

Challenges for water infrastructure asset management in South Korea

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Abstract

Most Korean citizens today have access to water services, owing to the enormous investment made in water infrastructure. Recently, however, Korean society is facing issues concerning rapid deterioration and inappropriate management of urban water infrastructure. It has been determined that 72.3% of all water infrastructure will have deteriorated by 2035, which implies that the standard of water services then would be even lower than the current standard. Given the complex institutional system required for urban water infrastructure, the vagueness of management authority, limited maintenance budget, poor information management, and issues with maintenance methods are the high priority issues currently being faced. This paper discusses the challenges that Korean society is facing and proposes the need for a change in cognizance for successful water infrastructure management in the future.

Keywords: Asset management; Cognizance; Deterioration; Water infrastructure; Water services

1. Introduction

South Korea has experienced unprecedented economic growth, leading to improved living standards. Simultaneously, there has been significant investment in water infrastructure, as a result of which most of the population has access to water and wastewater services (KEI, 2014). Despite considerable investment, the infrastructure has been poorly managed. In particular, the aging of the water infrastructure in urban areas has resulted in various social accidents and incidents that have negatively affected the urban water services. Approximately 21.3% of Korean citizens were found to feel unsafe with regard to their facilities due to the collapse of old reservoirs and the rupture of water supply systems (Ministry of Land,

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Transport and Maritime Affairs, 2012). The majority (~27%) of these facilities collapsed due to inadequate facility management (National Emergency Management Agency, 2013). For example, several water supply pipes in many cities burst every year, causing traffic jams and the suspension of water supply to nearby areas. In addition, there have been many incidents of the collapse of old reservoirs over 60 years after their construction (for example, the Sandae reservoir and the Chosan reservoir in 2013 and the Goiyeon reservoir in 2014). In 2011, an interruption in the operation of sewage treatment plants caused untreated sewage to enter the Paldang Lake, which is a source of drinking water for more than half of the nation's population. The environmental impact of the wastewater system is the most critical, as it directly affects the quality of urban streams and the living environment.

Urban water services are fundamental for sustaining the social and economic quality of life. In this respect, advanced urban water infrastructure management, such as asset management, has been suggested as a key factor for achieving adequate and sustainable levels of water services in the long run. Asset management is a modern term for an old concept, as the task of managing assets has existed for many thousands of years (Amaral *et al.*, 2017). Infrastructure asset management is the act of maintaining a demanded service level of an asset for the present and future generations based on the most economically effective management system (IPWEA & NAMS, 2015). The application of asset management to water infrastructure has significantly advanced in the last decade. In England, infrastructure asset management is performed according to the PAS-55 Asset Management (British Standards Institution, 2012), which emphasizes the importance of the consideration of the cost, risk, and performance of the infrastructure asset during its life cycle. Australia developed the International Infrastructure Management Manual (IIMM) with New Zealand, which proposes the following core factors of asset management for the efficient and sustainable operation of public facilities: life cycle costs, cost-effective management strategies, and risk management programs. In addition, the Public Sector Accounting Board of Canada introduced new accounting standards, called PSAB 3150, for managing public infrastructure assets. The information provided by PSAB 3150 has triggered several key initiatives such as the national report card on the state of public infrastructure (CCA *et al.*, 2012). In Portugal, more than €4,300 million was invested in the construction of water supply and wastewater systems as a part of the 2000–2006 Strategic Plan for Water Services (Amaral *et al.*, 2017). The huge investment effort resulted in significant changes in access to urban water services, but it was accompanied by problems of financial sustainability. Thus, a national strategic plan for 2014–2020 that focuses more on the sustainable management of existing infrastructure assets has been put in place (Amaral *et al.*, 2017).

The management of water infrastructure in Korea has been limited to manual post-maintenance activity centered on structural safety inspection. The Korea Infrastructure Safety Corporation under the Ministry of Land, Infrastructure, and Transport developed the Facility Management System, which provides basic information such as a list of the infrastructure, safety inspections, and life cycle costs, for effective management. However, data on the life cycle cost are insufficient and difficult to find (Park *et al.*, 2016). The Korea Water Resources Corporation under the Ministry of Environment implements asset management based on an asset management manual that is developed. However, the core factors such as asset management policies and strategies are not included in the manual; the manual only focuses on taxes and accounting of assets (Park *et al.*, 2016). Although the social problems caused by the aging of facilities and inadequate management have gradually increased, the introduction of asset management to address these issues in the water sector is very recent. There are only a few studies on the development of an asset management system for water supply and wastewater facilities (Koo, 2017; Park, 2017). Studies on aging and management of water infrastructure are also very rare.

The objective of this study is to analyze the deterioration rate and methods of the maintenance of water infrastructure in Korea, based on a large amount of data on water infrastructure collected from government ministries, organizations, and local governments and surveys and interviews of water infrastructure managers. This paper begins with a discussion on the aging rate of general water infrastructure. Then, issues with current maintenance methods such as poor information management and the absence of a long-term plan are discussed in the second part. Lastly, proposals for future water infrastructure management are discussed. The findings of this study can provide important information that can be used to introduce more efficient water infrastructure management in Korea.

2. Materials and methods

The water infrastructure considered in this study includes water supply systems (pipes, filtration, and intake stations), sewage arrangements (pipes and sewage treatment equipment), river facilities (riverbanks and water gates), agricultural facilities (reservoirs and pumping stations), and dams. Data were collected from government departments (Ministry of Environment and Ministry of Land, Infrastructure and Transportation), ordering authorities (Korea Water Resources Corporation, Korea Rural Community Corporation, and Korea Infrastructure Safety Corporation), and local governments, and the current and future deterioration rates of water infrastructure were analyzed. However, for sewage pipes, the records before 1990 were insufficient and statistical data on pipe types were recorded only after 2010. This means that there is a large gap in the historical data on sewage pipes constructed before 1990. Hence, the deterioration rate of the sewage pipe was estimated through the data of a nationwide survey of water infrastructure managers conducted by the Ministry of Environment in 2011 (Korea Environment Corporation, 2012). In addition, for calculating the deterioration rate of water infrastructure, it was assumed that no new facilities would be constructed, and existing facilities would not be repaired in future.

In the determination of the aging of facilities, a facility was considered ‘aged’ after 30 years had elapsed since its completion. This number was used because according to the 2014 *Local Public Enterprises Act* (The National Law Information Center, 2018), and the service life of water supply and sewage facilities is primarily 30 years. Furthermore, the criteria for the Korea Infrastructure Safety Authority to review the results of close inspection and precision safety diagnosis are 30 years old. In this study, the standard period for the deterioration was set as more than 30 years of an infrastructure’s life cycle.

Furthermore, 164 water infrastructure managers from local government were surveyed and interviewed to analyze the status of management methods and managers’ cognition towards water infrastructure. The survey was conducted in 2015, and the content included management methods, maintenance budgets, and conditions required for asset management.

3. Results

3.1. Physical condition of water infrastructure

The coverage of Korea’s public water infrastructure in the 1960s was clearly below the average coverage levels of industrialized countries. However, significant efforts to improve the coverage in the 1980s

and 1990s resulted in a sharp increase in these levels and, towards the end of the century, the population in urbanized areas had almost full access to water supply and wastewater services. In 2016, over 98.9% of the population had access to clean water. Compared with the conditions in 1998, in which only ~82% of the population had access, this is clearly a notable progress (Ministry of Environment, 2018a). The number of people that benefited from water supply services increased from 40 million in 1998 to ~52 million in 2016.

A more remarkable improvement was observed in the penetration rate of wastewater services, i.e., over 93.2% of the population had access to wastewater services compared to the 65.9% that had access in 1998 (Ministry of Environment, 2018b). A remarkable increase in the number of people that had access to wastewater services was also observed, i.e., from ~32 million in 1998 to ~49 million in 2016. Considering the high rate of urbanization (91.9%) in South Korea, almost the entire population in urban areas achieved better living standards owing to improved water services.

Table 1 presents the comparisons of the deterioration rate of water infrastructure operating for over 30 years in the present and the near future. In terms of water supply, the deterioration percentages of filtration plants, intake stations, and pipes operating for over 30 years in 2014 were 18.8%, 33.4%, and 9.6%, respectively. In addition, 20.6% of all the water supply facilities have been running for over 30 years in 2014, but the deterioration rates in 2025 and 2035 are expected to increase to 50.3% and 84.1%, respectively. Especially in 2035, more than 93% of the filtration and intake stations will have been operating for over 30 years. With regard to wastewater infrastructure, the deterioration rates of sewage treatment equipment and sewage pipes running for over 30 years in 2014 were 6.8% and 14.1%, respectively. In 2035, it is expected that the deterioration rate of sewage treatment equipment and sewage pipes with a lifetime of over 30 years will be 83.6% and 51.5%, respectively. In addition, the deterioration rate of agricultural facilities was 70% in 2014, but it will be 94% in 2035, which is much higher than the deterioration of other facilities. According to the data, agricultural facilities were intensively built between the 1950s and 1970s; hence, their current deterioration rate is quite high. In this way, in the near future, water supply and wastewater facilities could also become rapidly superannuated as the current high rate of agricultural facilities. The results show that 72.3% of all water

Table 1. Deterioration rates of water infrastructures operating for more than 30 years.

| Infrastructure | | In 2014 | | | In 2025 | | | In 2035 | | |
|-----------------------|----------------------------|----------|-------------|------|----------|-------------|------|----------|-------------|------|
| | | Rate (%) | Average (%) | | Rate (%) | Average (%) | | Rate (%) | Average (%) | |
| Sewage arrangement | Pipe | 14.1 | 10.5 | 27.8 | 38.1 | 45.3 | 50.4 | 51.5 | 67.6 | 72.3 |
| | Sewage treatment equipment | 6.8 | | | 52.5 | | | 83.6 | | |
| River facility | River bank | 4.3 | 10.8 | | 8.1 | 20.8 | | 12.4 | 36.3 | |
| | Water gate | 17.2 | | | 33.4 | | | 60.1 | | |
| Water supply | Pipe | 9.6 | 20.6 | | 35.9 | 50.3 | | 65.4 | 84.1 | |
| | Filtration | 18.8 | | | 50.0 | | | 93.8 | | |
| | Intake station | 33.4 | | | 65.1 | | | 93.2 | | |
| Agricultural facility | Reservoir | 95.9 | 70.0 | | 97.7 | 80.7 | | 99.2 | 94.0 | |
| | Pumping station | 44.0 | | | 63.6 | | | 88.8 | | |
| Dam | Dam | 34.4 | 34.4 | | 59.4 | 59.4 | | 75.0 | 75.0 | |

infrastructure will have been operating for over 30 years by 2035, which means that Korean society would experience a rapid deterioration of its water infrastructure.

Figure 1 shows the relationship between the deterioration rate of water infrastructure and the financial independence rate for all the provinces and cities. The deterioration rate in Figure 1 is the mean value of the deterioration rates for each infrastructure category. If the management and financial status remain unchanged in the future, the level of water services in provinces and cities with poor finance will deteriorate rapidly. In particular, water services in regions of area IV are expected to worsen compared to those in other areas owing to the relatively high aging rate and low financial independence.

Furthermore, datasets on the water infrastructure for each province and city indicate that the deterioration rates of water supply pipes and sewage facilities in big cities are higher than those in the other regions. Figure 1 shows that Seoul, the capital of South Korea, in which one-fifth of the population resides, has a low aging rate, but this is because Seoul has no agricultural facilities such as reservoirs. If agricultural facilities are excluded, Seoul has a very high aging rate of the water infrastructure. In Seoul, 14.7% of the water supply pipes have been running for over 30 years, which is the highest compared to other cities. Over 30% of the sewage treatment equipment has been running for more than 30 years with the longest sewage pipes also being more than 30 years old. Recently, the frequency of accidents and incidents related to water infrastructures has been increasing in big cities, and it can be assumed that this is due to the aging urban water infrastructure. This implies that the rapid deterioration of water infrastructure in urban areas would lower the level of water environment services, which is a challenge faced by Korean society today.

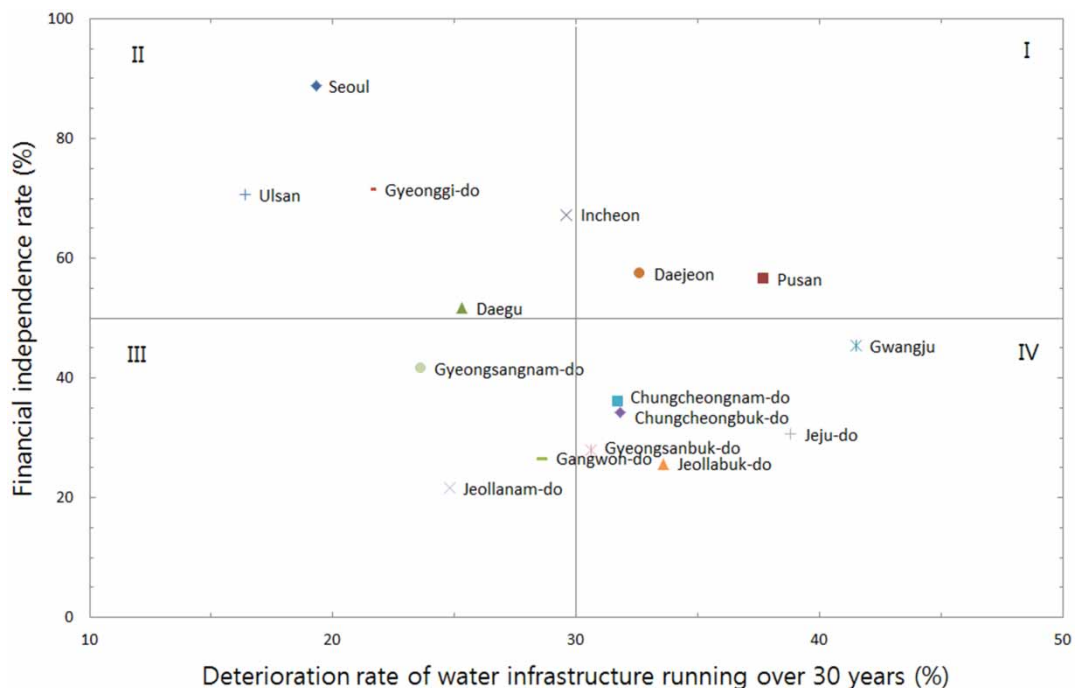


Fig. 1. Financial independence rate and deterioration rate of water infrastructure in provinces and cities.

3.2. Management of water infrastructure

Water infrastructure management is embedded in a complex institutional system that contains various stakeholders and interests with a high degree of interconnectedness rather than merely technical aspects (De Bruijn & Herder, 2009). In this respect, not only the rapid deterioration discussed above, but also inappropriate management including improper maintenance methods and the absence of long-term strategy plan, needs to be addressed.

3.2.1. Vagueness of infrastructure management authority. Decision-making for infrastructure management is inherently complicated, because it is embedded in a complicated social structure related to various infrastructures (Too, 2011). In particular, the complexity increases under circumstances in which the management authority for certain infrastructure is unclear. If the duties and tasks of the various government agencies and departments engaged in the maintenance and management of water infrastructure are assigned clearly on a legal basis, maintenance and management works can be carried out without uncertainty, but the actual circumstances are quite different. For example, a scrutiny analysis of management authority reveals that many parts of the social infrastructure such as water supply systems, dams, ports, and roads are recognized as nationally owned assets under the 2017 *National Accounting Act* (The National Law Information Center, 2018) but sewers are not included in this Act. This means that sewers are not nationally owned assets although they were built using the national budget. In accordance with the 2017 *Sewerage Act* (The National Law Information Center, 2018), sewerage arrangements belong to the local government in that region and their maintenance is the local government's duty. However, under the 2017 *Rules for Local Government Accounting Standards* (The National Law Information Center, 2018), sewerage arrangements are not subject to local accounting regulations. Only roads, water supply facilities, urban railroads, and water supply facilities, etc., except for sewerage arrangements are regulated by local government in accordance with the Act, which can be interpreted to mean that sewerage facilities do not belong to any institution.

3.2.2. Improper information management. Planning can be effective only if based on useful information. Hence, it is necessary to obtain the necessary information and data through the established information management systems for proper management planning (Rouse, 2014). The lifetime of underground networks varies considerably based on a number of elements such as the material from which the pipe is made, the condition of the soil, and the character of the water or wastewater flowing through it (US EPA, 2002). Without proper information, it is virtually impossible to understand the exact deterioration rate. The results of the survey on the method of information management of water infrastructure show that 31.3% of water infrastructure managers in local governments do not use any tools or methods for information management. Of these, 32% use only Microsoft Excel or Word programs for information management. Only 19.5% of them use GIS programs and 12.5% use more advanced systems.

The survey results show that the methods of recording the history of water infrastructure are not appropriate and reliable. The evaluation of the conditions of the water infrastructure is up to the administrator and their experience, and no systematic procedure is followed. If a decision is made solely based on implicit knowledge, the managers might face difficulties in recalling the underlying tradeoffs, considering investments, and determining whether budgets have been disbursed effectively (van Riel *et al.*, 2014). Similarly, poor knowledge on the conditions of water infrastructure makes it difficult to predict system performance.

3.2.3. Absence of management strategy plan. In accordance with the 2013 *Special Act on Facility Safety Management* (The National Law Information Center, 2018), safety diagnosis and maintenance are carried out every 5 years for water infrastructure of river facilities and water supply facilities. In addition, a technical examination of sewage facilities such as pipes and public sewage treatment plants is carried out every 5 years according to the 2017 *Sewerage Act* (The National Law Information Center, 2018). However, the level of service and sustainable management strategy including long-term budget planning are not evaluated, as confirmed by the survey of water infrastructure managers. In order to maintain water infrastructure efficiently, it is essential to set an order of priority for management. Then, according to this order of importance, budgets can be disbursed with a strategic plan. However, 69.5% of managers said that there is no standard for prioritizing facility maintenance. In addition, most managers in Korea do not consider the degree of public satisfaction with the level of service and no public opinions are reflected in the plan.

The survey also shows that budget planning for the maintenance of water infrastructure is also problematic. 53.7% of managers said that the budget for the next year is planned based on the previous year's budget. 24.9% of them consider quotations from facility management firms and 10.7% only consider the inflation rate. 6.2% of managers use a simple prediction model and 2.8% do not predict the budget at all.

3.2.4. Limited budget on maintenance. To examine the budget for water infrastructure maintenance, the performance of a maintenance company was analyzed based on the facility maintenance data obtained from the Korea Facilities Maintenance Association. The facility maintenance company included in the analysis was the company registered under the 2014 *Framework Act on the Construction Industry* (The National Law Information Center, 2018). The amount of investment in social infrastructure maintenance was ~\$3.18 billion, which is 15.2% of that for construction, i.e., \$21 billion. The amount seems to be increasing, but it is still much less than that of other industrialized countries, i.e., 40–50% of the overall budget (Park *et al.*, 2016). In addition, the amount of investment in water infrastructure maintenance was estimated to be \$131.4 million, which is only 2.65% of the total amount of investment in water infrastructure. Thus, to maintain the current level of water service, more budget should be allocated for future infrastructure maintenance.

Overall, the ineffectiveness and complexity of the maintenance system does not allow long-term planning and only reactive maintenance works can be conducted without a systematic management plan. Ineffective maintenance methods, the absence of a long-term plan, and low budgets for maintenance are all interconnected, which has led to a vicious cycle of poor management.

4. Discussion and further thoughts

Industrialized countries experienced a rapid deterioration in social infrastructure from the 1980s to the 1990s and a significant amount of investment in maintenance was required, which was a major financial burden. With regard to the sewage facilities, the shift from construction to maintenance was initiated in industrialized countries after connectivity reached 90% (van Riel *et al.*, 2014). Rather than planning massive construction projects, they started to adopt more advanced strategies for proper maintenance. Likewise, it is expected that South Korean society would follow a similar path. Based on the experience of these countries, we can predict that South Korean society will inevitably face financial burdens from the maintenance of deteriorating facilities. Water infrastructure services have continued to be promoted and constructed through industrialization and urbanization in the developing world by mimicking

traditional systems of the industrialized world (GWRC, 2009). However, owing to rapid changes in the status of water infrastructure, there is increasing pressure on the government to provide improved water services to its citizens, and the need to reflect on changing priorities in water infrastructure planning for water and wastewater has been emphasized (ADB, 2012). Traditional approaches to urban water infrastructure may not be the best suited for these rapid changes, especially after reaching certain levels of the living standard (Bieker *et al.*, 2010).

For more effective management of water infrastructure, asset management has long been suggested as an effective infrastructure management mechanism considering the level of service, life cycle approach, risk management, and long-term financial plan (IPWEA & NAMS, 2015). The purpose of asset management is to achieve long-term goals that the organization pursues and to meet the changing needs of customers on a legal basis (Too *et al.*, 2006). In other words, the key issue is to optimize the balance between various stakeholders' aspirations and the costs over the life cycle of the asset. There are certain steps and various elements that must be considered to establish an effective asset management system (Grigg, 2003). Recently, the necessity for more effective maintenance methods in South Korea such as asset management has been realized, but there is still a limited amount of research on effective water infrastructure management. Hence, more effective water infrastructure management methods ought to be introduced and implemented.

Besides the methods required, however, according to this study, there is still a negligible social consensus for more efficient water infrastructure management, and the lack of social cognizance on the necessity of efficient management of water infrastructure is the real issue behind this. This lack of cognizance has caused or involved many complicated circumstances such as a limited budget, improper information management, and issues related to maintenance methods. Thus, a change in the cognizance of water infrastructure, from focus on massive construction to effective management with long-term goals, is required. This change would create a more desirable circumstance that realizes the principle of asset management, i.e., how effectively and efficiently existing assets can be utilized in the long term. This is evident in the results of the survey of managers. According to the survey on what is needed to implement asset management, 19% of managers said that the economic benefits of introducing asset management should be presented before implementing it, and 18.5% said that it is important to present the risks that aged infrastructure poses to communities. This finding indicates that, to realize the change in cognizance, clear information regarding the current problems must be communicated. However, 49.2% of the managers said implementation of asset management depends on the cost of introducing asset management in their cities. This response is related to the response of 84.1% of the managers, stating that they were not aware of asset management, including the education and promotion of asset management are important for its effective implementation.

Meeting the fundamental needs of citizens is one of the priorities of the government. However, in Korea, the goal for meeting the fundamental needs such as access to water services has already been achieved quantitatively, and as of now, utilizing the existing assets is a matter of great importance. To this end, a change from construction to management is needed for future water infrastructure management. The realization of this particular change requires retiring the existing system, and to do this, the grounds for change should be persuasive. Addressing the question of why the change is necessary with convincing answers can help motivate the departure from the existing system (Tichy, 1993). To put it simply, only when the necessity of change is recognized, can the cognizance of members of the organization change accordingly. This 'awakening' may be the beginning of the change in cognizance (Kotter, 1996). As demonstrated by the abovementioned results of the survey of managers, explaining

the benefits of utilizing existing water infrastructure efficiently with a long-term perspective can be one of the ways of convincing citizens. Similarly, realizing a ‘sense of urgency’ based on the financial burden and lower levels of service linked to the conventional approach towards water infrastructure management can also help bring about this awareness.

During the period of industrialization, the top-down approach was used to achieve quantitative improvement. Especially, in case of South Korea, throughout the rapid industrialization phase, the participation of citizens was mostly absent in planning or policy decisions. Even though the social system does not favor citizen involvement in Korean society, Korean citizens have started to become more active with regard to seeking better water environment services (KEI, 2013). In other words, this phenomenon could be a precursor to a new paradigm, i.e., from intense construction to advanced management. However, the recognition of this issue by social water infrastructure managers is far behind the citizens’ recognition of it. Hence, the perspective of water infrastructure managers should be changed from providing basic services to improving the level of services, i.e., from construction to appropriate maintenance, from the provider’s perspective of a centralized system to the consumer’s perspective of meeting their changing needs and expectations.

5. Conclusions

The objective of this study was to analyze the physical conditions and management methods of water infrastructure in South Korea to clarify the importance of appropriate management methods of water infrastructure. Based on an analysis of these factors, the necessity of cognizance change with regard to future water infrastructure management was realized. Providing water services in South Korea has been an essential task for the government, and through large amounts of investment, a high level of accessibility for citizens has been achieved. However, even after this massive investment, rapid deterioration has been observed in urban areas. With the high population density in urban areas in South Korea, it is expected that this deterioration would lead to a decline in the level of water services in urban areas.

In addition to the deterioration, an ineffective maintenance system could negatively affect the water services. However, a significant amount of the budget has been invested in massive construction projects and only a small portion of it has been disbursed for maintenance. This reflects public ignorance of the importance of appropriate and systematic management of water infrastructure. The poor information management system prevents the collection of reliable data and rational decision-making based on this data. According to the surveys conducted, most water infrastructure managers do not utilize advanced methods to manage data and do not even store any information or data. Under these circumstances, decision-making only can be performed based on the manager’s intuition or subjective thoughts based on experience, which may lead to ineffective or infeasible planning. Furthermore, the maintenance of water infrastructure does not include long-term plans and the level of service. In addition, the maintenance of water infrastructure overlaps between various institutions and in some cases, even the absence of responsibility was observed in the sewage system. This can be explained by the fact that the various Acts relevant to maintenance lack coherence.

Many developed countries have introduced and implemented asset management as an efficient water infrastructure management method. In addition, asset management is beneficial for overcoming various issues that Korean society has faced, but cognizance change towards water infrastructure management

should be a top priority. For cognizance change to occur, the government should present a clear vision for it and create an environment conducive for the active involvement of citizens.

This paper contributes to understanding current challenges related to urban water infrastructure in South Korea. Based on the analysis, various challenges were observed, and the importance of cognizance change is discussed. The next step is to introduce more sustainable water infrastructure management methods, which can be implemented with more detailed data and on a legal basis.

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