A Study on the KPIs for Smart Water Management in Developing Countries

By

NA, Duckkyu

CAPSTONE PROJECT

Submitted to

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ABSTRACT

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By

Duckkyu Na

The purpose of this study is to develop KPIs (Key Performance Index) to assess the level of smart water management in developing countries for the development and application of business models in developing countries. With existing projects centered on water resources, capital and complex projects, K-water is urgently needed to come up with new business alternatives for future K-water blueprints.

K-water already developed 65 KPIs for the assessment of water management level (K-water, 2017). This study derived KPIs of an appropriate size considering water supply status in developing countries through Delphi technique as a first step. Twenty of the 65 existing indicators were selected as shown below.

A. Water supply system features (6 items)

B. Adequacy of Water Supply Facilities (7 items)

C. Operational and Maintenance Reliability (7 items)

In step 2, AHP analysis determined the priority of each indicator. It is expected that K-water will be able to support the expansion of new waterworks and overseas projects through assessment of smart water management level developed through this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

Water management has recently become an important issue in the international community. Massive floods and droughts caused by climate change are adding to difficulties on the demand side in terms of water supply and management, as well as the increase in the population and the rapid spread of large cities. These environmental changes are a great crisis in terms of water management, but on the other hand, they are a great opportunity in terms of industry. Accordingly, Smart Water Management, which combines advanced Information Technology (IT) technologies with water management to ensure sustainable water management in preparation for changes in the water environment, is drawing attention as a new paradigm for the future society.

Smart water management refers to a series of moves to reduce costs and increase productivity by incorporating information and communication technologies into water and water management, and smart water management will be possible in underdeveloped and developing countries as well as in developed countries to meet the current status of water supply facilities in each country and city. However, this will require a level diagnosis of the target areas first, and an indicator that suits the conditions of developing countries should be developed.

Therefore, in this paper, the adequacy of the existing Key Performance Indicators (KPIs) as the evaluation index of developing countries was checked and the assessment index was selected, and the development case of the water management level evaluation index at home and abroad was investigated and analyzed. For the establishment of a business model using smart water management technology that can be applied to developing countries, KPIs that can be applied to developing countries will be derived based on KPIs that have already been developed in water supply.

2. Literature review

2.1 KS-Tech 3.1 innovation

As part of a follow-up project under the "Post Water Forum SWMI Innovation Roadmap" to become a Leading Global Company, K-water developed and implemented KPIs development plan to evaluate the status and level of water management in the target areas based on technology components.

In addition, the concept of business standard models is presented for each representative project. The applicable systems of level, scale and technology associated with national and regional status are provided as in Table 1.

Region/Model	**Low Developing Countries**	**Developing Countries**	**Developed Countries**
Rural			
Urban	**TYPE-1**	**TYPE-2**	**TYPE-3**
New Town	**(SAM)**	**(NAM)**	**(SWC)**

Table1: Applicable system considering regional condition

Item		**(TYPE-1)**	**(TYPE-2)**	**(TYPE-3)**
Current status		lack of water supply facilities lack of O&M skill	Water coverage ratio 80% Needs for reduction of NRW	Need for Optimum operation thru integrated O&M
Objective		Secure the water supply facilities	Optimum operation of each facilities	Optimum operation thru integrated O&M
Water treatment Process		Conventional type (Slow filtration) Small size facilities	Conventional type (Rapid filtration)	Advanced water treatment ($O3$+GAC, RO, etc)
Device	Metering	Flow, Pressure	Flow, Pressure, Water Quality	Smart-Metering
	Data collection	Logger (manual)	Digitalizing data(Near Real	AMI

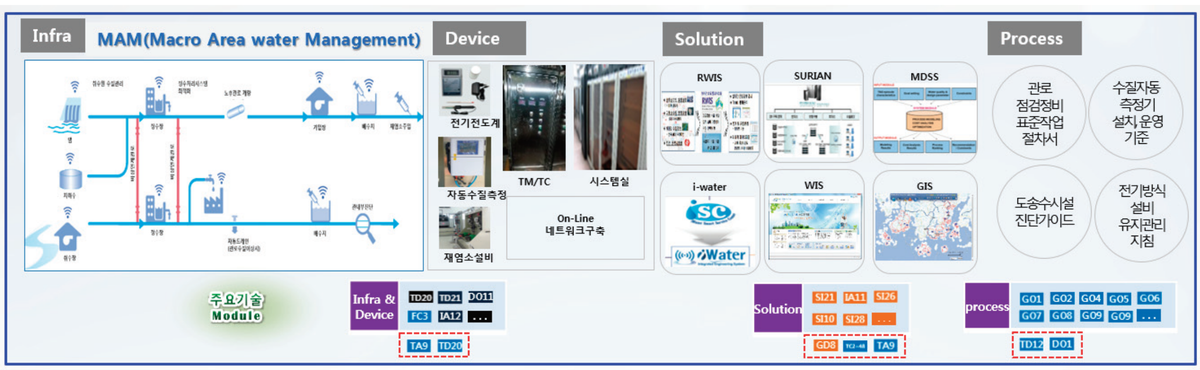
			Time)	
Solution	Integrated Operation Tool	Pipeline model	Automation of each facilities	water-NET
	Base Facilities	SCADA i-Water	SCADA, i-Water, WIS, water-INFOs, GIS	SCADA, i-Water, WIS, water-INFOs, GIS, RWIS

TYPE-1 (SAM, Small Area Water Management) Areas where village water supply infrastructure is urgently needed, such as rural areas where small streams or wells are collected and used.

Figure 1 : SAM (Small Area water Management)

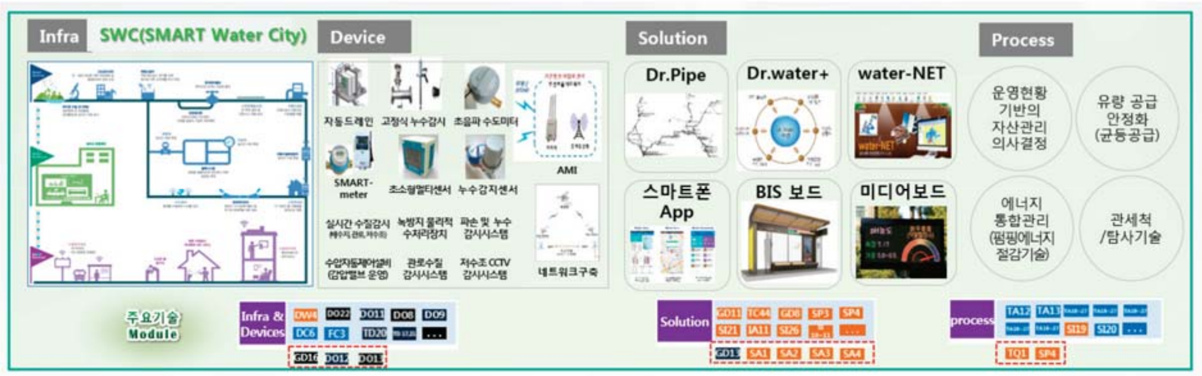
TYPE-2 (MAM, Macro Area water Management) Areas requiring the establishment of medium-sized waterworks in urban areas of developing countries → Implementing Water Supply System Optimized for Quantity/Quality Management

Figure 2 : MAM (Macro Area water Management)



TYPE-3 (SWC, Smart Water City) Areas that need to introduce smart water management based on ICT according to water distribution system also the areas saturation of water service coverage, already establishment of technology for operation/management of development facilities.

Figure 3 : SWC (Smart Water City)



Small Area Water Management (SAM) is an area where it is urgent to secure infrastructure for supplying water to village units, such as rural areas where small streams or wells are being collected and used. Developing countries (NAM) are required to install large and medium-sized water supply facilities in urban areas of developing countries, and they need to implement optimized water supply systems for water quantity and water quality and water management. Lastly, SWC (Smart Water City) is an important area for saturation of water service coverage, the establishment of technology for operation and management of development facilities, and introduction of ICT-based Smart Water Management (SWM) tailored to water circulation distribution system.

2.2 Development of KPIs for smart water management

The development direction of the SWM evaluation indicators and the following four taxonomies and performance indicators for each classification are presented.

A. Water supply system features (10 items)

B. Adequacy of water supply facilities (18 items)

C. Operational and maintenance reliability (21 items)

D. Smart water management utilization (15 items)

Each assessment criteria has a detailed evaluation index, consisting of 64 KPIs, as shown in Table 2. (K-water, 2016)

Table. 2: KPIs for level evaluation of SWM

Evaluation index	KPIs
A. Water supply system features (10 items)	1. Non-Revenue Water
	2. Operation rate of water treatment facilities
	3. Service coverage
	4. Rate of service complaint
	5. Water quality test location density
	6. water meter density
	7. Number of restricted days for water supply
	8. Nonconformity rate of water quality standards
	9. Unit public water supply population
	10. Power usage basic unit for tap water supply
B. Adequacy of water supply facilities (18 items)	11. Real-time flow monitoring of water sources and remote control scope
	12. Real-time water quality monitoring of water sources
	13. Real-time water quality monitoring rate or possible scope of water treatment facilities
	14. Real-time water level and flow rate monitoring range of water treatment facilities
	15. Stable water production facility acquisition rate (%)
	16. Real-time flow monitoring and control scope of water supply facilities
	17. Real-time water pressure monitoring and control scope of the transmission facilities
	18. Real-time water quality monitoring scope of water transmission facilities
	19. scope for detecting leakage/damage in the real-time pipeline of the water supply facility
	20. a distributing reservoir Construction Rate (%)
	21. Real-time distribution reservoir flow monitoring and control

	rate or possible range
	22. Installation rate (%) of the equipment for real-time water quality measurement or range of real-time water quality monitoring
	23. Real-time flow monitoring and control of the distribution system
	24. Rates of the control facilities for the pressure relief valve in the distribution system
	25. Installation rate of real-time water quality measuring equipment (%) of the distribution system
	26. Valve Installation Density
	27. District Metered Areas (DMA) construction rate (%)
	28. Energy Self-reliance Facility Construction Rate (%)
C. Operational and Maintenance Reliability (21 items)	29. Annual Failure Rate of Major Facilities
	30. Annual failure (error operation) rate of operating system
	31. Real-time data missing rate
	32. Inspection rate of major facilities
	33. Key Software Calibration Rate
	34. Key Software Upgrade Rate
	35. Major System Inspection Rate
	36. No. of annual software operations
	37. Water supply possibility rate in case of emergency
	38. Inter-DMA Emergency Linkage
	39. Water source reserve ratio
	40. Self-generated power in an emergency
	41. Data backup rate in case of emergency
	42. Server operating rate in an emergency
	43. Establishing physical environmental measures for data integrity
	44. Whether to establish network management measures for data integrity
	45. Water Supply Pressure Inadequacy Rate
	46. Pipeline rehabilitation rate
	47. The bursts rate in the pipeline
	48. Water treatment plant accident rate
	49. Water quality inspection and service on tap

	50. Establishing a standard HMI-based operation
	51. Smart metering system installation rate (%)
	52. Establishing a Water Treatment Process Diagnostic System
	53. Building a chemical/chlorine automated injection system
	54. Establishing an Integrated Energy Management System
	55. Energy Monitoring and Management System
	56. Pipe Network Information Management System Deployment Rate (%)
D. Smart Water Management utilization (15 items)	57. Establishing an Asset Management System
	58. Customer Management System Establishment
	59. Establishing a Real-Time Water Quality Monitoring System
	60. Establishing a Diagnostic Operation System for Water Supply Pipe Networks
	61. Establishing a Pipeline Water Quality Modeling Analysis System
	62. Pumping Station Optimal Operation System
	63. Establishing a Stabilizing System for Water Supply
	64. Visualization System for the Consumer's Supply Situation (Integrated Information on Water Supply Path, Water Quality, etc.)

3. Methodology

3.1. Delphi technique

The Delphi technique can be defined as a set of procedures for organizing the final consensus into collective judgment by repeating the process of experts in the field, making comments and coordinating on a single subject. The Delphi technique features procedures for repeat and controlled feedback of procedures, anonymous respondents, and statistical group responses (Listone et al., 1975; Lee, 2006). The basic premise is that those surveyed can reach an agreement on decision-making without having a face-to-face survey method.

The Delphi method sends three to four survey to the same subject for replying and comment, and each questionnaire provides information derived from individual respondents (Choi, 2002). In this process, experts' opinions are converging as the number of questions are repeated by referring to other people's opinions (Kim, 1996), i.e. Delphi techniques are an alternative method of investigating closely planned, anonymous repeated surveys and providing feedback on previous survey results to elicit consensus on the questions from those surveyed (Anderson, 1997).

The general procedure consists of a group of experts and a series of repeated surveys. For the Delphi survey, there is no specific standard for selecting panels, which is very important in the Delphi implementation process. The most important thing in the Delphi technique is the selection of experts, and the quality of experts who participated in the survey is a crucial factor, given that the Delphi technique is a method of representing expert intuition in objective figures. In addition, experts should carefully consider representation, appropriateness, professional knowledge, the integrity of participation and the number of participants (Choi, 2002; Kim, 1996). According to a previous study, the recovery rate of the Delphi study is approximately 50% to 57% (Song, 2012). The basic assumption of the Delphi technique is to use a group of experts rather than a single expert that 'the judgment of the two is more accurate than the judgment of one'. However, there is also a counterargument based on the empirical adage that "many cooks spoil the broth." In addition, group estimates may include uncertainty and ambiguity, and it has not been demonstrated experimentally that group estimates are more accurate than individual estimates. However, the Delphi technique is to use statistical methods to find accurate estimates, assuming that group estimates are likely to contain the range of answers. Various statistical analysis methods are being used to obtain accurate estimates through the Delphi method.

3.1.1 Verification of Content Validity

Content validity is analyzed based on the Content Validity Ratio (CVR) as presented by Lawshe (1975). The CVR provides a minimum value depending on the number of panels, and it is deemed that there is a validity of the statement when it is more than the minimum value.

$$CVR = \frac{ne - \frac{N}{2}}{\frac{N}{2}}$$

Where ne is the number of cases in which reply is important and N is the number of respondents. The minimum value of the CVR according to the number of respondents is shown in Table 2.

Table 3:Minimum value of the percentage of CVR according to the number of respondents

No. of Respondents	Minimum CVR	No. of Respondents	Minimum CVR
10	.62	20	.42
11	.59	25	.37
12	.56	30	.33
13	.54	35	.31
14	.51	40	.29
15	.49		

*source: Lawshe, 1975

3.1.2 Validity verification

The validity of the Delphi technique can be presented by analyzing the expert's opinion collection and agreement (Lee, 2001; Jeon, 2005). Convergence has a value of zero when all opinions are collected in a single point, and if there is a large difference in opinions, the value becomes larger. Agreements have a value of 1 when Q_1 and Q_3 are matched and fully agreed, and the figure decreases if there is a significant deviation of opinion. In other words, the closer the convergence is to zero and the closer the consensus is to one, the more reasonable the question is.

Convergence = $\frac{Q_3 - Q_1}{2}$ Agreement = $1 - \frac{Q_3 - Q_1}{Mdn}$

* where, *Mdn* = Central values, Q_1 and Q_3, are the first and third quartiles coefficients, respectively, representing 25% and 75% of the cumulative values of the total number of cases.

3.1.3. Verification of stability

In a repeat of the survey, the stability of the panel is considered to have been achieved if the response is consistent due to the small differences in the panel's survey responses. Measured by the coefficient of variation, the standard deviation divided by the arithmetic mean. No further survey is required if the variation coefficient is 0.5 or less, and is relatively stable if 0.5 to 0.8. An additional survey is required if it is 0.8 or higher (Roh, 2006).

3.2. Analytic Hierarchy Process (AHP)

AHP is a measurement theory for dealing with quantitative or qualitative criteria, based on the principle that people's experience and knowledge in making decisions are as valuable as the data they use (Vargas, 1990). Based on this principle, AHP can derive efficient decision making through the assessment of the relative importance among the evaluation elements by experts' experience and knowledge, which is often used in decision-making processes where the hierarchy of decision making is complex or where a number of evaluation elements are involved (Lee, et. al., 2015). AHP, one of the multi-criteria decision-making tools, and it is widely used in decision-making processes in a variety of areas, including planning, optimal alternative selection, resource allocation, dispute resolution, and optimization (Vaidya & Kumar, 2006), and is a four-step analysis to apply the AHP technique.

Step 1 should be structured to simplify complex structures. The final objective should be established, and the detailed steps to achieve the final goal should be specified below. That is, the Hierarchy structure is constructed.

The second step is to bridge structured and hierarchical factors. The fewer the alternatives, the easier it is to distinguish between the good and the bad, but the more, the easier it is to judge. Therefore, it is the principle of comparing factors by pair to derive essential or high priority factors among many factors. In other words, all factors compare with all other factors once.

Step 3 estimates the relative weights for each factor using the measured binoculars as above. A brief description of the relative weight collection method allows you to create a two-to-one comparison matrix with the importance value of the factors, then divide the factors in each column by the sum of the columns to standardize the sum of the cell numbers by 1, and estimate the weights by factor by factor by averaging the rows.

Step 4 should verify the consistency of the weights estimated for each factor. If the weighting consistency was found to be better than B at which stage of the bridge by factor, and B was better than C, would A question be better than C at the next two-way? If, of course, A should respond better than C to the question, it would be inconsistent to say that C is better than A. To maintain consistency, AHP techniques calculate and verify consistency indices. As such, AHP techniques are a way to secure the reliability of decision making by creating a hierarchy to solve complex problems and determining the importance through a cross-comparative bridge between elements in the structure.

Many studies use a nine-point scale when measuring the two mutual importance in a twin-contrast bridge of AHP technique. A real study found that the nine-point scale was closest to the actual results compared to the three-point and seven-point scale (Cho, et. al., 2003)

4. Research model design

4.1. Research Procedures

In this study, the pre-research was reviewed for the development KPIs for level evaluation of SWM in developing countries, and the evaluation index and KPIs were deemed suitable for the assessment of water supply was selected first, and the expert survey technique Delphi technique was used to secure feasibility and collect opinions on them. In this study, a total of two Delphi surveys were conducted from Dec. 1, 2019, to Dec. 31. In two steps, an investigation was conducted for the AHP evaluation to obtain the weight of the evaluation index derived from Step 1. The delivery and retrieval of questionnaires utilized the survey program which called Qualtrics.

Table 4 : Research procedure

[1st Stage] Deriving KPI from existing studies using delphi (64 → 20)

[2nd Stage] Evaluation using AHP

[3rd Stage] Developing KPI for developing countries

[4th Stage] Case studies on foreign countries (KPI), further studies

4.2. Selecting Delphi Panels

Although there is no explicit provision for the size of the sample group required for Delphi panels, Dalkey (1969), found that the larger the number of panels, the more reliable they become. Ewing (1991), stated that at least 10 panels are needed to minimize group errors and maximize group reliability, and Anderson (1997), said that even 10-15 experts from the group could produce meaningful results.

In this study, 12 experts with expertise were selected for the overall water supply, water treatment plant, pipe network, and overseas projects, as in Table 3.

Table 5: Panels list

Panel	Field	Career
*******wook**	Water supply, Pipe network, O&M	16
*******hoon**	Water supply, Pipe network, O&M	16
*******gab**	Water supply, Pipe network, Overseas business	15
*******geun**	Water supply, Pipe network, O&M, Overseas business, Design	17
*******sun**	Water supply, Pipe network, Overseas business, Design, Mechanic	14
*******e-jung**	Water supply, Pipe network, O&M	15
*******wan**	Water supply, Pipe network, O&M, Overseas business	15
*******moon**	Water supply, Pipe network, O&M, Overseas business	6
*******h-jung**	Water supply, Pipe network, O&M, Overseas business	13
*******ki**	Water supply, Pipe network, Overseas business, O&M, Mechanic	12
*******seok**	Water supply, Pipe network, O&M	13
*******yong**	Water supply, Pipe network, Overseas business	10

4.3. Questionnaire design

4.3.1. 1st Round Delphi

The questionnaire was aimed at analyzing the feasibility of four evaluation index and 64 detailed assessment items selected as a priority. The scale was used to measure the validity of the assessment items by simply using a Likert scale expressed in a simple order, and the scales were selected as ‘very appropriate’, ’appropriate’, ’medium’, ‘not appropriate’, ‘Not very appropriate.’

4.3.2. 2nd Round Delphi

The second Delphi survey calculates the concentration tendency and variability (e.g., the range between the median and the quadrant) of the panel's response recovered from the primary. The secondary survey provides each panel with a concentration and variability measurement of each question and its own response. It also includes a column that allows them to write down the reasons for being outside the quadrant.

4.3.3. Analytic Hierarchy Process (AHP)

The survey was conducted through Qualtrics over the period 2020.1.1-1.14, and instant messaging (SNS) and telephone conversations were conducted to encourage survey participants to understand the purpose and content of the survey. A total of 12 surveys were analyzed using the AHP technique, and the composition of the survey used a binary comparison method to compare two evaluation elements for each question. The scope of the scale used in the binoculars includes the number from 1 to 9 and its reciprocal, and measures the relative importance between the evaluation elements for each question. Table 6 shows examples of binoculars for ‘A1’ and ‘A2’. Survey respondents will respond to the relative superiority of the two assessment items.

Table 6: Binary Comparison between Assessment Items

Item																		Item
A1	⑨	⑧	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	⑧	⑨	A2
Importance					**The meaning of a measure**													
①					equal importance													

③	weak importance of one over other
⑤	essential or strong importance
⑦	very strong or demonstrated importance
⑨	absolute importance
②, ④, ⑥, ⑧	median of adjacent scales

4.4. Survey Analysis

4.4.1. Delphi Technique

The collected data are average and standard deviation using EXCEL. Median, minimum, maximum, quadrant, Content Validity Index (CVI), consensus, convergence, and stability were calculated on a number of occasions. The second survey item was selected with a consensus of 0.75 or higher and a convergence of 0.5 or less (Im et al., 2012). The content feasibility index varied depending on the number of panels and was determined to be reasonable based on more than 0.56 (Lawshe, 1975).

The Coefficient of Variation (CV) was used to measure the stability of the additional round, and no further investigation of expert opinion was conducted when within the range of 0.5 (Im et al., 2012).

4.4.2. AHP

In this study, in calculating the weights among evaluation index that are higher in the hierarchy, the corresponding ranges were presented in consideration of the number of KPIs that belong to the lower part of each assessment index, rather than the binoculars between the assessment indexes, and the respondents were required to weigh the total to be 100 points within that scope. The reason why this method is applied is that excessive weight is given to specific assessment items, which can cause problems with the fairness of the assessment (Kim, et. al., 2019). The most important thing in assessing relative importance through AHP is the logical consistency of respondents who participated in the assessment (Lee, et al., 2015). Consistency Ratio (CR) values that measure the individual error in the assessment are widely used to determine the logical consistency of the response (Cho, et al., 2003). In general, the smaller the CR, the more consistent the response is, and if the value is less than 10% (.10), the higher the consistency that the response will accept (Saaty, 1990). If the CR value is greater than .10, there is a need to consider ways to improve consistency (Saaty, 1990), and the method to exclude sub-standard Questionnaire answers from the effective sample (Lee, et al., 2015; Cheong, 2012). In this study, a method of re-investigation was used to obtain acceptable CR values.

5. Findings

5.1. Delphi Analysis Results

Table 7: Results of the 1st and 2nd Delphi (N=12)

Item	1st Delpi result						2st Delpi result						Remarks
	M	SD	Mdn	Agreement	Convergence	CVR	M	SD	Mdn	Agreement	Convergence	CVR	
A-1	4.58	0.76	5.00	0.13	0.95	0.67	4.75	0.60	5.00	0.00	1.00	0.83	Accept
A-2	4.25	0.72	4.00	0.50	0.75	0.67	4.25	0.60	4.00	0.50	0.75	0.83	Accept
A-3	4.50	0.65	5.00	0.50	0.80	0.83	4.58	0.49	5.00	0.50	0.80	1.00	Accept
A-4	3.17	0.90	3.00	0.63	0.58	-0.33	3.58	0.49	4.00	0.50	0.75	0.17	
A-5	3.67	1.03	4.00	0.63	0.69	0.17	3.67	0.75	4.00	0.50	0.75	0.33	
A-6	4.08	0.86	4.00	0.50	0.75	0.67	4.17	0.37	4.00	0.00	1.00	1.00	Accept
A-7	4.50	0.50	4.50	0.50	0.78	1.00	4.33	0.47	4.00	0.50	0.75	1.00	Accept
A-8	4.50	0.50	4.50	0.50	0.78	1.00	4.25	0.43	4.00	0.13	0.94	1.00	Accept
A-9	3.67	1.03	4.00	0.63	0.69	0.17	3.75	0.72	4.00	0.50	0.75	0.17	
A-10	3.83	0.80	4.00	0.63	0.69	0.17	3.83	0.69	4.00	0.50	0.75	0.33	
B-11	3.75	1.01	3.50	1.00	0.43	-	3.75	0.83	4.00	0.50	0.75	0.33	
B-12	3.42	0.76	3.00	0.50	0.67	-0.17	3.67	0.62	4.00	0.50	0.75	0.17	
B-13	4.08	0.64	4.00	0.13	0.94	0.67	4.25	0.43	4.00	0.13	0.94	1.00	Accept
B-14	3.83	0.69	4.00	0.50	0.75	0.33	3.83	0.69	4.00	0.50	0.75	0.33	
B-15	4.25	0.72	4.00	0.50	0.75	0.67	4.33	0.47	4.00	0.50	0.75	1.00	Accept
B-16	4.17	0.69	4.00	0.50	0.75	0.67	4.33	0.47	4.00	0.50	0.75	1.00	Accept
B-17	4.08	0.76	4.00	0.63	0.69	0.50	4.33	0.47	4.00	0.50	0.75	1.00	Accept
B-18	3.92	0.86	4.00	1.00	0.50	0.17	4.33	0.85	5.00	0.63	0.75	0.50	
B-19	3.58	0.64	3.50	0.50	0.71	-	3.33	0.47	3.00	0.50	0.67	-0.33	

B-20	4.08	0.64	4.00	0.13	0.94	0.67	4.00	0.41	4.00	0.00	1.00	0.83	**Accept**
B-21	4.00	0.82	4.00	1.00	0.50	0.33	4.17	0.69	4.00	0.50	0.75	0.67	**Accept**
B-22	3.50	0.87	3.00	0.50	0.67	-0.17	3.67	0.62	4.00	0.50	0.75	0.17	
B-23	3.75	1.01	4.00	0.63	0.69	0.33	3.75	0.72	4.00	0.13	0.94	0.50	
B-24	3.17	0.99	3.00	0.25	0.83	-0.50	3.33	0.85	3.00	0.13	0.92	-0.50	
B-25	3.42	0.95	3.00	0.50	0.67	-0.17	3.83	0.69	4.00	0.50	0.75	0.33	
B-26	3.42	0.49	3.00	0.50	0.67	-0.17	3.17	0.37	3.00	0.00	1.00	-0.67	
B-27	4.08	0.86	4.00	0.50	0.75	0.67	4.42	0.49	4.00	0.50	0.75	1.00	**Accept**
B-28	3.00	1.00	3.00	0.25	0.83	-0.50	3.00	0.82	3.00	0.00	1.00	-0.83	
C-29	3.92	0.49	4.00	0.00	1.00	0.67	4.00	-	4.00	0.00	1.00	1.00	**Accept**
C-30	3.83	0.55	4.00	0.13	0.94	0.50	4.08	0.28	4.00	0.00	1.00	1.00	**Accept**
C-31	3.75	0.60	4.00	0.50	0.75	0.33	3.83	0.55	4.00	0.13	0.94	0.50	
C-32	3.75	0.60	4.00	0.50	0.75	0.33	3.67	0.62	4.00	0.50	0.75	0.17	
C-33	3.42	0.86	3.50	0.50	0.71	-	3.75	0.60	4.00	0.50	0.75	0.33	
C-34	3.50	0.76	3.50	0.50	0.71	-	3.67	0.62	4.00	0.50	0.75	0.17	
C-35	3.50	0.65	3.00	0.50	0.67	-0.17	3.25	0.43	3.00	0.13	0.92	-0.50	
C-36	3.25	0.72	3.00	0.13	0.92	-0.50	3.00	0.41	3.00	0.00	1.00	-0.83	
C-37	3.83	1.07	4.00	1.00	0.50	0.33	3.83	1.07	4.00	1.00	0.50	0.33	
C-38	3.50	0.96	3.50	0.50	0.71	-	3.25	0.83	3.00	0.50	0.67	-0.33	
C-39	3.83	0.69	4.00	0.50	0.75	0.33	3.75	0.60	4.00	0.50	0.75	0.33	
C-40	3.75	0.83	4.00	0.50	0.75	0.33	3.67	0.75	4.00	0.50	0.75	0.33	
C-41	3.50	0.87	3.00	0.50	0.67	-0.17	3.33	0.75	3.00	0.50	0.67	-0.33	
C-42	3.67	0.75	3.50	0.50	0.71	-	3.42	0.64	3.00	0.50	0.67	-0.33	
C-43	3.08	0.95	3.00	0.13	0.92	-0.67	3.00	0.41	3.00	0.00	1.00	-0.83	
C-44	3.08	0.86	3.00	0.25	0.83	-0.50	3.08	0.64	3.00	0.00	1.00	-0.83	
C-45	4.25	0.60	4.00	0.50	0.75	0.83	4.33	0.47	4.00	0.50	0.75	1.00	**Accept**
C-46	4.25	0.83	4.00	0.50	0.75	0.83	4.42	0.49	4.00	0.50	0.75	1.00	**Accept**
C-47	4.50	0.50	4.50	0.50	0.78	1.00	4.58	0.49	5.00	0.50	0.80	1.00	**Accept**
C-48	4.17	0.55	4.00	0.13	0.94	0.83	4.08	0.28	4.00	0.00	1.00	1.00	**Accept**
C-49	3.83	0.99	4.00	0.25	0.88	0.50	4.08	0.49	4.00	0.00	1.00	0.83	**Accept**
D-50	3.58	0.95	4.00	0.50	0.75	0.17	3.83	0.69	4.00	0.50	0.75	0.33	
D-51	3.42	0.86	3.50	0.50	0.71	-	3.67	0.75	3.50	0.50	0.71	-	
D-52	3.50	0.87	3.00	0.50	0.67	-0.17	3.58	0.76	3.00	0.50	0.67	-0.17	
D-53	4.00	0.71	4.00	0.25	0.88	0.50	3.92	0.64	4.00	0.13	0.94	0.50	
D-54	3.17	0.55	3.00	0.13	0.92	-0.50	3.17	0.55	3.00	0.00	1.00	-0.83	
D-55	3.25	0.60	3.00	0.50	0.67	-0.33	3.33	0.62	3.00	0.13	0.92	-0.50	
D-56	4.00	0.91	4.00	0.63	0.69	0.50	4.00	0.71	4.00	0.25	0.88	0.50	
D-57	3.17	0.80	3.00	0.13	0.92	-0.50	3.33	0.75	3.00	0.00	1.00	-0.67	
D-58	3.75	0.72	4.00	0.50	0.75	0.17	3.92	0.64	4.00	0.13	0.94	0.50	
D-59	3.67	1.11	4.00	0.75	0.63	0.33	3.83	0.69	4.00	0.50	0.75	0.33	
D-60	3.17	0.90	3.00	0.63	0.58	-0.33	3.33	0.62	3.00	0.13	0.92	-0.50	
D-61	3.00	0.71	3.00	0.25	0.83	-0.50	3.25	0.60	3.00	0.00	1.00	-0.67	

D-62	3.25	0.83	3.00	0.50	0.67	-0.33	3.33	0.62	3.00	0.13	0.92	-0.50
D-63	3.33	0.94	3.50	0.63	0.64	-	3.50	0.65	3.00	0.50	0.67	-0.17
D-64	3.08	0.95	3.00	0.63	0.58	-0.17	3.17	0.90	3.00	0.13	0.92	-0.50

As you can see in Table 7, the first Delphi survey found that 16 out of 65 items were satisfied with the evaluation criteria (convergence ≤0.50, consensus ≥ 0.75 and CVR ≥0.56). According to the 2nd Delphi survey, items that satisfy all evaluation criteria were finally sorted into 20 out of 65 items. What was unusual was the consensus is that the SWM utilization items had a low level of content validity. The results of the second Delphi study showed that the standard deviation, consensus and convergence were changed in a desirable direction. This translates into more consensus among the panels as the Delphi study progresses. The assessment index derived from the Delphi study in this territory is shown in Table 8 for three evaluation index and for 20 KPIs.

Table 8: KPIs for evaluation of smart water management in developing countries

5.2. AHP Analysis Results

The AHP's hierarchical structure, which was finally constructed as a result of the Delphi analysis, consisted of three evaluation index and two phases of the 20 KPIs. The weighting results for the first hierarchical assessment criterion were evaluated as follows in Table 9, according to the important priority.

Table 9: Simple weighting of evaluation index

Evaluation Index	Weight	Per cent	Priority
A. Water supply system features	0.392	39.2%	1
B. Adequacy of water supply facilities	0.329	32.9%	2
C. Operational and Maintenance Reliability	0.279	27.9%	3
Total	**1.000**	**100.0%**	

The simple weight of the evaluation index for water supply in developing countries was specifically examined in terms of percentage, as set out in Table 9. 39.2% of 'Water supply system features', 32.9% of 'Adequacy of water supply facilities', and 27.9% of 'Operational and Maintenance Reliability' were found to be weighted. The second hierarchy of assessment of water quality in developing countries consists of 6 KPIs of the 'Water supply system features' assessment criteria, 7 KPIs of the 'Adequacy of water supply systems', and 7 KPIs of the 'Operational and Maintenance Ability'. The simple weights of the KPIs and the combined weights of KPIs are as follows in Table 10. Consistency ratios are 0.021, 'Water supply system features', 'Adequacy of water supply facilities' 0.038 and 'Operational and Maintenance Reliability' 0.025, which experts' responses can be considered highly consistent.

Table 10: Evaluation Index Simple Weight

Evaluation Index	**KPIs**	**Simple weight**	**Per cent**	**Priority**
A. Water supply	1. Non-Revenue Water	0.261	26.1%	1
	2. Operation rate of water treatment facilities	0.155	15.5%	3
	3. Service coverage	0.185	18.5%	2

system features (CR=0.021)	6. water meter density	0.125	12.5%	6
	7. Number of restricted days for water supply	0.135	13.5%	5
	8. Nonconformity rate of water quality standards	0.138	13.8%	4
B. Adequacy of water supply facilities (CR=0.038)	13. Real-time water quality monitoring rate or possible scope of water treatment facilities	0.219	21.9%	1
	15. Stable water production facility acquisition rate (%)	0.094	9.4%	7
	16. Real-time flow monitoring and control scope of water supply facilities	0.121	12.1%	6
	17. Real-time water pressure monitoring and control scope of the transmission facilities	0.135	13.5%	4
	20. a distributing reservoir Construction Rate (%)	0.167	16.7%	2
	21. Real-time distribution reservoir flow monitoring and control rate or possible range	0.142	14.2%	3
	27. District Metered Areas (DMA) construction rate (%)	0.122	12.2%	5
C. Operational and Maintenance Reliability (0.025)	29. Annual Failure Rate of Major Facilities	0.149	14.9%	4
	30. Annual failure (error operation) rate of operating system	0.159	15.9%	3
	45. Water Supply Pressure Inadequacy Rate	0.165	16.5%	1
	46. Pipeline rehabilitate rate	0.105	10.5%	7
	47. The accident rate in the pipeline	0.160	16.0%	2
	48. Water treatment plant accident rate	0.141	14.1%	5
	49. Water quality inspection and service on tap	0.120	12.0%	6
Total		**1.000**	**100.0%**	

As Table 10 illustrates, the results of a detailed analysis of the simple weighting of KPIs in developing countries as a percentage are as follows. First, after examining the simple weighting of the six KPIs belonging to the ‘Water supply system features’ assessment criteria, the ‘non-revenue water’ was identified as the most important one. Second, after examining the simple weighting of the seven KPIs belonging to the assessment criteria of the ‘Adequacy of water supply facilities’, the ‘Real-time quality monitoring rate’ was identified as the most important criterion. Finally, when we looked at the sample weights for the seven KPIs in the ‘Operational and Maintenance Reliability’, we found that the ‘Water supply pressure inadequacy rate’ was the most important one.

Table 11: Comprehensive Weight of Evaluation Indicators

Evaluation Index	Weight	KPIs	Simple Weight	Comprehensive Weight	Priority
A. Water supply system features	0.392	1. Non-Revenue Water	0.261	0.102	1
		2. Operation rate of water treatment facilities	0.155	0.061	4
		3. Service coverage	0.185	0.073	2
		6. water meter density	0.125	0.049	8
		7. Number of restricted days for water supply	0.135	0.053	7
		8. Nonconformity rate of water quality standards	0.138	0.054	6
B. Adequacy of water supply facilities	0.329	13. Real-time water quality monitoring rate or possible scope of water treatment facilities	0.219	0.072	3
		15. Stable water production facility acquisition rate (%)	0.094	0.031	19
		16. Real-time flow monitoring and control scope of water supply facilities	0.121	0.040	16
		17. Real-time water pressure monitoring and control scope of the transmission facilities	0.135	0.044	13
		20. a distributing reservoir Construction Rate (%)	0.167	0.055	5
		21. Real-time distribution reservoir flow monitoring and control rate or possible range	0.142	0.047	9
		27. District Metered Areas (DMA) construction rate (%)	0.122	0.040	15

C. Operational and Maintenance Reliability	0.279	29. Annual Failure Rate of Major Facilities	0.149	0.042	14
		30. Annual failure (error operation) rate of operating system	0.159	0.045	12
		45. Water Supply Pressure Inadequacy Rate	0.165	0.046	10
		46. Pipeline rehabilitate rate	0.105	0.029	20
		47. The accident rate in the pipeline	0.160	0.045	11
		48. Water treatment plant accident rate	0.141	0.039	17
		49. Water quality inspection and service on tap	0.120	0.034	18
Total			**1.000**	**1.000**	

As indicated in Table 9, we specifically looked at the overall weighting of the assessment indexes for the level assessment of water supply in developing countries. Among the 20 KPIs, the five most weighted KPIs from the panel of experts are:

i) Non-Revenue Water (0.102)

ii) Service coverage (0.073)

iii) Real-time water quality monitoring rate of water treatment facilities (0.072)

iv) Operation rate of water treatment facilities (0.061)

v) Distributing reservoir Construction rate (0.055)

Three of the KPIs from 1st to 5th rank fall within the 'Water supply system features' evaluation criteria. Such analysis results can be interpreted as the most important weighting given to the assessment of 'Water supply system features'.

6. Conclusion

In this study, KPIs were developed for assessing water supply levels in developing countries. Finally, 20 items were extracted from 64 existing items through Delphi technique in step 1, and the priority of each KPIs was determined through AHP evaluation in step 2. However, the KPIs developed have limitations on their applicability as there are no cases that have actually been applied to assessing water supply facilities in developing countries. Future research will select one or two developing countries to check the applicability of KPIs through Case Study. Through this, we hope to support the expansion of K-wtaer's new overseas business through the development and application of business models in developing countries.

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Appendix. KPIs for level evaluation of smart water management

A. Water supply system features (10 items)

KPIs	Definition	Formula	Criteria
1. Non-Revenue Water	Percentage of revenue water to annual water supply	(Annual revenue water(㎥))/(Annual water supply(㎥)) × 100(%)	N/A
2. Operation rate of water treatment facilities	The ratio of maximum production to the design capacity indicates the stable operation margin of the waterworks	(Maximum daily supply(㎥/day)) / (design capacity(㎥/day)) × 100(%)	N/A
3. Service coverage	Percentage of service population to the resident population in the water supply area	(Service population)/(total population) × 100 (%)	N/A
4. Rate of service complaint	Evaluate the customers' satisfaction	(The total number of complaints such as water pressure, water quality and charges)/(the number of service population)	N/A
5. Water quality test location density	Number of water quality tests per water supply unit	(number of water quality test) / (number of water supply population (1,000))	N/A
6. water meter density	Rate of installation of water meter in the water supply area	(number of water meters) / (total number of households) × 100(%)	N/A
7. Number of restricted days for water supply	Annual number of restricted days for water supply	Annual number of restricted days for water supply (days)	N/A
8. Nonconformity rate of water quality standards	Nonconformity rate of water quality standards in all the water supply processes	Number of nonconformities on water quality standards / (number of total inspections) × 100(%)	N/A

KPIs	Definition	Formula	Criteria
9. Unit public water supply population	Evaluation of the population receiving water service from public faucets or water tower	(Population who receive services to public faucets or water towers) / (number of public faucets and water towers)	N/A
10. Power usage basic unit for tap water supply	Unit Cost of Electricity Consumption in the Production of Tap water production	Power consumption unit price for tap water production (kWh/m3) (kWh/㎥)	N/A

B. Adequacy of water supply facilities (18 items)

KPIs	Definition	Formula	Criteria
11. Real-time flow monitoring of water sources and remote control scope	Monitoring and evaluation of the real-time water intake of water sources and flow control	N/A	1. Real-time flow monitoring and control 2. Monitoring and partial control of the flow rate during the actual period 3. Real-time flow monitoring only 4. No real-time monitoring and control
12. Real-time water quality monitoring of water sources	Indicators for evaluating the number of real-time water quality measurement items (14) in the intake area and the establishment of dualization of equipment for stable data acquisition	N/A	1. 14 items are monitored in real-time and dualization 2. 14 items can be monitored in real-time 3. Water quality monitoring of less than 14 items 4. Unconstructed real-time water quality control facilities

KPIs	Definition	Formula	Criteria
13. Real-time water quality monitoring rate or possible scope of water treatment facilities	Indicators for evaluating the possibility of real-time water quality measurement in water treatment plants and the establishment of dualization of equipment for stable data acquisition	(Number of processes that can be monitored in real-time) / (number of all process) × 100(%)	1. Real-time water quality monitoring and dualization. 2. Real-time water quality monitoring of all process 3. Real-time water quality monitoring of some processes 4. Unconstructed real-time water quality monitoring system for the all process
14. Real-time water level and flow rate monitoring range of water treatment facilities	An indicator that evaluates the adequacy of basic measuring equipment (water level and flow rate) installed in a water treatment plant	N/A	1. Real-time water level and flow rate monitoring and dualization. 2. Real-time water level and flow rate monitoring of all processes. 3. Real-time water level and flow rate monitoring of some processes 4. Unconstructed real-time water level and flow monitoring facilities for all processes.
15. Stable water production facility acquisition rate (%)	An indicator of the daily supply (production) capacity of the water treatment plant compared to the daily maximum demand of the water treatment plant.	(Total water supply capacity (m3/day)/(maximum demand (m3/day) × 100(%) of the water treatment plant	1. Less than 125% or more than 130% (poor or over-production) 2. 125% or less or less than 130% (appropriate production)
16. Real-time flow monitoring and control scope of water supply facilities	evaluation of real-time monitoring of the flow rate and the flow rate control of the pipeline	N/A	1. Real-time flow monitoring and controllable 2. Real-time flow monitoring and partial control 3. Real-time flow monitoring only 4. No real-time monitoring and control

KPIs	Definition	Formula	Criteria
17. Real-time water pressure monitoring and control scope of the transmission facilities	An indicator that evaluates the adequacy of basic measuring equipment (water pressure) installed in a pipeline.	N/A	1. Real-time water pressure monitoring and controllable 2. Real-time water pressure monitoring and partial control. 3. Real-time water pressure monitoring only 4. Unable to monitor and control real-time water pressure
18. Real-time water quality monitoring scope of water transmission facilities	Indicators for evaluating the adequacy of water measuring equipment installed in the pipeline	N/A	1. Real-time water quality monitoring between bulbs is possible and dualization 2. Real-time water quality monitoring between bulbs 3. Real-time water quality monitoring in some sections 4. Non-Construction of Real-Time Water Quality Monitoring System between the bulbs
19. scope for detecting leakage/damage in the real-time pipeline of the water supply facility	An indicator that evaluates the construction of a system that detects leakage and damage of a pipe in real time during a pipeline	N/A	1. Real-time leak detection by analyzing prefrontal flow rate and water pressure data 2. Leakage can be identified by analyzing the flow rate and water pressure of some sections. 3. Undetectable

KPIs	Definition	Formula	Criteria
20. a distributing reservoir Construction Rate (%)	It is an indicator that assesses stable water supply capability through the ratio of the distribution reservoir that obtains the amount of extra water out of the total. * Target facilities: Distribution reservoir in the evaluation zone * Fulfillment facility: A distribution reservoir that has an extra capacity of 12 hours or more of the maximum daily water supply.	(No. of fulfilment facilities)/(No. of target facilities) × 100(%)	N/A
21. Real-time distribution reservoir flow monitoring and control rate or possible range	Real-time monitoring of the flow rate of the distribution reservoir and evaluation of the possibility of the flow control * Installation criteria (target) · 1 inlet valve by distribution reservoir · 1 outlet valve by distribution reservoir	(No. of installation Equipment)/(No. of installation target) × 100(%)	1. Real-time flow monitoring and control is possible 2. Real-time flow monitoring and partial control 3. Real-time flow monitoring only 4. No real-time monitoring
22. Installation rate (%) of the equipment for real-time water quality measurement or range of real-time water quality monitoring	Indicators for evaluating the number of real-time water quality measurement items in the distribution reservoir (5EA) and the establishment of dualization of equipment for stable data acquisition * INSTALLATION TO Number of water measuring equipment to be installed in the distribution reservoir according to the installation criteria * Installation equipment: redundant water quality measurement equipment installed * Installation criteria · Location of installation: 1 installation for each distribution reservoir · Installation items: turbidity, water temperature, residual chlorine, pH	(No. of installation equipment)/(No. of installation target) × 100(%)	1. All items can be monitored in real-time and are duplicated. 2. All items can be monitored in real-time 3. Real-time water quality monitoring of certain items is possible 4. Failure to establish the real-time water quality monitoring system for all items

KPIs	Definition	Formula	Criteria
23. Real-time flow monitoring and control of distribution system	Real-time monitoring of the flow rate and evaluation of the flow rate control of the distribution system	N/A	1. Real-time flow monitoring and control is possible 2. Real-time flow monitoring and partial control 3. Real-time flow monitoring only 4. No real-time monitoring
24. Rates of the control facilities for the pressure relief valve in the distribution system	Evaluation of the de-pressure valve control facility for optimal operation of the pipe network, which can be controlled in real-time through the information of the monitoring point of water pressure in the block * INSTALLATION Criteria: Install monitoring control (TM) at the block entry point	(No. of install block of pressure relief valve control facility)/(No. of the overall block) × 100(%)	N/A
25. Installation rate of real-time water quality measuring equipment (%) of distribution system	Indicators for evaluating the number of real-time water quality measurement items (5 items) in the distribution system and the establishment of dualization of equipment for stable data acquisition * Installation equipment: Number of dualization water quality measurement equipment installed in the pipe. * Installation target (criteria) · Location of installation: One or more of each small block · Installation items: turbidity, water temperature, residual chlorine, pH, electrical conductivity	(No. of dualization installation subblocks)/(No. of all subblocks) × 100(%)	N/A

KPIs	Definition	Formula	Criteria
26. Valve Installation Density	Evaluation of flexibility of drainage operation or pipeline maintenance flexibility	(No. of valve installed)/(total length of pipeline (km))	N/A
27. District Metered Areas (DMA) construction rate (%)	Indicators for evaluating the block system construction rate for enhancing the flow rate and improving the efficiency of water supply and water network management * Large block: Water supply area of water supply system in the water supply system * Medium block: Water supply area in pressurized water supply area (a scale between 1,500 and 5,000 taps) * Subblocks: Considering topographical requirements such as roads and streams (scale between 500 and 1,500 taps)	(a daily mean water supply in the block system(m3/day))/ (a daily mean water supply in the space range (m3/day) × 100(%)	N/A
28. Energy Self-reliance Facility Construction Rate (%)	It is an indicator that evaluates the energy self-reliance rate of water purification plant operation when operating water purification facilities such as production and utilization of renewable energy. * Total power usage: Amount of electricity used by water purifiers in the space range per year * Renewable energy usage: Amount of renewable energy produced and utilized annually in water treatment plants within the space range	(Renewable Energy Utilization (kWh)) / (Total Power Usage (kWh) × 100(%))	N/A

C. Operational and Maintenance Reliability (21 items)

KPIs	Definition	Formula	Criteria
29. Annual Failure Rate of Major Facilities	Annual average failure rate of facilities and equipment that can affect water supply * Targeted facilities: pressure gauges, flow meters, water gauge, valves, pumps and other accessories	(Number of failures per year)/(number of target facilities)	N/A
30. Annual failure (error operation) rate of operating system	Number of failures and malfunctions of the operation management system * Target facilities: water treatment schedule management system, network operation management system, etc.	(Number of target system failures per year)/(number of target systems)	N/A
31. Real-time data missing rate	Real-Time Measuring Facility Data Missing Rate * Target facilities: Real-time information received from water treatment processes, instruments, valves, pumps, and other auxiliary facilities	(Total data count)/(total transmission data count) × 100(%)	N/A
32. Inspection rate of major facilities	Percentage of inspection of major * Targeted facilities: pressure gauges, flow meters, water gauge, valves, pumps and other accessories	(No. of inspection (repair, upgrade, calibration)/ (No. of target) × 100(%)	N/A
33. Key Software Calibration Rate	Key software calibration rates * Targeted software : programs for analysis and information processing such as GIS, network repair model, water quality model, asset management program, etc.	(No. of calibration SW)/ (No. of target calibration SW) × 100(%)	N/A

KPIs	Definition	Formula	Criteria
34. Key Software Upgrade Rate	Key Software Upgrade Rate * Targeted software : programs for analysis and information processing such as GIS, network repair model, water quality model, asset management program, etc.	(No. of upgrade SW)/ (No. of target upgrade SW) × 100(%)	N/A
35. Major System Inspection Rate	Major System Checkout Rate * Target facilities: water treatment schedule management system, network operation management system, etc.	(No. of inspection (repair, upgrade, calibration) system)/(No of target inspection system) × 100(%)	N/A
36. No. of software annual operations	No. of software annual operations * Targeted software : programs for analysis and information processing such as GIS, network repair model, water quality model, asset management program, etc	Number of annual targeted software operations (counts/year)	N/A
37. Water supply possibility rate in case of emergency	Indicators for evaluating the ability to supply unauthorized water in preparation for single-water situations, such as accidents and improvements in pipelines - Daily linked capacity (m3/day): The amount of water that can be supported in connection with other water sources - Daily alternative water supply capacity (m3/day) : indicates the quantity available in an emergency from the water source that can replace existing main water sources such as underground water	{(Daily linked capacity) (m3/day)+(Daily alternative water supply potential (m3/day)+(Daily water supply availability (m3/day)}/{(Average daily water supply (m3/day)) × 100(%)	Quantitative calculation formula result value of indicator 1. 75% or more 2. 50% or more, less than 75% 3. 25% or more, less than 50% 4. Less than 25%

KPIs	Definition	Formula	Criteria
38. Inter-block Emergency Linkage	Evaluating the rate of construction of emergency inter-block water flow paths for uninterrupted water supply in the event of pipeline accident and maintenance	(Number of blocks that are unrelated)/(number of total blocks) × 100(%) * Target facilities: Medium and small blocks set within the space range * Completion of the construction: Medium and small block with emergency counter-station installed according to the installation criteria * Installation criteria · One or more emergency links between small blocks · At least one emergency link between medium and large blocks	Quantitative calculation formula result value of indicator 1. 75% or more 2. 50% or more, less than 75% 3. 25% or more, less than 50% 4. Less than 25%
39. Water source reserve ratio	The percentage of water that can be collected through auxiliary drinking water sources in case of emergency (damage of water supply plant, water pollution, etc.) by diversification of water sources	(Emergency Water Supply Capacity)/(Average Daily Demand) × 100(%)	Quantitative calculation formula result value of indicator 1. 75% or more 2. 50% or more, less than 75% 3. 25% or more, less than 50% 4. Less than 25%
40. Self-generated power in an emergency	Evaluate the possibility of self-development of pumps, instrumentation and communication facilities in an emergency	(accumulated time (hr) for emergency self-generation) / (accumulated time of emergency) × 100(%)	Quantitative calculation formula result value of indicator 1. 75% or more 2. 50% or more, less than 75% 3. 25% or more, less than 50% 4. Less than 25%

KPIs	Definition	Formula	Criteria
41. Data backup rate in case of emergency	Data backup rate (%) of measurement data such as flow rate, water level, water quality and water pressure in an emergency	(emergency backup data (bytes)) / (normal data (bytes)) × 100	Quantitative calculation formula result value of indicator 1. 75% or more 2. 50% or more, less than 75% 3. 25% or more, less than 50% 4. Less than 25%
42. Server operating rate in an emergency	Server operation rate (%) for data processing of measurement data such as flow rate, water level, water quality, and water pressure in an emergency	(accumulated time (hr) of emergency server operation) / (accumulated time of emergency) × 100(%)	Quantitative calculation formula result value of indicator 1. 75% or more 2. 50% or more, less than 75% 3. 25% or more, less than 50% 4. Less than 25%
43. Establishing physical environmental measures for data integrity	Restrictions on network server accessibility, measures to protect transmission lines such as cables or connectors, and measures needed to protect communication hardware and data storage from power line surges, static discharges, and magnetic forces.	N/A	System establishment or operational log (O, X)
44. Whether to establish network management measures for data integrity	Protect network server accessibility, document system management procedures, management items, and maintenance, and take precautions against unexpected disasters such as power outages, server failures, and virus attacks	N/A	System establishment or operational log (O, X)
45. Water Supply Pressure Inadequacy Rate	Evaluation of the proper water pressure management rate	(Number of measurement for not inadequate water pressure)/(No. of tootal water pressure measurement) × 100(%)	N/A

KPIs	Definition	Formula	Criteria
46. Pipeline rehabilitation rate	Ratio of rehabilitate water pipes, water pipes and distribution pipes annually	(Rehabilitated Pipeline Extension (km))/(Total Extension of Pipeline) × 100(%)	N/A
47. The bursts rate in the pipeline	The number of accidents in the water supply and drainage channels as a percentage of total extension of the pipe line indicates the soundness of the pipe line	(No. of total accidents)/(Total extension of pipes (100 km)) × 100(%)	N/A
48. Water treatment plant accident rate	Evaluation of accident rate in treatment purification plant	(Number of water treatment plant shutdown accidents in 10 years)/(Total number of water treatment plant)× 100(%)	N/A
49. Water quality inspection and service on tap	Provide services such as water quality testing and indoor plumbing inspection during the water supply process at the acceptance level	N/A	1. Water quality inspection of faucets and provision of additional services 2. Conducting a legal tap water quality test 3. Failure to comply with legal standards

D. Smart Water Management utilization (15 items)

KPIs	Definition	Formula	Criteria
50. Establishing a standard HMI-based operation	An indicator to evaluate whether a real-time integrated operation system that monitors and controls facilities such as water intake, pressurization, and water purification facilities at a remote integrated center	N/A	System deployment status (O, X)
51. Smart metering system installation rate (%)	It is an indicator that evaluates the efficiency of water management by evaluating the installed rate of smart metering systems that can measure real-time water usage and obtain water consumption information.	(No. of AMI installation)/(No. of target equipment) × 100 (%) * Targeted equipment: Total number of water meters (based on charge notice) in the space range	Remote inspection pilot acquisition (O, X)
52. Establishing a Water Treatment Process Diagnostic System	An expert program for the water purification process of water treatment facilities. An indicator that evaluates whether or not a tool for the entire water treatment process, including advanced treatment and membrane filtration facilities, is available.	N/A	System deployment status (O, X)
53. Building a chemical / chlorine automated injection system	Evaluate whether a system that automatically determines and injects drug and chlorine injection rates according to equations for equalization and optimization of integer processing	N/A	System deployment status (O, X)

KPIs	Definition	Formula	Criteria
54. Establishing an Integrated Energy Management System	Based on real-time demand prediction, an indicator for evaluating whether to have an integrated energy management system that takes into account the flow rate, pressure, and level of the water supply system in the water supply network.	N/A	System deployment status (O, X)
55. Energy Monitoring and Management System	Construction of Energy Monitoring and Operation Management System for Water Treatment Plant-Tap Production and Supply Process	N/A	System deployment status (O, X)
56. Pipe Network Information Management System Deployment Rate (%)	An indicator of the GIS system implementation rate for the overall pipe extension for the evaluation of efficient operation and management of pipelines	(GIS system establishment pipe extension (km)/ (total extension of pipework) km 100 (%)	N/A
57. Establishing an Asset Management System	Evaluate whether an asset management system is in place for efficient maintenance of a facility, decision to replace a facility, and rational allocation of investment resources	N/A	System deployment status (O, X)
58. Customer Management System Establishment	To improve customer service satisfaction, evaluate whether the customer management system is in place to manage civil service handling, customer response management, comprehensive customer situation version, customer notification management, and job handling status.	N/A	System deployment status (O, X)

KPIs	Definition	Formula	Criteria
59. Establishing a Real-Time Water Quality Monitoring System	Real-time water quality integrated data collection and decision-making system evaluation for the entire process of water treatment from water intake to faucet	N/A	System deployment status (O, X)
60. Establishing a Diagnostic Operation System for Water Supply Pipe Networks	To provide a total solution of the water network from the pipeline to the supply/drain pipe network, evaluate whether or not to have a water network diagnostic/operation management system that can support facility and operation DB analysis, diagnosis and evaluation of the operation and management of the network through the IT-based (GIS and real-time data) system.	N/A	System deployment status (O, X)
61. Establishing a Pipeline Water Quality Modeling Analysis System	Evaluation of the presence of a modeling analysis system for equal residual chlorine concentration in the pipeline during the water supply process	N/A	System deployment status (O, X)
62. Pumping Station Optimal Operation System	Evaluating the optimal operation system (pump scheduling technology, etc.) of the pump station, which reduces transportation energy (pump) by reflecting the construction status, demand prediction, and level of the drainage.	N/A	System deployment status (O, X)
63. Establishing a Stabilizing System for Water Supply	Indicators for evaluating the retention of integrated flow control systems throughout production and supply, such as securing stability in the water treatment process, dispersion of the water supply flow rate, and controlling the flow rate of the aquifer.	N/A	System deployment status (O, X)

KPIs	Definition	Formula	Criteria
64. Visualization System for the Consumer's Supply Situation (Integrated Information on Water Supply Path, Water Quality, etc.)	Evaluate whether a system that can be integrated into the real-time water operation data and check the supply status via the Web for consumers	N/A	System deployment status (O, X)