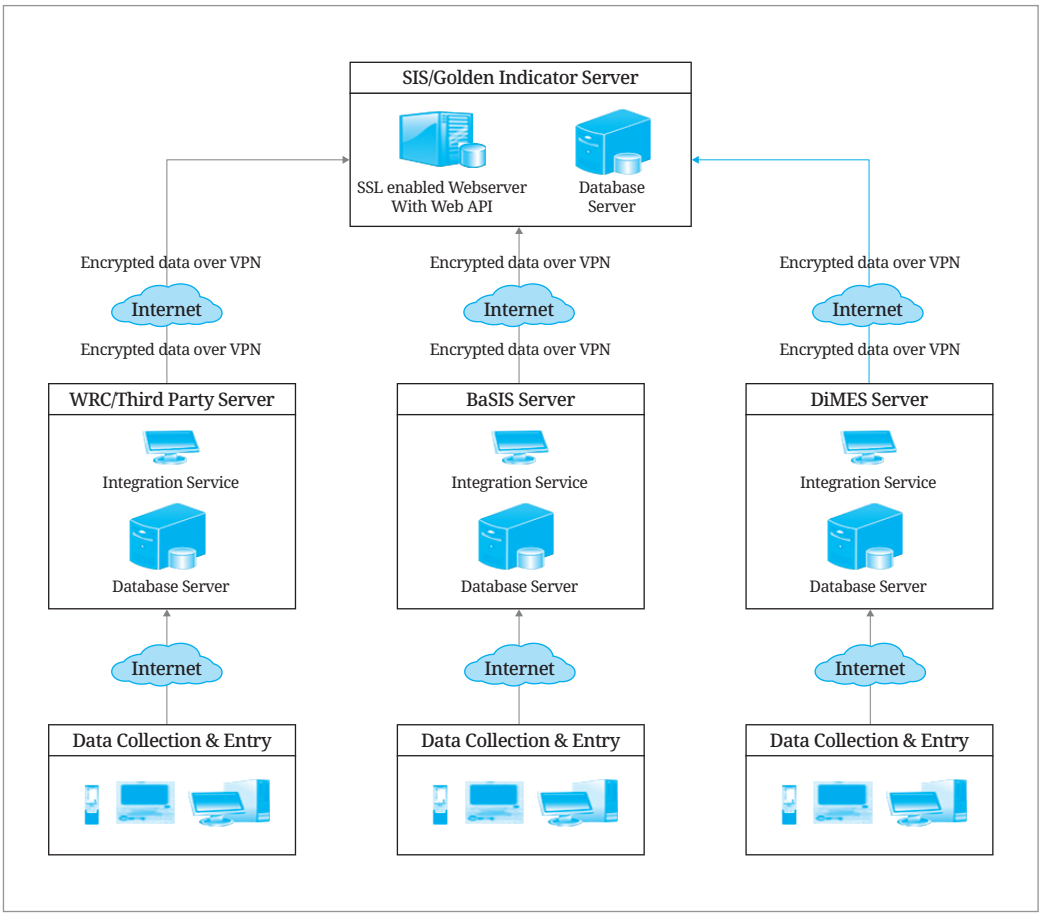
The mobile penetration rate of Ghana in general was reported to be 88% in 2012 (World Bank, 2012). According to the National Communications Authority, mobile broadband penetration rose from 65.3% in 2015 to 68.4% in 2016 with total mobile broadband subscriptions rising from 18,031,188 to 19,331,239 in 2015 and 2016, respectively. Ghana is presently the country with the highest mobile broadband penetration in Sub-Saharan Africa.

Most of the buildings where government agencies reside are well equipped with communication networks, and there is no problem with the system for sharing information. However, the environment for transmitting data from the outside uses private sector networks or mobile networks. In areas where communication is not widespread, other alternatives may also need to be considered.

MSWR is under way with "The Improving WASH Evidence-Based Decision-Making (IWED) Project" funded by USAID. Depending on the degree of completeness of the system, additional necessary parts should be considered. The communication network proposed by the IWED project is shown in [Figure 3-3], and it is judged that sufficient network capacity

is considered to include the integration of existing systems and the expansion of decision-making support of SIS systems.

[Figure 3-3] Communication Network Presented in the IWED Project



Source: USAID (2020), (https://www.youtube.com/watch?v=zRdlRuDa3wU&t=103s, accessed on May 04, 2023).

2.1.3. Possibility of Mobile Phone Application

WASH service delivery and monitoring is undergoing some changes as a result of developments in ICT and mobile phone applications. The use of mobile phone technology for data collection (baseline, evaluation, consumption, billing, etc.,) is one of the striking manifestations of these changes (Shouten and Smith, 2015). Monitoring of WASH services using mobile phone technology where trained enumerators or District Assembly staff regularly monitor and update the service delivery characteristics of water and sanitation points.

In some projects in Ghana, WASH service users in communities report breakdowns using SMS as in the SKY FOX SMS platform under the "Strengthening Local Government

Capacity to Deliver Water Services Project" (2014–2017) implemented by IRC Ghana in the Sunyani West District.

Mobile phones have the potential to transform the fortunes of the water and sanitation sector and accelerate coverage and service levels in all communities in Ghana. Another case study is the IRC Ghana SMARTER WASH project implemented between 2014 and 2016.

SMARTER WASH (2014–2016) was a commendable effort to scale up and consolidate the monitoring system by developing ICT monitoring tools and systems for data collection, processing, and analysis at scale, using the Community Water and Sanitation Agency (CWSA) District Monitoring and Evaluation System (DiMES), AkVo's FLOW (a smartphone platform for data collection), and an SMS-based system for tracking functionality and ordering spare parts developed by SkyFox Ltd.

Training was conducted for 131 districts' staff in eight regions, data were collected from 23,000 handpumps, 900 piped schemes, and almost 15,000 water and sanitation management teams (WSMTs) and 131 service authorities were involved. The data were processed and made available in the form of regional- and district-level factsheets and an online atlas.

Many other ICT tools have been used to facilitate WASH data management. The Water Point Mapper (WPM) was developed by WaterAid, a spreadsheet-based tool. The WPM operates via Microsoft Excel and is capable of generating maps that can be viewed in Google Earth or Google Maps. Spreadsheet-enabled mapping has become a popular solution for government-led monitoring initiatives that lack the resources, finance, and skills required to implement smartphone data collection, cloud-based data storage, or online dashboards for spatial representation and graphical analysis.

Common ICTs for data collection can be divided into three categories based on the type of device used: smartphones, feature phones, and smart devices embedded in water devices. The SMS and smartphone data collection tools are the most mature tools in terms of reliability and usability. For example, recently, the GWCL introduced SMS billing and payment of bills via smartphone applications using mobile money (MoMo). Smart handpumps and other affordable embedded devices have not yet undergone mass production, are still being piloted, and usually require specialized skills for implementation.

The use of feature phones for data collection is significant among field workers, including meter readers of GWCL mostly in urban and peri-urban areas, where mobile phone connectivity allows. As a result, there is still substantial demand for applications that use

SMS, voice, and short codes (for example, the user enters a code *333#, and is provided with a text-based menu) that can work on all low-cost feature phones.

In order to integrate the data collection tools into sector monitoring there is also a need to ensure that the data collected feed into monitoring and decision-making. This may require linking the data collection systems to the national- and district-level databases (for example, DiMES, BaSIS, and the master SIS as is projected in the future for Ghana).

SMS application/ICT would be of immense support in the WASH sector if promoted very well. It needs to be scaled up and moved from the pilot approaches to full scale by integrating into all aspects of WASH services delivery. In Ghana, a significant portion of mobile applications used in African countries have already been introduced and are being used, but integration of databases and applications is required in terms of sharing and information flow.

2.1.4. Understanding ICT Operational Capacity

The Ghanaian government has recently actively promoted the introduction of ICT, placing it as a top priority in government policy. MSWR also has departments and personnel dedicated to ICT at the ministry and key agencies and allied agencies, and the task of integrating systems in relation to WASH as well as internal systems is a priority. Therefore, it is necessary to analyze in terms of WASH-related system integration, organization and human resources, infrastructure, and integration of existing systems so that the strengths are maintained while appropriate alternatives are prepared for the deficiencies.

First, the operational capabilities in terms of organization and human resources are as follows:

Organizations related to WASH include MSWR, its affiliated organization, GWCL, Environmental Health and Sanitation Directorate, Community Water and Sanitation Agency, Ghana Health Service, Ghana Education Service, Water Resources Commission, and Ghana Statistical Service. Since related organizations have their own tasks, the WASH sector may be a relatively minor part for those organizations. Therefore, it is necessary to reduce the burden on the institutions since they may be passive in collecting data. This means that data collection methods need to be restructured.

In terms of human resources, related fields have staff and equipment with various abilities along with departments in charge of ICT, but it is judged that supplementation

of existing capabilities is necessary to solve many problems so far. It is determined that the areas identified as areas requiring supplementation require personnel at the DB administrator level with database management capabilities that are one step upgraded from those of general users. The DB administrator must perform roles such as DB integration among systems, data mining and tuning, and database maintenance. In addition, human resources for data acquisition may require a large number of people in each field. It is judged that it is necessary to build an automation system through sensors in areas where automation is possible rather than continuous input of manpower.

Next, the infrastructure aspect is as follows: First, communication infrastructure is introduced and managed at the national level, so it is difficult to consider at the ministry level, where ICT is not a major business field. However, Ghana's communication infrastructure is judged to be more stable than other African countries. In addition, since not only the internet network but also the mobile network have considerable capabilities, it is determined that additional consideration is not necessary. Next, in terms of hardware, it is deemed that the computer hardware has sufficient specifications but there is insufficient quantity, and the quantity of sensors for data collection does not seem sufficient or sufficient operation time is not secured to save power. For example, the sensor for flow data acquisition in the SCADA system operates 24 hours a day, but data transmission is performed once a day. In terms of software, most of the solutions are developed in projects provided by developed countries, and software from developed countries is applied as it is. Cloud services are applied in the case of storage, so it is judged to be an area that needs improvement. If possible, it will be necessary to adopt open-source software, configure an internal database for data that require security, or use a national data center and have a backup server.

Finally, the system integration is as follows: Data for measuring WASH indicators should be integrated from systems of various institutions, although some data are collected from the MSWR and affiliated institutions. However, it has been experiencing difficulties in integration until now, which is one of the main reasons why the system has not been developed individually and standardized without an overall master plan.

The problems occurring in terms of system integration for measuring WASH-related indicators are outlined in <Table 3-2>.

<Table 3-2> Problems of System Integration

Challenges	Description
Standardization	It is developed in a bottom-up method in individual projects of each institution and is not standardized, and in some cases, limitations in data acquisition occur. These problems act as a major stumbling block when considering integration between systems.
Data Compatibility	Data compatibility issues arise because individual systems can store and manage data in different formats or structures. For example, a difference in format such as MMDDDYY or MMDDYYYY HH:MM:SS may occur in the date format. To solve this, work is needed to match the data conversion.
Technical Limitations	As different technologies and software are used at the time of individual system development, interworking may be difficult due to this. In other words, the absence of a standardized interface for communication or data exchange between systems makes integration between systems difficult.
Lack of Accuracy in Data Collection	In terms of data collection, it is challenging to assert that the database was constructed with consideration for MSWR's WASH-related information. This can lead to issues such as data collection cycles, accuracy, and units.
Interorganizational Selfishness	Systems integration will require collaboration and coordination among multiple organizations and stakeholders. However, since each organization is operated and managed independently, it is difficult to collaborate or share data among organizations.
Lack of Resources and Infrastructure	Sufficient resources and infrastructure are required to build an integrated system, but the lack of financial, technical, and organizational support to secure these resources and infrastructure makes integration difficult.
Duplication of System Functions	All development systems include GIS functions and each GIS database is built. This can cause problems due to the time lag in updating the GIS database.
Low System Utilization	Information systems can be utilized based on accurate information. However, if correct statistics cannot be generated due to insufficient or inaccurate input information, system utilization will inevitably be low. It is a problem that occurs in some systems, and it is judged to be a handwriting input problem.
Database Management Skills	All information collected is stored in a database. A database is composed of tables, and required data can be extracted and analyzed through connections between the tables. After all, excluding technical matters between software, the database configuration and the absence of professional manpower handling it can be obstacles to system integration.

Source: Author.

2.1.5. Stakeholder Analysis

The WASH sector has many institutions playing different but complimentary roles to promote and actualize the Government of Ghana (GoG) vision of water and sanitation for all by 2025 and the Sustainable Development Goal (SDG) agenda of leave no one behind by 2030.

The MSWR, which was established in 2017, has the mandate to formulate policies and strategies to accelerate the development of sustainable water and environmental sanitation

for all. The ministry has policies and strategies for water resources, water supply, and sanitation subsectors. However, some of these policy and strategy documents are outdated and need revision. The National Water Policy and National Environmental Sanitation Policy intended to guide and regulate the implementation of WASH services are currently under review. A national drinking water quality management framework making water safety plans mandatory is also in place.

The MSWR coordinates the activities of the sector through WASH Sector Working Groups. The WASH Sector Working Groups comprises government, WASH DPs Group, technical working groups, and civil society groups-coalition of NGOs in water and sanitation (CONIWAS). The WASH Sector Working Group meets regularly to review critical issues and overall progress of the sector. The group is chaired by the directors for water, and environmental health, and sanitation.

<Table 3-3> Key Roles and Responsibilities of Relevant Stakeholders

Organization	Summary of Roles and Responsibilities
Ministry of Sanitation and Water Resources (MSWR)	The MSWR was created in 2017 to enhance the delivery of WASH services to the people of Ghana and to coordinate activities of the water and environmental sanitation sectors effectively for efficient and productive use of resources.
Ghana Water Company Limited (GWCL)	Management of urban water supply
Community Water and Sanitation Agency (CWSA)	Management of rural and small town water supplies
Ministry of Local Government, Decentralization, and Rural Development (MLGDRD)	Coordinate the development programs of MMDAs to ensure the sustainable development of towns, communities, and rural areas, including sanitation management issues
The Office of the Head of Local Government Service (OHLGS)	Management of staff at the various MMDAs
Metropolitan, Municipal, and District Assemblies	Responsible for the development of towns and communities within the jurisdiction, which includes provision of water and sanitation facilities
Ghana Education Service/ School Health Education Programme Unit	Coordinate and implement policies on WASH and health promotion at pre-tertiary institutions
Public Utilities Regulatory Commission (PURC)	Economic and quality-of-service regulation for urban water supply, including guidelines on tariff setting
Water Resources Commission (WRC)	Protection and regulation of water resources in Ghana
Ministry of Health/ Ghana Health Service	Prevention and management of communicable diseases

Source: Author.

The Ghana Standard Authority (GSA) is another stakeholder. It has developed drinking water quality standards and sampling procedures covering the quality of water supplied by public water utilities in Ghana. The Ghana Statistical Service (GSS) conducts surveys and census and generates information on socioeconomic indicators including those for the water and sanitation sector. Data from the GSS are used by all development partners, international NGOs, and UNICEF/GoG Joint Monitoring Platform (JMP). Surveys such as the Multiple Indicator Cluster Survey (MICS), Ghana Demographic Health Survey (GDHS), and the Ghana Living Standard Survey (GLSS) are conducted by the GSS. These surveys capture WASH data as well.

2.1.5.1. Level of Interest and Influence of Key Stakeholders

The key stakeholders mentioned in <Table 3-3> have different levels of interest and influence on the WASH sector and can influence the MSWR with differing levels of interest and influence. For instance, the GWCL and CWSA have high interest in every issue relating to water, sanitation, and hygiene. This is because poor sanitation and hygiene directly affect the quality of water the GWCL and CWSA produces for drinking.

High levels of pollution of water sources, especially intake points, means huge volumes of resources would be used to treat the water to make it safe for household and industrial use. Pollution during transmission may invariably reach the final consumer who may unknowingly drink the contaminated water. When there are poor hygiene practices, water transmitted can be contaminated and make people sick when they drink it.

The level of influence of GWCL and CWSA on the MSWR may be mediocre because of the reporting line. They both report to the MSWR on all activities they undertake, and may respect their authorities in attempt to exact high-level influence on key decisions. However, to the extent that a particular decision can be technical in nature, the level of influence can be high.

The WRC has high interest in water volume and quality issues. When water bodies are well preserved and managed, it makes production and distribution economics easy since the cost of production and quality control would be minimal. However, on the level of influence, the analysis on GWCL and CWSA also apply to the WRC.

The Environmental Protection Agency (EPA) monitors environmental quality and ensures environmental safeguards. They also check the levels of pollution to ensure acceptable levels are not violated.

The Ministry of Health and Ghana Health Service are interested in the health and well-being of the people. They have high interest in the safety of water consumed by people and the quality of the air people breath. Thus, environmental sanitation and public health issues are of major concern to the Ministry of Health. They can therefore influence decisions made by the MSWR.

The Ghana Education Service (GES) and School Health Education Programme (SHEP) have high interest in the availability of safe WASH in schools to promote quality teaching and learning and provide the right enabling environment for quality teaching and learning. They have high interest in WASH issues and concern themselves with availability of toilets and handwashing facilities in schools. Their level of influence may be low, but they can also ensure new school buildings have WASH facilities and services. The GES and SHEP can also promote digital education and ensure ICT-led education curriculum in all schools.

The Ministry of Environment, Science and Technology and Innovation (MESTI) is another stakeholder with medium interest and low influence. They have the interest to use WASH outputs such as sachet water bags to innovate on many product lines such as producing school bags with the empty sachet water bags.

2.1.5.2. Challenges to Resolve

Stakeholders may need the same information in different organizations, create new information based on the same information, or need different information. To share information according to each role and type of information and improve work efficiency, consistency and integration of data will be essential.

In addition, the current problems among stakeholders include the following, and some of these can be resolved through smooth data acquisition and sharing.

a. The stakeholders above are all competent in their areas of operation. However, there are challenges with low staff numbers that can slow down the pace of work when available staff are overwhelmed with the volume of work.

b. Weak coordination and collaboration is another challenge with the various stakeholders. There is minimal interagency coordination among the various stakeholders which impacts the quality of work. Weak coordination leads to duplication of efforts and waste of resources. There is high potential for unnecessary competition where interagency coordination is weak, with poor communication and information flow among institutions.

c. Regular interagency collaboration, communication, information flow, and exchange of work plans may help resolve some issues of weak coordination among stakeholders.

2.1.5.3. Information Requirements Analysis

First, in the drinking water sector, measures to reduce non-revenue water rates were identified as the greatest requirement.

a. Non-revenue water rates are reported to be over 45%.

b. Because of the deterioration of water pipes and facilities, drinking water is leaked while being supplied to consumers.

c. A big percentage of NRW is generated through unauthorized connection to the supply pipe or to the consumer meter, which is the end of the pipe.

d. Usage is not properly recorded due to errors in the customer meter or an insincere report of usage.

The second information requirement is locating pipelines and identifying leak locations. To this end, among other things, GWCL hopes to introduce GPR (ground penetration radar). The ICT department has continued activities to secure the location information of pipelines and meters, and has a certain amount of related equipment. However, since most of the pipelines were made of PVC material in the past, it was impossible to measure the location accurately, and it is necessary to have equipment to check the location of non-metallic pipelines. The location of the leak in the pipeline could not be confirmed because it was buried underground, but the GPR equipment could detect the leak point even if not 100% by using changes in the density and humidity of the underground soil due to the leaked water.

Third, as one of the ways to reduce NRW, GWCL is preparing for the introduction of smart meters. Smart meters will help eradicate fraudulent acts such as metering errors, illegal acts or errors caused by manpower meter reading, non-reporting, and reduction in usage.

Ultimately, in order to reduce NRW, pipeline improvement must be preceded. Smart meters will help, but they will not be a groundbreaking alternative, and it is considered that they will exert a great influence on reducing NRW if they are combined with pipeline improvement. For pipeline improvement, it is necessary to select the area to be repaired through zonal measurement, identify the location of a lot of leaks within the area, determine

whether to repair the leaked location or replace the entire pipeline, and repairs should be made according to the results.

In the field of sanitization, information needs for waste management and water quality management have been identified. Several decades of uncontrolled and improper handling, treatment and disposal of both solid waste, and liquid effluent from industrialization and unbridled urbanization has resulted in severe environmental degradation of both inland and coastal waters. Major sources of potable water production as the Oda and Owabi Rivers in the Ashanti Region and the Pra River in the Western Region have become highly polluted with industrial and domestic waste, leading to increased cost of production by the national utility company GWCL (Ramboll, 2020).

a. Even though a protection zone has been set up in the upper reaches of drinking water sources, it is necessary to protect drinking water sources that are highly likely to be contaminated by private activities such as sand extraction.

b. The treated water discharged after human fecal treatment is discharged without reprocessing at the sewage treatment plant and meets the government's water quality standards, but the water quality standards themselves are lax, which may increase river or ocean pollution.

c. Although domestic sewage is a system that is discharged after treatment at a sewage treatment plant, it is necessary to improve and expand the pipeline system including ICT due to the lack of pipeline extension, and there is a large amount of unauthorized discharge.

Waste is divided into solid waste and liquid waste. In particular, liquid waste is deeply related to water pollution and to the quality of water discharged from all industrial sites. Therefore, strong legal regulation will be needed along with the means to obtain accurate information from the emission site.

2.2. Analysis of ICT Policies and Plans Relating to WASH

Innovations in ICT provide opportunities to open monitoring practices to more stakeholders at national, regional, district, and community levels. Accurate data on the level of service received by users and the performance of service providers (GWCL, CWSA, MMDAs, etc.) make it possible to improve WASH services.

Within the context of WASH monitoring and service delivery, ICT commonly includes

internet services, mobile telecommunication networks, mobile phones, and feature phones. ICT is a key driver for long-term economic transformation, serving as an enabler of development of the key sectors of the economy (IRC, 2014).

In the Water Sector Strategic Development Plan (WSSDP, 2012–2025) which was published in March 2014, the then Ministry of Water Resources, Works and Housing had a clear vision to use ICT in WASH in the foreseeable future. It among others indicates that "in the long term, Government of Ghana will explore the possibility of introducing SMS messaging at the sub-district level to facilitate data transfer from communities and reduce monitoring and evaluation costs."

Similarly, the CWSA District Operations Manual (2014) makes a clear statement on the use of SMS and District Assembly staff to collect data on water and sanitation projects and update the same in the districts on a regular basis.

The National Solid Waste Management Strategy indicates government commitment to establish a National Waste Management Information System and integrate the indicators of solid waste into sector monitoring systems.

2.2.1. Water Sector

In the water field, various technologies and devices such as ICT-based GIS, SCADA systems, and CCTVs are leading to the reduction of non-revenue water, improvement of productivity, and energy saving in terms of water quality and water volume.

Data collection on water volumes produced, transmitted, distributed, and consumed by users should be monitored regularly using ICT to generate the needed data for reporting, resource allocation, and management decision-making. Customer metering, billing, payment for services, complaints, and redress mechanisms all need to be ICT based and ICT driven to promote quality service delivery on timely basis.

Recently, the GWCL introduced mobile applications for billing and customer bill payments, as well as complaint mechanisms by customers. This is expected to improved water service delivery and make service delivery efficient and effective.

It is important to note that there are limitations of the application of ICT because of limited internet access for most customers and low levels of education for some customers. Also, at the organization level, ICT design and application need to go hand in hand with changes in people, processes, and institutions.

2.2.2. Solid Waste Treatment in the Sanitation Sector

The National Solid Waste Management Strategy dedicated pillar six—monitoring and evaluation. It makes a clear statement on the need to integrate solid waste management (SWM) indicators into a national monitoring and evaluation system. The National Solid Waste Management Strategy indicates that "National and local-level M&E of SWM is extremely weak and will be a focus of government action – specifically through commitments to harmonised data management systems and monitoring of policy implementation."

It also establishes common key performance indicators (KPIs) to enable the measurement and comparison of MMDA and service provider performance. Central to M&E strengthening is the definition of robust SWM performance, integration of M&E with ICT solutions for cost-effective and reliable reporting, and the establishment of mechanisms for independent oversight.

2.2.3. Sewage Treatment in the Sanitation Sector

Ghana is facing a waste management crisis. Access to liquid waste sanitation services remains critically low, with 56% of the population benefiting from limited liquid waste sanitation services and 14% from basic services, while access to safely managed water services is limited (UNICEF, 2018). In all urban areas of the country, sewage/liquid waste is indiscriminately directed into streets, drains, or the sea/waterbodies, crudely in unapproved areas.

These challenges are most acute in the larger cities of Accra, Kumasi, Takoradi, and Tamale, and reflect extremely poor behavior control by households, commercial businesses, and sewage/liquid waste management service providers/cesspit emptiers. Challenges related to poor behavior and practices are compounded by inadequate, ineffective, or unaffordable service delivery arrangements.

2.2.4. Water Quality Management

The MSWR has developed a National Water Quality Safety Plan/Framework. This framework provides clarity on drinking water safety standards in both urban and rural areas, as well as in river basins. The water quality framework established the value chain for water service delivery from production to consumption. The framework was developed with support from key stakeholders such the Public Utility Regulatory Commission (PUCR), GWCL, CWSA, and WRC. The framework also provides for water quality monitoring using various methods including ICT.

2.3. Analysis of National-Level Administration and PPP for WASH

2.3.1. Legal Framework

Ghana has a well-elaborated legal framework for public-private partnership (PPP). The National Policy on PPP seeks to, among others, increase the availability of public infrastructure and services and improve service quality and efficiency of projects. The proposed benefits of PPP include (a) accelerated delivery of needed infrastructure and public services on time and within budget, and (b) encouraging the private sector to provide innovation, design technology, and finances.

The Public-Private Partnership Act 2020 (Act 1039), which was assented to by the president of Ghana on December 29, 2020, also provides comprehensive guidance on PPP in all sectors of Ghana's economy, including WASH. The two main objectives of the act are

a. Regulate public-private partnership arrangements

b. Promote the use of private sector resources for the provision of infrastructure and services through public-private partnerships

To achieve the above objectives, the following specific objectives are designed:

(a) Creation of an environment and framework to enable private parties to participate in partnership projects and offer value for money to the public sector and users of the partnership projects

(b) Delivery of efficient infrastructure and services with assured quality

(c) Establishment of efficient institutional arrangements for the identification, structuring, procurement implementation, and monitoring of partnership projects

(d) Leverage of public assets to encourage private sector investment in the provision of infrastructure and services

(e) Protection of the interests of the public and private sector stakeholders and end users

(f) Establishment of a framework for optimal risk sharing in partnership projects

(g) Promotion of local participation in partnership projects

(h) Establishment of a regulatory framework for contracting authorities for the purpose of partnership arrangements

(i) Establishment of a framework for the management of financial commitments with respect to partnership arrangements

All PPP arrangements in Ghana shall be guided by the principles of value for money, risk allocation, local content, and technology transfer, among others. Value for money is the driver of adopting the PPP approach, rather than capital scarcity or balance sheet treatment. The PPP policy applies to all sectors and levels of government, and shall be pursued where they represent priority projects, are affordable to the government and consumers, represent value for money, and allow for appropriate risk transfer. The policy makes provision for sector-specific PPP policies to be developed to accommodate the needs of specific sectors such as WASH.

2.3.2. Public-Private Partnership in WASH

The provision of public infrastructure and services is one of the prime mandates of government all over the world. Infrastructure (WASH, power, sea and ports) is a fundamental prerequisite for economic growth and development. In terms of application, the PPA Act applies to

(a) all contracting authorities

(b) public sector projects undertaken in the form of partnership arrangements between a contracting authority and a private party

(c) functions that relate to the identification, studies, document preparation, structuring, bidding, evaluation, award, implementation, and monitoring of partnership arrangements

(d) commercial arrangements carried out through partnership arrangements with respect to contracting authorities

Pillar two of the National Solid Waste Management Strategy (Pennink & Carley, 2020) is devoted to private sector participation in solid waste management. It states partly, “working to improve cost recovery mechanisms is key to strengthening the enabling environment of Ghana’s waste management, recycling, and recovery value chains.” It also argues, strongly that the private sector can never effectively participate in service provision so long as the inclusion of informal actors, including waste pickers and Borla Taxis, is not recognized, or more systemically engaged with, by national government.

The overarching recommendation is that the government should ensure that sector institutions, policies, and regulations for private sector participation are realigned to promote healthy competition and reduce barriers to entry for the private sector.

The provision of quality SWM services across Ghana is a basic public utility right, but largely operates in an organic and uncoordinated manner. Supporting an enabling environment that provides conducive investment and operational conditions for prospective and existing solid waste service providers is key to promoting and increasing private sector participation across the sector.

Stakeholder consultation by contracting authority is mandatory. A contracting authority shall ensure that adequate stakeholder consultation is carried out in each stage of the public-private partnership process with respect to each partnership arrangement that the contracting authority engages in.

Tailoring regulations for the importation of different goods and products is essential to ensuring Ghana's private sector can source the necessary technology and equipment for beneficial waste recovery and recycling operations. Developing countries like Ghana are reliant on imports due to a weaker local manufacturing sector, lower access to skills and finance, and stronger export markets elsewhere (Europe, America, China, etc.). Building on this point, MSWR, working in collaboration with MESTI, could develop guidance on specific types of imports that do not compete with local industry, such as advanced waste recycling machinery, and seek to waive or ease the tax and administrative burden of importing such equipment into Ghana. According to the Solid Waste Management Strategy, the MSWR is to develop guidelines for PPPs (based on the PPP Bill, while still being tailored to suit the needs of SWM).

The guidelines will provide directions on how to respond to unsolicited PPP proposals.

a. The guidelines will provide a framework for the systemic assessment of proposals.

b. For solicited PPPs, MSWR will outline and prepare a list of all projects that require investment (similar to GWCL SIPs), showing the projected cost, etc.

c. At the local level, a guidance document for procurement and assessment of service providers will be developed for the MMDAs.

The MSWR has good examples of PPP arrangements on solid waste management and liquid waste management subsectors. For example, the Jospong Group is a mega-company that has a partnership with the MSWR.

2.4. Analysis of Korea's ICT Applicable Components by Target Sector

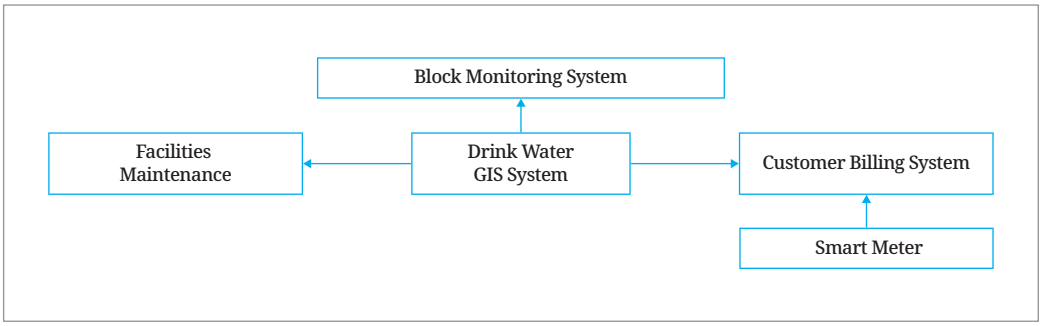
Information systems applied to the WASH sector in Korea can be divided into central government systems and local government systems. Local governments mainly operate their own drinking-water-related information systems, and waste-related sectors use the central government's system. It is configured to link to the central government system from inputting information to providing statistics.

Representative systems among central government systems are introduced in Chapter 2. Therefore, this chapter introduces the drinking water sector from local government, water quality management, and the waste management sector.

2.4.1. ICT Introduced in Non-revenue Water Management

In Korea, various ICT technologies such as smart metering, big data analysis, GIS, and SCADA technology are being used for non-revenue water management, and even AI (artificial intelligence) is being introduced. This contributes to the reduction of non-revenue water by quickly detecting damage or leaks in water pipes and promptly handling repairs and maintenance. In addition, by providing information through each institution's homepage or mobile application, consumers can check water usage in real time, and institutions can provide information on how to save water to support efficient water usage management.

[Figure 3-4] The System that the Local Government Is Operating



Source: Author.

1) Smart Metering

This is a technology that monitors water consumption in real time. Unlike existing analog meters, it is a technology that collects and analyzes usage information by installing a meter equipped with a wireless communication function at the consumer. Smart metering enables timely identification of problems such as water leaks and customer manipulation of meters,

and can be used for water pipe leak detection and repair planning based on metering information. Most of Korea's metering devices are analog, but they are being replaced by smart meters.

a. Smart meters: These are digital meters equipped with communication capabilities that allow them to send and receive data.

b. Communication infrastructure: This includes the communication network and protocols used to transmit data between smart meters and the central system.

c. Data management system: This is the central system that collects, stores, and processes the data received from smart meters.

d. Analytics and applications: These are the tools and software used to analyze the data collected from smart meters and provide insights and recommendations for better management of resources.

Smart meters are not a system that is currently distributed to all local governments, but they are gradually expanding their supply. The measured value from the smart meter is the basis data for estimating the NRW along with the value of the zonal system.

2) Block Monitoring System

The block monitoring system is similar to GWCL's SCADA system. The system comprehensively monitors the drinking water supply information and production of water purification wells by zone. The system monitors for problems, adjusts production and supply, and finally calculates NRW in real time by comparing it to customer usage.

3) GIS System and Database

All local governments in Korea are required by law to establish a GIS DB related to water supply, and it is continuously updated. In addition, related organizations of the central government build, utilize, and share the GIS DB related to drinking water. In Korea, GIS systems related to water resources are used to collect and analyze information on non-revenue water. Non-revenue water refers to water that is produced but not supplied to customers in the water supply network. This waste of water not only wastes a precious resource, but also reduces the efficiency of the supply network, making it necessary to minimize it.

4) Application of Big Data Analysis Techniques

Big data can be applied to non-revenue water management by analyzing and processing

large amounts of data from smart metering systems and other sources, such as customer billing systems and GIS data. This data can be used to identify patterns and trends in water consumption, leaks, and other losses, and develop predictive models that can help utilities anticipate and prevent problems before they occur.

For example, big data analytics can be used to identify areas with high rates of non-revenue water, pinpoint the sources of loss, and track changes in consumption over time. It can also be used to analyze customer behavior and identify opportunities to promote water conservation and efficiency.

Furthermore, big data analytics can enable utilities to optimize their operations by predicting demand patterns and adjusting production and distribution accordingly. This can help reduce energy costs, increase system efficiency, and improve service quality for customers.

Overall, the application of big data to non-revenue water management can help utilities improve their operations, reduce losses, and ensure sustainable and efficient water service delivery.

2.4.2. ICT for Water Quality Management

South Korea operates various water quality information systems, including the Central Water Quality Information Center and local-government-based systems. These systems collect and analyze water quality monitoring data to assess water quality conditions and develop policies and response strategies for water quality management.

South Korea collects and analyzes large amounts of data generated in the water quality sector to conduct big data analysis. This contributes to predicting future water quality conditions and developing water quality management policies.

South Korea applies the Smart Water Grid to water quality management by collecting and analyzing water quality data from various sources, such as groundwater, surface water, and sewage. This enables real-time monitoring of water quality conditions and prediction of future conditions. Smart Water Grid technology is also used to develop water quality management policies and response strategies.

South Korea uses IoT-based water quality monitoring technology to monitor water quality conditions in real time and detect anomalies. This contributes to predicting future water quality conditions and developing response strategies.

South Korea provides mobile applications that allow citizens to access and monitor water quality conditions easily in real-time. This contributes to environmental protection and improvement efforts.

2.4.3. Waste Management Sector

The waste treatment business field is also handled by private companies in Korea, and is divided into food waste, household waste, industrial waste, medical waste, and manure treatment. Representatively, household waste can be seen as a solid waste category in Ghana.

Korea introduced a volume-rate garbage disposal system, where each discharger must discharge household waste in a standard plastic garbage bag, and strong penalties are imposed for unauthorized dumping. The volume-rate garbage disposal system is a system that bears the disposal cost according to the amount of waste discharged. Local governments enter the amount of standard plastic garbage bags produced and sold into the central government system, and private waste disposal companies must enter the weight they collect. Of course, for different types of waste, the collection operator must enter the relevant system as well. The government manages waste through it.

[Figure 3-5] Volume-Rate Garbage Disposal System

Source: Author.

3. Establishment Plan of a WASH-Integrated Information Platform

3.1. Target System Definition and Establishment

For the extraction of 14 indicators set by MSWR, priority is given to integrating systems operated by existing related institutions and maintaining information acquisition procedures to date. In addition, the target system was set by considering the establishment

of a development model by applying advanced cases as the next priority to the information needs and improvement of problems of the WASH sector.

3.1.1. WASH Integration Platform Considerations

The indicators that measure the achievement of the existing WASH goals consist of a structure that is integrated in a platform called SIS based on the data submitted from the following four systems and organizations.

<Table 3-4> Each Institution's System Applied to Acquire WASH Indicators

Subsector	System being used	Institution
Rural Sanitation	**(BaSIS) Basic Sanitation Information System**	Environmental Health and Sanitation Directorate
Rural Water Supply	**(DiMES) District Monitoring Information System**	Community Water and Sanitation Agency
WASH in Healthcare Facilities	**(DHiMS) District Health Information Management System**	Ghana Health Service
WASH in Schools	**(EMIS) Education Management Information System**	Ghana Education Service
Urban Water Supply	Excel Spreadsheets	Ghana Water Company Limited
Water Resources Management	Excel Spreadsheets	Water Resources Commission
Urban and Rural WASH	Survey Data on WASH	Ghana Statistical Service

Source: USAID (2020), (https://www.youtube.com/watch?v=zRdlRuDa3wU&t=103s, accessed on May 04, 2023).

However, as described in Section 2.1.4, the SIS system is currently not in operation due to various obstacles to integration, and even if the integration is smooth, the problem of data collection is expected to remain, and the problem of water quality control is not considered.

One of the main reasons for these various problems is that each organization developed the system individually with the goal of success in the project carried out piecemeal by each institution without considering the issue of overall integration, and did not consider the acquisition of common WASH indicators. Therefore, since subsector problems for system integration and new development can be seen as already derived, MSWR establishes a top-down master plan for the overall system by considering data collection, database structure, technical considerations, and utilization of existing systems. In addition, in terms of data collection, it is necessary to exclude boldly the parts that have not achieved a great effect so far, establish a new direction, and consider an automated data collection method as much as possible.

In order to define the overall target system, MSWR should first present top-down standards, consider integration, and strengthen the efficiency, transparency, accuracy, and sustainability of indicator calculation to support Ghana's WASH performance evaluation and management. For this purpose, the contents of <Table 3-5> should be considered.

<Table 3-5> Considerations for System Integration and Development

Consideration	Description
Integration Between Systems	Data related to Ghana's WASH are generated from a variety of systems from a variety of institutions. Therefore, the generated data must be in a form and structure that can be integrated into the upper system, and must be developed to enable comprehensive monitoring through integration into other systems by reflecting the characteristics of each institution's unique field.
Real-time Monitoring	Manual data collection methods may have limitations in terms of data collection cycle or accuracy. Therefore, at the present time when the problem occurs, the parts that can be automated, such as water volume measurement, should be automated, and the parts that have not been input so far should be investigated by region at once, and only the parts that have to be input at each occurrence point should be input manually. To this end, IoT sensors, automation devices, and real-time notification functions should be introduced as much as possible.
Data Accuracy	Only the establishment of an accurate and reliable data collection and management system can ensure the accuracy of indicator measurement. Data collection must be continuous without interruption in the middle, and accurate measurement of indicators cannot be guaranteed if the data to be collected are missing. In addition, the management system should be able to generate standardized data and provide accurate means of analysis.
System Accessibility	Various stakeholders should be able to access the system and utilize the data and results. To do so, the user's access authority must be well managed, and a user-friendly UI must be provided to facilitate system use.
Reporting, Visualization, and Decision Support	Reports suitable for each user organization must be provided, and results must be visually displayed and provided in an easy-to-understand manner using visualization tools. To this end, data mining, visualization tools, dashboards, etc., are used to perform quantitative and qualitative analysis, which provides information necessary for decision-making and supports the establishment of policies and improvement measures.
Sustainability	Sustainable models for long-term operation and management and financing options should be considered. In addition, considering the scalability of the system, it should be able to respond to future changes.
Quality Management	Quality control procedures should be introduced to maintain data accuracy and standardized consistency. Secure reliable data by performing procedures such as data input standardization, error correction, and verification.
Easy Tracking and Reporting for Indicators	An automated system to acquire and track data for Ghana's 14 WASH indicators should be established to monitor the indicator's progress in real time. In addition, a mechanism to provide periodic indicator reports to government stakeholders should be established. Reports should be presented in a clear and easy-to-understand format and be used for policy formulation and decision-making.
Collaborate and Share	Collaboration and knowledge sharing among various stakeholders should be facilitated to support experience sharing and capacity building through workshops, trainings, and community gatherings.

Source: Author.

3.1.2. Integrated WASH Platform Development Strategy

The developed platform should be able to integrate the advantages of the existing operating system as much as possible, and should be flexible enough to embrace data in an integrated platform even if the system is built individually by presenting a standardization direction. In addition, the system should be configured so that the public and external experts can easily access necessary information, not just a platform for acquiring indicators in MSWR. Since each user has a different depth of information to use, the information provided by classifying the level of the user must be different. Therefore, for general users, general information about the user's surroundings should be provided, external experts should provide information with more specialized values, and indicators and information for decision-making should be provided for institutions.

<Table 3-6> Integrated Platform Informatization Strategy

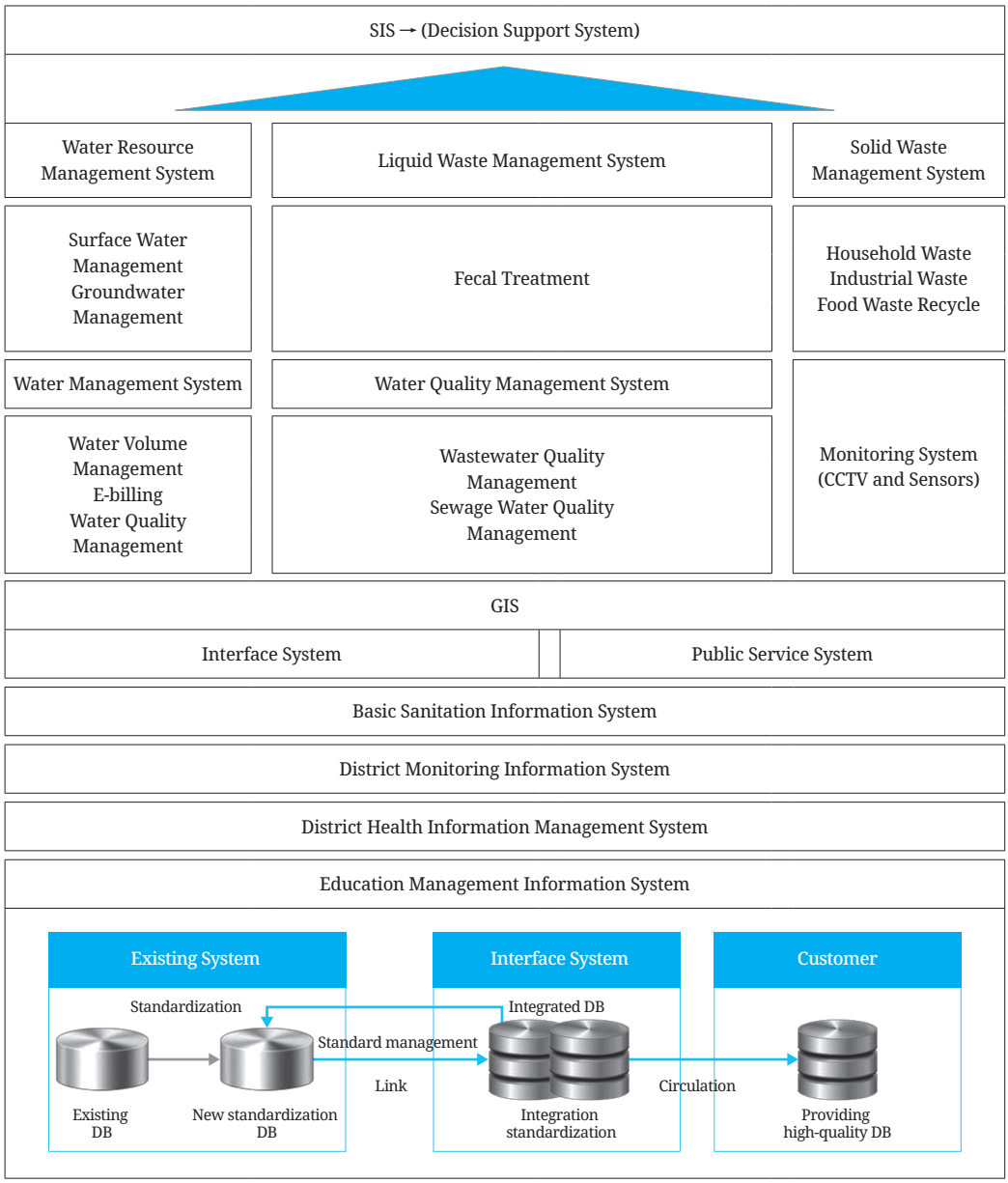
Vision	Build a Smart and Integrated WASH Management System		
Platform Goal	Establishment of a Scientific National Integrated WASH Management System that is Standardized and Shared through Data Convergence and Utilization		
Service Target	For the Public	For Experts	For Institutions
	Provide a service that allows non-experts to use WASH-related information easily and freely	Efficiently use all information linked, collected, managed, and provided by the platform	Automated WASH-related indicator creation and decision support
Strategy	Provide comprehensive WASH information by sector based on one click	Unification of information provision window through SIS information portal	Decision support, and boldly disclose data with public interest and demand
	Directly connect and share data among related organizations	Perform quality control of SIS information DB and processing/analysis information	Establishment of a system that can process and analyze WASH information segmented by sector and region into convergence information such as quantity, water quality, and solid waste

Source: Author.

3.1.3. Integrated WASH Platform Development Model Definition

The integrated platform model derived by analyzing the existing WASH-related systems, the requirements of the related personnel, and advanced cases are defined as follows:

<Table 3-7> Integrated Platform Model



Source: Author.

The target model may include WASH-related systems and data collection across Ghana, but it has not been confirmed how far the currently operating system has spread regionally,

and some data are still being collected in the form of Excel spreadsheets. A step would be necessary to include a database structure that considers only the data collection of the Greater Accra Region but considers nationwide spread.

Initially, indicators for drinking water, sanitation facilities, solid waste, and liquid waste were set, and all indicators were calculated based on data from the National Statistical Office as factors for population, household, institutes, and communities. Therefore, not only the four systems, but also the system of the National Statistical Office was composed of a structure that is linked to the interface system.

BaSIS or DiMES are not systems that have been distributed to all private sectors that discharge or collect solid waste or liquid waste. Some of the waste is partially converted into compost for agriculture or partially recycled, but most of it is landfilled or discharged into rivers as treated sewage. In addition, there are cases where solid waste is illegally landfilled or abandoned, so there are cases that are not captured in statistics. Most of the collection is carried out by private companies. For solid waste, the amount collected and buried is recorded, and for liquid waste, the collected amount is recorded, and the discharged water quality is managed independently and reported to the government in the form of a report. However, statistics on the among of treated water collected, landfilled, and discharged cannot be considered reasonably reliable. The reason is that only the final results are reported without government intervention, and citizens still see unimproved waste and water quality on land and in rivers.

In conclusion, the WASH integrated platform should be a system for MSWR decision-making for the whole country. Therefore, the system function should be expanded to include the function for decision-making by analyzing the existing function of SIS. In addition, private collection companies must have a system in which the amount collected and processed is directly entered into the government system or automatically entered into the government system from the measurement stage. In addition, institutional arrangements must be established with the management of water pollution, which has a great impact on drinking water and agriculture.

3.1.4. Target System Description of an Integrated Platform

The target system includes the improvement of functions and the introduction of a new system, including the integration of the existing system for calculating indicators and socio-statistical data related to WASH of the National Statistical Office.

<Table 3-8> System Description of the Integrated Platform Model

Sector	Description
SIS	(As is) - A system developed for the purpose of extracting 14 indicators from existing systems and supporting decision-making.
	(To be) - In accordance with the direction of automated data collection, integration capabilities are strengthened by augmenting system improvements and decision support capabilities.
Water Resources Management	(As is) - Provided in the form of Excel data by the Water Resources Commission
	(To be) - System for integrated management of surface water and lake water management and groundwater Step 1) Develop the current provided data into a GIS-based information system to provide various statistical data and utilize spatial analysis for various infrastructure development Step 2) Provide information suitable for characteristics by adding a system for groundwater management
Drinking Water Volume Management	(As is) - It is managed by GWCL and CWSA and provides information mainly in the form of Excel data - Volume management with SCADA system (Greater Accra Region) - Customer fee management through GIS-based e-billing system - Pipeline GIS DB construction (Greater Accra Region)
	(To be) - Water volume monitoring system, fee management system, water quality management system - Expanded to manage drinking water quantity by zone by introducing a zone metering system - Incorporate functions for maintenance, including leaks in pipelines, into the quantity monitoring system and consider integrating with the asset management system. - Expand the existing SCADA system and integrate it into a quantity monitoring system for each area - Maintain the existing e-billing system and introduce a smart meter - Added functions for water quality monitoring and water quality test data management
Liquid Waste Management	(As is) - Manage only the percentage of communities where collection services exist - Private operators self-manage and report on collection weight and handling weight
	(To be) - From managing the community that provides liquid waste collection service, to integrated management of information on the provider company, information on the amount of treatment by waste type and procedure, etc. - Private companies establish a system to input directly the weight of collection and treatment by type, and the government provides various statistical information by institution and community - Encourage entry of new businesses through GIS management for processing areas (communities) - Liquid waste needs to be linked with the management system for the part that can be produced as fertilizer in the treatment process and the quality of discharged water after water treatment.
Solid Waste Management	(As is) - Manage only the percentage of communities where collection services exist - Private operators self-manage and report on collection weight and handling weight
	(To be) - For solid waste, it is necessary to control the treatment status through management of the weight of each vehicle collected by the community and management of the weight of landfill. - Establish a system that allows business operators to input directly by separately managing domestic waste, industrial waste, and medical waste in order to induce proper treatment. - Separate management of recycling amount is required to increase the recycling rate.

<Table 3-8> Continued

Sector	Description
Water Quality Management	(As is) - No function identified for water quality management - The sewage treatment rate is known to be about 5%, and the operation is entrusted to a private company. - All human waste treatment is handled by a private company and self-managed water quality. - There is a monitoring function by PEA, but it is not efficient due to lack of manpower.
	(To be) - Reinforce the monitoring function for discharged water quality in both public and private sectors for wastewater-generating businesses of a certain size or larger. - The automatic sensing and monitoring function for some water quality items is strengthened from the function monitored by manpower, and the manpower is given a function to manage abnormal workplaces and inspect measurement equipment. - Regarding the quality of discharged water, the generating business self-inputs the contents of the water quality inspection items at regular intervals.
GIS	(As is) - The system currently in operation covers the entire GIS part. - Four operating systems of other organizations and GWCL operate their own GIS systems. - Database composition using specific SW as GIS engine - Features required for each system type are limited - Most storage uses cloud service
	(To be) - Need to introduce GIS integration and open source - Common terrain DB needs to be supplied centrally (Mapping agency cooperation required) - Sharing the system so that only features suitable for each subject can be registered - Introduction of open source considering operation and maintenance costs and scalability - Data for feature classes that are currently lacking need to be investigated for data completeness.
Interface	(As is) - Problems with current system integration - Integration limitations due to problems discussed in Section 2.1.4
	(To be) - Preparation of top-down standardization (draft) - Elimination of problems through standardization and interface systems - Intermediate interface system development for integration of existing system data - Data verified through the interface are stored as minimal redundant data in the DB for SIS
Public Use	(As is) - BaSIS and DiMES information inquiry
	(To be) - 14 integrated WASH indicator information and processed information from the system - Inquiry of basic information and processing information in each field - Include user feedback and complaint service system

Source: Author.

3.2. Scope and Function of Integrated Platform

The scope of the integrated platform should be able to generate the 14 indicators selected primarily by MSWR and include decision support functions. To this end, it is necessary to be able to integrate the data of related systems operated by existing related institutions, and it is necessary to target regions where the system is spread and data are generated smoothly. In conclusion, the Greater Accra Region, where the system is popular and data are being generated, should be the target.

Systemically, it will be necessary to include interfaces for integration into existing systems, water resources management, and drinking water systems. Currently, in the field of water resources and drinking water, it is judged that data are provided in the form of Excel spreadsheets rather than automatically provided for index calculation, and it is judged that there is no related system and statistical information is generated and provided whenever necessary. Of course, expansion of some infrastructures and reexamination of indicator-related data may be necessary, but the success story of the Greater Accra Region will give more confidence to its expansion to other regions.

Second, liquid waste and solid waste were selected as the target range, and these two fields are waste treatment by private companies. Currently, the percentage of communities where collection services are provided has been extracted, but management of actual occurrence and throughput is required. In addition, the management of various facilities for measuring indicators in the sanitation field, such as restrooms and handwashing facilities, is also included in the secondary construction target.

Finally, it will require development and integration in the field of water quality management, which is far from index measurement but is the most important.

Next, the functions of the systems selected for each stage are shown in <Table 3-9>. First, it is impossible to integrate data seamlessly into the integrated system, so it is possible to standardize the data in a consistent format and structure through the interface system according to the standardization guidelines in the middle and then use them in the integrated system. The functions for this are given in <Table 3-9>.

<Table 3-9> Interface System Capabilities

Function	Description
Data Integration and Transformation	It is a function that integrates data collected from each department's system and converts them into a necessary format so that they can be linked. ETL (extract, transform, load) technology can be used for data integration, and data conversion rules can be defined to maintain consistency and quality.
Data Mapping and Matching	It is a function to perform mapping and matching between data elements used in each department system, thereby guaranteeing mutual compatibility of data and making it possible to connect data elements representing the same concept.
Data Communication and Transmission	A communication interface must be established to transfer data between departmental systems safely and quickly. To this end, it is a function to support data communication by utilizing web services, APIs (application programming interfaces), and messaging systems.
Data Security and Access Control	Functions for security and access control of linked data must be provided. Security policies and access control mechanisms must be implemented to prevent unauthorized access to data and ensure that only authorized users have access to those data.
Error Handling and Monitoring	It should include a function to detect and handle errors that may occur in the data linkage process. It is a function that allows system operators to identify and respond to problems quickly through error logging and error notification functions.

Source: Author.

The representative functions of the water resource management system required to obtain Ghana's WASH indicators are shown in <Table 3-10>, but are not limited to the following content.

<Table 3-10> Water Resource Management System Functions

Function	Description
Data Collection	Ability to collect and edit data relating to water resources including surface water, groundwater, rainfall, and water quality
Data Analysis and Modeling	Analysis and modeling capabilities are needed to process the collected data and generate useful information, including the ability to analyze water availability, assess water demand, predict water availability in different scenarios, and perform water balance calculations.
Water Allocation and Planning	The ability to support the water allocation and planning process by assessing water availability, prioritizing water use, and providing tools to develop a water allocation plan, taking into account various factors such as competing needs, environmental considerations, and water rights .
Infrastructure Management	Capabilities to support management of water infrastructure such as dams, reservoirs, and water distribution networks include capabilities for monitoring infrastructure performance, optimizing water storage and distribution, and identifying maintenance and repair requirements.
Monitoring	It includes data collection functions such as meteorological, hydrological, and water quality test data, and monitoring functions for pollution conditions.

Source: Author.

The drinking water volume management (block monitoring system) system maintains the existing functions as much as possible and supplements only the functions of the insufficient parts to develop into a whole system by adding the functions shown in <Table 3-11>. GWCL operates a system named SCADA, and the expanding monitoring system includes management by zone and GIS data of pipelines in the maintenance part.

<Table 3-11> Block Monitoring System Function

Function	Description
Real-time Data Collection	Monitoring systems must be able to collect real-time data from multiple sources, including SCADA systems, zoning meters, and GIS. To this end, a data communication interface and protocol are established to capture and transmit data continuously. It consists of a flow meter and an IoT sensor. The customer usage through the customer meter is linked to the information of the already established e-billing system.
Data Integration and Statistics	The system is intended to integrate and aggregate data collected from various sources to provide a comprehensive picture of drinking water supply. This means integrating data from SCADA systems, district meters, GIS, and other relevant sources into a unified database or platform.
Data Visualization and Reporting	Interactive and user-friendly data visualization tools and report generation are important features. This should provide dashboards, charts, maps, and custom reports so that stakeholders can easily access and interpret the monitored data.
Alerts and Anomaly Detection	Implementing alarm and anomaly detection mechanisms is an important function for detecting deviations or abnormal patterns in drinking water supply. This includes setting boundaries or rules to trigger alerts or notifications when certain predefined conditions are met.
Maintenance	ICT monitoring systems must support maintenance and management of pipeline networks and drinking water facilities. This requires maintenance functions including failure diagnosis, maintenance scheduling, resource allocation, and work ordering.
Security	To ensure safe storage, transmission, and access control of data, and to maintain data confidentiality, monitoring systems should have appropriate security features for data security and privacy protection.
Trend Analysis and Forecasting	The system should have the ability to analyze historical data and generate trend analysis reports. In addition, predictive models need to be incorporated to predict the future of drinking water supplies based on past patterns and related factors. This is a feature that can help an organization identify and support decisions about efficiency, problem areas, and opportunities for improvement in the drinking water supply.
GIS	Integrated into GIS system and managed.

Source: Author.

From water management to food monitoring, all systems include GIS functions. Among them, information relating to drinking water and all information for supplying drinking water should be managed in this system. This system should be the basis for future expansion into tasks such as waste management and water quality management.

<Table 3-12> Required Features of a GIS System

Function	Description
Data Collection	Collects and records geographic data such as mapped WASH facilities, water sources, water and sewage networks, etc.
Data Visualization	A function to visualize the data collected using the GIS system on a map to identify the location of WASH facilities, supply status, population distribution, etc.
Spatial Analysis	GIS provides spatial analysis tools to perform various analyses relating to WASH implementation, which analyzes regional priorities, suitability of water sources, water supply and sewage networks, etc.
Risk Assessment	It is a function to evaluate risks such as natural disasters, environmental pollution, etc., using a GIS system, and through this, it identifies vulnerabilities of WASH facilities and establishes appropriate response strategies.
Facility Management	A function to establish an efficient maintenance plan by managing the location, status, and maintenance records of the facility by utilizing it for management and maintenance of WASH facilities.
Decision Support	The ability to integrate diverse data to provide insightful information to aid decision-making, supporting effective policy and strategy formulation through the interconnection of spatial and other data.

Source: Author.

In the second stage, the composition of the WASH center is a system for waste management, including liquid waste and solid waste, and its functions are given in <Table 3-13>.

<Table 3-13> Required Functions of the Waste Management System

Function	Description
Data Collection	Manage the status of registered or newly established collection companies and individual collection companies.
	Liquid waste is automatically entered into the DB at the same time as when the collection company measures the weight after warehousing the vehicle, or the measured weight is manually entered immediately. In addition, the amount of recycling after treatment and the quality of discharged water are input.
	For solid waste, the collection company automatically inputs the weight into the DB at the same time as when the vehicle is stored and the weight is measured, or the measured weight is manually entered immediately. In addition, the recycling amount and landfill weight before being transferred to the landfill are reentered.
	Finally, the landfill weight measured at the landfill is managed to manage the amount generated by community.
Other Functions	The above table functions are additionally included.
GIS	Enter the status of the collection company, the boundary of the collection community, and the status of the households subject to collection as GIS data.

Source: Author.

The last stage is the water quality management system, which manages matters relating to the water quality of the treated sewage discharged from the sewage treatment plant and the treated water discharged after treatment at the business site. In addition, it records and manages sensor acquisition data in real time to monitor sewage water quality and water quality near water intake sources, and includes a CCTV monitoring function.

<Table 3-14> Required Functions of the Water Quality Management System

Function	Description
Data Collection	Water quality discharged after sewage treatment and related information are managed to be input immediately after water quality testing at the sewage treatment plant. Sewage and wastewater should be managed separately if different information is required.
Illegal Activity Management	Administrative order management, such as imposing penalties on workplaces that emit in excess of the standard.
Disclosure	Openable information built at every stage is disclosed to the public according to the user's level. Also, develop a communication channel with the government for user complaints.
Other Functions	Implement necessary functions similar to the contents of the above tables.
GIS	Enter the status of the collection company, the boundary of the collection community, and the status of the households subject to collection as GIS data.

Source: Author.

If possible, it is also necessary to make it mandatory to attach the discharge water quality sensor at the discharge site and to interlock it to monitor it. The monitoring system at this stage needs to be implemented so that real-time information can be checked in conjunction with the above water quality management system.

<Table 3-15> Required Functions of the Water Quality Monitoring System

Function	Description
Sensors and Data Acquisition	The information measured by the sensor is automatically entered into the DB as digital data.
Data Storage and Management	Store and manage the collected information in a DB server or cloud DB.
Real-time Monitoring and Visualization	Function that monitors collected information in real time and visualizes and displays various information.
Alerts and Alarms	When information above the standard value is entered, an alarm is issued to the manager to take action on abnormal situations.
Illegal Activity Management	Since laboratory records can be manipulated, they are managed to be compared in real time with information measured by sensors.
Data Analysis and Trend Prediction	It is necessary to reflect AI functions so that water quality change patterns can be analyzed and predicted, and implementation is required so that managers can use the prediction results.

<Table 3-15> Continued

Function	Description
Remote Monitoring and Control	Real-time automation enables control of equipment, managing geographically dispersed sensors to operate.
Reporting Function	Ability to report required information for each manager level.
Data Integration	In the previous stage, it is linked to the DB in operation to extract additional information and implement comprehensive management.
Security and More	It provides a security management function to prevent data from being altered or lost, duplicates the DB server, and manages possible risky situations.
Other Functions	Among the functions listed in the above tables, necessary functions are included.

Source: Author.

The implementation of the last stage requires the construction of an integrated WASH center and completes the integrated management of all environmental information. In particular, at this stage, machine learning and AI functions are sufficiently included to be used for prediction and judgment.

3.3. Process Improvement Plan

In the task of data input or data collection of the existing system, it is necessary to consider the task of "data collection and lack of accuracy" among the problems presented in Section 2.1.4. Existing methods of acquiring data for obtaining WASH indicators were mainly performed by manpower, some automated sensors, and extraction of experimental results. Personnel have tasks such as entering the location of toilets, handwashing facilities, or meters, inputting the usage amount displayed on the meter by individual customers, and recording test results by water quality laboratory personnel.

In addition, as one of the main tasks performed by human resources, GWCL has tasks relating to the verification of drinking water consumption. It is a task to extract consumers who have not entered measured values or who show a large difference from the average usage in normal times and verify the values. As another task, the EPA has to supervise the quality of discharged water, but it is neglected due to a lack of trained experts as well as manpower.

In conclusion, data acquisition by manpower will inevitably have limitations. <Table 3-16> shows a comparison of data acquisition by manpower and data acquisition by automation, and shows that the introduction of an automation method is essential despite the potential for various disadvantages.

<Table 3-16> Comparison of Advantages and Disadvantages of Data Acquisition Methods

	Data collection by manpower	Automation
Advantages	• Acquisition of various information in the same location	• Data acquisition rate adjustable • No possibility of error or lack • Excellent accuracy and precision • Can be used immediately after installation • Possibility of semipermanent use • Only maintenance costs incurred after installation
Disadvantages	• Data collection is slow • Possibility of requiring various tools • Possible lack of accuracy and precision • Requires training for data acquisition • Fixed costs such as labor costs	• Possibility of mechanical failure • Unable to acquire information other than specified • Excessive initial installation cost

Source: Author.

In addition, it is necessary to consider the process of acquiring and transmitting information. For example, reading customer meters was a task that the government had to do, but by acquiring and inputting data directly from customers, the meter reading task was reduced to monitoring and verification. Likewise, in the fields of solid waste, liquid waste, and wastewater treatment, if private companies directly enter data into the system, the government will be able to reduce to monitoring and verification tasks. To this end, the functions of the system must be developed flexibly to accommodate the tasks of each ministry related to WASH.

A method of automating the acquisition of information can also be considered, and a system for monitoring sensors and acquired information can be mainly considered. Until now, it was not possible to verify all necessary information automatically, but if an organization considers just a few essential items for information verification, they will be able to reduce the work process even more, and it can be applied to the tasks shown in <Table 3-17>.

<Table 3-17> Jobs Can Automate Information Acquisition or Introduce an Automated System

	Task	Automation
Drinking Water	Acquisition of Customer Usage Information	• Smart meter and monitoring • Acquisition of usage automatically from smart meter • Introduction process in progress
	Automatic Acquisition of Supply Information and Calculation of NRW	• Introduction and monitoring of additional flow meter sensors • Flow measurement from water purification plant to reservoir • Flow measurement from reservoir to consumer • Divide the drainage area into zones and measure the flow rate • Calculation of NRW in comparison to consumer usage • Analysis of problems by region through NRW monitoring by zone

<Table 3-17> Continued

	Task	Automation
Drinking Water	Quality Management	• Water quality sensor and monitoring • Water quality measurement at water sources and water treatment plants • Database of water quality analysis data • Trend analysis of water quality analysis data • Management of water quality and pollutants in intake areas
	GIS Tasks	• Business system for utilizing acquired information • Pipeline leakage location and history management • Facility maintenance history management
Solid and Liquid Waste	Waste Generation-Treatment Status Management	• Waste treatment business system by community • Enter waste receipt and output amount at each business site • Production and sales management of volume-based bags • Recycling management
Sewage and Wastewater	Discharged Water Quality Management	• Water quality sensor introduction and water quality monitoring at the outlet • Automatic inspection of water quality standards • Input of discharged water quality by individual establishment

Source: Author.

Next, the process of acquiring data for acquiring indicators under the new system is shown in <Table 3-18>.

<Table 3-18> Indicator Acquisition Procedure

Indicators	Acquisition Procedures
Water Sector Indicators	
Percentage of households using improved water sources	• Automated acquisition of drinking water in large cities based on the consumer list of the e-billing system integrated into GWCL's block monitoring system and population/housing survey data of the National Statistical Office • Rural area is obtained through a newly developed interface system based on the existing DiMES system
Percentage of schools with access to improved water sources	• Acquisition of data from National Statistical Office data and GIS data in which institutions are classified, as it is a factor of the number of institutions and the institution customer list • Status is newly created by integrating data
Percentage of health facilities with access to improved water sources	
Percentage of institutions (prisons, police stations, etc.) with access to improved water sources	
Sanitation Sector Indicators	
Percentage of households with access to improved sanitation facilities	Percentage of the population with access to basic handwashing facilities
Percentage of schools with access to improved sanitation facilities	Percentage of health facilities with access to improved sanitation facilities

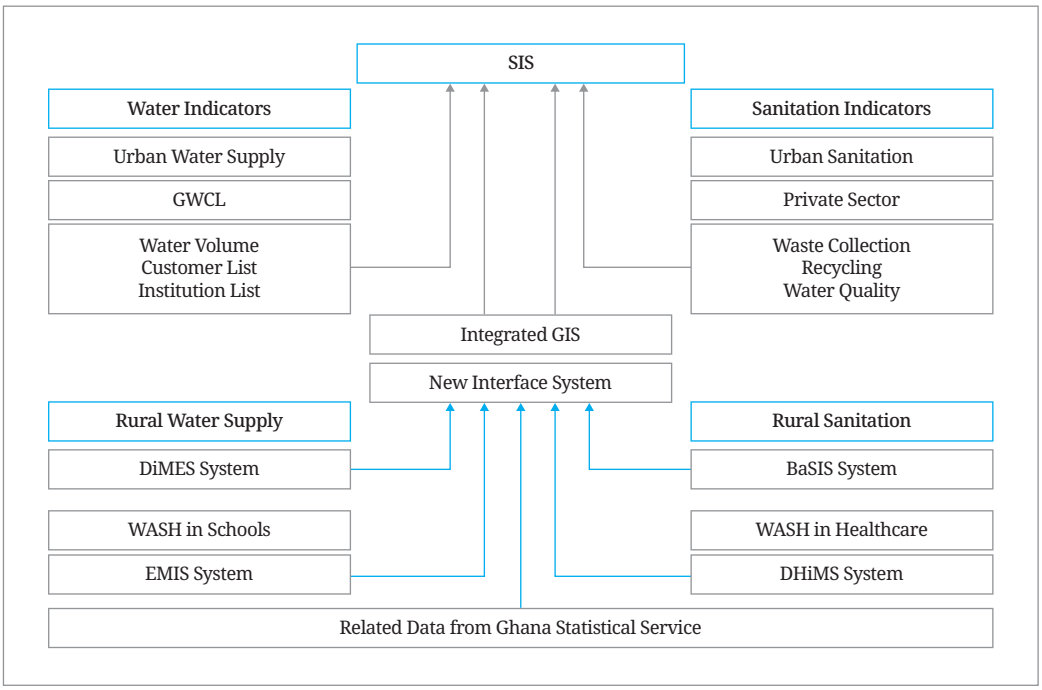
<Table 3-18> Continued

Indicators	Acquisition Procedures
Percentage of institutions with access to improved sanitation facilities	Percentage of households with access to latrines that meet basic standards
Percentage of households with access to basic handwashing facilities at home	
• This sector is a structure that generates indicators from the existing BaSIS system • Obtained through the interface system according to the standard	
Percentage of communities with access to solid waste collection services	• The data are boundaries and responsible companies list • Data acquisition is obtained from private associations • Indicators are automatically extracted from the GIS system
Percentage of communities with access to liquid waste collection services	
Percentage of households with children under five who practice basic handwashing at critical times	• Acquisition of survey data of the existing National Statistical Office through the interface system

Source: Author.

Finally, the interconnection between WASH-related systems is shown in [Figure 3-6].

[Figure 3-6] Intersystem Connectivity of the Target Model



Source: Author.

3.4. ICT Infrastructure Establishment Approaches

The WASH center system consists of a total of ten unit systems by sector, from water resources to water quality management, including water supply, liquid waste, and solid waste, as in the integrated model configured in Section 3.1.3. Among them, the decision support system improves the existing SIS system, expands the integration of the distributed system, acquires the target WASH index, and strengthens the decision-making function.

The architecture of the system should consider maintenance, scalability, and security, and consider the following in terms of data stability and failure response.

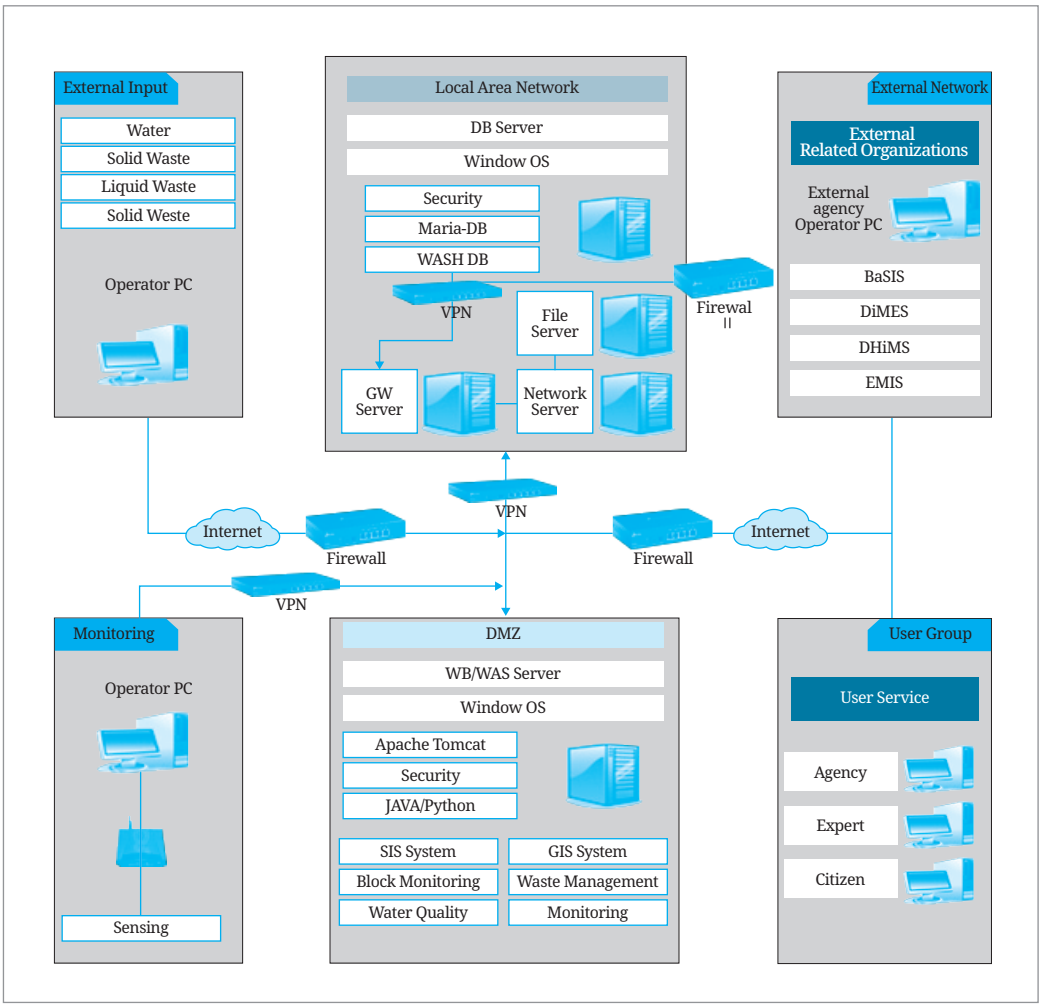
<Table 3-19> Considerations for System Architecture Configuration

Consideration	Details
Integration and Recycling	• Consider the integration of the existing operating system as much as possible • System supplemental development that can be used rather than new development
Web, WAS Server Use	• Possibility of high load and slowdown when using WAS only • Requires static and dynamic responses to user needs
Server Redundancy	• Respond to failures through system self-mirroring • Need for security response to cloud service use
Database	• Stable database implementation for a large user base • Cost savings compared to commercial services by using open source
Application of Open-source GIS	• Cost reduction compared to required functions • Consider compatibility with existing software • Freely modifying and distributing

Source: Author.

1) Architecture Diagram

[Figure 3-7] System Architecture



Source: Author.

2) HW and SW Configuration

The HW configuration is divided into system framework development, accessibility development, and development environment.

<Table 3-20> Contents of the HW Configuration

Configuration	Description
System Framework Development	• Provides a web frame where users can use one or more program modules at the same time • Module function development using spring framework
System Accessibility Development	• Use of W3C-based standard HTML tags • Compliance with Web Accessibility Guidelines • UTF-8 for multilingual support
System Development Environment	• Development language: JAVA, Python • OS: Windows Server 2018 or Linux • Web Server: Apache • Was: Tomcat • SW security solution: LifeKeeper, Kaspersky

Source: Author.

The SW composition is built based on Java and Python that can share and edit the DB by applying an open-source GIS engine and DB construction software.

<Table 3-21> Contents of the SW Configuration

Configuration	Description
Open-Source GIS Engine and DB Construction Software	• Application of open-source-based GIS engines such as Geo Server • Apply Google Maps JavaScript API • QGIS, Google MAP Tool (spatial information DB construction) • MS Excel Tool (property information DB establishment)

Source: Author.

3) Database

Since it can be dangerous to store security-critical data in the cloud, open-source-based PostgreSQL is applied as database SW. It is necessary to build a basic data database (spatial information, attribute information) through a management system that combines an MIS (management information system) and GIS in the web environment.

4. Financing Plan

4.1. Private Sector Investment Possibilities

Among Ghana's WASH fields, drinking water is a public domain, and liquid waste and solid waste are handled by private companies. Human waste treatment among liquid waste is carried out by private companies, and the sewage treatment field was operated by the public sector, but it is currently being consigned to private companies. In addition, solid waste is divided into domestic waste, industrial waste, and medical waste, and is treated by private companies. Therefore, apart from the public sector, the liquid waste and solid waste areas, which are handled by private companies, are judged to be an area where foreign or multinational companies as well as private companies in Ghana can enter.

Ghana is a politically stable and relatively secure country, and economic development in recent decades elevated Ghana to the status of a lower-middle-income country in 2011. This stability of the country has provided a base for local and foreign investors to invest in various fields. Nonetheless, decades of industrialization and uncontrolled urbanization have resulted in uncontrolled and inadequate handling and treatment of solid waste and liquid effluents, resulting in significant environmental degradation in both inland and coastal waters.

More than 70% of Ghana's major industries are concentrated in the Greater Accra Region, and most industries require large amounts of water resources. In addition, about 30% of the water resources used for facility operation are discarded as wastewater, chemical waste, and biowaste, but the wastewater treatment field remains the most underdeveloped field. According to Ghana's EPA wastewater treatment regulations, wastewater must be treated below an acceptable level before being discharged or used as reused water. However, the reality is that it is generally known to be illegally discharged without permission, and domestic sewage is dumped into rivers in an untreated state due to poor sewage infrastructure.

To overcome this, the government consigned the operation of the sewage treatment plant to Zoomlion of the Jospong Group, a private wastewater treatment company. However, expansion of sewage infrastructure and sewage treatment plants and strong water quality monitoring should be preceded, but the government lacks human resources to manage and supervise them.

After the solid waste is collected by trucks owned by private companies or individuals, it is reclassified by waste transport companies and transported to landfills. As a joint venture with a foreign company, Zoompac is one of the largest companies in the solid waste sector, responsible for the disposal of domestic and medical waste.

Among solid waste, industrial waste such as used electronics imported from abroad are not properly separated and collected. And the wastewater generated from them is known to flow into the river. In addition, among household waste, recyclable waste is not properly separated and collected, and the entire collected waste is landfilled. In addition, since the waste landfill is located near a drinking water source, there is a concern about river pollution due to leachate.

Waste disposal companies in Ghana simply transport the collected waste onto large transport trucks and transport it to landfills, but they do not have functions such as incinerating or resorting the waste on site.

Ghana currently operates 16 industrial complexes, most of which require large-scale industrial water and generate large amounts of wastewater. However, there is no wastewater treatment facility in the industrial complex, and individual workplaces are obliged to treat wastewater, but most of them are discharged without treatment, and it was investigated that the workplace monitors only the direction of the government.

The Ghana government plans to create additional industrial parks in the future. Various industrial fields can exist in an industrial complex. However, it is known that the private sector will play a leading role, and the government is actively supporting it.

In terms of policy, the Ghana government has established an independent organization called the EPA to implement environment-related government policies and perform management and supervision roles. Independent businesses must treat and discharge contaminated water below the baseline for wastewater discharge in accordance with EPA regulations. In addition, business sites for export to countries such as the U.S. and EU must not only comply with Ghana's wastewater treatment regulations according to their regulations, but also comply with EU and U.S. environmental regulations. These policy aspects will give a positive signal to the international community and private companies entering the environment-related industry.

Private companies in Ghana and multinational companies operating in Ghana must comply with environmental regulations and strive to create a better water environment in accordance with corporate social responsibility (CSR) obligations relating to the

environment. Despite the negative aspects of this increasing pressure from the international community, environmental considerations recognize that the government's cost reduction, expansion of new business opportunities, and the creation of a healthy civil society will act as positive aspects.

Korea's waste treatment field is divided into household waste, industrial waste, and medical waste, etc., and household waste is partially incinerated and partially landfilled. In terms of solid waste, Korea has introduced a system called the volume-rate waste system, and the discharger purchases a bag to dispose of the waste. The purchase of bags by the waste emitter eventually plays a role in sharing the cost of garbage disposal, and the volume-based bag purchase volume allows the estimation of emissions, and the amount is estimated by combining the weight of the collection company and the weight measurement at the landfill. In addition, an environmentally friendly waste incineration facility can reduce the amount of landfill, and the waste heat generated can act as an additional source of income such as electricity or hot water production, which would be in line with Ghana's policy promotion plan.

Liquid waste is divided into human waste, livestock manure, and food waste. The local public and businesses indirectly contribute to environmental improvement by paying environmental charges according to the amount generated, and the government is responsible for waste disposal. Therefore, the policy of opening the door to foreign companies possessing waste reuse and generation reduction technologies will be of great help in improving the environment. However, the Ghana government should focus on environmental monitoring with an active will and policy to improve the water environment, and support the private sector to act within the institutional framework. This ability to execute will be the way to show the strong willingness of the government and will be the only way for the international community's environmental industry to settle down safely.

4.2. Priority and Implementation

The implementation task proposed by this KSP is the WASH monitoring center, which will become the control tower in the WASH field. This task will include all fields of drinking water, solid waste, and liquid waste, and it is set that the integrated platform will be completed with the completion of the monitoring system. In addition, among the first priorities, integration of existing systems for extracting WASH indicators is included to achieve the goal of building an integrated platform. This implementation task was composed of some construction fields with the goal of improving the indicators among the problems analyzed.

Even if a more advanced model is established, a new field is added, or a plan is changed during the course of the task, the existing task is configured to maintain sustainability as much as possible. The integrated platform consists of nine systems and decision support systems: water resources, drinking water, liquid waste, solid waste, water quality management and monitoring systems, GIS, system interface, and information provision, and the priorities between systems are set as shown in <Table 3-22>.

<Table 3-22> Establishment of Priorities for System Construction

Priority	Sector	Reasons for Selection
First Priority	Drinking Water	• Drinking water accounts for a large portion of the WASH indicators and is the most important sector for improving quality of life. • The decision-making structure is simple as GWCL, an affiliate of MSWR, is in charge of supplying drinking water to the entire Greater Accra Region. • Areas where public institutions are the subject of business operations • Solving the NRW problem is absolutely essential for expanding drinking water and reducing costs. • Possible without the introduction of a legal system, but the effect is expected to be greater than other fields
Second Priority	Waste	• The waste field is a sector where the private sector is the subject of business, and the structure is a bit more complicated with the local government as a stakeholder. • The three systems, including liquid waste, solid waste, and manure treatment, are expected to be relatively large in scale. • Areas requiring improvement of the legal system
Third Priority	Water Quality	• Areas not included in the current 14 WASH indicators • Necessary consultation process in the field related to the EPA, which controls wastewater discharge workplaces as a major cause of drinking water source contamination • Essential fields to reduce water treatment costs • Necessary to protect people's quality of life and source of income

Source: Author.

4.3. Project Cost Estimation

Essentially, the purpose of requesting a KSP is to integrate the existing system. However, there are limitations in enhancing the WASH indicators just by integrating the system and DB. Therefore, the goal of the project in this report aims to integrate the system and enhance the WASH indicators, in particular, by enhancing the drinking water sector by improving NRW. By considering the inflation rate and price fluctuations in the preliminary stages of the project, in addition to investigating the components of project and planning the components carefully, there must be a specific plan to estimate the project costs.

However, the current KSP has not been conducted just to compose the project targeted at specific institutions or projects, as time is limited. It simply investigated the priorities by extracting the factors of improvement in each field. Moreover, the WASH sector, a subject of policy suggestion, includes various fields, such as drinking water, hygiene, and health, and there are over 100,000 target institutions. Therefore, in this process, the priorities have been selected by visiting three private institutions related to waste in the hygiene field, GWCL in the drinking water field, and MSWR in system integration.

The configuration procedure for the project cost in Korea is as follows: Select the process for specific projects and goal accomplishment, and estimate the costs per process by investigating project equipment costs and wage levels obtained from the Department of Statistics. Moreover, cost of developing applied program will be applied regulation of KOSA project cost selection process by its scale, and service and construction will be applied quantity information of process by the Ministry of Land. However, there does not exist a national regulation for project costs in Ghana, making it difficult to compose processes for certain fields. Therefore, the project cost has been estimated by investigating similar projects in Korea.

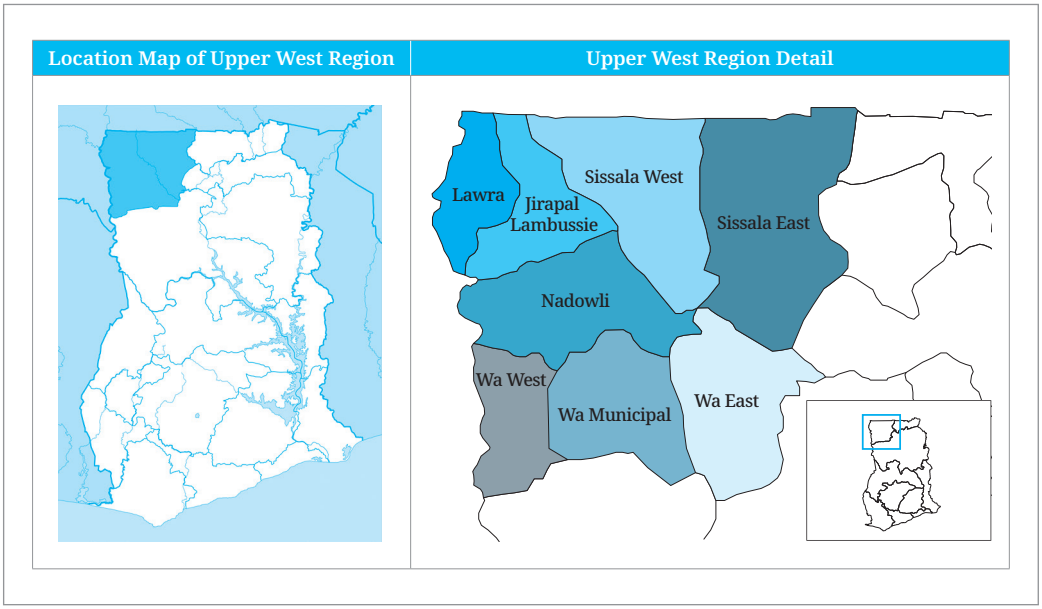
<Table 3-23> Understanding the Prerequisites for Cost Estimation

Project Cost Component	Reference
Programming Cost	• Applied assuming that it is similar to similar application development projects in Korea
Personnel Expenses	• Since the level of labor costs in Korea is lower than that of advanced OECD countries and higher than that of underdeveloped countries, the statistics of the Korean government are applied. • Local labor costs are estimated by considering local circumstances.
Material Cost	• Market prices apply for materials, rent, computers, and software.
Cost of Stay	• Application of actual expenses

Source: Author.

The first stage aims to improve the drinking water sector and build an integrated system. To improve NRW, a block monitoring system (SCADA) will be introduced to identify the areas with severe leaks and improve pipelines through leakage detection. After pipeline improvement, an integrated drinking water management system will be developed and utilized for pipeline maintenance, integrating the SCADA and e-billing systems. The pilot project target area is the Upper West Region; see [Figure 3-8].

[Figure 3-8] Selecting the Primary Project Target Area



Source: Author.

About 300 km of existing pipelines are installed, and two sensors for flow measure meters are installed, but they are currently neglected in a broken state. About 50 km of the pipeline length is targeted for retrofitting and the activities envisioned are outlined in <Table 3-24>.

<Table 3-24> Pilot Project Components

ICT	Construction
• Drinking water integrated system - Block monitoring (SCADA) - GIS (maintenance) - E-billing (integration)	• Digital flowmeter (15) • Digital water p-pressure meter (30) • Solar panel for meters (45) • Leakage detection • Pipeline replacement or repair (50 km)
Capacity Building	Equipment
• System operating and DB management • Drinking water facility management	• Computing and telecommunicating • Ground-penetrating radar systems
Others	
• Master plan for NRW improvement • GIS of replacement pipeline	

Source: Author.

Even though grant aid will be primarily used as a funding source, the composition of the project and its degree of approval may differ depending on the ideas from each institution, resulting in the need for renegotiation.

The cost structure of the first stage project is shown in <Table 3-25>.

<Table 3-25> Stage 1 Project Detail and Cost

(Unit: 1,000 USD)

Component	Subcomponent	Cost	Remarks
Masterplan		300	Planning and financing
System Development	Block monitoring (SCADA)	1,200	
	Water Integrated System	1,500	
	Build Database	500	
Construction (Rehabilitation)	Leakage Detection	500	
	Repair or Replacement of Pipeline	5,300	Pipeline / solar system / meters
Capacity Building	ICT Facility Management	200	Invitation training Local training
Equipment	Computing and Network	500	

Source: Author.

Based on the evidence, which is required to prove the effectiveness of the project for NRW improvement in the first stage, a plan to expand to the Greater Accra Region needs to be established in the pipeline. Loan aid will be used from the second stage of water supply improvement since the scope of this project greatly expands.

The second stage targets the development of a new information system in the waste field. The improvement of NRW is treated as a separate item from the development of the waste system. However, in the larger framework of the WASH sector, we propose loan aid as a sub-item. However, if new ideas spark from negotiation with international institutions including those in Korea, grant aid or self-budget may be considered.

The composition of fees of the second stage of the project is as follows. It does not include the entire project cost for NRW improvement, which may differ from the plan established in the first stage.

<Table 3-26> Stage 2 Project Detail and Cost

(Unit: 1,000 USD)

Component	Subcomponent	Cost	Remarks
Program Development	Solid Waste Management	750	Installed for private companies to enter
	Liquid Waste Management	750	Installed for private companies to enter
Construction DB	GIS Survey and Construction	500	
Capacity Building	Invitation Training Local Training	100	Operating
Equipment	Computing and Network	500	HW/SW/network

Source: Author.

The third stage aims to complete the WASH integrated center. The solution is a new system that includes functions for water quality management and monitoring. And the integrated system will combine the systems from the drinking water and waste fields.

The water quality field requires voluntary participation of the private sector through improvement of the legal system and cooperation among institutions, making the improvement of governance crucial. In addition, even though there may be confrontation between the public and private sectors, water quality improvement musty be improved for national development, which requires thorough preparation from the second stage.

The third stage of project is as follows:

- Develop a monitoring system for the water quality field
  - Manage the quality of discharged water from every business that disposes over a certain amount.
  - Monitor quality of public water
  - Issue warnings to businesses that exceed water quality standards.
- Upgrade system for the water quality and waste fields based on technological advancement
- Compose integrated center control room
  - Establishment of an integrated WASH center should be premised on the participation of related agencies, including EPA.

The costs for the third stage of project are shown in <Table 3-27>.

<Table 3-27> Stage 3 Project Detail and Cost

(Unit: 1,000 USD)

Component	Subcomponent	Cost	Remarks
Program Development	Waste Water Quality Management	1,500	Includes public services
	Water Resource Quality Management	500	
	Monitoring	500	
Construction DB	GIS Survey and Construction	500	
Construction	Build a Control Room	1,700	
	Water Quality/Rainfall Meter		Water source quality management (70 locations)
Capacity Building	Invitation Training Local Training	300	For decision-makers For technicians
Equipment	Computing and Network	500	

Source: Author.

The project cost is divided into stages as follows:

<Table 3-28> Estimated Project Cost by Stage

(Unit: 1,000 USD)

Sector	Water	Waste	Water Quality Monitoring	Subtotal
	Stage 1	Stage 2	Stage 3	
Masterplan	300			300
System Development	2,700	1,500	2,500	6,700
Building Database	500	500	500	1,500
Construction	5,800		1,700	7,500
Capacity Building	200	100	300	600
Equipment	500	500	500	1,500
Total	10,000	2,600	5,500	18,100

Source: Author.

<Table 3-28> does not include the total cost of NRW improvement at the national level, but the improvement cost of some pilot areas and the selection of the pilot area is the cost to prove the effectiveness of the project.

4.4. Financing Plan Detail

As a result of the survey, the total project cost for ICT in the WASH field is estimated to be USD 9,750,000, and if pipeline improvement is included, it is estimated to be USD 18,250,000. However, a large part of the WASH indicators is drinking water, and in order to improve the supply of drinking water, the improvement of NRW is also an urgent task and occupies a large part of the information demand. In addition, although not included in the WASH indicator, water quality improvement has emerged as an urgent issue to reduce the costs in the drinking water sector and secure people's right to health, so the third step includes water quality management.

In the first stage, in order to secure the legitimacy of pipeline improvement, only part of the area with high leakage selected through area measurement is included, and the pipeline improvement of the entire area will have to be passed on to a later task.

Since the water quality sector in step 3 is the EPA's management area, MSWR and EPA should cooperate, and the water quality management of drinking water sources should be considered in terms of reducing MSWR's drinking water production cost.

Overall, the composition of financial resources should be composed of a mixture of grants and loans, but it would be reasonable to move to the loan stage after proving effectiveness in the first stage. Grant requests can be considered by grant aid agencies of the international community, including the Korean government, and loan aid needs to consider the EDCF of the Export-Import Bank of Korea in consideration of the project formation period and procurement conditions.

GWCL has already requested an EDCF loan for the introduction of smart meters and is currently preparing for a feasibility study. The smart meter project is a way to improve NRW, and if effectiveness is demonstrated in currently considered projects, GWCL will need to consider further introduction.

5. Policy Proposal

Information systems cannot do much to improve the WASH situation. However, information systems can provide various advantages, such as improvement of business processes, accurate recording of official data, and periodic acquisition of accurate data through automation. However, in Ghana, the WASH sector is not handled by one agency, and there are various organizations involved as well such as MSWR, GWCL, CWSA, Environmental Health and Sanitation Directorate, Ghana Health Service, and Ghana Education Service, and indirectly related organizations such as the EPA. Therefore, enactment of a legal system or revision of the existing laws is necessary, and capacity building must precede.

First, it is necessary to promote the WASH integrated control center. The role of the control center is to contribute to the achievement of WASH targets through the management of drinking water, sanitation, and water quality. Although it is not a WASH indicator, the most problematic part is water quality, and water pollution is a major factor that makes it difficult to address the WASH problems, such as increased drinking water production costs and adverse effects on public health. Furthermore, as various organizations share roles, the gaps and selfishness among organizations make integration difficult. Each agency has its own primary goals, and since achieving WASH goals may not be an agency's primary task, it may be passive in producing WASH data. Therefore, the control center should operate the information system together with a common goal beyond the organization and seek to achieve the goal through monitoring activities.

Second, it is necessary to overhaul the legal system. Regarding drinking water, since GWCL is in charge of the urban area and CWSA is in charge of the rural area, it is necessary to expand the infrastructure and improve the NRW rather than improving the system. However, the local government is in charge of licensing subsectors such as solid waste and liquid waste, and private companies are in charge of treatment. It is necessary to change the work processing system so that the devices are directly linked and the data are entered into the center's management system.

Third, it is recommended to introduce a volume-rate garbage bag system for solid waste. Illegal dumping of garbage that does not use volume-rate bags should not be allowed. By managing the production, sales volume, and collection amount by community in the system, transparency of waste treatment should be secured and strong legal penalties should be imposed on waste dumping without permission.

Fourth, in order to improve water quality, businesses that discharge wastewater of a certain size or more need to input the results of discharged water quality directly into the system and directly monitor some items. More than 70% of Ghana's industries are concentrated around the Greater Accra Region, and most industries are known to require a large amount of water resources, but they are generally discharged without permission. Among governmental organizations, the EPA is responsible for managing and supervising industrial water quality, but it has difficulties in monitoring water quality due to the limited number of employees, which leads to increased costs for other institutions. Contamination of drinking water sources increases the cost of water treatment and is a threat to securing the right to public health. A system for inputting and analyzing water quality data should be prepared by the government, but a system for monitoring water quality should be prepared by individual business sites and monitored in conjunction with the system. From the standpoint of a private company, it may be difficult to have a system for monitoring water quality right away. However, CSR (corporate social responsibility) activities are becoming established as an obligation for private companies, and for exports to the U.S. or Europe, the environment-related legal system of the manufacturing country must be observed, so the law needs to be strengthened urgently.

Lastly, it will be necessary to strengthen the capacity of related organizations and civil society. Officials of relevant organizations must have expertise in technology trends and technologies that need to be introduced in the fields of drinking water, sanitation, and water quality in relation to WASH, and must have the ability to maintain equipment. In particular, in terms of ICT, expertise in databases is required, and it is necessary to train employees so that they have the technical ability to perform the role of database manager. Of course, it cannot be ruled out that personnel who have acquired specialized knowledge will be hired to the private sector with higher salary, but rather, this should be used as an opportunity for technology exchange and should be the basis for the development of technology in the private sector. In addition, civil society needs to understand government policies relating to the environment and play the role of an environmental monitor, so it is necessary to strengthen its capacity.

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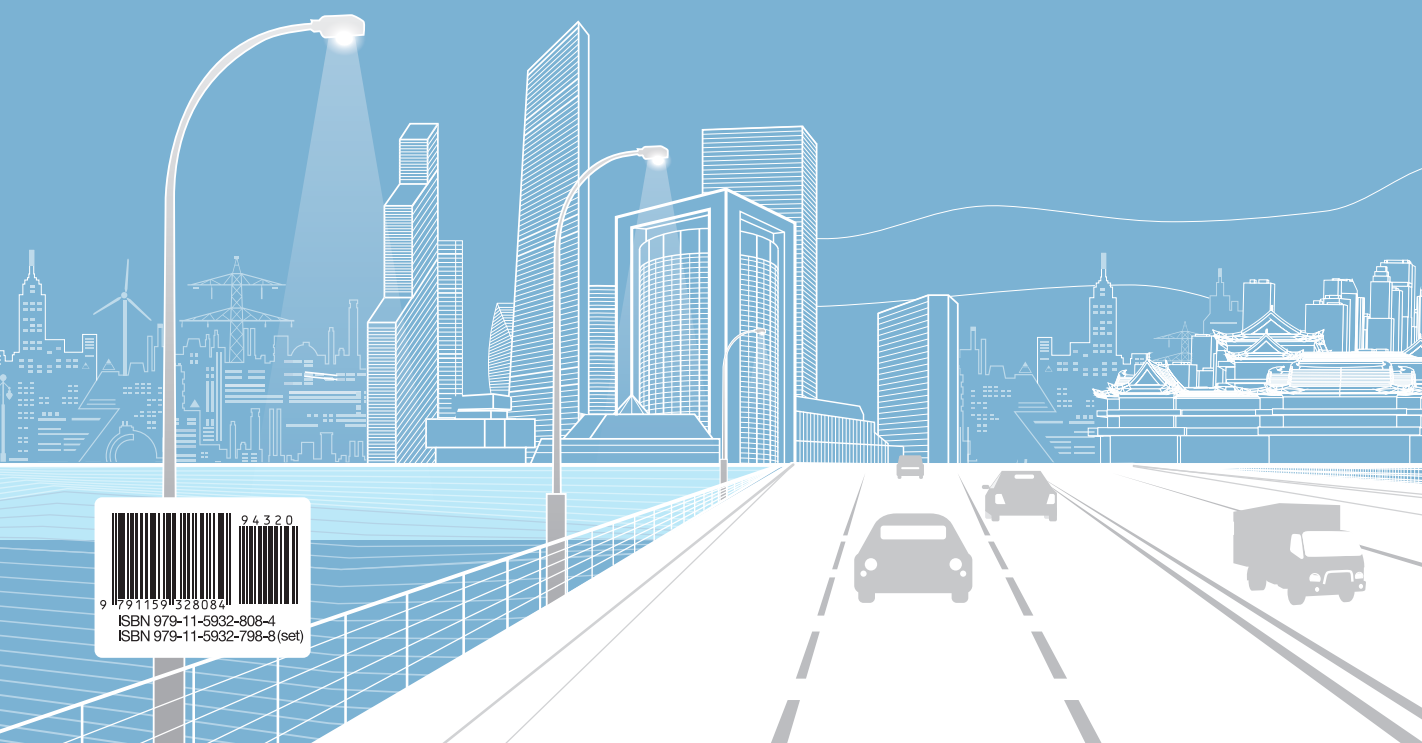

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