A Study on the improvement of national water supply system for improving water reliance

By

KOO, Sunghun

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

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Committee in charge:

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EXECUTIVE SUMMARY

The water supply system is a social infrastructure for the development of public welfare and industry, which has contributed to improving the quality of people's sanitation and economic growth. Korea's water supply service has grown rapidly with economic growth despite its short history of about 100 years. Today, safe tap water is available essentially everywhere in the country and, the quality of tap water is also comparable to that of developed countries.

However, behind this growth there are various problems such as public water supply coverage rates and service imbalances in urban and rural areas, profit structures that cause chronic deficits, leakage and water supply service interruption due to aged facilities, and deep distrust of tap water. These problems remain a long-standing challenge. In addition, more systematic water management is required as the risk of water management from recent climate change is increasing while the people's expectations for water services are rising.

The one of the fundamental causes of such problems is the waterworks' structure which is directly operated by local governments, unlike other services, and water supply management system that is divided into multi-regional and local. South Korea has continued to manage water supply projects in the public sector at the national level to enhance the equity of water welfare services and balanced regional development. However, since many utilities, including K-water and 161 local governments, have been operating separate water supply systems under the control of two central ministries, they have produced various inefficiencies over the decades, including overlapping investments, reduced supply stability and an imbalance in water services.

Fortunately, Korea's water supply service is entering a new phase as Framework Water Management Act was enacted in 2018 that led to the water management function being integrated into the Ministry of Environment. Accordingly, the government is pushing for the reorganization of the water management system, the adjustment of functions, and the establishment of new policies for the rational use of national water resources. I would like to analyze the problems of the Korean water supply system from various perspectives such as structure, process, human resource management and propose a direction for the improvement of the national water supply system and specific implementation measures in this study.

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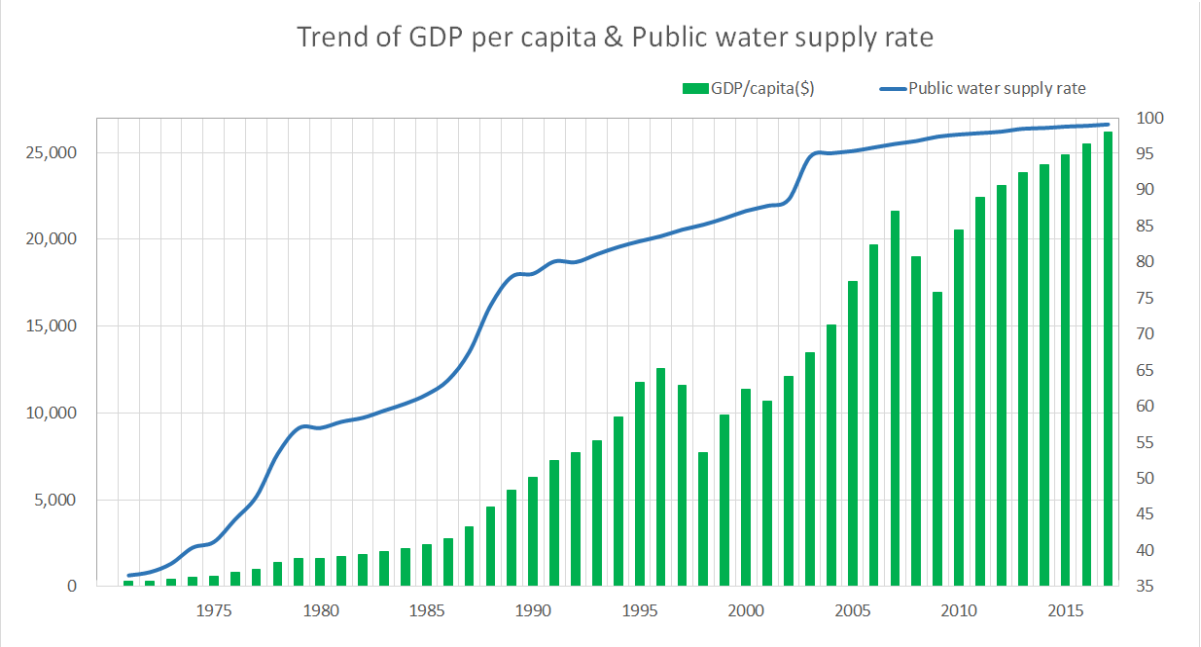
1. Introduction

Since its introduction in 1908, the Korean water supply system has been a driving force for economic growth and improving the quality of people's. Despite its short history of around 100 years, domestic water supply system has continued to grow with economic growth, with the nationwide water supply coverage rates reaching 99% as of 2018, and safe tap water is available anywhere in the country, and operational management and service levels have also made witnessed significant improvements. The revenue water, which is the standard for evaluating the efficiency of water supply operation, is 84% on average nationwide as of 2018 and it also secures world-class tap water quality.

Figure 1. Trend of GDP per capita & public water supply coverage rates



However, water works' structural limitations such as the 161 water utilities and the water management system divided into the Ministry of Land, Infrastructure and Transport (hereafter MOLIT) and the Environment Ministry (hereafter ME) have caused numerous inefficiencies at the national level. Behind this rapid growth there are various problems. Each

local government is in charge of supplying tap water to the respective administrative regions, resulting in a wide gap in the level of tap water services and tariffs in urban and rural areas. Compared to large cities with economies of scale, such as Seoul Metropolitan City, rural areas have lower quality of service with high water tariffs. And profit structures that cause chronic deficits make it difficult to improve facilities and service. This leads to water leakage and water supply interruption due to the aging of the infrastructure, causing social and economic losses. In particular, the structure divided into multi-regional and local water supply systems causes multiple water utilities to operate a single water supply system separately, resulting in many inefficiencies in the operation aspects, such as energy management and water accident response. These problems remain a long-standing challenge.

In addition, changes in the environment surrounding the water work are making water management more difficult. While the risk of water management increases because of worsening water quality in water resources, draught due to climate change, the increase in harmful materials and the rapid aging of infrastructures, the level of people's expectations for water services is increasing in accordance with health-conscious social trends. Accordingly, it is time to need more systematic water management.

To solve the fundamental problems of waterworks, the government implemented a unified water management system in 2018 and is pushing for a new water management policy. I would like to analyse the problems of water supply system from various perspectives and find ways to improve management to enhance the rationality and efficiency of water supply operation and management, based on the new direction of the government's water management unifying policy. And I will propose a direction for the improvement of the national water supply system and specific implementation measures in this study.

2. Necessity of improving the water supply system

2.1 Changes in water supply policy environment

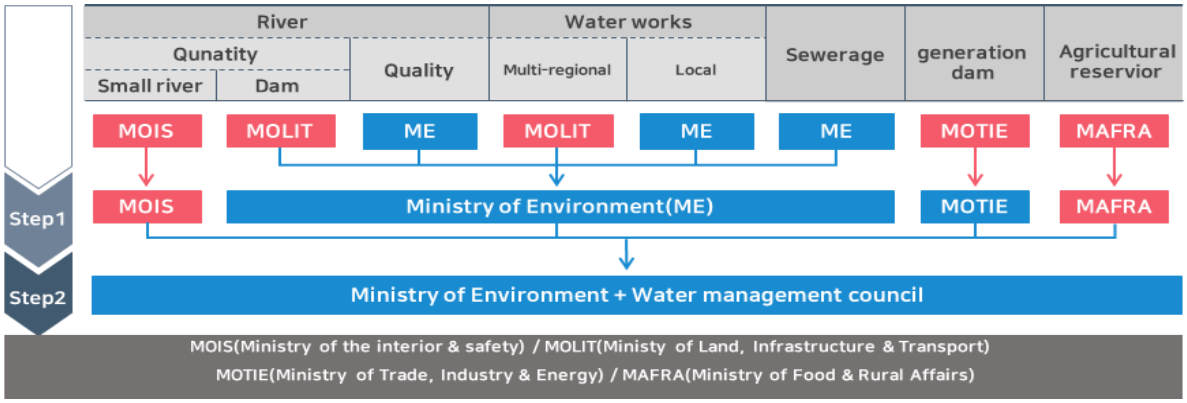
Korea's water management policy has been focused on securing sufficient quantity, and water management functions, including water supply, have been distributed to various institutions. The division of roles by administrative agencies in achieving quantitative growth through the government-led development of national water resources and the establishment of large-scale water supply infrastructure during the economic development period had a positive impact. However, due to the progress of urbanization and industrialization and climate change, the water management environment has become complicated and diversified, and social needs for water use have increased, and the existing water management system has faced limitations and is being called for many changes.

(1) Unification of water management

In order to solve the national water problem rationally, the government enacted the Framework Water Management Act in 2018 and transferred the major functions of water management, including water supply, to the Ministry of Environment. The basic direction of the water management unification policy lies in the integrated management of water quantity and quality centered on the basin, which aims to provide water services felt by the people. Accordingly, the water supply sector, the final phase of the national water utilization system, has also laid the foundation for policy changes. In particular, as the water supply business was defined as the inherent work of local governments and continued to be managed in the public domain, the individual operation of the water supply system by a number of water utilities resulted in many inefficiencies. The government has implemented various policies, including financial support for infrastructure investment, to solve the problem of water supply, but temporary financial support has been limited in solving fundamental problems. With the central ministry in charge of water supply functions

unified and the integrated policy on overall national water management was implemented, conditions were prepared to systematically restructure the national water supply system. It is time for various efforts to switch to a sustainable system by improving the national water supply system in line with social and environmental changes.

Figure 2. Current status of water management function adjustment



(2) Supporting the advancement of local waterworks

Due to the Incheon Metropolitan City's contaminated tap water accident in 2019, citizens in Incheon suffered from inconvenience in using tap water for about 50 days. Large-scale water supply failures in metropolitan areas, which are considered to have a high level of water supply operation, have caused a huge social impact. Although the main cause of water quality accidents is the aged infrastructures, experts pointed out problems in operation and management as a bigger cause. Accordingly, the Ministry of Environment is supporting the improvement of the local water supply operation environment by preparing comprehensive measures for safety management of tap water. The government is pushing ahead with projects to improve aged water pipes, which are the main causes of water leaks and water supply failures, and plans to build and operate water support centers in each of the four basin areas that are responsible for responding to water supply failures in provincial areas. The central government will more actively intervene in water supply projects managed by local governments and implement various state-level support policies. The project to improve aged water pipes has been carried out individually by local governments

from the perspective of "increasing revenue water" In the case of water leakage management, local water supply management, such as production costs and water tariffs, has a significant impact on overall management. In addition, as in the case of Incheon Metropolitan City, if they are linked to water supply failures, it could lead to distrust in tap water services and public policies, which could hamper the promotion of water supply policies in the future. Accordingly, the national project is being carried out simultaneously, and the financial authorities also recognized the necessity of the project and decided to provide large-scale state support. In addition, the Water Supply Supporting Center was established to provide technical support to local governments in order to solve the problem of poor operation and management, which was pointed out as the main cause of the Incheon Metropolitan City accident. This change in water supply policy disproves the need to improve the national water supply system. The problem lies in the sustainability of financial support for infrastructure improvement and technical support from specialized institutions. The support policy for local governments with poor financial conditions is desirable, but at the same time, it is necessary to come up with a national-level step-by-step strategy to solve fundamental problems.

(3) Strengthening national safety policies

One of the government's key policies is public safety. Tap water is a public goods closely related to national health and sanitation, and the tap water safety management is the basic responsibility of the state. In the meantime, the national water supply policy has been focused on expanding tap water supply, but now it is time to shift to a policy focused on systematic water quality management so that tap water can be produced and supplied safely from all risk factors. The water supply system should be improved so that the public can use tap water safely by preparing measures to improve the overall water supply system, such as infrastructure, operation management system, and service.

2.2 Social and environmental changes related to water supply system

(1) Increasing the risk of water management due to climate change

As the climate crisis such as heat waves, droughts and heavy rains has become visible in Korea recently, unexpected risk factors such as tap water larvae are increasing, and more careful water management is needed. Drinking water safety is threatened due to worsening water quality in water sources, such as the occurrence of algae due to abnormal high temperatures and the increase in trace harmful substances, and intermittent water supply and the number of cases of intermittent water supply continues to increase due to increased frequency of drought. In 2015, seven cities and counties in western South Chungcheong Province suffered from tap water supply cut off due to drought, and in areas with poor water supply and demand conditions, the shortage of water during the dry season continues to deepen. In Korea, water management is very disadvantageous due to seasonal and regional rainfall deviations and rapid river discharge. Therefore, it is urgent to improve the water management system in response to rapid climate change.

Table 1. Number of days of algae alerting

Category	2013	2014	2015	2016	2017	2018
Total	266	372	608	404	643	552
Han river basin	35	47	180	0	0	112
Geum river basin	47	0	54	91	161	77
Young-san river basin	0	0	0	0	0	0
Nak-dong river basin	184	325	374	313	482	361

(2) Increasing social demand for drinking water safety

With the transformation of health-conscious social trends, the level of public interest and demand for tap water continues to increase. The drinking rate of tap water in Korea is 45%, which is very low compared to advanced countries such as the OECD countries.

Despite continuous state-level investment to strengthen the safety of tap water, such as the introduction of advanced water treatment and improvement of aged water pipes, the fact that it is not trusted by the public as drinking water is a must to be considered in the process of establishing water supply policies in the future. Until now, water supply policies and services have been d on supplier's perspective and operational efficiency, but now they should be shifted to public view and water quality safety view.

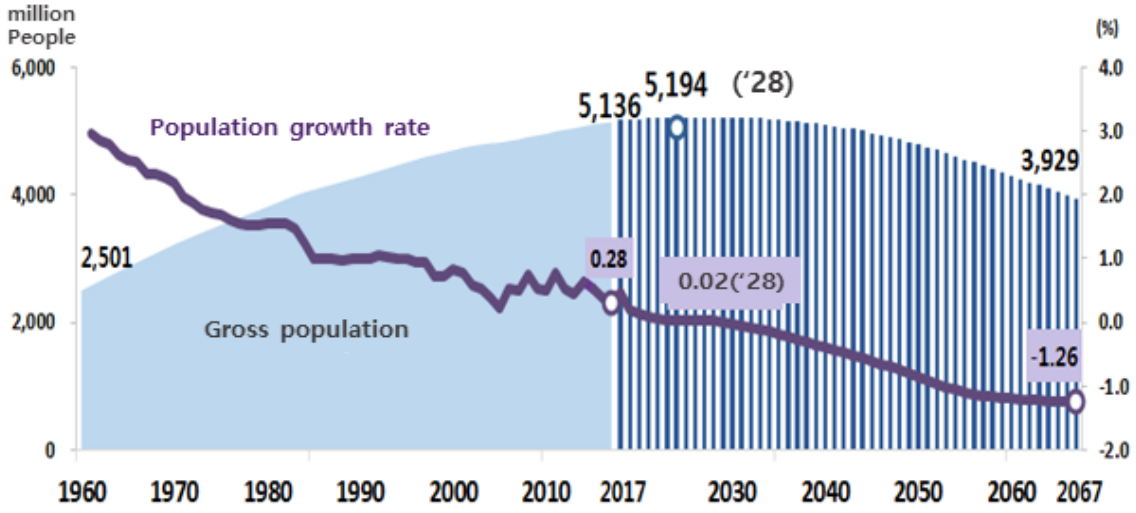
(3) Advancing the technology of the fourth industrial revolution

With the recent development of the fourth industrial revolution technology, services utilizing artificial intelligence (AI) and information and communication technologies (ICT) are being introduced throughout everyday life. The introduction of public services is already spreading in other industries and in areas of public service that are closely related to the lives of the people. And abroad, smart water management system is becoming a major technology in the water industry. The fourth industrial revolution technology is a technology that can drastically transform existing systems based on real-time data, and new and diverse approaches to solve water problem are needed by utilizing advanced technology in the water supply sector. In particular, Korea has advantages in introducing smart water management system as the rate of establishment of information and communication infrastructure is high. In response to the Korean government's recent digital transformation policy, it is necessary to expand the introduction of smart technologies in the water supply sector as well.

(4) Population decline and entry into an aging society

According to the National Statistical Office (NSO) survey, Korea needs to analyze the impact of these social environment changes on water supply businesses as its population decreases and it is entering an aging society.

Figure 3. Gross population and population growth rate (1960~2067)



Based on the risk index of local extinction (Lee Sang-ho, 2018) due to the decrease in population, a study analyzed the risk level of 161 local governments nationwide (Koo Ja-yong, 2019) showed that the number of high-risk areas increased to 16 local governments as of 2019, and the number of local governments entering the entry stage increased. In the case of Japan, a social structure similar to Korea, water use is expected to continue to decrease due to the decrease in population and thus the management status of water utilities is expected to be difficult. As worsening financial conditions will reduce investment in water supply facilities and eventually lead to a drop in water service, Korea should also carefully consider reforming the water supply business in consideration of social changes such as population reduction.

3. Analysis of water supply system problems

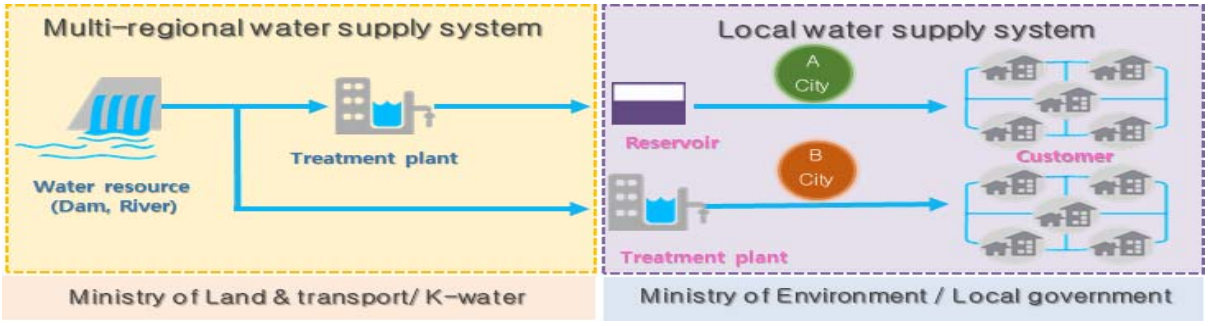
Problems in domestic water supply were analyzed from various perspectives, including business structure, management system, human resource management, and finance, in order to derive improvement measures considering recent government policies and social and environmental changes.

3.1. Structure

The Korean water supply system has been managed in the public sector. During the economic development period, multi-regional water supply infrastructure was constructed under the central government's initiative to provide water for new cities and industrial complexes timely, and tap water supply was managed by placing it as a unique task for local governments. Accordingly, water supply system has been operated separately as a multi-regional and local water supply system. In particular, some of water management function was transferred to the ME in order to strengthen the water quality management of the water resource in the wake of the Nakdong River water accident in 1994, which led two government ministries to manage multi-regional water supply and local water supply system separately. The multi- regional water supply system was managed by MOLIT and K-water, while local systems were operated by the ME and 161 local governments. In general, the whole process from water resource to end-users is a tap water supply system. However, as a result of the functional adjustment, Korean water supply system has become a complex structure that is managed by multiple agencies.

The structure of the water supply management system in Korea is shown below

Figure 4. Past water supply system management structure in Korea



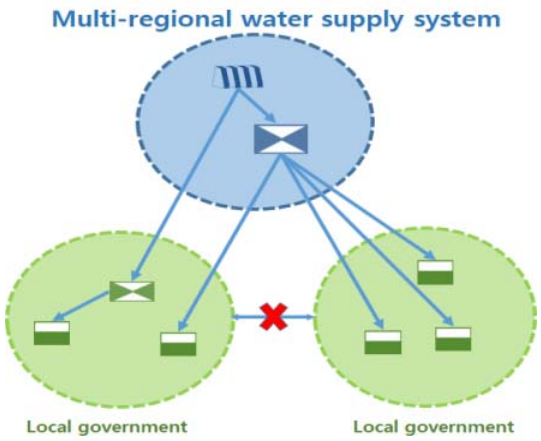
Each government ministry is in charge of policy, planning, budget and standards, while K-water and local governments are in charge of construction, operation and service affairs.

Table 2. Waterworks function by organizations

Organization	Government	K-water	Local government
Function	■ Policy, Planning ■ Budget & Regulation ■ Monitoring & Control ■ Evaluation	Multi-regional sys.	Local sys.
		■ Construction, operation & maintenance ■ Customer service & Support of policy	

Multi-regional water supply system is a large infrastructure that supplies water to two or more local governments and industrial complexes, and is responsible for 48% of the nation's water supply. Of the total 161 local governments, 113 are supplied with water through the multi-regional water supply system (ME, 2013), yet the vertical division of the water system is causing many problems at each stage of the water supply project.

Figure 5. Waterworks structure



The structure of water supply management in Korea has also been divided horizontally. Many small local governments that use the same water source have operated water supply system independently and cooperation between the local governments has not been successful.

3.1.1 Problems with vertical divisions

(1) Redundant investment

The division of water supply system has resulted in national inefficiency due to overlapping investment. As each infrastructure was individually promoted from the planning stage, overlapping investments in multi-regional and local water supply system occurred in some areas. The problem arose because some local governments, which were

already supplied with in multi-regional water supply, planned to set up their own facilities for stable water use. According to a survey by the Board of Audit and Inspection (2014), the cost of such water supply system redundancy plans amounted to 4 trillion won. Recently as Seoul City, which was supplied with multi-regional water supply system, pushed for the construction of its own water intake plant, there was controversy over overlapping investment (2017).

(2) Inefficiency in water supply operation and accident response

As one water supply system is operated and managed by another institution, inefficiency in water supply operation and disaster and accident response is occurring. There is a lack of linkage between the facilities as well as operational data, and the Multi-regional water supply and local water supply system are operated individually. This results in excessive energy losses such as inefficient pump operation in the process of producing and supplying tap water. In the event of a water accident, it often takes a long time to repair the water due to a lack of inter-utilities cooperation, which adds to public inconvenience. In addition, as the improvement cycle, such as the replacement of each infrastructure, is different in terms of infrastructure improvement, the effect of the public's feeling, such as improving tap water quality, is halved despite the huge investment in financial resources. For example, if aged pipes are existed in local water supply despite an advanced water treatment plant is introduced in a multi-regional supply system that supplies tap water to a local system, risk factors such as water pollution in the supply process will not be resolved, and eventually, end users will not feel the effect of the project. In any way, improvements are needed to ensure that a single water supply system can be operated and managed in an integrated manner.

3.1.2 Problems with horizontal division

(1) Water supply service level imbalance among local governments

Small local governments' fiscal conditions are weak due to declining and aging population. Although the government subsidizes local governments with low financial independence, citizens still pay high tariffs due to high production cost. Large cities with economies of scale have high water service quality. On the other hand, residents in small cities and rural areas are paying higher fees despite their low level of service as shown in the table below.

Table 3. Public water service comparison between urban and rural area

Pyeongchang County	Service status comparison	Seoul City
35thousand	Service population (0.3%)	10millinon
1,467 won/㎥	Average water tariff (2.6times)	568 won/㎥
4,832 won/㎥	Production cost (6.9times)	702 won/㎥
20.8m	Pipeline length per person (15.5times)	1.3m

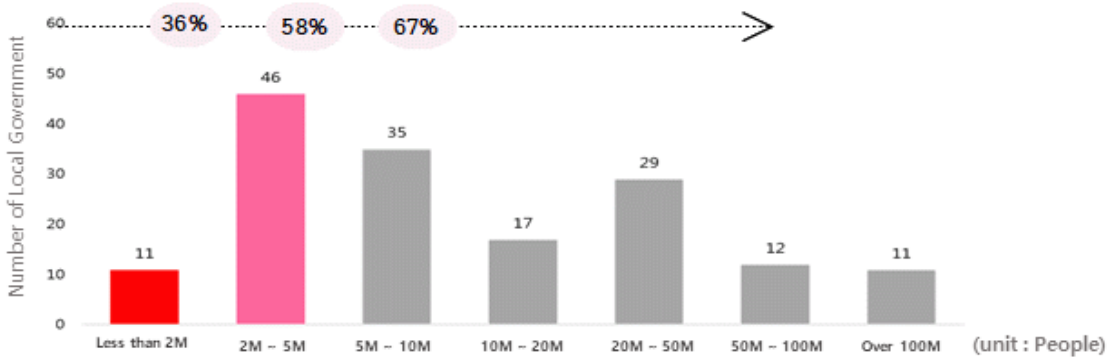
Therefore, mitigating the imbalance in water supply services between urban and rural areas is one of the major challenges.

(2) Vulnerability of water supply business structure

In the case of water supply, there are various management facilities, such as water intake, water treatment plant, and pipelines, which require a lot of fixed costs for operation and maintenance, which can be a major factor that causes increased production costs. In order to keep water supply charges at an appropriate level and operate the facilities in a stable manner, it is essential to maintain an economy of scale such as service population. According to a study on the efficient implementation strategy of the local water supply project (Korea Association of Local Public Enterprises, 2004), the service population should be at least 500,000 people in order to secure economic efficiency of local water

supply. In Korea, however, most local governments, except for the Seoul metropolitan area, are facing a decline in population. Of the 161 local governments, 57 have a water supply service people of less than 50,000, accounting for 36% of the total. There are 92 local governments with a water supply of less than 100,000, or 67% of them.

Figure 6. Status of local governments by population size



Local governments that do not have economies of scale are at high risk of rising production costs, but they are not able to reflect them in water bills due to the nature of tap water as a public good. As this leads to water supply failures and poor service quality, a review is needed to secure economies of scale such as linkage and integrated management between water supply system.

3.2. Water supply system management

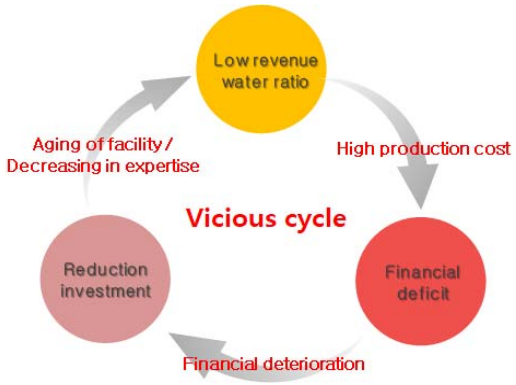
As water supply facilities, which were built intensively in the 1980s and 1990s, have aged, it has led to water leaks and water quality accidents. About 16% of all 210,000 kilometers of water pipes in Korea are pipes that are due to be replaced, and the number of aged pipes is expected to continue to increase in the future. Aged facilities not only reduce service stability, but also have a very large impact on the overall water supply business, which raises production costs for leaks, etc., so systematic management is needed. However, as most local governments with poor financial conditions fail to manage their aged facilities in a timely manner, heavy losses are occurring across the country.

The nation's average revenue water is 84%. Water leaks in the process of being supplied with produced water, causing many national losses. If the amount of water leakage is calculated economically, it amounts to 600 billion won a year. Also, the revenue water varies much between regions. The revenue water in rural areas is lower than that in big cities. The revenue water is also an indicator of the efficiency of the water supply operation, and the lower revenue water, the higher the production cost.

Table 4. Comparison between the revenue water and production cost

Revenue water	**~60%**	**60~70%**	**70~80%**	**80~90%**	**90%~**
Number of City	27	36	35	42	21
Production cost (won/㎥)	1,960	1,814	1,802	1,191	857

Figure 7. vicious cycle of waterworks

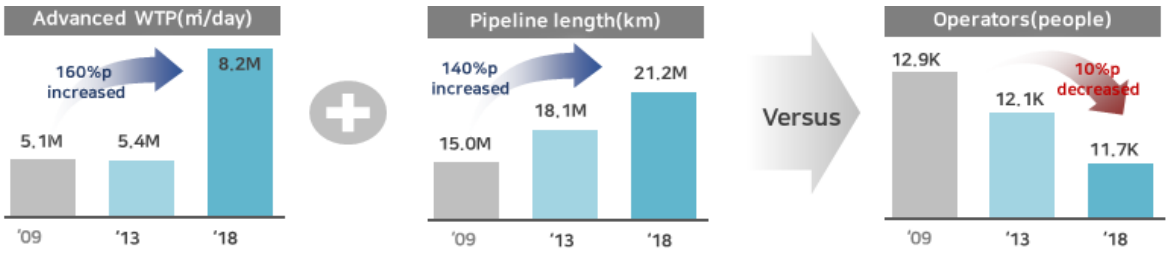


Therefore, this has a significant impact on the local government's finances and water tariffs. Small local governments with poor financial conditions have low revenue water due to aged facilities. This increases production costs and aggravates their financial capacities. As a result, local governments' investment for water supply will be delayed, resulting in lower revenue water. Yet, the damage caused by this vicious circle will be inflicted on the entire nation. The nation suffers a lot of economic losses from water leakages, and local citizens are forced to pay more for water than in other areas. In this regard, the central government has been pushing for a "modernization project" to improve the revenue water of small local utilities since 2017; the government will provide 50% of the budget in consideration of the financial conditions of local governments. At the same time, more fundamental changes are needed.

3.3 Human resource management (HRM)

Due to the modernization of infrastructure, such as the introduction of advanced water treatment facilities to improve the safety of tap water, along with the expansion of water supply, the number of facilities to be managed by water utilities continues to increase, but the number of professionals managing them continues to decrease. The capacity of advanced water treatment facilities has increased 1.6 times over the past 10 years, but the number of local administrative personnel has decreased by 10%.

Figure 8. Current status of water supply management personnel



In addition, as water supply services such as water supply failures and customer complaints are recognized as heavy duty within the organization of public officials, their expertise is deteriorating due to frequent personnel changes. In particular, the water treatment process that produces tap water is complicated and very important to secure safety, so the expertise of operating personnel is essential, and although it is operated by preparing the qualification system and manpower placement standards at the national level, the placement rate of professionals at water treatment plants across the country is around 70%. Along with the improvement of water supply facilities and systems, it is necessary to train professionals who operate them.

3.4. Finance management

The management principle of Korea's water supply business is to establish a water utility tariffs system based on reasonable cost estimation, and to secure funds for the provision of tap water services and the maintenance of project sustainability through water tariffs income. As a result of analyzing the capacity of local water utilities to reinvest in water supply facilities based on their water tariffs income, the current water supply charges are barely able to cover the cost of maintaining the status quo, such as maintenance costs and repayment of principal and interest. In particular, local governments with small scale and poor financial conditions had no capacity for reinvestment, making it difficult to maintain the operation of the water supply business just by importing water bills. More than half of the nation's 161 local water utilities were found to have no capacity for reinvestment. As a result, additional investment costs to improve water supply services immediately lead to a fiscal deficit, with most of the domestic water supply projects operating under a chronic deficit structure. Although the government subsidizes more than half of the cost of infrastructure investment at the national level to strengthen the safety management of tap water, it is necessary to establish a virtuous cycle system that can solve problems on its own in consideration of sustainability.

Table 5. Status of reinvestment capability of local governments

Category	Metropolitan city	City	County
Total number(161)	8	75	78
Number of local governments that can’t afford to reinvest	1(12.5%)	36(48.0%)	52(66.7%)

4. Literature review

Various policies and research have been carried out to advance national water supply and enhance safety of tap water. Although there were differences in methodologies, most of the policies and studies suggested the reorganization of the waterworks structure as a long-term alternative to overcome the limitations of the horizontal and vertically divided water supply system. The common goal of water supply policy was to realize economies of scale. The government and experts proposed policies to realize economies of scale through integration and linkage between small water utilities and to shift to a business structure that is public service but can secure economic feasibility, thereby inducing safety management of tap water and service improvement in the long term. Since then, the government has been pushing for policies to secure competitiveness through sound competition among water utilities and revitalize the entire domestic water industry, including entering overseas markets. The following are the major policies and studies that have been carried out in Korea.

(1) Privatization

The first National Waterworks Comprehensive Plan (Ministry of Environment, 1998) focused on the privatization of waterworks. Although the central government or regulatory body promoted the method of managing and supervising public services by integrating waterworks by basin, it was not carried out due to concerns over privatization of public services and rising water charges.

(2) Integrating and broadening waterworks

In 2006, through the establishment of a plan to foster the domestic water industry (ME), 161 small-scale water supply projects were integrated into less than 30 units so that the economy of scale could operate, and the service function was presented to specialized

utility and the management and supervision functions to local governments. Local governments were required to participate in the project by considering the scope of management, etc. of the project as the main body of structural reform, and to select the integration method from among various forms, such as establishing public company or consignment of specialized institutions, and to establish and operate an appropriate management and supervision organization.

This is similar to the integrated model of waterworks in the UK, which in the UK privatizes waterworks and operates the Office of Water Services (OFWAT), an independent regulatory body, to control private businesses through evaluation of water supply and regulation of charges.

In the case of Italy, through the establishment of the Gali ACT in 1994, the waterworks business was integrated through financial and institutional support by providing an appropriate scope for integrating 13,000 projects into 91 sizes. Italy also has COVIRI, a supervisory body, to carry out functions such as monitoring structural reform.

Table 6. Role & function by institution

State	Local gov.	Specialized institution
- Law related Support - Setting tariff and service evaluation criteria - Setting water quality (WQ) standard and Monitoring	- Business supervision - Selection participant - Tariff determination	- water supply service - Construction & operation - Maintenance & management

The government induced autonomous participation of local governments based on overseas cases, but failed to implement them due to the lack of concrete measures on the scope and method of integration of these policies.

(3) Integrated management of specialized institutions

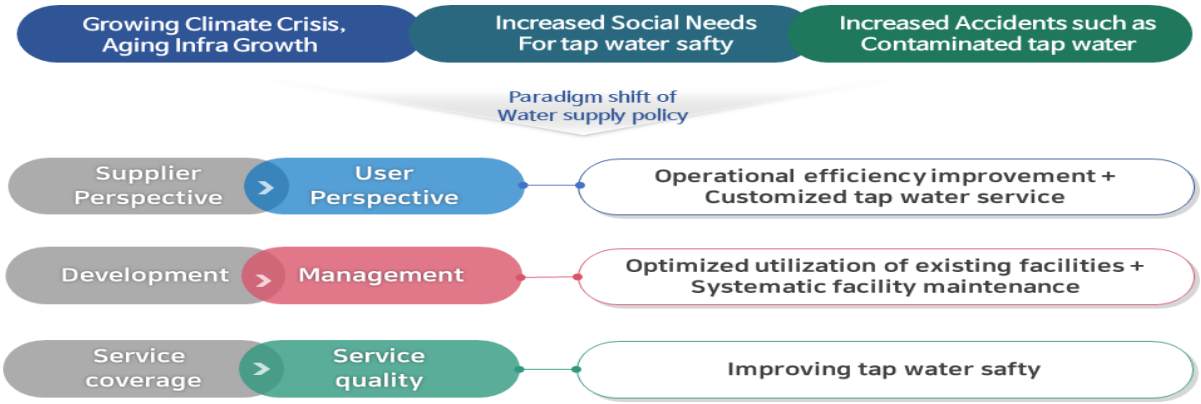
In 2008, the Ministry of Public Administration and Security proposed a plan to manage the local water supply system professionally by broadening them to supply clean and cheap tap water to the people by improving the cost reduction and inefficiency of local water supply system. The method of integrated management of local water supply systems by specialized institutions was not a privatization method of transferring ownership to the private sector, but rather a mid- to long-term stabilization of water charges and improvement of water quality through cost reduction through wide-area management and professional management while maintaining the public nature of water service. Each year, the government assessed the management performance of the local waterworks and supported separate incentives so that the project could be expanded as soon as possible. The scope of integration was divided into 39 areas, taking into account the size of water supply service population, regional characteristics, and integration of administrative districts. The project was carried out first for local governments hoping for it. Only 13 local governments carried out integrated operation by entrusting water supply to specialized institutions to achieve business results such as raising the revenue water, but it has not been developed into a follow-up process such as management integration or expanded to other regions.

5. Findings and proposal

5.1 Policy direction

As analyzed earlier, it is necessary to improve the national water supply system due to changes in the water-related policy environment and social and environmental conditions. While the risk of water management due to the climate crisis is increasing, social demand for tap water safety is increasing. Therefore, it is necessary to shift the direction of water supply policy from the perspective of suppliers in the past to the focus on public view and

Figure 9. Water supply policy direction



5.2 Strategy establishment

In developing strategies to efficiently implement these water supply policies, a comprehensive review of sustainability, social acceptability and system stability should be carried out. To ensure the effectiveness of the water supply policy, and to ensure the viability of the plan it is necessary to establish an effective strategy.

- Fundamental measures to ensure long-term performance rather than short-term effects
- Realizable strategy with consensus with stakeholders such as end users and utilities
- Comprehensive measures for overall projects, not simple system improvement

Figure 10. Strategic direction

5.2.1. Strategic Direction

Considering the characteristics of the current national water supply system, such as the waterworks structure managed only in the public sector and the situation in which economic feasibility is not considered when pricing as public goods and considerations in establishing strategies, the strategic direction for improving the national water supply system was reviewed.

Table 7. Strategic direction for improving water supply system

Sustainability	- Shift to business structure that can ensure economic feasibility for reinvestment
Social Acceptability	- Securing fairness in water supply service between regions - Creating tangible results for the people
System stability	- Comprehensive improvement for entire water supply sector, including infrastructure, operation & management, customer service

(1) Sustainability

While state subsidies for improving facilities to local governments with poor financial and operational conditions are necessary, there is a limit to solve the fundamental problems of domestic water supply. The realization of economies of scale should allow the use of water tariffs to reinvest in infrastructure improvements and establish a virtuous cycle system that leads to improvements in tap water service quality. Depending on the social environment and the financial conditions of the government, the local government's subsidy policy may change in size and object, so water supply policies should be implemented in such a way that water utilities can independently advance water supply services and develop the entire national water supply through sound competition among utilities.

(2) Social Acceptability

The domestic water supply is operated individually by 161 local governments, and each local government has different business sizes such as operation and financial conditions and service population. In addition, the water supply project is defined as a unique office of local governments, which limits the management and supervision of central government departments. Therefore, it is necessary to establish a consensus with many stakeholders such as local governments and citizens in order to improve the overall system of national water supply. In order to strengthen the implementation of policies and encourage active participation of water utilities, objective standards for improving acceptance, such as evaluation criteria and quantification of business performance, are needed.

(3) System stability

In the meantime water supply policies have focused on improving aged infrastructure, but water supply failures continue to occur due to insufficient operation management even after the modernization of infrastructure such as contaminated tap water accidents in Incheon, and the need for more detailed water management is increasing due to the increase in unpredictable factors caused by changes in the climate environment, so it is necessary to improve the system in a way that can advance the overall water supply business.

5.2.2 Integrated management of national water supply

According to a comprehensive analysis of domestic water supply policies, social and environmental changes, policy directions, and directions for establishing strategies for the efficient implementation of policies, integrated management of water supply is needed from a long-term perspective to solve fundamental problems of the national water supply system. The goal is to enhance the stability of the system by linking and integrating the horizontal and vertical divided water supply system, and to secure sustainability by establishing economies of scale in the long term. In the meantime, water supply integration measures were proposed and implemented in prior research and policies, but there were limitations in actually implementing them. In this study, I would like to propose the direction of integrated management of water supply, which should be pursued in the future, through analysis of the limitations of past policies. The reasons why the existing water supply integration policy was not implemented were largely divided into three reasons: 1) lack of strategic procedure; 2) lack of strategic diversity; and 3) lack of acceptability.

(1) Procedure of strategy

Conditions for the operation of facilities by 161 water utilities were not fully considered. The integration effect, such as service and tariff equity, is considered in the stage of reviewing the integration. Due to different operating conditions and service levels of facilities, financial resources and integrated performance may not be reasonably distributed among local governments. Benefits can be the biggest stumbling block in pushing for integration. Therefore, a prior step is needed to ensure that all local governments provide more than a certain level of service and operate the system stably, but the push for simple integration without this process can be seen as a major cause of failure. Integrated

management of water supply is desirable in phases, considering the level of operation of local governments.

(2) Diversity of strategy

The 161 water utilities have diverse water use environments. 113 local governments are supplied with multi-regional water supply, while the rest of the local governments manage their own water sources to consumers. Some local governments need a vertical link to the multi-regional water supply system, while others do not. Since rational allocation of water sources and linkage between supply facilities are typical achievements when integrating water supply, it is necessary to review water use environment such as water resource and facilities. Therefore, the integration of waterworks requires a variety of integrated models, but diversity has not been considered in existing policies.

(3) Acceptability of strategy

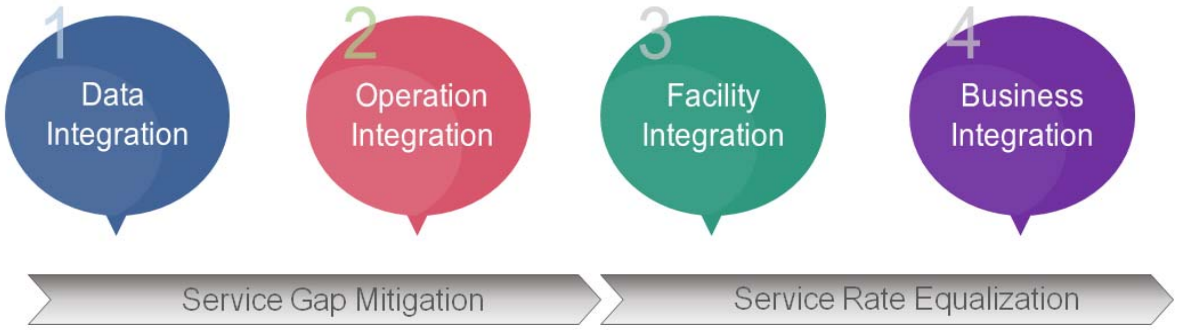
As previously analyzed, water supply stakeholders vary widely. Accordingly, the process of promoting integration also requires the process of collecting and approving opinions from Congress and citizens. Integration requires not only facilities and services, but ultimately assets and management integration, so sufficient information is needed to make decisions. Objective data on the selection of local governments subject to integration, and the decision on how to integrate, and the effect of integration helps increase social acceptance. However, there was a lack of this information in the past policy-making process.

5.2.3 Action plan for integrated management of national waterworks

In this study, we would like to present specific action plans for the integrated management of national water supply. First of all, in order to integrate water supply, steps are needed for final integration of business and management.

The steps for integrating water supply are as follows.

Figure 11. Waterworks integration phase



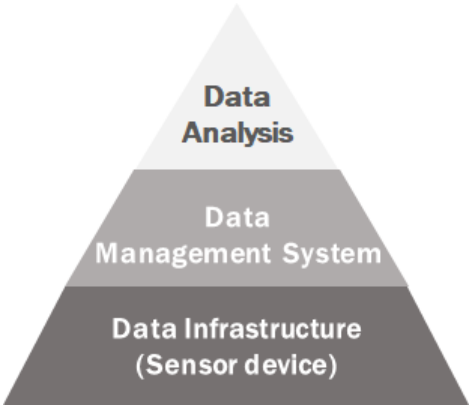
(1) Data Integration

Data integration is the most fundamental and necessary process. Data management is an important part of modern water supply operations, and all water utilities are pursuing information services, although there are differences in level. It is necessary to integrate and manage the data accumulated by each water utility in connection with the water utilities or management regulators. It is a process necessary for the operation of individual facilities, and there is less resistance from local governments to the integration process, and its effectiveness is excellent. In particular, local governments that receive tap water from multi-regional water supply system need data linkage. This enables energy management such as pump control on a regular basis, and effectively responds to various water supply failures to reduce customer damage. In addition, the problem of individual supply systems can be analyzed through the analysis of accumulated data to increase safety. This is

because regulators and specialized agencies can utilize the data to provide effective technical support. Integrating water supply data is already being promoted at the national level. The government is seeking to introduce a smart water management system for 161 local governments and multi-regional water supply operator(K-water) nationwide to integrate data on national water supply. Smart water management system is a system that systematically manages water quantity and water quality by establishing a real-time monitoring system based on ICT in the entire tap water supply process. Smart water management systems are part of the data integration process. Data integration requires the following steps.

Figure 12. Information integration phase

- Installing devices that can acquire real-time data
- Establish a system to collect and process information acquired from devices
- Data analysis to make the decision required for operation, Support and stakeholder data sharing



Through the smart water management system construction project, the quantity and water quality data acquired from the devices installed in the tap water supply process will be collected by the integrated system, corrected the wrong and missing data to be used for monitoring individual water systems, analyzed through solution programs such as the pipe network operation management system, and used for operation and improvement of the water system. Individual information systems will be linked to the national integrated information system, enabling the entire national water supply system to be monitored and responded in real time. In addition to helping improve existing water supply systems, upgrading and integrating information systems is an essential element for the next phase of

integration. Since infrastructure and system construction requires a great deal of cost, the government should first support the financial resources needed to build information integration systems and also push for system improvement to utilize data linkage after system construction.

(2) Operation integration

From this stage, practical integration between water utilities is made, and the integration effect is visible. In the past, the water supply integration policy has been partially implemented up to this stage. Local governments that are currently carrying out integrated operations have also been pushing ahead with the information integration process proposed by this study. After establishing an integrated operation center, data was integrated first, and then operational integration was achieved. Information and technology sharing among local governments through integrated operation can reduce energy generated in the process of supplying tap water and effectively increase the revenue water. It is also the stage where operating personnel are reduced or used in other processes during the integration process. By doing so, production costs will be reduced, and the reduced costs will be reinvested in infrastructure improvements, or help local governments improve their business conditions. The most important thing in the integrated operational phase is control. This is also a threshold for information integration. In order to apply the acquired real-time information to the operation, the authority to control the operation of the infrastructure must be granted to the main body of the integrated operation. Local governments, which are currently engaged in integrated operation, are managing such integrated operation authority by granting it to specialized institutions. In order for waterworks integration to be further expanded, it will be very important to rationally decide who is the main body of integration and who is the actual operator. Among the integrated water supply models, direct management of local

governments can be considered in addition to the current system of entrusting specialized institutions. In the information system integration-based operation integration phase, the improvement of individual water system operation can be achieved, and the foundation for infrastructure and business integration can be established. Information integration and operational integration can mitigate to some extent the operational and service level gap of 161 local governments. The next step is necessary for the integration of practical services and charges.

(3) Infrastructure & Business integration

In fact, water supply can be seen as the final step in integrating. Facilities and management must be integrated to realize economies of scale. However, this process can be seen as a practical phase of waterworks integration that is difficult to implement due to the many factors to consider and complex interests. All waterworks in Korea are the assets of individual local governments as they are defined as local governments' own waterworks. In order to integrate facilities, measures to deal with asset management are needed. In addition, there are no cases of infrastructure and business integration in Korea except for some cases in which water supply is integrated through the integration of administrative districts, as there may be problems such as investment in facilities and distribution of water tariffs.

In addition, local governments must carry out relevant procedures to entrust or integrate waterworks. Usually, the project feasibility study and residents' briefing sessions and parliamentary approval procedures are required. It is difficult to pass this process unless the need for integration and the effectiveness of integrated management are fully explained.

Figure 13. Local water supply integration procedure

Therefore, indicators are needed to determine the needs and effects of integration and various integrated models considering the characteristics of each local government. As previously analyzed, the diversity of the integrated model and the integrated management indicators for decision making were insufficient in promoting the integration of water supply. I would like to further refine the domestic applicable water supply integrated model and present integrated management performance indicators in this study.

5.2.4 Water supply integration model

Since there are differences in basic water use environments as well as the level of operation by local governments, various models are needed to integrate water supply. Basically, it should be able to display integrated effects such as linking water resource and supply systems. In addition, if tap water is supplied from multi-regional water supply system or a local government of a certain size or larger exists nearby, the scope of water supply integration can be narrowed. Out of 161 local governments, 113 local governments are supplied with multi-regional water supply system, and each local government has different rates of dependence, so they presented an integrated model that considered this and analyzed the specific advantages and disadvantages of each integrated model

Figure 14. Waterworks integration method

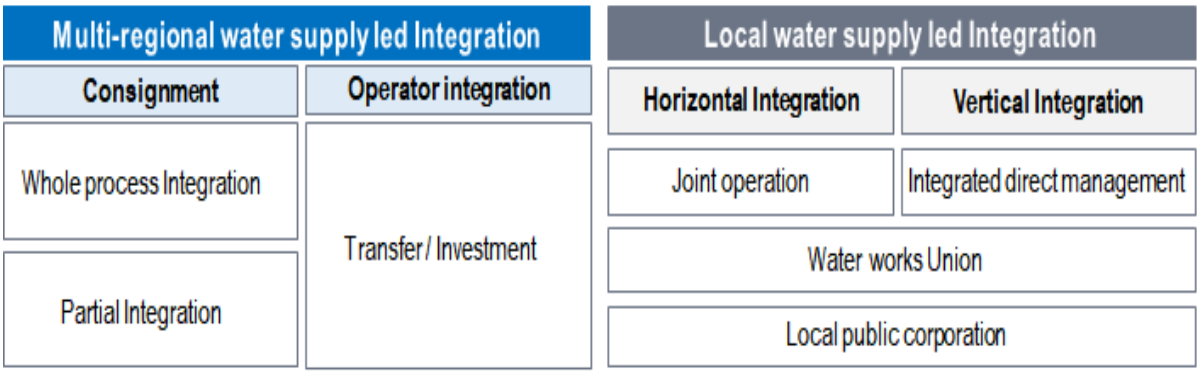


Figure 85. Waterworks integration method and main contents

Category	Main Contents
Whole Integration (Consignment)	• (concept) Entrusting local government waterworks to a specialized institution • (Advantage) Strengthen efficiency and responsibility by entrusting the completion of the entire project • (Limitation) Inefficiency in entrusting specialized institutions to simple fields (such as meter reading) & conversion of public officer's position
Partial Integration (Consignment)	• (concept) The method of entrusting part of the waterworks process • (Advantage) Customized integrated management • (Limitation) Need to secure close links between unit facility operators
Transfer/Invest (Operator integration)	• (concept) Transfer of status as a waterworks operator of a local government to a specialized institution • (Advantage) Improving facility efficiency & unifying rate system through practical water works integration • (Limitation) The need to revise laws and regulations to secure the status of local waterworks operators
Joint Operation	• (concept) The operation and management of facilities by forming a consultative body among local governments • (Advantage) Realizable under the current system • (Limitation) Difficulty in compromising interests among local governments and concerning lack of expertise
Integrated direct management	• (concept) The method of integrating water works operators among local governments and directly operating water supply system • (Advantage) Improving facility efficiency & unifying rate system through practical water works integration • (Limitation)) Difficulty in compromising interests among local governments and concerning lack of expertise
Water works Union	• (concept) The establishment of a water works union with the investment of a number of local governments • (Advantage) Realizable under the current system / No conversion of public officer's position • (Limitation) Conflicts related to contributions, shares, exercise of voting rights / lack of belonging among those in charge
Local public corporation	• (concept) The method of transferring the authority of waterworks operators of local governments • (Advantage) Improving facility efficiency & unifying rate system through practical water works integration • (Limitation) Need to revise the Local Public Enterprises Act / Conflict of related with conversion of public officer's position

5.2.5 Integrated management indicators

In this section, integrated management indicators are reviewed to determine the justification for integrated management and the customized integration methods for each local government. In Korea, indicators are managed to assess the status of water supply operation, but there are no cases of operation and utilization of indicators for water supply integration. Basically, by analyzing the business indicators (PIs) of Akihyun, Japan, which successfully integrated water supply, the indicators were readjusted to suit the domestic situation, and the necessity of integrating water supply by local government was analyzed.

(1) Case study of Akita, Japan

- 16 indicators in 4 Section (Water demand, Infra, Finance & Organization management)

Table 8. Evaluation indicator of integrated water supply in Japan

Category	Water demand	Infra & Risk	Finance	Organization
Indicator	- Water supply coverage rate	- Average / Maximum operating rate - Storage quantity per service population - Density of facilities - Pipe replacement rate - Reservoir capacity - Water wagon rate - Earthquake-resistant rate(WTP, Pipe, Reservoir)	- Revenue per capita (employee) - Rate of realization of tariff - Service tariff	- Revenue water per employee - Technician ratio
	1ea	10ea	3ea	2ea

- The areas to be assessed were selected as six areas that meet the following conditions

  ✓ Integrity in the natural conditions, such as geography and in the residents' right

  ✓ Similar trends in facilities, such as the type of water source & service population

  ✓ Within the scope of possible joint action on waterworks

- In the case of Japan, indicators were used to determine the level of integration consisting of four stages as well as the necessity of integrated management.

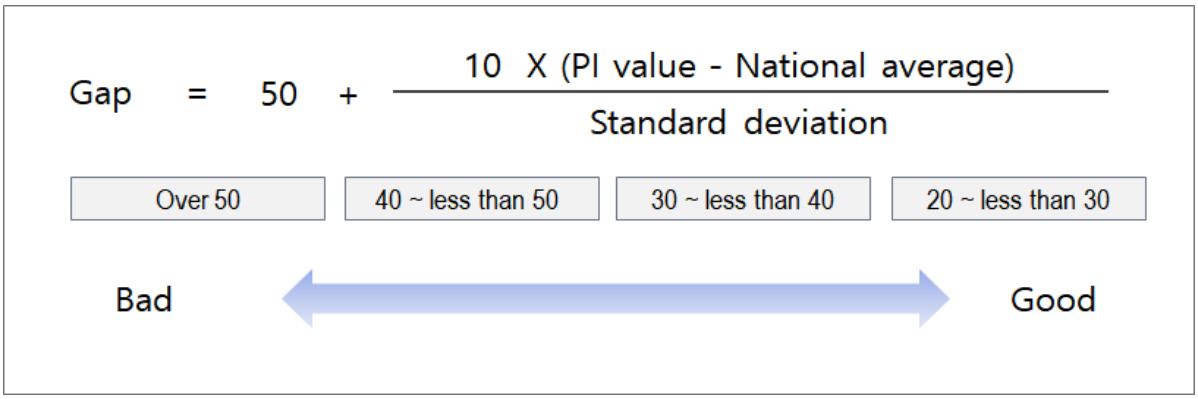
Japan's integration steps are as follows.

Table 9. Waterworks integration steps and indicator (Japan)

Category		Contents
Level 1	Joint operation of facilities	- Possession of shared facilities (WTP, Pipeline etc.) - Mutual Cooperation in the event of a disaster
		Analysis of 10 indicators for infrastructure and risk management
Level 2	Management unifying	- Joint maintenance (including consignment) - Joint implementation of administrative affairs
		Analysis of 6 indicators (Reservoir capacity, Density of facilities Water wagon rate, Revenue water per employee, Technician ratio)
Level 3	Management Integration	- One management entity, another form of personal business - Different tariffs system by regions
		Analysis of 2 indicators (Revenue water per capita, Technician ratio)
Level 4	Business Integration	- Integrating management entities and businesses into one - Significant changes in infra maintenance, operation, services
		Analysis of 16 indicators

- Reviewing the necessity and level of integration according to the results of calculating the gap by region based on 16 business indicators

Figure 16. Equation for determining method of waterworks integration



(2) Reviewing domestic application

- Comparing and analyzing current waterworks evaluation indicators (PIs) and water service evaluation indicators for domestic application
- Establishing indicators for domestic application by evaluating the representativeness and measurability of performance indicators

✓ Review the adequacy of indicators such as water supply operation, service level and management level and whether it is possible to analyze the effects before and after the project through the discussion process of the working group

✓ Determining the possibility of measurement by utilizing the latest statistical data

Table 10. Indicator review method

Indicator representation	Measurability
· Public management evaluation index(23) · Water and sewerage service level assessment index(72)	· Up-to-date statistics · Water supply statistics(ME, 2019)

- Final selection of 11 detailed indicators in 4 Section

Table 11. Waterworks integration indicator

Category	Water demand	Infra & Risk	Finance	Organization
Indicator	- Water supply coverage rate	- Average / Maximum operating rate - Storage quantity per service population - Pipe replacement rate - Reservoir capacity	- Revenue per capita (employee) - Rate of realization of tariffs - Service tariff	- Revenue water per employee - Technician ratio
	1ea	6ea	3ea	2ea

- Evaluation of 161 local governments nationwide based on Japanese cases
- As a result of the evaluation, the majority of 161 local governments nationwide need to be integrated into the four types of linkage proposed by the Japanese Ministry of Health and Welfare. In particular, it is analyzed that the joint operation of facilities is urgent (118/161)

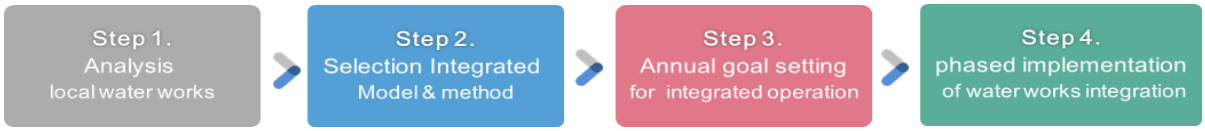
Table 12. Result of waterworks integration indicator analysis (Summary)

Category		Analysis result		
Level 1	Joint operation of facilities	Over 50	43 local governments	118 governments (Require to execute)
		40 ~ less than 50	89 local governments	
		30 ~ less than 40	6 local governments	
		20 ~ less than 30	23 local governments	
Level 2	Management unifying	Over 50	57 local governments	104 governments (Require to execute)
		40 ~ less than 50	94 local governments	
		30 ~ less than 40	10 local governments	
		20 ~ less than 30	0 local governments	
Level 3	Management Integration	Over 50	72 local governments	89 governments (Require to execute)
		40 ~ less than 50	81 local governments	
		30 ~ less than 40	8 local governments	
		20 ~ less than 30	0 local governments	
Level 4	Business Integration	Over 50	57 local governments	104 governments (Require to execute)
		40 ~ less than 50	82 local governments	
		30 ~ less than 40	22 local governments	
		20 ~ less than 30	0 local governments	

5.2.6 Integrated waterworks roadmap

Although analysis of indicators needs to be advanced considering domestic conditions, the analysis of the environment and indicators confirmed that integrated management of water supply is necessary in the long term to improve the chronic problem of domestic water supply. It is suggested that the following step-by-step roadmaps should be established and implemented by utilizing integrated water supply models and performance indicators for systematic implementation of integrated water supply management. The general procedures for the waterworks integration roadmap are as follows.

Figure 17. Integrated water supply roadmap



However, as presented in this study, many uncertainties, such as resistance from water utilities and limitations of technical and financial factors, can act as obstacles, so the scenario of integrating water supply by conditions is proposed. Although this study presents the direction of implementation for each scenario, an in-depth review is required in the actual water supply integration implementation process.

(1) Scenario 1. Case with high expected integration effect and high acceptance

In this case, it is suggested that the integration of water supply is the most advantageous condition, so the integration of facilities and services should be carried out quickly. To this end, the government should establish plans for the consolidation and closure of facilities and the conversion of supply systems based on supply areas, not on administrative districts, and implement financial sharing and long-term financial effects analysis. After the integrated analysis of facilities and services, a financial plan shall be

established based on it. The method of integration should be determined based on financial plans, and necessary system improvements should be made for each local government. Since this case is easy for local governments and citizens to make decisions, it is suggested that they be prepared to speed up the integration of actual services and charges.

(2) Scenario 2. Cases with high expected integration effect but low acceptance

Business resistance due to concerns over downsizing of the organization is the biggest obstacle to integrating water supply. If the expected effects of integration are high, but the resistance within the organization is high, a gradual implementation is proposed from the integrated operational stage. When operating an integrated agency, the reduction of related personnel is inevitable, so a plan is needed to convert existing personnel into service and maintenance tasks. In the case of personnel change, a thorough review is needed to enable productive tasks such as realizing efficient integrated operations and improving the revenue water, rather than simply changing positions. After the establishment of the integrated operation plan, the efficient allocation and reinvestment plan of production costs saved through the integration of operations should be reviewed, and based on this, procedures such as gathering opinions on long-term water supply integration models and methods should be carried out.

(3) Scenario 3. Cases with poor operation condition and low acceptance

In this case, it is necessary to improve facilities and prioritize information service plans. The level of operation of each local government should be upgraded on the premise of integrated operation, and integrated indicators and effects should be carefully reviewed to maximize social resistance. As the most common case, it is necessary to review the consignment of specialized institutions and to provide financial support from the government to facilitate the integrated operation.

6. Conclusion

Tap water is a public good directly linked to the health and sanitation of the people, and tap water safety management is the basic responsibility of the state. The national water supply system has been rapidly developing over a relatively short period of time, contributing to economic development and public sanitation. The operation of the water supply project through 161 local governments has contributed greatly to the expansion of tap water supply in the development stage, but over time, such a business structure has become a barrier to tap water safety management. While the risk of tap water supply increases as the climate crisis becomes visible and facilities age, the reduction of investment capacity due to the small business structure and the control of tap water tariffs at the national level make tap water management more difficult. The gap in water service between regions is widening, and contaminated tap water supply failures can threaten the health and safety of citizens at any time.

This is the time for fundamental changes in the national water supply system. As seen in overseas cases such as Europe and Japan, the sustainability of water supply services cannot be guaranteed if economies of scale are not secured. Innovative reorganization of the waterworks business structure is needed to ensure that all citizens can use tap water with confidence. It is necessary to establish a virtuous cycle system that can realize economies of scale by integrating and linking water supply to areas where water sources and supply systems can be linked, and improve services through reinvestment in infrastructure improvement. I believe that the number of water utilities with expertise will increase, and through good-will competition among them, the water supply service will be further advanced and the tariff gap between regions will be eased. However, based on successful

integration cases abroad and failures of domestic policies in the past, it is suggested that the integrated water supply management should be carried out step by step while establishing consensus with many stakeholders.

In this study, the integrated water supply model and performance indicators were proposed, but in the case of water supply models, institutional restrictions and so on were not fully addressed. Research is needed on how to improve regulations by water supply model in the future. In addition, the study did not fully address the fact that the nation's water supply projects, which are carried out on an administrative basis, are highly related to the overall financial structure of local governments. There is a high possibility that urban environment will change due to population decline, and cities will be able to do so.
Although it can be divided into declining, stagnant, and growing types, this study lacked analysis of urban size. Therefore, research on the link between urban size and water supply projects is also needed in the future.

The opportunity to improve the water supply system was provided through the unification of water management. As in the past, integrated water supply management should not be delayed due to the reduction of the public service organization and so on. It is necessary to establish effective policies and come up with effective measures to implement them. I expect small changes to continue so that clean and safe tap water can be used anywhere in the country.

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