A Study on Setting Appropriate Revenue Water Rate Target Reflecting the Operating Characteristics of Each City

By

JANG, Heonwoo

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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PUBLIC MANAGEMENT Committee in

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EXECUTIVE SUMMARY

In 2015, the Ministry of Environment in Korea has been pushing for the 2nd operation efficiency improvement project of tap water management for 103 local governments whose RWR(Revenue Water Rate) is still less than 70% among total 161 local governments. The main contents of this project are to establish a DMA system and replace old water supply networks. Through this project, the Ministry of Environment in Korea subsidizes 70% of total facility investment to local governments. However, the conditions of grant support must be achieved and maintained at least 85% of the RWR(Revenue Water Rate) for five years after the DMA system is established. The target of RWR for 1st operation efficiency improvement project was 80% 15 years ago in 2000, but now it is questionable why the RWR target for the 2nd project has been changed to 85%. Furthermore, it is also questionable whether it is the right policy to target all local governments at the same 85%, even though the RWR varies greatly depending on the size of the city, the density of the city, and the financial status of the city. For example, should the two local governments achieve the same 85% target if the current RWR is 45% of local governments A and that of local governments B is 69%. Rather, it can be more reasonable for both local governments to improve 20% to set targets at 65% for local governments A and 89% for local governments B. Therefore, the research questions to be reviewed in this study are as follows. First, what is the most suitable RWR target in Korea, and 80% of the 2010s is a reasonable target? Or is 85% of the 2020s the right target? Second, is the Ministry of Environment's correct policy to present the same RWR target to all local governments? Or should different RWR targets be presented according to the unique characteristics of local governments? Third, if local governments have to set different RWR targets according to their unique characteristics, what are the variables that affect the RWR target, and what is the predictive model for an appropriate RWR target? Lastly, if the RWR target is low due to the characteristics of local governments with low density like in rural areas, if leakage continues, what other alternatives are there to solve this problem? Therefore, in this study, the RWR and the regression analysis on various variables are performed to review the RWR target suitable for each local government.

In order to determine which variables affect RWR, I first performed a correlation analysis of RWR with 15 independent variables. As a result, RWR has the greatest correlation with urban density factors. In other words, the higher the city's density, the higher the RWR, and the lower the city's density, the lower the RWR. In addition, the financial status of each local government and the technical variables such as GIS, DMA systems were also analyzed to have some correlation with RWR. For the prediction of suitable RWR targets for each local government, I conduct multiple regression analyses by combining these 15 variables. Thus, the RWR prediction model was created by combining 7 independent

variables through stepwise regression. As a result of the verification of the RWR prediction model for 161 local governments in Korea, the coefficient of adjustment determination was analyzed to 0.7238, creating a highly reliable prediction model. In other words, the target of RWR for each local government can be explained by the prediction model by approximately 72%. Therefore, it is not reasonable for the Ministry of Environment to apply the same RWR target to all local governments at 85% for 2nd operation efficiency improvement project for tap water management. The Ministry of Environment should set different RWR targets suitable for each local government by comprehensively considering their urban density, financial status and level of technology of WDS (Water Distribution Network) management.

As previously mentioned, it is not the right government policy to set the same RWR target for all local governments, as RWR depends on the unique characteristics of each city, such as density. Therefore, I would like to propose an improvement policy for a suitable RWR target setting that reflects the unique characteristics of each city. First, it is required to introduce the global standard, Infrastructure Leakage Index (ILI), in Korea. Because ILI presents an objectified target called Unavoidable Annual Real Loss (UARL), depending on the density and pressure of various cities, it is possible to set the correct leak index target reflecting the unique characteristics of each city. Second, in case of small cities where UARL is highly generated due to low density, the latest SWM(Smart Water Management) technologies such as Sub-DMA and smart metering should be introduced more actively. By installing many of these smart water flow rate, pressure, and quality measurement sensors in the WDS (Water Distribution System), it is easier to find and repair leaks of vast pipelines even in small cities with low density. Ultimately, these smart technologies can reduce leakage by dramatically reducing the ALR(Aware−Location−Repair) time for leakage.

It is clear that leakages in pipes will improve when SWM technology is introduced to small cities with low density. However, there are some limitations and challenge to the introduction of SWM technology by government policy. First, there is still a lack of cases in Korea that have overcome the problem of leakage in cities with low density by applying SWM technology. Therefore, more studies on SWM application cases are required. Second, the development of a big data system (S/W) for analyzing vast smart sensors according to the introduction of SWM technology is required first. No matter how many sensors and budgets are invested, if there is no big data analysis S/W, we may fail to achieve the leak reduction goal because it takes a lot of time to analyze and process vast amounts of data by human resources. Finally, a Benefit-Cost (B/C) analysis study of SWM infrastructure deployment is also required first, even though SWM technology dramatically reduces leaks.

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1. Introduction & Research Question

Since the early 2000s, the Ministry of Environment in Korea has introduced a DMA (District Metered Area) system based on ICT technology to reduce leaks from water supply networks to the ground. The DMA system was renamed the block system as it was spread through neighboring Japan, which in effect is about the same content as the UK DMA system. The DMA system was first introduced in the United Kingdom by Malcolm Farley in 1982, and has been the most commonly applied system in the world to date. DMA system refers to a system that accurately measures the amount of leaks generated in a pipe by dividing a large water supply area into a certain area and installing a flow meter at the entrance of a DMA. This DMA system refers to a management system that strategically conducts water leakage location detecting by accurately identifying which areas have many leaks.

The Ministry of Environment in Korea encouraged local governments to introduce DMA systems in their water supply networks, which are suffering from a large amount of leaks. And the Ministry of Environment in Korea provided subsidies ranging from 50 to 70% of facility investment to local governments that adopt the DMA system. The conditions for government subsidy support were to achieve and maintain 80% or more of the RWR(Revenue Water Rate) within five years of implementing the DMA system. This government policy was called the 1st operation efficiency improvement project in tap water management policy for local governments. 15 years later, all 20 local governments that introduced the DMA system with the support of the government have maintained a total of over 80% of the RWR. However, the most important issue of this policy was that there was no clear scientific basis for why the target of achieving the RWR was 80%, and critics say that it was subjectively determined by government officials and did not reflect the specificity of the operation of each local government's water supply network.

In 2015, the Ministry of Environment in Korea has been pushing for the 2nd operation efficiency improvement project of tap water management for 103 local governments whose water revenue rate is still less than 70% among total 161 local governments. The main contents of this project are to establish a DMA system and replace old water supply networks. Through this project, the Ministry of Environment in Korea subsidizes 70% of total facility investment to local governments. However, the conditions of grant support must be achieved and maintained at least 85% of the RWR(Revenue Water Rate) for five years after the DMA system is established.

The target of RWR for the first project was 80% 15 years ago, but now it is questionable why the target for the second project has been changed to 85%. Furthermore, it is also questionable whether it is the right policy to target all local governments at the same 85%, even though the RWR varies greatly depending on the size of the city, the density of the city, and the financial status of the city. For example, should the two local governments achieve the same 85% target if the current RWR is 45% of local governments A and that of local governments B is 69%. Rather, it can be more reasonable for both local governments to improve 20% to set targets at 65% for local governments A and 89% for local governments B. Therefore, I would like to verify what the appropriate target of RWR for each local government is by conducting a regression analysis on RWR and various variables in this study. And I would also like to analyze whether the target of RWR can be improved if the latest smart water technology is introduced into the water supply network. And I would like to propose this research result as a government policy to set the target of RWR.

The reserch questions to be reviewed in this study are as follows.

First, what is the most suitable RWR target in Korea, and 80% of the 2000s is a reasonable target? Or is 85% of the 2015s the right target?

Second, is the Ministry of Environment's correct policy to present the same RWR target to all local governments? Or should different RWR targets be presented according to the unique characteristics of local governments?

Third, if local governments have to set different RWR targets according to their unique characteristics, what are the variables that affect the RWR target, and what is the predictive model for an appropriate RWR target?

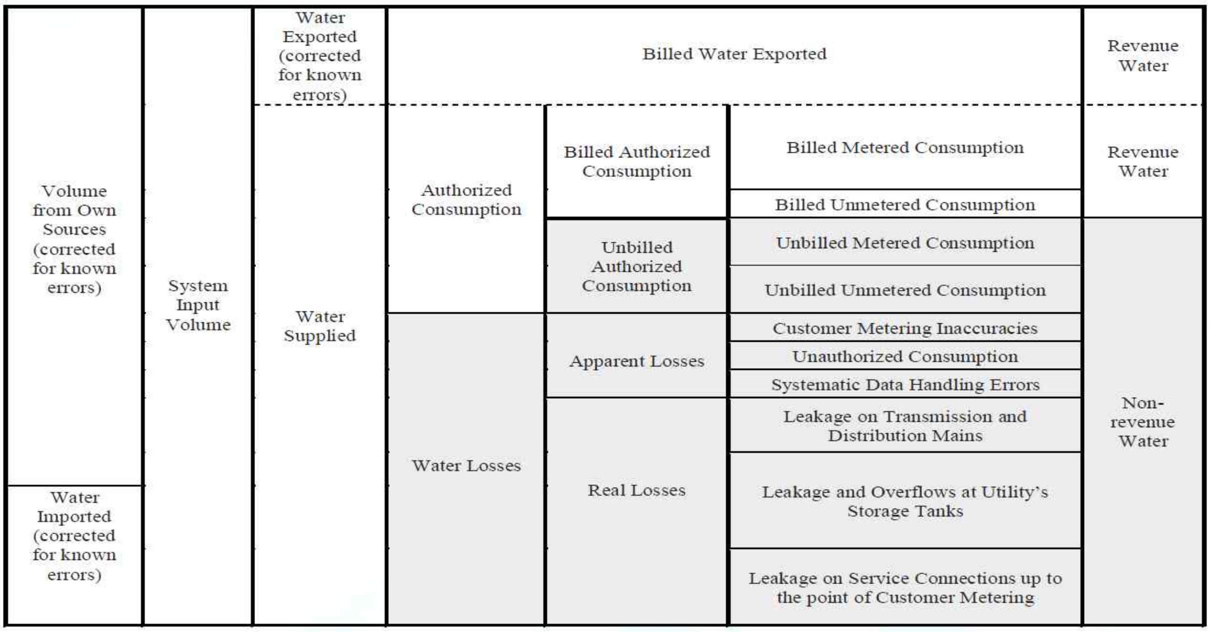
Lastly, if the RWR target is low due to the characteristics of local governments with low density like in rural areas, if leakage continues, what other alternatives are there to solve this problem?

Therefore, in this study, the RWR and the regression analysis on various variables are performed to review the RWR target suitable for each local government. And I would like to propose the findings of this study as a government policy that sets the target of RWR.

2. Literature Review

Before analyzing the target of the RWR(Revenue Water Rate) in Korea, I've reviewed the leakage analysis method in other advanced countries around the world. The IWA(International Water Association) presented the concept of 'NRW(Non-Revenue Water)' as a global standard for leakage analysis, and most countries are conducting NRW analysis. However, PI(Performance Indicator) for NRW analysis varies somewhat from country to country. The details are shown in Figure 1 below.

Fig 1. Standard AWWA water balance



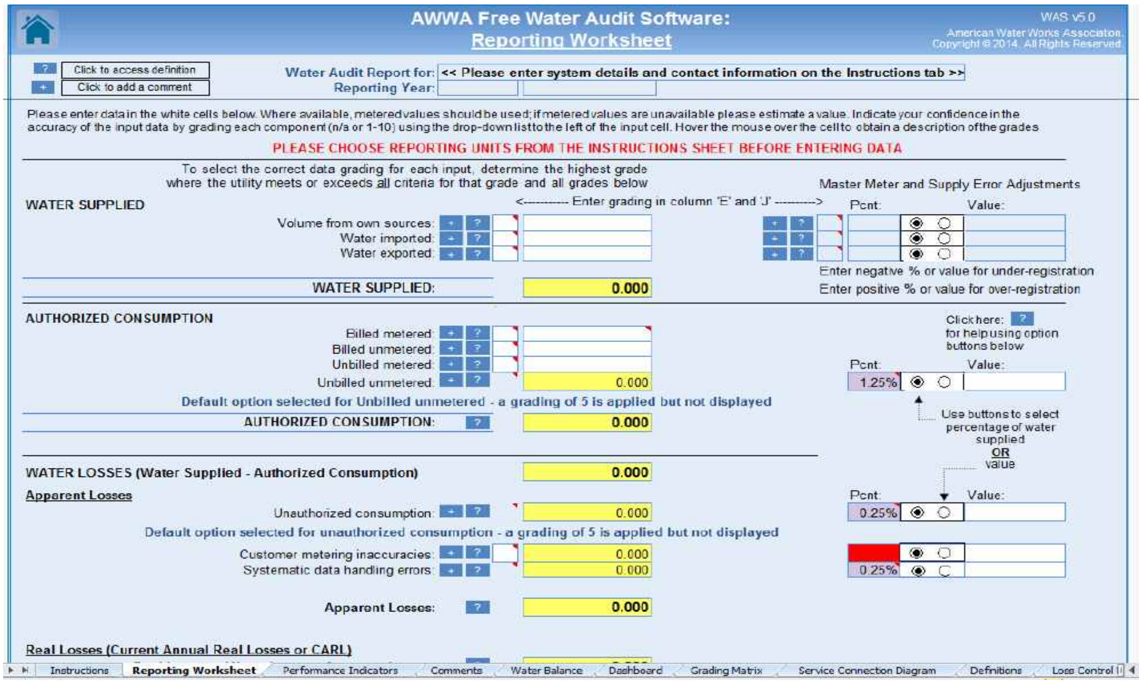
* *Source : Water Audit and Loss Control Programs (AWWA M36, 2009)*

Ministry of Environment in Korea uses RWR method as a PI that evaluates the level of leakage. RWR is the rate of total water supply to revenue water. The advantage of RWR is that the calculation is very simple by top-down approach, and it is possible to intuitively find out which DMA is leaking a lot.

However, RWR analysis does not allow precise leakage amount calculations because it excludes another details(public usage, apparent losses, etc.) from the calculation. In addition, the biggest problem with RWR analysis is that it can be misleading to prioritize leak detection investigation activities because of 'trap of percentage'. RWR analysis may be an objective PI under the condition that the DMA size (water supply volume, number of water meter, etc.) is the same, but it cannot be an objective PI, if the DMA volume is different. For example, DMA A is a priority for leak detection investigation activities where RWR are much lower than DMA B. However, the leak detection investigation activity must take precedence over DMA B because NRW of DMA B is much larger than DMA A.

On the other hand, IWA and AWWA(American Water Works Association) provide M36 manuals(Water Audits and Loss Control Programs) for accurate leak calculation. AWWA presents the concept of 'Water Audit' in M36, which performs a leak analysis in a 'Component Analysis' method that includes all unit elements. Therefore, the Water Audit analysis is very complicated in the computation process, but more sophisticated leak assessment is possible. Furthermore, the biggest advantage of the Water Audit analysis is that it presents an objective water leak assessment index compared to the RWR analysis that simply compares the %.

Fig 2. Water Balance Calculation by using AWWA Water Audit Software



* *Source : AWWA M36*

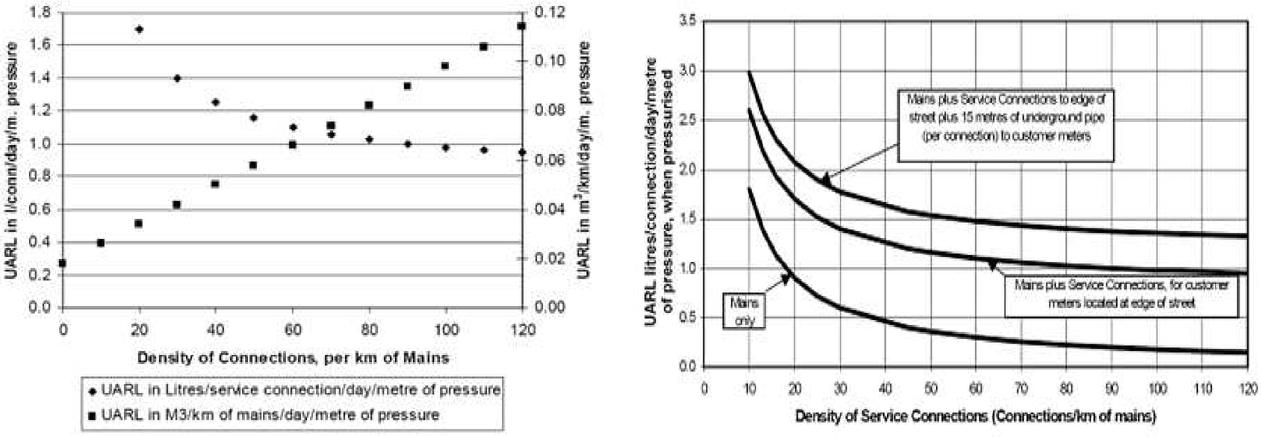
Furthermore, the Water Audit analysis includes not only the amount of water leaks but also the economic utility of reducing water leaks. To this end, PI such as UARL, ILI, and ELL are introduced, and the definitions for each PI are as follows.

1) UARL means Unavoidable Annual Real Loss. Figure 3 shows that the density and UARL are inversely proportional. On the other hand, UARL is proportional to pressure. In other words, as shown in Fig. 3, the lower the density, the higher the UARL.

The equation for UARL(㎥/d) = (6.57 x Lm + 0.292 x Nc + 9.132 x Lp) x P

- Lm = mains length (km),
- Nc = number of service connections (main to property line)
- Lp = total length of underground pipes, property line to meter = Nc x lp/1000 (km)

Fig 3. UARL and density of connections



* *Source: A Review of Performance Indicator for Real Losses from Water Supply System(IWA, 1999)*

2) ILI means the ratio of UARL and CARL. In other words, the closer the ILI is to 1.0, the better the leak is controlled, and the larger the ILI, the more unnecessary leaks occur. Table 1 below is a comparative data of ILI sample data from various countries.

The equation for ILI = CARL / UARL

- CARL = Current Annual Real Loss
- UARL = Unavoidable Annual Real Loss

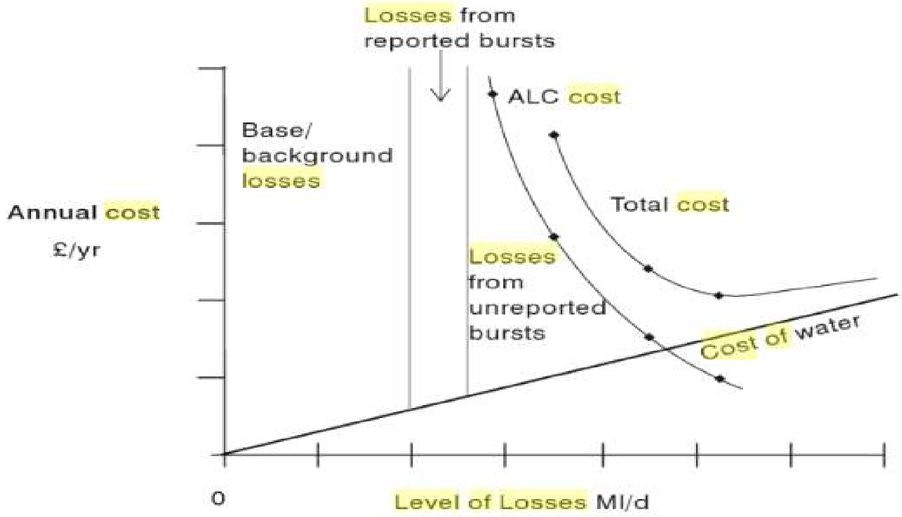
Table 1. Overview of ILI sample data from 12 countries and regions

A	B	C	D	E	F	G	H	I	J
Country or Region	Source of Data	See Note	Period	No. of Utilities in Group	% of Utilities in Sample	No. of Utilities in Sample	Median of Average Pressure (m)	Median ILI of Sample	% of Sample Utilities with ILI ≥2.0
The Netherlands	ILT	1	2015	10	100%	10	32	0.6	0%
Denmark	DANVA	2	2014	170	22%	37	34	0.7	3%
Belgium (Flanders)	AQUAFlanders	3	2014	7	100%	7	39	1.0	14%
Germany	Wasser-Praxis	4	2011	6000	0.7%	44	40 to 50 (est)	1.0	25%
Austria	OVGW	5	2007/2011	5500	0.9%	50	50	1.0	36%
Australia	WSAA	6	2014/15	70	93%	65	41	1.1	21%
England/Wales	EU Ref. Doc	7	2011/12	26	35%	9	43	1.7	22%
Georgia (USA)	Env. Prot.Div	8	2011	107	100%	107	46	1.8	44%
North America	AWWA	8	2011	50000	0.5%	25	51	2.4	64%
Portugal	Global ILIs	9	2013/15	129	11%	14	40	2.6	57%
Canada	Global ILIs	10	2003/14	33	100%	33	50	2.7	67%
Croatia	Global ILIs	11	2005/14	150	15%	23	50	4.5	80%

* *Source : Overviews of Leakage by Country using reported ILI data(Leaks suite Library Ltd, 2019)*

3) ELL means Economic Level of Leakage. ELL is defined as follows on ‘Losses in Water Distribution Network’ published in 2003 by Malcolm Farley and Stuart Trow. “The value of the water saved is less than the cost of making the further reduction. this is known as the economic level of leakage(ELL)”

Fig 4. General relationship betwwen operating cost and the level of losses



** Source: Losses in Water Distribution Network (Malcolm Farley & Stuart Trow, 2003)*

So far, I have reviewed various methods of leakage analysis in Korea, IWA, and AWWA. Leakage analysis varies widely depending on the purpose of the analysis, the approach to leakage assessment, and the difficulty of calculating leakage. The IWA presented the PI according to the difficulty of the analysis as shown in Table 2 below.

The Ministry of Environment's leakage analysis is based on level 1, which is the ratio of total water supply to leakage. Therefore, the Ministry of Environment needs to improve its leakage analysis method to a more economical and advanced level.

Table 2. Water Audit Method (Performance Indicator)

Function	Level	Performance Indicator
Financial: NRW by Volume	1 (Basic)	Volume of NRW (% of System Input Volume)
Operational: Apparent Losses	1 (Basic)	(gal/customer/day)
Operational: Real Losses	1 (Basic)	(gal/connection/day) Or (gal/mile of mains/day)
Operational: Real Losses	2 (intermediate)	(gal/con./d/pressure) Or (gal/mile/d/pressure)
Financial: NRW by cost	3 (Detailed)	Value of NRW (% of annual cost of running system)
Operational: Real Losses	3 (Detailed)	ILI (Infrastructure Leakage Index)

** Source : Evaluating Water Loss and Planning Loss Reduction Strategies(AWWA, 2007)*

3. Methods

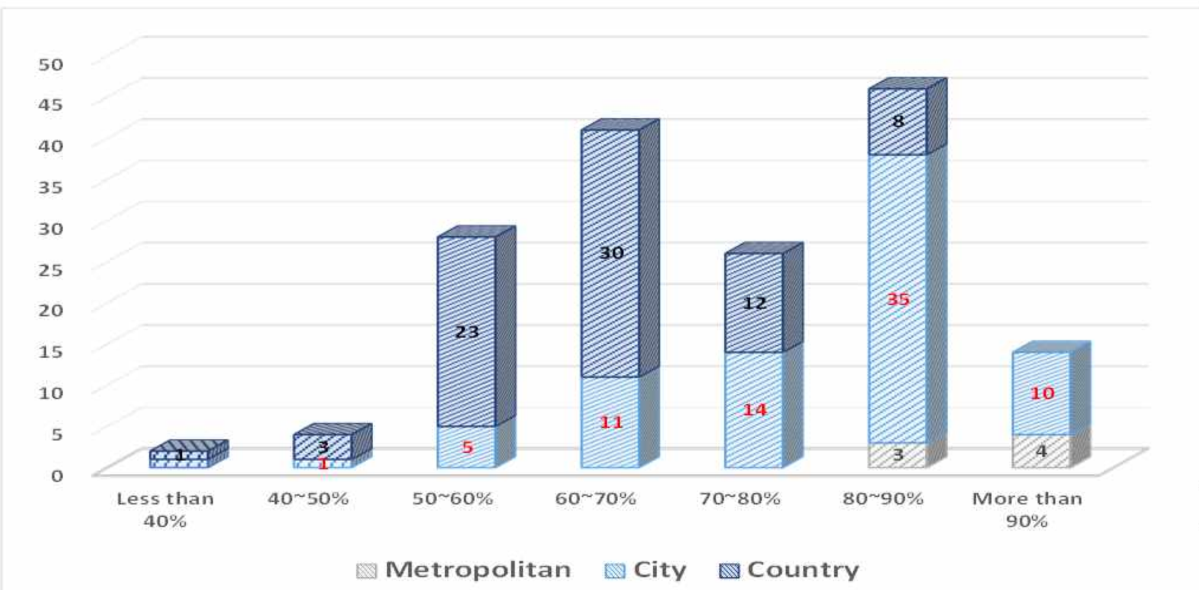
3.1 Data Analysis Procedure

As described in introduction, the Ministry of Environment has invested about 2.4 trillion won in large-scale financial resources for 106 local governments with less than 70% RWR in order to reduce leakage since 2015, and this policy is called 2nd operation efficiency improvement project. The goal of this project is to achieve and maintain at least 85% of RWR within five years of the project. However, according to K-water's report which is development of water loss performance indicator based on cost-benefit in 2018, the RWR of local governments has very different, as shown in Table 3, depending on the unique operation characteristics of municipalities, such as the size of the city, the tap water charge rate, and the financial status of the local government. As shown in Fig 5, the RWR also tends to rise as the size of the city increases.

Table 3. RWR distribution of local government in Korea

RWR	Less than 40%	40~50%	50~60%	60~70%	70~80%	80~90%	More than 90%
Metropolitan						3	4
City		1	5	11	14	35	10
Country	1	3	23	30	12	8	
Sum	1	4	28	41		46	14

Fig 5. RWR distribution bar chart of local government in Korea



* *Source : Development of Water Loss Performance Indicator based on Cost-Benefit (K-water, (2018)*

Therefore, it is inefficient to set the same goal of 85% for all municipalities, excluding these unique characteristics of municipalities. Rather, it is necessary to set customized RWR targets that reflect the unique operational characteristics of each local government. In this study, I will review the factors that affect RWR, and conduct correlation analysis and regression analysis between RWR and variables. Table 4 below shows the method and procedure for this study.

Table 4. Method and Procedure for Suitable RWR Target Selection study

Collecting basic data for 161 local governments (All data are obtained from 2018 water supply statistics)
⇩
Selection of variables affecting RWR
⇩
Correlation Analysis between RWR and Each Factor Variables
⇩
Multiple Linear Regression Analysis by Stepwise Method
⇩
RWR prediction model generation and validation

3.2 Data Collection (Factors influencing RWR)

The factors affecting RWR were largely divided into four sectors and analyzed by subdividing them into 13 independent variables. The basic data for 161 local governments were analyzed using the 'Korea Waterworks Statistics' published in 2018 by the Ministry of Environment.

1) Size of Local Government: The logical hypothesis was established that the larger the city, the higher the RWR, and the smaller the city. The size of the city was further subdivided into four independent variables: the population of tap water service, the annual supply of tap water, the length of water supply pipeline, and the number of water service meters

2) Deterioration of water supply facilities: In general, a logical hypothesis was established that the higher the ratio of pipeline requiring replacement, the greater the leakage.

3) Density of Local Government : In general, a logical hypothesis was established that the higher the density, like a large city, the higher the RWR, and the lower the density, like the countryside, the lower the RWR. The density was further subdivided into three variables: pipeline length per water supply (km/M ㎥/yr), service meters per water supply (ea/M ㎥/yr), and pipeline length per service population (km/person).

4) Financial indicators: In general, a logical hypothesis was established that the better the local government's financial condition, the higher the RWR. Financial indicators were further subdivided into three variables: Production cost of tap water (won/㎥), Tap water charge rate (won/㎥), and Realization rate of tap water charge (%).

5) Technical indicators: In general, a hypothesis was established that the more advanced the local government's pipe network management technology, the higher the RWR. The technical indicators were subdivided into three variables: Management consignment to water utility, DMA system adoption rate(%), and GIS adoption rate(%). Table 5 summarizes the independent variables for RWR.

Table 5. Summary of factors influencing RWR

Items	Variables	Unit
Size of local governments	Tap water service population	person
	Total amount of water supply	M ㎥/yr
	Amount of revenue water	M ㎥/yr
	Length of pipeline	km
	Number of water meter	ea
Density of local governments	Pipeline length per water supply	km/M ㎥/yr
	Service meters per water supply	ea/M ㎥/yr
	Pipe length per service population	km/person
Deterioration degree of water supply facilities	Ratio of pipeline requiring replacement	%
Financial indicators of local governments	Production cost of tap water	₩(won)/㎥
	Tap water charge rate	₩(won)/㎥
	Realization rate of water charge	%
Technical level of local governments	Management consignment to water utility	○, X
	DMA system adoption rate	%
	GIS adoption rate	%

3.3 Findings

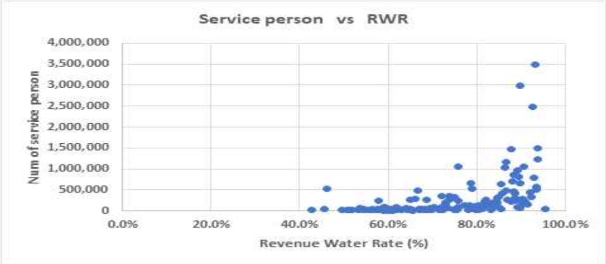
3.3.1 Linear Regression Analysis

1) Correlation Analysis between RWR and Tap water service populations

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and tap water service population as an independant variable (x). The R-Square(R2) is 0.1223, and the detailed results are shown in Table 6. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the tap water service population, and the RWR can be explained by about 12% by the change in the tap water service population.

Table 6. Regression analysis result with Tap water service populations

Summary measures	
Multiple R	0.3574
R-Square	0.1277
Adj R-Square	0.1223
StErr of Est	0.1202
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.3364	0.3364	0.0000
Residuals	159.0000	2.2968	0.0144	
계	160.0000	2.6331		

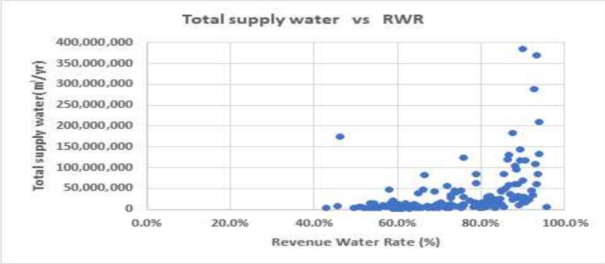
	Coefficient	Std Err	t-value	p-value
Constant	0.7210	0.0100	71.7690	0.0000
Water service populations	0.0000	0.0000	4.8256	0.0000

2) Correlation Analysis between RWR and Amount of water supply

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and the total amount of water supply(㎥/yr) as an independant variable (x). The R-Square(R2) is 0.1106, and the detailed results are shown in Table 7. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the total amount of water supply, and the RWR can be explained by about 11% by the change in the total amount of water supply.

Table 7. Regression analysis result with Amount of water supply

Summary measures	
Multiple R	0.3408
R-Square	0.1161
Adj R-Square	0.1106
StErr of Est	0.1210
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.3058	0.3058	0.0000
Residuals	159.0000	2.3273	0.0146	
Sum	160.0000	2.6331		

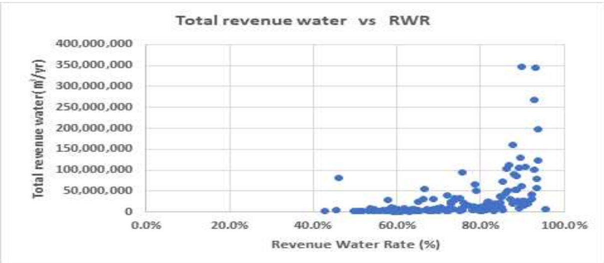
	Coefficient	Std Err	t-value	p-value
Constant	0.7201	0.0102	70.3901	0.0000
Total amount of water supply	0.0000	0.0000	4.5710	0.0000

3) Correlation Analysis between RWR and Amount of revenue water

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and amount of revenue water(㎥/yr) as an independant variable (x). The R-Square(R2) is 0.1207, and the detailed results are shown in Table 8. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the amount of revenue water, and the RWR can be explained by about 12% by the change in the an amount of revenue water.

Table 8. Regression analysis result with Amount of revenue water

Summary measures	
Multiple R	0.3553
R-Square	0.1262
Adj R-Square	0.1207
StErr of Est	0.1203
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.3324	0.3324	0.0000
Residuals	159.0000	2.3008	0.0145	
Sum	160.0000	2.6331		

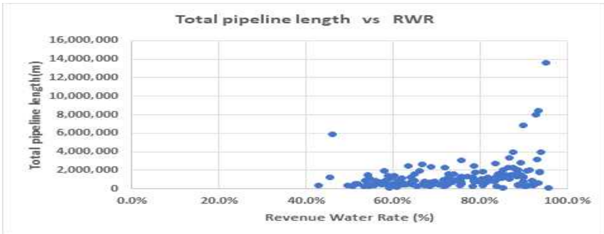
	Coefficient	Std Err	t-value	p-value
Constant	0.7211	0.0101	71.7517	0.0000
Amount of revenue water	0.0000	0.0000	4.7925	0.0000

4) Correlation Analysis between RWR and Length of pipeline

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and pipeline length(km) as an independant variable (x). The R-Square(R2) is 0.0974, and the detailed results are shown in Table 9. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the pipeline length, and the RWR can be explained by about 9% by the change in the pipeline length.

Table 9. Regression analysis result with Length of pipeline

Summary measures	
Multiple R	0.3210
R-Square	0.1031
Adj R-Square	0.0974
StErr of Est	0.1219
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.2714	0.2714	0.0000
Residuals	159.0000	2.3618	0.0149	
Sum	160.0000	2.6331		

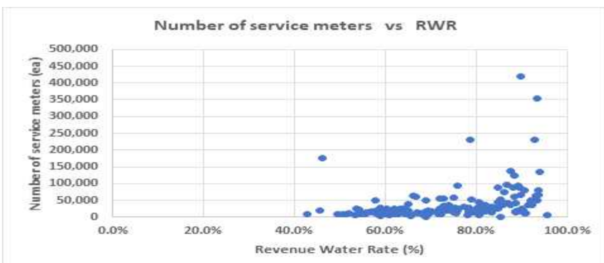
	Coefficient	Std Err	t-value	p-value
Constant	0.7026	0.0125	55.9886	0.0000
Length of pipeline	0.0000	0.0000	4.2742	0.0000

5) Correlation Analysis between RWR and Number of service water meters

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and number of service water meters(ea) as an independant variable (x). The R-Square(R2) is 0.0469, and the detailed results are shown in Table 10. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the number of service water meters, and the RWR can be explained by about 4% by the change in the number of service water meters.

Table 10. Regression analysis result with Number of service water meters

Summary measures	
Multiple R	0.2298
R-Square	0.0528
Adj R-Square	0.0469
StErr of Est	0.1252
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.1391	0.1391	0.0034
Residuals	159.0000	2.4941	0.0157	
Sum	160.0000	2.6331		

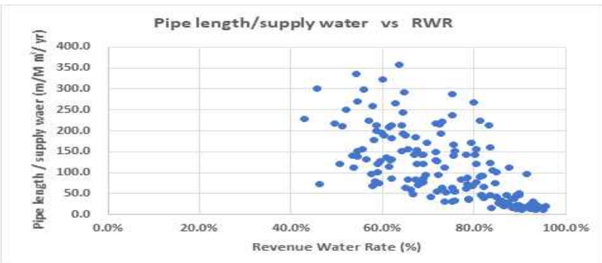
	Coefficient	Std Err	t-value	p-value
Constant	0.7289	0.0102	71.1399	0.0000
No. of water meters	0.0000	0.0000	2.9777	0.0034

6) Correlation Analysis between Pipeline length per water supply amount and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and pipeline length per water supply amount(km/㎥/yr) as an independant variable (x). The R-Square(R2) is 0.4208, and the detailed results are shown in Table 11. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the pipeline length per water supply amount, and the RWR can be explained by about 42% by the change in the pipeline length per water supply amount.

Table 11. Regression analysis result with Pipeline length per water supply amount

Summary measures	
Multiple R	0.6515
R-Square	0.4244
Adj R-Square	0.4208
StErr of Est	0.0976
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	1.1175	1.1175	0.0000
Residuals	159.0000	1.5157	0.0095	
Sum	160.0000	2.6331		

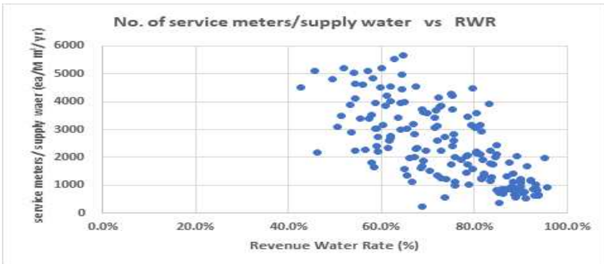
	Coefficient	Std Err	t-value	p-value
Constant	0.8510	0.0130	65.2955	0.0000
Pipe length per water supply	-0.0010	0.0001	-10.8273	0.0000

7) Correlation Analysis between No. of water meters per water supply amount and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and number of water meters per water supply amount(ea/㎥/yr) as an independant variable (x). The R-Square(R2) is 0.4726, and the detailed results are shown in Table 12. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the number of water meters per water supply amount, and the RWR can be explained by about 47% by the change in the number of water meters per water supply amount.

Table 12. Regression analysis result with No. of water meters per water supply amount

Summary measures	
Multiple R	0.6898
R-Square	0.4759
Adj R-Square	0.4726
StErr of Est	0.0932
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	1.2531	1.2531	0.0000
Residuals	159.0000	1.3801	0.0087	
Sum	160.0000	2.6331		

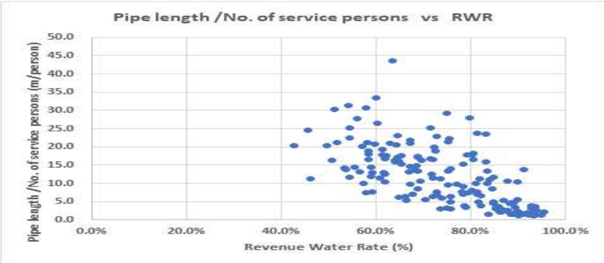
	Coefficient	Std Err	t-value	p-value
Constant	0.8948	0.0150	59.487	0.0000
No. of water meters per water supply	-0.0001	0.0000	-12.01	0.0000

8) Correlation Analysis between Pipe length per service population and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and pipeline length per service population(km/person) as an independant variable (x). The R-Square(R2) is 0.4128, and the detailed results are shown in Table 13. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the pipeline length per service population, and the RWR can be explained by about 41% by the change in the pipeline length per service population.

Table 13. Regression analysis result with Pipe length per service population

Summary measures	
Multiple R	0.6453
R-Square	0.4165
Adj R-Square	0.4128
StErr of Est	0.0983
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	1.0966	1.0966	0.0000
Residuals	159.0000	1.5365	0.0097	
Sum	160.0000	2.6331		

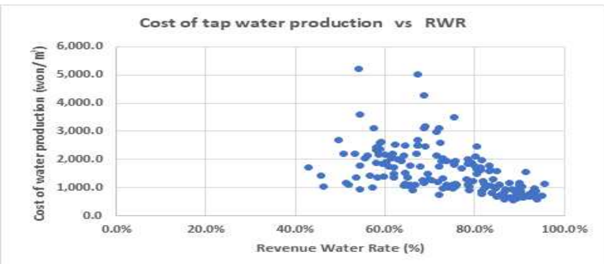
	Coefficient	Std Err	t-value	p-value
Constant	0.8572	0.0137	62.6720	0.0000
Pipe length per service population	-0.0100	0.0009	-10.6524	0.0000

9) Correlation Analysis between Production cost of tap water and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and production cost of tap water(won/㎥) as an independant variable (x). The R-Square(R2) is 0.2636, and the detailed results are shown in Table 14. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the production cost of tap water, and the RWR can be explained by about 26% by the change in the production cost of tap water.

Table 14. Regression analysis result with Production cost of tap water

Summary measures	
Multiple R	0.5178
R-Square	0.2682
Adj R-Square	0.2636
StErr of Est	0.1101
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.7061	0.7061	0.0000
Residuals	159.0000	1.9270	0.0121	
Sum	160.0000	2.6331		

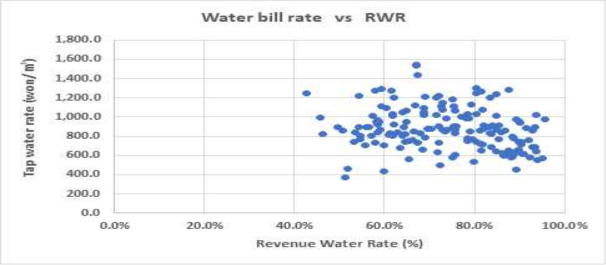
	Coefficient	Std Err	t-value	p-value
Constant	0.8651	0.0189	45.8243	0.0000
Production cost of tap water	-0.0001	0.0000	-7.6330	0.0000

10) Correlation Analysis between Tap water charge rate and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and tap water charge rate(won/㎥) as an independant variable (x). The R-Square(R2) is 0.0401, and the detailed results are shown in Table 15. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the tap water charge rate, and the RWR can be explained by about 4% by the change in the tap water charge rate.

Table 15. Regression analysis result with Tap water charge rate

Summary measures	
Multiple R	0.2147
R-Square	0.0461
Adj R-Square	0.0401
StErr of Est	0.1257
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.1214	0.1214	0.0062
Residuals	159.0000	2.5118	0.0158	
Sum	160.0000	2.6331		

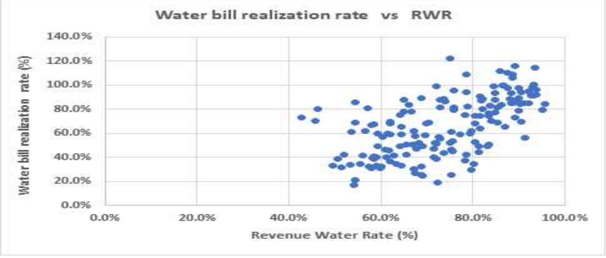
	Coefficient	Std Err	t-value	p-value
Constant	0.8480	0.0412	20.5796	0.0000
Tap water charge rate	-0.0001	0.0000	-2.7721	0.0062

11) Correlation Analysis between Realization rate of water charge and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and realization rate of water charge(%) as an independant variable (x). The R-Square(R2) is 0.3464, and the detailed results are shown in Table 16. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the realization rate of water charge, and the RWR can be explained by about 34% by the realization rate of water charge.

Table 16. Regression analysis result with Realization rate of water charge

Summary measures	
Multiple R	0.5920
R-Square	0.3505
Adj R-Square	0.3464
StErr of Est	0.1037
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.9228	0.9228	0.0000
Residuals	159.0000	1.7103	0.0108	
Sum	160.0000	2.6331		

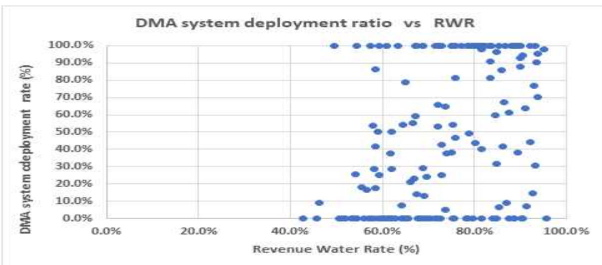
	Coefficient	Std Err	t-value	p-value
Constant	0.5307	0.0237	22.3570	0.0000
Realization rate of water charge	0.3132	0.0338	9.2624	0.0000

12) Correlation Analysis between DMA adoption rate and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and DMA adoption rate(%) as an independant variable (x). The R-Square(R2) is 0.1444, and the detailed results are shown in Table 17. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the DMA adoption rate, and the RWR can be explained by about 14% by the DMA adoption rate.

Table 17. Regression analysis result with DMA adoption rate

Summary measures	
Multiple R	0.3869
R-Square	0.1497
Adj R-Square	0.1444
StErr of Est	0.1187
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.3942	0.3942	0.0000
Residuals	159.0000	2.2389	0.0141	
Sum	160.0000	2.6331		

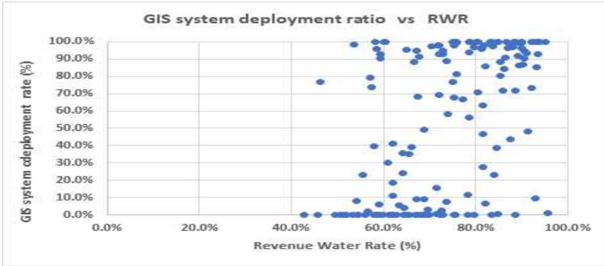
	Coefficient	Std Err	t-value	p-value
Constant	0.6809	0.0141	48.1287	0.0000
DMA adoption rate	0.1167	0.0221	5.2912	0.0000

13) Correlation Analysis between GIS adoption rate and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and GIS adoption rate(%) as an independant variable (x). The R-Square(R2) is 0.2649, and the detailed results are shown in Table 18. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the GIS adoption rate, and the RWR can be explained by about 26% by the GIS adoption rate.

Table 18. Regression analysis result with GIS adoption rate

Summary measures	
Multiple R	0.5191
R-Square	0.2695
Adj R-Square	0.2649
StErr of Est	0.1100
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.7096	0.7096	0.0000
Residuals	159.0000	1.9236	0.0121	
Sum	160.0000	2.6331		

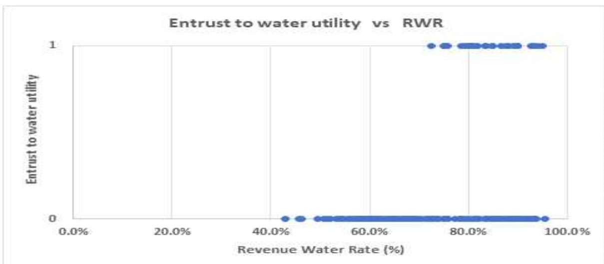
	Coefficient	Std Err	t-value	p-value
Constant	0.6543	0.0139	47.2058	0.0000
GIS adoption rate	0.1546	0.0202	7.6585	0.0000

14) Correlation Analysis between Management consignment to water utility and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and management consignment to water utility as an independant variable (x). The R-Square(R2) is 0.1868, and the detailed results are shown in Table 19. As a result of the analysis of variance of the regression model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. Therefore, there is a correlation between RWR and the GIS adoption rate, and the RWR can be explained by about 18% by the GIS adoption rate.

Table 19. Regression analysis result with Management consignment to water utility

Summary measures	
Multiple R	0.4416
R-Square	0.1950
Adj R-Square	0.1868
StErr of Est	0.0957
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.2176	0.2176	0.0000
Residuals	98.0000	0.8982	0.0092	
Sum	99.0000	1.1158		

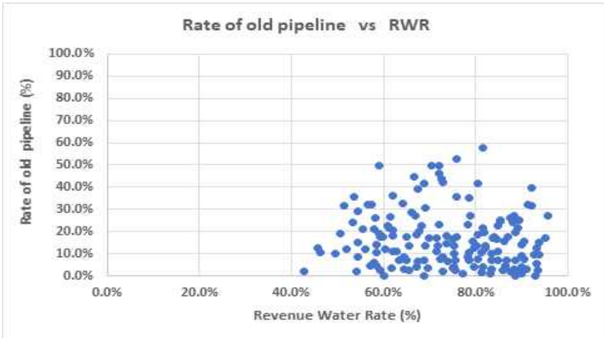
	Coefficient	Std Err	t-value	p-value
Constant	0.6503	0.0105	61.888	0.0000
Management consignment to water utility	0.1242	0.0255	4.8729	0.0000

15) Correlation Analysis between Ratio of pipeline requiring replacement and RWR

Linear regression analysis was performed with RWR(%) as a dependent variable (y) and rate of pipeline requiring replacement(%) as an independant variable (x). The R-Square(R2) is 0.0029, and the detailed results are shown in Table 20. As a result of the analysis of variance of the regression model, both f-value and p-value are bigger than the significance level of 0.05, so they are not considered to be statistically significant. Therefore, there is not a correlation between RWR and the rate of pipeline requiring replacement, and the RWR cannot be explained with the rate of pipeline requiring replacement.

Table 20. Regression analysis result with Ratio of pipeline requiring replacement

Summary measures	
Multiple R	0.0955
R-Square	0.0091
Adj R-Square	0.0029
StErr of Est	0.1281
No. of observation	161



ANOVA Table

	df	SS	MS	f-value
Explained	1.0000	0.0240	0.0240	0.2282
Residuals	159.0000	2.6091	0.0164	
Sum	160.0000	2.6331		

	Coefficient	Std Err	t-value	p-value
Constant	0.7530	0.0166	45.4218	0.0000
Rate of pipeline requiring replacement	-0.0966	0.0799	-1.2097	0.2282

3.3.2 Multiple Linear Regression Analysis

So far, the correlation between RWR and individual independent variables has been analyzed. This time, the RWR prediction model was created through multiple linear regression analysis including several independent variables. And in order to generate a reliable predictive model, a stepwise regression analysis was performed. Based on the results of stepwise regression analysis, the formula of the RWR prediction model reflecting the operating characteristics of each local government is as follows.

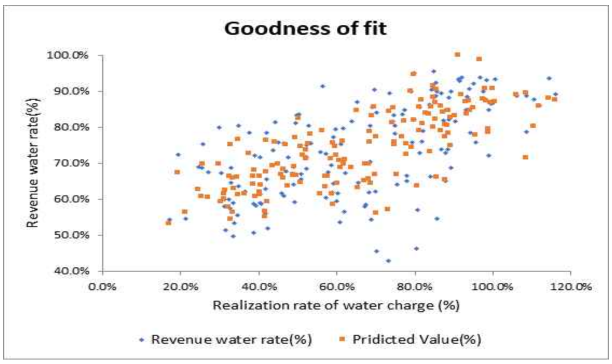
$$y = 0.8580 + 0.0526x_1 - 6.6E\text{-}09x_2 + 6.6E\text{-}09x_3 + 2.9E\text{-}08x_4 - 0.00004x_5 - 0.0031x_6 - 0.0001x_7 + 0.0731x_8 + 0.0460x_9$$

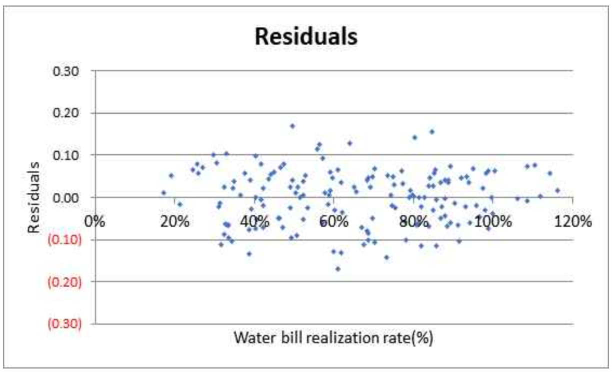
(y : RWR(Revenue Water Rate, x_1 : Management consignment to water utility, x_2 : Total amount of water supply, x_3 : Amount of revenue water, x_4 : Length of pipe, x_5 : Number of water meters per water supply, x_6 : Pipe length per service population, x_7 : Tap water charge rate, x_8 : Realization rate of water charge, x_9 : GIS adoption rate)

As a result of performing the fit and residual analysis for the RWR prediction model, the variables related to urban density and financial indicators tend to generally agree as shown in Fig 6 below, and almost all residuals are formed evenly within 0.1(10%).

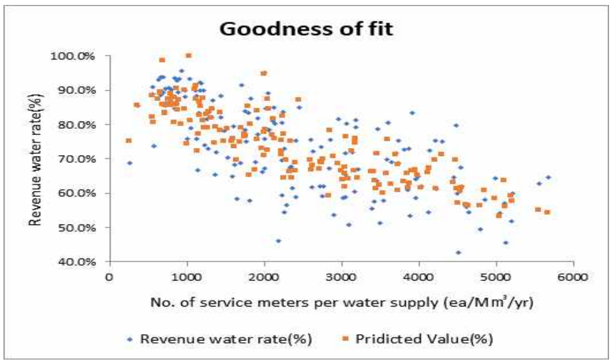
Fig 6. Goodness of fit and Residuals for the RWR prediction model(Urban density)

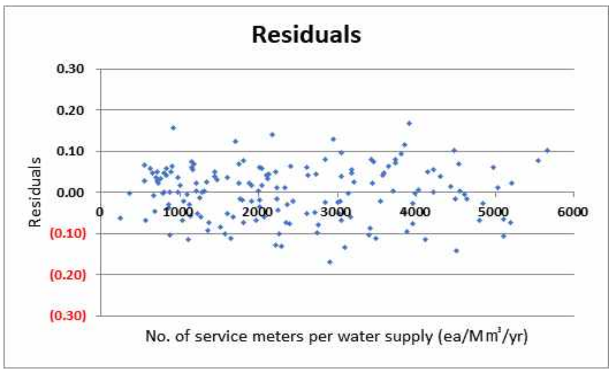
RWR vs Realization rate of water charge





RWR vs No.service meters per supply water

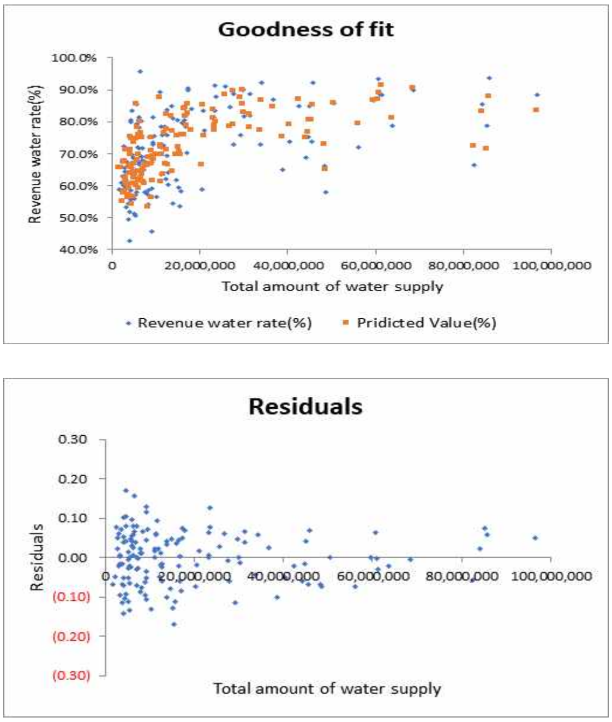




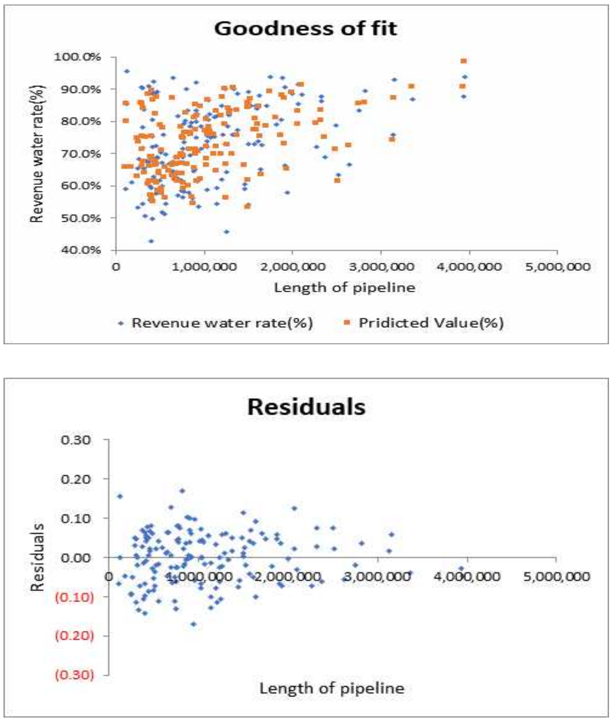
On the other hand, variables related to city size, such as water supply volume and pipeline length, have very large residuals in small cities as shown in Fig 7 below. However, as the city size increases, the residuals tend to decrease.

Fig 7. Goodness of fit and Residuals for the RWR prediction model(City size)

RWR vs Amount of water supply



RWR vs Length of pipeline



3.4 Summary

So far, I have conducted a correlation and regression analysis between 15 variables and RWR. The results are summarized as follows.

First, As a result of a comprehensive analysis of the correlation between RWR and each influencing factor, it can be seen that the urban density factors have the highest correlation. As the next factor, it was found that local governments' financial and technical factors had some correlation in order. On the other hand, the size of the city had a low level of correlation with RWR, and it was found that the aging of water pipes was not correlated with RWR. The summary of the results of the correlation analysis for each influencing factor is shown in Table 21 below. Therefore, rather than setting the same 85% RWR target for all local governments, it is considered more efficient to set the RWR target for local governments differently according to influence variables such as urban density.

Table 21. Summary of Correlation Analysis

No	Variables	Unit	Adj R-Square	Standard deviation	p-value	Result
1	Service meters per water supply	ea/㎥/yr	0.4726	0.0932	0.0000	O.K
2	pipe length per water supply	km/㎥/yr	0.4208	0.0976	0.0000	O.K
3	Pipe length per service population	km/person	0.4128	0.0983	0.0000	O.K
4	Realization rate of water charge	%	0.3464	0.1037	0.0000	O.K
5	GIS adoption rate	%	0.2649	0.1100	0.0000	O.K
6	Production cost of tap water	₩(won)/㎥	0.2636	0.1101	0.0000	O.K
7	Management consignment to water utility	O, X	0.1868	0.0957	0.0000	O.K
8	DMA adoption rate	%	0.1444	0.1187	0.0000	O.K
9	Tap water service population	person	0.1223	0.1202	0.0000	O.K
10	Amount of revenue water	㎥/yr	0.1207	0.1203	0.0000	O.K
11	Total amount of water supply	㎥/yr	0.1106	0.1210	0.0000	O.K
12	Length of pipe	km	0.0974	0.1219	0.0000	O.K
13	Number of water meters	ea	0.0469	0.1252	0.0034	O.K
14	Tap water charge rate	₩(won)/㎥	0.0401	0.1257	0.0062	O.K
15	Ratio of pipeline requiring replacement	%	0.0029	0.1281	**0.2282**	**N.G**

Second, As a result of stepwise regression analysis for the RWR prediction model, both f-value and p-value are less than the significance level of 0.05, so they are considered to be statistically significant. And Adj R-Square(R2) is 0.7238. Therefore, the RWR can be explained by about 72% by RWR predictive model. The details of the stepwise regression analysis are shown in Table 22 below.

Table 22. Summary of Stepwise Regression Analysis for RWR Prediction Model

$$y = 0.8580 + 0.0526x_1 - 6.6E\text{-}09x_2 + 6.6E\text{-}09x_3 + 2.9E\text{-}08x_4 - 0.00004x_5 - 0.0031x_6 - 0.0001x_7 + 0.0731x_8 + 0.0460x_9$$

(y : RWR(Revenue Water Rate, x_1 : Management consignment to water utility, x_2 : Total amount of water supply, x_3 : Amount of revenue water, x_4 : Length of pipe, x_5 : Number of water meters per water supply, x_6 : Pipe length per service population, x_7 : Tap water charge rate, x_8 : Realization rate of water charge, x_9 : GIS adoption rate)

Summary measures

Multiple R	R-Square	**Adj R-Square**	StErr of Est	No. of observation
0.8599	0.7394	**0.7238**	0.0674	161.0000

ANOVA Table

	df	SS	MS	f-value
Explained	9.0000	1.9469	0.2163	**0.0000**
Residuals	151.0000	0.6863	0.0045	
Sum	160.0000	2.6331		

	Coefficient	StErr of Est	t-value	p-value
Constant	0.8580	0.0393	21.8540	0.0000
Management consignment to water utility	0.0526	0.0177	2.9650	0.0035
Total amount of water supply	0.0000	0.0000	-7.3099	0.0000
Amount of revenue water	0.0000	0.0000	7.5780	0.0000
Length of pipe	0.0000	0.0000	2.8315	0.0053
No. of service meters per water supply	0.0000	0.0000	-5.6624	0.0000
Pipe length per service population	-0.0031	0.0013	-2.3731	0.0189
Tap water charge rate	-0.0001	0.0000	-3.2423	0.0015
Realization rate of water charge	0.0731	0.0349	2.0961	0.0377
GIS adoption rate	0.0460	0.0160	2.8797	0.0046

4. Policy Recommendation

4.1 Implications for small cities with low density

It was analyzed that the RWR depends largely on the density of the city. So, why does pipe leakage increase when urban density decreases? The reason is that it is very difficult to find the exact leak location as the pipeline length per amount of water supply becomes relatively long. Therefore, AWWA emphasizes that ALR (Awareness-Location-Repair) time is very important for leakage reduction in the M36 manual. For example, the metropolitan city of Seoul is highly dense, so it takes less time for ALR (Awareness-Location-Repair) because it easily recognizes the occurrence of leaks, finds the location of the leak, and repairs it quickly. On the other hand, Cha-ri sector in Seosan city, a countryside, has a very low density in similar area. so it is difficult to recognize whether or not a leak has occurred, and to find the location of the leak. To solve this problem, a lot of human resources, time and cost are required. As a result, the ALR time is greatly delayed, and the amount of leakage continues to increase.

Therefore, it is reasonable for small cities with low urban density to set low RWR targets. However, leakage due to the limitations of the urban density structure continue to deteriorate the financial status of local governments, and these local government deficits eventually lead to a decrease in investment, resulting in a vicious cycle in which leakage continue to increase. Improving these structural problems requires a dramatic increase in tap water charge rates, but it is virtually difficult for politicians to implement policies that are unpopular with citizens.

Then, is there any way to solve these structural problems of leakage in small cities? In the early 2000s, innovation in communication technology enabled the introduction of the concept of DMA systems, and this innovative technology had led to a significant reduction in pipeline leaks. Wouldn't it be possible to overcome the structural limitations of the lack of urban density if the latest SWM(Smart Water Management) technologies such as IoT(Internet of Things) and AI are applied to water distribution system? Therefore, I would like to conduct a case study that has dramatically improved RWR by introducing SWM technology to small cities in this chapter.

4.2 Case Study on Application of SWM(Smart Water Management) Technology

What can be done to shorten the ALR time in a small city with low density? It can be alternative to increase the density of leak monitoring by expanding the installation of flow metering sensors in water distribution network. As the number of flow monitoring points increases, the leak suspicious area is drastically reduced and the ALR time is also shortened. For example, it is very difficult to find out where the leak is in Figure 8. So, they usually perform the Step-Test first at night when the amount of water use is low by putting a lot of human resources and then, suspicious point of leakage should be narrowed down. After that, active leak detection activities only can be possible.

On the other hand, SWM(Smart Water Management) technology was introduced in Chari region of Seosan City. The vast water supply area of Cha-ri region was subdivided into 9 sub-DMAs as shown in Figure 9 in order to efficiently improve the delay problem in ALR time. And IoT-based smart meters were installed in all service connections.

Fig 8. 1 of DMA System (As-Is)

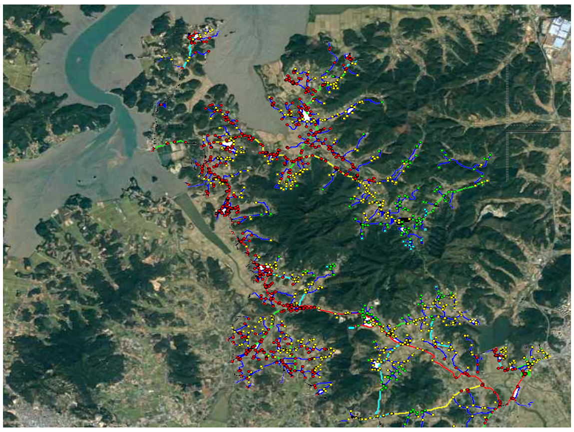
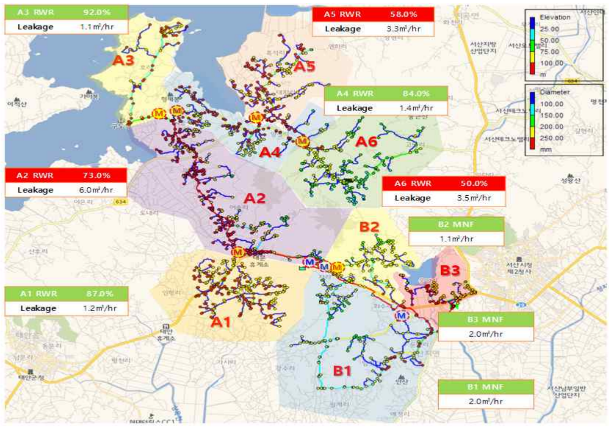


Fig 9. 9 of Sub-DMA System (To-Be)



As a result of applying such smart technology, it is possible to easily identify in real time in which sector the leak is occurring, as shown in Table 23. Therefore, we conducted intensive leak detection for the A2, A5, and A6 sectors with low RWR, and as a result, the leak location was easily found and the ALR time was also shortened. Through this SWM pilot projects, RWR was improved by about 30%, and leakage costs of about 600 million won/year also were reduced.

Table 23. RWR Analysis Result for Each Sub-DMA

RWR	Sub-DMA A1	**Sub-DMA A2**	Sub-DMA A3	Sub-DMA A4	**Sub-DMA A5**	**Sub-DMA A6**
'16. July	87%	**73%**	92%	84%	**58%**	**50%**
'16. Sep	95%	90%	88%	97%	88%	89%
variation		↑17% (Repair 3ea)			↑30% (Repair 2ea)	↑39% (Repair 2ea)

Fig 10. MNF Reduction Case of Sub-DMA 5

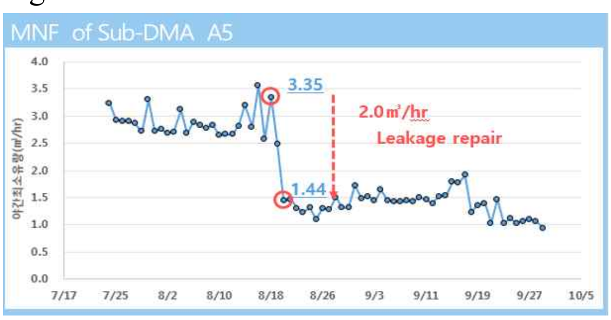
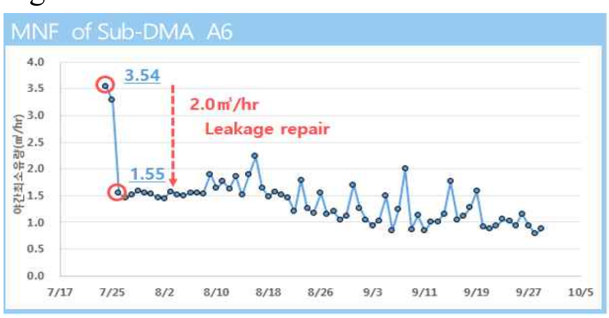


Fig 11. MNF Reduction Case of Sub-DMA 6



* *Source : SWM Project Performance Report for Seo-san city (K-water, 2016.11)*

4.3 Policy Recommendation

As previously described, it is not the right government policy to set the same RWR target for all local governments, as RWR depends on the unique characteristics of each city, such as density. Therefore, I would like to propose an improvement policy for a suitable RWR target setting that reflects the unique characteristics of each city.

First, it is required to introduce the global standard, Infrastructure Leakage Index (ILI), in Korea. Because ILI presents an objectified target called Unavoidable Annual Real Loss (UARL), depending on the density and pressure of various cities, it is possible to set the correct leak index target reflecting the unique characteristics of each city.

Second, in case of small cities where UARL is highly generated due to low density, the latest SWM(Smart Water Management) technologies such as Sub-DMA and smart metering should be introduced more actively. By installing many of these smart water flow rate, pressure, and quality measurement sensors in the WDS (Water Distribution System), it is easier to find and repair leaks of vast pipelines even in small cities with low density. Ultimately, these smart technologies can reduce leakage by dramatically reducing the ALR(Aware-Location-Repair) time for leakage.

5. Limitation & Future Question

It is clear that leakages in pipes will improve when SWM technology is introduced to small cities with low density. However, there are some limitations and challenge to the introduction of SWM technology by government policy.

First, there is still a lack of cases in Korea that have overcome the problem of leakage in cities with low density by applying SWM technology. Therefore, more studies on SWM application cases are required.

Second, the development of a big data system (S/W) for analyzing vast smart sensors according to the introduction of SWM technology is required first. No matter how many sensors and budgets are invested, if there is no big data analysis S/W, we may fail to achieve the leak reduction goal because it takes a lot of time to analyze and process vast amounts of data by human resources.

Finally, a Benefit-Cost (B/C) analysis study of SWM infrastructure deployment is also required first, even though SWM technology dramatically reduces leaks.

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Appendix. Basic Operation Data for 161 local governments Water Works from water supply statistics by published Ministry of Environment in 2018

Local Governments	RWR	Size / Volume					Density			Financial Status			Technical Level			
		Service Population	Water Supply	Revenue Water	Length of Pipes	Service Connection	Length of Pipes/Water Supply	Water Supply/Connection	Length of Pipes/Population	Production cost of water	Tap water charge rate	Realization rate of water charge	DMA adoption rate	GIS adoption rate	consignment to utility	Rate of old pipe
	%	number	㎥/yr	㎥/yr	m	ea	km/M㎥/yr	M㎥/yr/ea	m/person	won/㎥	won/㎥	%	%	%	O,X	%
서울특별시	95.1	10,049,607	1,169,585,797	1,112,125,942	13,571,214	2,220,674	12.2	1997	1.4	713.2	569.32	79.8	97.6	100	O	17
부산광역시	93.3	3,487,191	370,047,893	345,157,388	8,479,853	354,089	24.6	1026	2.4	982.3	894.51	91.1	100.0	100	O	12.6
대구광역시	92.8	2,489,156	289,078,136	268,236,994	8,013,841	232,154	29.9	865	3.2	750.2	685.66	91.4	14.5	100	O	9.6
인천광역시	89.9	2,986,455	385,785,327	346,903,014	6,848,407	420,141	19.7	1211	2.3	682.5	664.98	97.4	92.8	100	O	14.2
광주광역시	87.7	1,480,864	182,951,935	160,495,240	3,932,902	138,237	24.5	861	2.7	666.7	653.45	98	61.3	99	O	26.2
대전광역시	93.9	1,506,903	210,613,280	197,830,991	3,954,581	134,804	20.0	681	2.6	576	556.44	96.6	70.4	100	O	15.3
울산광역시	86.7	1,157,532	130,493,934	113,147,680	3,360,470	97,254	29.7	860	2.9	857.6	857.6	100	100.0	100	O	7.4
세종특별자치시	88.8	304,953	31,280,935	27,774,895	455,413	15,357	16.4	553	1.5	912.5	779.33	85.4	0.0	0		0
경기도수원시	93.8	1,241,683	132,366,359	124,192,151	1,750,972	80,700	14.1	650	1.4	704	647.24	91.9	95.5	100	X	9.9
경기도성남시	89.3	972,041	118,308,931	105,605,790	1,493,065	93,200	14.1	883	1.5	613	449.84	73.4	100.0	91.9	X	2.1
경기도의정부시	92.1	448,547	45,781,760	42,146,704	904,477	49,810	21.5	1182	2.0	795.1	755.79	95.1	100.0	73.2	X	31.7
경기도안양시	93.4	584,239	60,654,265	56,650,860	648,975	50,677	11.5	895	1.1	685	688.59	100.5	30.6	85.2	X	5.8
경기도부천시	88.5	868,106	96,607,091	85,499,602	1,379,664	122,936	16.1	1438	1.6	626.2	584.6	93.4	100.0	100	X	27.4
경기도광명시	92.3	332,799	34,172,715	31,557,929	418,180	36,922	13.3	1170	1.3	680.6	580.55	85.3	44.0	100	X	39.7
경기도평택시	93.6	517,779	85,730,414	80,283,882	1,878,874	66,595	23.4	829	3.6	895.8	1,024.98	114.4	90.1	92.9	X	2.9
경기도동두천시	89.2	98,066	11,073,184	9,881,405	460,611	20,193	46.6	2044	4.7	839	974.45	116.1	100.0	99.5	X	21.8
경기도안산시	88.1	716,413	103,631,391	91,248,258	1,619,144	88,256	17.7	967	2.3	652	578.56	88.7	100.0	96.8	X	24.2
경기도고양시	90.7	1,053,589	118,339,608	107,325,748	1,915,507	80,862	17.8	753	1.8	659.6	619.05	93.9	0.0	94.7	X	7.6
경기도과천시	95.6	57,420	6,488,115	6,201,686	124,434	5,718	20.1	922	2.2	1,153.7	976.9	84.7	0.0	1.3	X	27.2
경기도구리시	83.8	204,811	23,240,576	19,465,981	319,273	24,968	16.4	1283	1.6	830.5	687.94	82.8	100.0	97.3	X	17.4
경기도남양주시	89.9	668,985	68,642,711	61,675,476	1,333,542	67,700	21.6	1098	2.0	870	745.06	85.6	87.7	96.4	X	9.4
경기도오산시	91	229,520	25,703,697	23,396,187	374,500	12,765	16.0	546	1.6	723	613.69	84.9	63.6	93.5	X	3
경기도시흥시	86.6	482,844	59,619,640	51,638,608	1,044,087	40,989	20.2	794	2.2	600.8	598.06	99.5	67.2	90.9	X	4.6
경기도군포시	90.3	283,859	29,778,510	26,885,860	297,635	21,330	11.1	793	1.0	880.4	741.07	84.2	0.0	86.8	X	3.4
경기도의왕시	90.5	154,972	17,394,561	15,748,621	286,728	11,281	18.2	716	1.9	1,029.5	717.56	69.7	94.4	90.2	X	15.7
경기도하남시	88.7	252,714	27,652,596	24,541,428	409,696	16,215	16.7	661	1.6	563	611.98	108.7	0.0	100	X	7.3
경기도용인시	86.3	1,043,886	120,816,113	104,208,186	2,319,340	73,949	22.3	710	2.2	749.1	626.76	83.7	41.7	84.1	X	15.7
경기도파주시	88.3	458,486	61,368,377	54,183,523	2,104,932	60,782	38.8	1122	4.6	934	793.15	84.9	100.0	100	X	3.3
경기도이천시	87.7	217,483	23,609,347	20,693,905	2,326,121	37,503	112.4	1812	10.7	1,163.1	1,285.87	110.6	0.0	43.8	X	2.1
경기도안성시	72.9	180,221	27,769,558	20,249,598	1,233,694	25,536	60.9	1261	6.8	1,320.8	1,073.72	81.3	100.0	93	X	2.3
경기도김포시	85.9	420,402	50,559,184	43,421,359	1,496,046	37,639	34.5	867	3.6	755.9	845.31	111.8	86.0	72	X	2.8
경기도화성시	93	797,990	109,439,480	101,770,684	3,156,736	62,940	31.0	618	4.0	878.8	863.63	98.3	76.6	9.8	X	0.3
경기도광주시	84.9	343,282	42,444,718	36,043,933	1,528,804	87,913	42.4	2439	4.5	686.8	640.04	93.2	31.6	100	X	11.1
경기도양주시	90	219,519	29,919,796	26,926,553	1,236,751	26,169	45.9	972	5.6	1,186	937.45	79	100.0	99.9	X	1.3
경기도포천시	77.2	138,585	21,105,364	16,294,531	1,369,252	30,997	84.0	1902	9.9	1,701	1,006.72	59.2	100.0	66.9	X	1.3
경기도여주시	81.2	101,760	13,918,078	11,303,624	1,012,138	23,746	89.5	2101	9.9	1,727.6	855.64	49.5	100.0	96.4	X	1.8
경기도연천군	58.4	44,531	15,631,280	9,123,486	733,766	14,969	80.4	1641	16.5	1,365	919.61	67.4	86.4	0	X	4.9
경기도가평군	59.2	52,192	8,963,949	5,304,972	397,756	14,539	75.0	2741	7.6	2,626	1,291.62	49.2	100.0	90.1	X	2.9
경기도양평군	81.5	90,653	9,334,306	7,603,236	697,239	22,414	91.7	2948	7.7	1,977.1	1,262.77	63.9	40.0	27.5	X	4

Local Governments	RWR	Size / Volume					Density			Financial Status			Technical Level			
		Service Population	Water Supply	Revenue Water	Length of Pipes	Service Connection	Length of Pipes/Water Supply	Water Supply/Connection	Length of Pipes/Population	Production cost of water	Tap water charge rate	Realization rate of water charge	DMA adoption rate	GIS adoption rate	consignment to utility	Rate of old pipe
	%	number	㎥/yr	㎥/yr	m	ea	km/M㎥/yr	M㎥/yr/ea	m/person	won/㎥	won/㎥	%	%	%	O,X	%
강원도춘천시	87	277,161	36,640,843	31,890,291	1,508,835	42,490	47.3	1332	5.4	941.4	613.67	65.2	9.4	96.2	X	17.8
강원도원주시	75.1	331,477	44,698,482	33,567,835	1,066,300	59,080	31.8	1760	3.2	969	1,184.03	122.2	38.0	77	X	16.5
강원도강릉시	72.9	204,728	33,869,355	24,679,590	1,565,258	55,496	63.4	2249	7.6	983.8	866.07	88	25.4	94.8	X	42
강원도동해시	70.4	91,390	17,097,184	12,041,288	505,418	18,282	42.0	1518	5.5	1,276	875.37	68.6	0.0	97.2	X	49.8
강원도태백시	57.5	44,191	7,968,242	4,585,122	446,035	15,632	97.3	3409	10.1	3,103	1,008.98	32.5	100.0	73.6	X	32.2
강원도속초시	75.8	82,349	12,599,164	9,551,623	530,320	19,149	55.5	2005	6.4	1,111	1,063.27	95.7	46.5	81.4	X	52.7
강원도삼척시	62	63,201	12,224,930	7,583,324	654,215	20,589	86.3	2715	10.4	1,722	1,202.2	69.8		11	X	18
강원도홍천군	67.2	52,219	9,170,773	6,165,253	513,713	12,359	83.3	2005	9.8	2,488	1,548.61	62.2	59.1	94.6	X	4.3
강원도횡성군	71.6	38,124	6,154,240	4,408,460	959,083	13,443	217.6	3049	25.2	2,977.1	1,197.95	40.2	100.0	15.6	X	11.1
강원도영월군	68.7	31,246	4,758,556	3,270,488	466,743	12,190	142.7	3727	14.9	4,289	1,095.2	25.5	100.0	9.2	X	7.1
강원도평창군	67.2	35,379	6,253,183	4,201,138	774,268	11,934	184.3	2841	21.9	5,026.7	1,533.03	30.5	100.0	9	X	18.7
강원도정선군	67.4	30,595	7,851,236	5,289,057	642,396	12,298	121.5	2325	21.0	2,485	1,433.33	57.7	100.0	68.4	X	39.2
강원도철원군	75.3	42,553	8,505,000	6,404,696	408,027	15,368	63.7	2399	9.6	1,827	1,114.26	61	54.5	0	X	13.9
강원도화천군	65.5	16,279	4,570,309	2,993,907	249,752	4,075	83.4	1361	15.3	1,108	561.74	50.7		0	X	13.8
강원도양구군	68.4	19,389	5,089,818	3,483,464	264,328	5,603	75.9	1608	13.6	1,266	661.92	52.3	0.0	0	X	22.9
강원도인제군	69	26,799	7,823,775	5,398,042	459,161	10,109	85.1	1873	17.1	2,479	1,215.49	49	0.0	0	X	13.5
강원도고성군	72.1	24,775	5,975,486	4,308,958	408,924	11,286	94.9	2619	16.5	3,117	1,216.78	39	100.0	92.6	X	49.7
강원도양양군	61.5	25,346	7,011,740	4,314,031	489,702	10,166	113.5	2356	19.3	2,123.2	1,276.5	60.1	0.0	0	X	26.6
충청북도청주시	89.4	826,639	144,057,749	128,814,946	2,819,710	88,897	21.9	690	3.4	745.4	646.06	86.7	38.1	86.2	X	25.2
충청북도충주시	84.7	198,691	26,828,340	22,719,700	1,709,790	45,607	75.3	2007	8.6	1,025.7	1,013.88	98.8	60.0	38.5	X	16.8
충청북도제천시	80.4	128,643	16,654,854	13,396,548	1,041,617	28,594	77.8	2134	8.1	1,508.5	1,034	68.5	100.0	71	X	7.8
충청북도보은군	65.5	17,867	3,075,529	2,012,954	314,428	6,111	156.2	3036	17.6	1,792	754.59	42.1	0.0	35.3	X	2.8
충청북도옥천군	66.9	45,387	6,260,471	4,188,000	598,191	13,413	142.8	3203	13.2	2,202	1,117.77	50.8	23.1	0	X	27.3
충청북도영동군	62.1	39,569	6,172,672	3,830,250	700,303	15,445	182.8	4032	17.7	2,533.2	923.02	36.4	50.0	18.5	X	11.3
충청북도증평군	78.2	38,010	6,117,154	4,783,067	293,008	7,037	61.3	1471	7.7	1,318	987.99	75	0.0	0	X	23.3
충청북도진천군	89.9	75,638	17,250,204	15,511,557	794,906	17,923	51.2	1155	10.5	1,077.7	961.54	89.2	100.0	99.1	X	4.1
충청북도괴산군	58.6	26,479	4,255,726	2,495,020	497,377	7,533	199.3	3019	18.8	2,390	970.29	40.6	17.6	0	X	10.6
충청북도음성군	83.5	91,229	23,341,980	19,484,186	911,706	22,391	46.8	1149	10.0	1,081	831.23	76.9	90.9	0	X	10.1
충청북도단양군	80.5	22,550	4,247,621	3,419,356	411,752	7,577	120.4	2216	18.3	2,455.9	1,298.41	52.9	100.0	100	X	18.9
충청남도천안시	85.4	642,542	84,183,088	71,872,720	2,065,288	51,894	28.7	722	3.2	1,110	766.65	69.1	6.9	88.5	X	24.5
충청남도공주시	78.5	90,666	11,970,343	9,393,851	834,800	16,439	88.9	1750	9.2	1,839	774.66	42.1	0.0	56.4	X	7.2
충청남도보령시	59.4	88,194	15,141,560	8,989,406	1,144,971	19,963	127.4	2221	13.0	1,856.5	1,113.27	60	25.0	92.6	X	17.8
충청남도아산시	84.8	320,226	45,008,226	38,151,556	1,576,540	31,841	41.3	835	4.9	983.6	865.1	88	0.0	0.4	X	22.6
충청남도서산시	83.4	172,158	20,666,296	17,240,755	2,753,055	30,904	159.7	1792	16.0	1,607.7	1,198.27	74.5	100.0	100	X	3.2
충청남도논산시	84.9	101,921	13,699,086	11,633,237	1,190,787	24,662	102.4	2120	11.7	1,598.2	1,236.45	77.4	96.2	100	X	7.4
충청남도계룡시	85.4	42,608	5,602,414	4,786,075	124,424	1,705	26.0	356	2.9	1,120.2	910.6	81.3	100.0	80.5	X	25
충청남도당진시	84	143,114	18,006,679	15,124,537	1,590,127	26,457	105.1	1749	11.1	1,305.3	915.67	70.2	0.0	23.1	X	17.8
충청남도금산군	80.3	43,914	6,769,819	5,438,812	779,796	16,601	143.4	3052	17.8	2,123	741.2	34.9	43.8	100	X	13.5
충청남도부여군	58.6	57,066	8,177,994	4,793,696	1,023,014	18,942	213.4	3951	17.9	2,182.8	841.97	38.6	41.7	95.9	X	14.1
충청남도서천군	71.6	45,359	7,075,579	5,066,184	757,699	17,389	149.6	3432	16.7	2,149.2	1,020.95	47.5	0.0	0.6	X	17.3
충청남도청양군	60.9	15,700	2,150,723	1,308,724	179,243	5,031	137.0	3844	11.4	1,760	816.96	46.4	100.0	30.2	X	22.8
충청남도홍성군	75.7	93,547	11,483,919	8,690,808	1,312,694	22,616	151.0	2602	14.0	1,938	870.1	44.9	0.0	0	X	2.9
충청남도예산군	56.5	57,221	10,203,805	5,762,585	756,428	13,183	131.3	2288	13.2	1,446.3	893.49	61.8	16.7	2.3	X	32.2
충청남도태안군	68.8	56,429	9,058,202	6,232,225	749,010	1,532	120.2	246	13.3	3,125	1,023.92	32.8	29.2	0	X	0

Local Governments	RWR	Size / Volume					Density			Financial Status			Technical Level			
		Service Population	Water Supply	Revenue Water	Length of Pipes	Service Connection	Length of Pipes/Water Supply	Water Supply/Connection	Length of Pipes/Population	Production cost of water	Tap water charge rate	Realization rate of water charge	DMA adoption rate	GIS adoption rate	consignment to utility	Rate of old pipe
	%	number	㎥/yr	㎥/yr	m	ea	km/M㎥/yr	M㎥/yr/ea	m/person	won/㎥	won/㎥	%	%	%	O,X	%
전라북도전주시	78.7	658,759	85,269,651	67,148,845	2,497,081	232,028	37.2	3455	3.8	905.1	982.95	108.6	100.0	93.8	X	35.2
전라북도군산시	68.8	275,361	44,243,536	30,425,436	2,371,555	51,085	77.9	1679	8.6	1,172.2	1,046.74	89.3	100.0	49.4	X	41.7
전라북도익산시	66.2	297,408	48,322,653	31,986,054	1,910,659	62,898	59.7	1966	6.4	905	759.68	83.9	21.2	39.3	X	28.8
전라북도정읍시	80.5	113,354	15,007,233	12,076,178	1,872,905	43,406	155.1	3594	16.5	1,662.8	1,246.13	74.9	100.0	100	X	41.8
전라북도남원시	75.4	76,904	9,640,086	7,264,973	1,029,596	27,127	141.7	3734	13.4	1,904	886.16	46.5	0.0	67.8	X	10
전라북도김제시	72.7	87,289	11,708,632	8,506,656	1,644,517	32,383	193.3	3807	18.8	1,934.5	1,108.64	57.3	0.0	2.9	X	43.6
전라북도완주군	69.5	78,564	12,633,364	8,780,927	841,797	19,574	95.9	2229	10.7	1,500	877.39	58.5	24.4	3	X	3.6
전라북도진안군	54.5	22,061	3,761,440	2,050,944	554,630	9,502	270.4	4633	25.1	3,600	765.72	21.3		0	X	15.3
전라북도무주군	50.7	20,104	5,386,477	2,732,060	328,600	8,433	120.3	3087	16.3	2,216	859.18	38.8		0.2	X	19.4
전라북도장수군	62.9	20,369	2,555,004	1,607,724	426,282	8,913	265.1	5544	20.9	2,003	837.6	41.8		0	X	11.1
전라북도임실군	57.9	27,027	5,517,769	3,192,915	827,656	11,306	259.2	3541	30.6	2,349.6	731.45	31.1	0.0	0	X	6.2
전라북도순창군	64.4	23,467	3,065,857	1,975,027	480,467	9,834	243.3	4979	20.5	1,520	897.64	59.1	54.5	4.4	X	8.7
전라북도고창군	63.5	57,780	11,092,026	7,043,801	2,515,741	24,237	357.2	3441	43.5	1,949.6	676.89	34.7	100.0	5.9	X	7
전라북도부안군	60.4	55,059	12,702,672	7,677,171	1,459,673	24,238	190.1	3157	26.5	1,908	1,093.54	57.3	0.0	100	X	12
전라남도목포시	81.7	234,880	30,148,281	24,636,526	1,135,734	30,775	46.1	1249	4.8	788.2	712.58	90.4	98.0	63.4	X	57.8
전라남도여수시	65	268,142	38,709,770	25,149,259	1,633,464	39,660	65.0	1577	6.1	1,364.6	1,063.76	78	78.7	95.2	X	17.6
전라남도순천시	82.1	271,429	31,453,302	25,829,322	1,056,893	37,047	40.9	1434	3.9	994.3	881.17	88.6	100.0	6.5	X	12.9
전라남도나주시	83.6	96,592	12,494,841	10,444,264	1,295,290	23,335	124.0	2234	13.4	1,625.2	819.33	50.4	81.5	100	X	7.4
전라남도광양시	82.1	138,896	16,882,419	13,866,128	918,729	18,156	66.3	1309	6.6	1,144	914.54	79.9	100.0	86	X	13.6
전라남도담양군	64.5	37,833	5,183,500	3,342,485	646,980	14,846	193.6	4442	17.1	1,126	738.49	65.6		0	X	7.5
전라남도곡성군	51.9	24,490	4,006,102	2,080,264	518,851	10,795	249.4	5189	21.2	1,098	464.02	42.3	0.0	0	X	12.2
전라남도구례군	42.8	19,740	4,097,564	1,753,213	402,225	7,906	229.4	4509	20.4	1,710	1,250.89	73.2		0	X	2.2
전라남도고흥군	45.6	51,194	9,135,412	4,161,989	1,255,810	21,270	301.7	5111	24.5	1,424.1	998.59	70.1	0.0	0	X	12.7
전라남도보성군	54.5	25,668	3,941,595	2,148,646	298,205	8,830	138.8	4110	11.6	940	805.29	85.7		0	X	29
전라남도화순군	61.7	57,118	9,198,535	5,680,072	734,065	14,847	129.2	2614	12.9	2,207.3	1,012.26	45.9	37.5	0	X	3.7
전라남도장흥군	83.3	34,476	4,559,754	3,797,787	813,159	14,826	214.1	3904	23.6	1,800	893.27	49.6	100.0	100	X	1.3
전라남도강진군	71.7	24,061	3,242,167	2,325,499	304,037	8,618	130.7	3706	12.6	1,207	630.26	52.2		97.8	X	13.8
전라남도해남군	65	55,515	7,242,637	4,711,137	893,371	18,743	189.6	3978	16.1	1,083	952.9	88	0.0	0	X	7
전라남도영암군	54.4	50,862	13,837,998	7,524,062	1,138,519	16,998	151.3	2259	22.4	1,781.1	1,224.2	68.7	100.0	0	X	8.9
전라남도무안군	78.4	82,538	11,316,392	8,876,932	1,264,208	18,100	142.4	2039	15.3	2,000	751.13	37.6	0.0	11.8	X	8.5
전라남도함평군	75.1	30,941	4,183,454	3,142,521	907,039	13,505	288.6	4298	29.3	1,114	580.99	52.2	100.0	100	X	3.9
전라남도영광군	61.3	51,730	7,184,258	4,401,779	921,090	18,584	209.3	4222	17.8	2,059	829.67	40.3	0.0	0	X	21.5
전라남도장성군	64.1	43,435	5,082,915	3,256,544	691,336	12,881	212.3	3955	15.9	1,067	804.89	75.4	7.7	24.3	X	8
전라남도완도군	75.3	51,540	6,176,416	4,653,579	1,106,222	19,587	237.7	4209	21.5	3,490	901.44	25.8	100.0	97.8	X	4
전라남도진도군	79.8	32,295	4,230,929	3,374,411	905,560	15,121	268.4	4481	28.0	1,800	534.82	29.7	100.0	96.6	X	4.2
전라남도신안군	64.6	37,782	4,621,375	2,984,515	872,583	16,901	292.4	5663	23.1	2,499	823.89	33	0.0	0	X	3.1
경상북도포항시	66.6	493,066	82,391,733	54,840,477	2,635,211	62,307	48.1	1136	5.3	1,097.3	853.74	77.8	55.1	88.1	X	44.9
경상북도경주시	57.9	256,092	48,518,595	28,080,253	1,935,040	50,657	68.9	1804	7.6	1,900	1,272.98	67	53.6	39.6	X	21
경상북도김천시	81.5	126,201	23,169,922	18,880,530	893,360	22,901	47.3	1213	7.1	882	655.51	74.3	0.0	46.8	X	21.6
경상북도안동시	91.4	149,950	23,414,310	21,390,284	2,064,958	36,313	96.5	1698	13.8	1,575.3	888.95	56.4	7.1	48.4	X	32.4
경상북도구미시	88.7	426,182	60,846,350	53,967,532	2,000,499	42,309	37.1	784	4.7	580.6	615.76	106.1	100.0	71.9	X	19.8
경상북도영주시	61.9	95,451	14,556,821	9,009,940	1,197,928	24,837	133.0	2757	12.6	1,504.8	1,027.49	68.3	28.9	41.1	X	36.4
경상북도영천시	58.9	100,587	20,411,591	12,020,972	1,451,778	28,807	120.8	2396	14.4	2,360.8	950.03	40.2	50.0	6	X	19.2
경상북도상주시	64.1	75,998	12,771,937	8,180,866	1,243,325	24,562	152.0	3002	16.4	2,133.7	1,044.95	49		35.7	X	32.7

Local Governments	RWR	Size / Volume					Density			Financial Status			Technical Level			
		Service Population	Water Supply	Revenue Water	Length of Pipes	Service Connection	Length of Pipes/Water Supply	Water Supply/Connection	Length of Pipes/Population	Production cost of water	Tap water charge rate	Realization rate of water charge	DMA adoption rate	GIS adoption rate	consignment to utility	Rate of old pipe
	%	number	㎥/yr	㎥/yr	m	ea	km/M㎥/yr	M㎥/yr/ea	m/person	won/㎥	won/㎥	%	%	%	O,X	%
경상북도문경시	53.6	67,691	15,574,511	8,349,923	939,833	24,169	112.6	2895	13.9	1,381.6	841.57	60.9	0.0	98.2	X	35.7
경상북도경산시	73.9	270,084	40,410,981	29,848,688	1,608,614	36,671	53.9	1229	6.0	1,006.6	872.72	86.7	37.7	58.1	X	6.5
경상북도군위군	51.3	18,267	5,102,110	2,616,771	553,606	9,125	211.6	3487	30.3	1,189	374.71	31.5		0	X	31.8
경상북도의성군	54.2	47,813	8,240,213	4,463,585	1,497,334	22,472	335.5	5035	31.3	5,221	893.66	17.1	25.6	8.1	X	2.1
경상북도청송군	59.8	18,505	3,283,586	1,965,046	385,052	8,834	196.0	4496	20.8	1,392	435.63	31.3		0	X	17.9
경상북도영양군	60	15,666	2,699,992	1,621,218	524,531	8,444	323.5	5208	33.5	2,178	705.16	32.4		100	X	0
경상북도영덕군	58.1	36,381	7,434,380	4,316,565	767,672	20,929	177.8	4849	21.1	2,425.5	950.07	39.2	28.6	100	X	26.3
경상북도청도군	57.1	35,171	5,508,236	3,145,250	705,084	16,069	224.2	5109	20.0	1,001	808.71	80.8	0.0	79.3	X	4.8
경상북도고령군	75.6	33,384	5,881,096	4,443,695	743,351	12,634	167.3	2843	22.3	1,142	608.35	53.3	100.0	99.8	X	7
경상북도성주군	69.8	34,218	4,673,490	3,260,564	559,067	11,658	171.5	3575	16.3	1,292	880.91	68.2	0.0	0	X	17.1
경상북도칠곡군	79.6	114,083	15,907,024	12,665,332	855,244	20,261	67.5	1600	7.5	1,252	772.92	61.7	0.0	0	X	12.5
경상북도예천군	81.3	46,466	6,093,367	4,955,781	1,106,858	15,750	223.3	3178	23.8	1,641.7	724.3	44.1	100.0	95.9	X	10.8
경상북도봉화군	72.4	22,340	2,831,549	2,050,837	443,828	8,487	216.4	4138	19.9	2,589	495.97	19.2	100.0	0	X	7.9
경상북도울진군	69	38,047	6,693,565	4,618,560	664,259	16,814	143.8	3641	17.5	3,184.5	783.13	24.6	13.0	0	X	30.8
경상북도울릉군	59	8,950	1,786,984	1,053,907	106,574	3,205	101.1	3041	11.9	2,598	866.44	33.4		0	X	49.7
경상남도창원시	75.8	1,051,334	124,843,579	94,600,922	3,133,435	94,583	33.1	1000	3.0	1,048.4	830.94	79.3	81.4	99.1	X	35.9
경상남도진주시	72	350,941	56,160,887	40,442,084	2,266,050	55,537	56.0	1373	6.5	744	735.57	98.9	65.7	69.2	X	46
경상남도통영시	78.5	136,148	16,677,662	13,089,853	962,343	27,024	73.5	2064	7.1	1,100	1,034.57	94.1	100.0	100	X	10.5
경상남도사천시	81.9	112,888	16,583,624	13,578,689	1,270,682	25,906	93.6	1908	11.3	1,239	1,079.89	87.2	100.0	97.8	X	19.6
경상남도김해시	78.9	541,866	63,700,446	50,282,516	1,814,752	52,415	36.1	1042	3.3	1,042	854.58	82	49.2	100	X	27.1
경상남도밀양시	72	89,252	11,216,802	8,072,419	1,030,495	25,308	127.7	3135	11.5	1,762	907.03	51.5	53.1	97.9	X	23.1
경상남도거제시	75.9	250,457	29,179,349	22,155,311	1,213,215	24,638	54.8	1112	4.8	1,111	908.79	81.8	100.0	100	X	17.6
경상남도양산시	73.7	349,115	45,491,948	33,532,472	1,031,092	18,932	30.7	565	3.0	1,111	982.36	88.4	5.1	89	X	14.7
경상남도의령군	49.6	19,801	3,750,852	1,861,924	403,887	8,925	216.9	4793	20.4	2,698.3	897.37	33.3	100.0	0	X	10.1
경상남도함안군	73.6	67,633	9,279,023	6,827,479	764,888	18,625	112.0	2728	11.3	1,936.7	846.44	43.7	65.0	7.5	X	18.1
경상남도창녕군	73	65,836	9,297,267	6,788,214	1,502,503	26,182	221.3	3857	22.8	2,048.8	1,146.23	55.9	42.9	0	X	8.9
경상남도고성군	79.3	43,486	5,668,250	4,494,116	771,694	14,259	171.7	3173	17.7	1,900	1,133.42	59.7	100.0	99.1	X	15.7
경상남도남해군	56	31,148	5,171,343	2,897,568	862,198	13,373	297.6	4615	27.7	2,144	891.63	41.6		0	X	12.3
경상남도하동군	61.9	26,505	3,350,622	2,074,030	442,245	9,438	213.2	4551	16.7	1,374.4	807.55	58.8		0	X	20.8
경상남도산청군	53.3	17,675	3,314,454	1,767,787	250,189	6,868	141.5	3885	14.2	2,208	741.97	33.6	0.0	0	X	24
경상남도함양군	55.6	26,454	4,431,306	2,463,665	382,239	8,356	155.2	3392	14.4	2,040	702.04	34.4	18.2	23.3	X	21.1
경상남도거창군	67.8	48,331	7,082,676	4,803,500	341,298	11,263	71.1	2345	7.1	1,765	828.7	47	0.0	91.1	X	20.2
경상남도합천군	67.4	25,155	3,539,757	2,384,832	369,219	10,803	154.8	4530	14.7	2,699	732.4	27.1	14.0	0	X	6.6
제주특별자치도	46.2	521,551	175,390,343	81,057,667	5,869,128	176,387	72.4	2176	11.3	1,028.8	825.77	80.3	9.3	76.8	X	10.6