A Study on the Correlation Analysis of the Factors Affecting the Water Revenue Ratio of Sub-Small Block

By

KANG, Byung-Uk

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

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Committee in charge:

Professor Lee, Junesoo, Supervisor

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ABSTRACT

According to the Ministry of Environment's 2017 water supply statistics, 10.5 percent of annual water production were lost by leakage which is mainly caused by aging water pipes, burst of pipes and inadequate pressure management, illegal usage of water, etc. Water pipe network system improvement is required to reduce losses caused by leakages and improve the water revenue ratio and for this purpose, block system and sub-small block of Goryeong local water supply were used.

There are 39 small blocks within the corresponding small blocks and 12 small blocks in GR3(Oe-ri/Naegok, Ssanglim I.C., Gogok, Strawberry Village, Anhwa, Singok2, Singok1, Songlim1ri, Sandang, Baeksan, Sinchon, Mahon), 10 small blocks in GR5(Junghwa P.S, Weolsan1, Huam2, Garryun1, Baekri, Weolsan2, Hwaam, Palsan, Daepyeong, Yeonbong P.S), 17 small blocks in GR5(Jikri, Yajeong/Sokri, Sajeon/Daegok, Yeonri samgeori, Gwangdo, Osa, Gu-gok, Ok-san2, Ok-san1, Kisan, Kijok, Eogok, Deukseong, Ogok, Buri, Yongso/Sangyong, Mugye)

For the analysis of the affecting factors of the small block in the small block of Goryeong local water supply, firstly, the correlation analysis and reliability verification were conducted and reliability analysis used 'F-verification:Two Groups for Variance' and a significant level of reliability analysis was applied at 5%. Next, a correlation analysis was conducted to identify the factors affecting the sub-small block with a significant level of correlation with the water revenue ratio of the small block. The independent variables are length of distribution pipe (X1), length of water supply pipe (X2), faucet (X3), night minimum flow (X4) and the dependent variable is set to the water revenue flow (Y).

The results showed that eleven sub-small blocks had a significant level of correlation with the water revenue ratio of the three small blocks. In detail, GR3 small block have 3 sub-

small blocks(Singok1, Baeksan, Sinchon) out of total 12 sub-small blocks, GR5 small block have 2 sub-small blocks (Hwaam, Yeonbong Pressure Station) out of total 10 sub-small blocks and GR6 small block have 6 sub-small blocks (Gwangdo, Gugok, Oksan1, Kijok, Deukseong, Yongso/Sangyong) out of total 17 sub-small blocks.

Secondly, 11 small blocks were analyzed for the correlation between the factors affecting the water revenue ratio. As a result of the correlation analysis between the factors affecting the water revenue ratio, all of the factors negatively related to the water revenue ratio.

According to the result of correlation analysis, faucet was the highest correlation with negative 0.3, length of water supply pipe is negative 0.23, night minimum flow is negative 0.17, and lastly length of distribution pipe extensions was corelated with negative 0.10.

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1. Introduction

According to the Ministry of Environment's 2017 water supply statistics, South Korea water supply population is 52.46 million people, and the water supply rate is 99.1%. About 110 years have passed since water supply in the modern period of South Korea, including the construction of the Ttukdo water treatment facility. It can be said that the current "water supply rate of nearly 100 percent" has made rapid progress in terms of the quantitative expansion of water supply infrastructure.

On the other hand, 10.5 percent of annual water production; about 682 million tons of water were lost. If this is converted into production cost (as of 2017), loss is estimated at 613 billion South Korea won. Leakage mainly caused by aging water pipes, burst of pipes and inadequate pressure management, illegal usage of water, etc.

Water pipes constructed nationwide (about 32.4%, 67,676km) were aged pipes constructed before 1997, and water pipe network system improvement is required to reduce losses caused by leakages and improve the water revenue ratio.

In South Korea, the water revenue ratio of local water supply is very low except Seoul special city and 6 Metropolitan cities. In construction step, it is necessary to construct an advanced water pipe network system, such as building a block system and maintaining a water pipe network system. Next, the step of operation, proper water pressure management for the block system and various and rapid water leakage recovery activities are required. Recently, many local governments have adopted sub-small block flow monitoring system which means a block smaller than a small block, and usually has a water supply of less than 500 faucets to enhance the water revenue ratio of small blocks with large areas and low the water revenue ratio. However, it has not yet been actively conducted on which factors in the sub-small block flow monitoring system affect the improvement of the water revenue ratio.

This study used the sub-small block flow monitoring system to analyze the effects of the water revenue ratio of the small block installed in Goryeong local water supply and verify the reliability of the results, moreover, a correlation analysis was conducted between factors that affect the water revenue ratio.

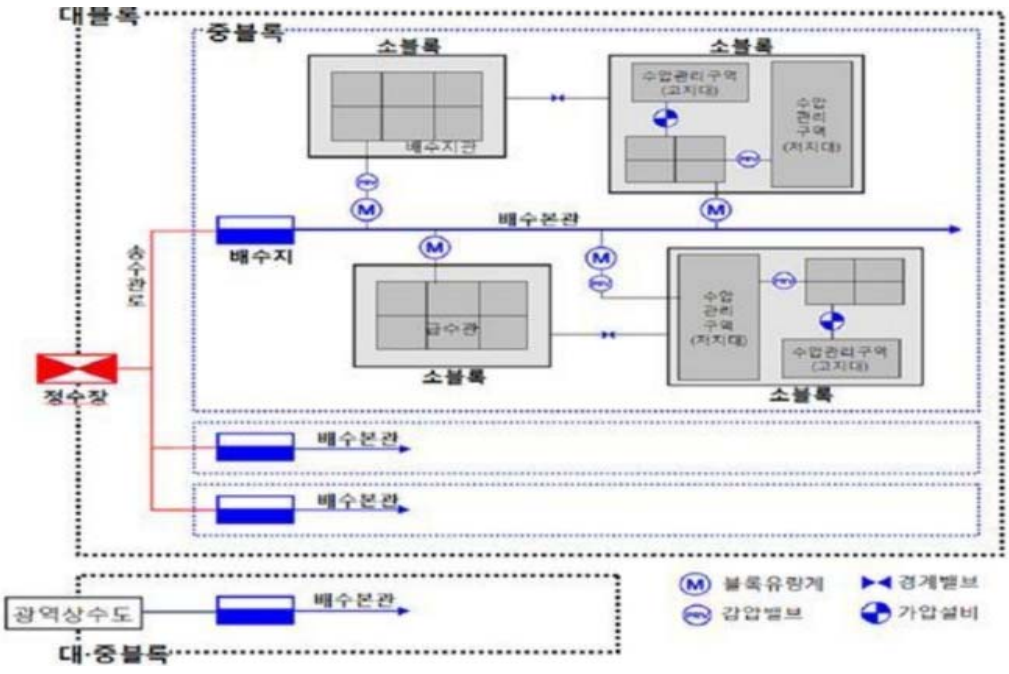
2. Literature Review

2.1 Block system of water pipe network

2.1.1 Concepts

The block system is system that divides the complex water pipe networks into blocks of 'large', 'middle', and 'small' according to the size of the water supply area and is continuously managed to maintain proper water pressure and quantity and in addition, organizes and manages water pipe networks so that activities such as timely detection of leakage signs can be carried out through monitoring of the injection point flow or night minimum flow of individual small blocks.

Figure 1 - Schematic diagram of block system



2.1.2 Construction of block system

When constructing a block system, the blocks shall be divided in consideration of the topographical conditions, water supply conditions, etc. of the water supply area and the divided blocks must be independent in terms of flow rate and water pressure, so the blocks must be clearly isolated. The following table is the application criteria for the block division of the block system.

Table 1 - Application criteria for the division of the block system

Classification	Main contents
Large Block	■ Water supply area of the transmission water system of the water purification plant ■ Separate wide-area water supply and local water supply systems ■ Roads (width of 25m or more), railways, rivers, and streams are on alert
Middle Block	■ Pressure plant and water supply areas of distribution reservoir ■ Roads (width of more than 8m), railways, rivers and streams, sewage mains, administrative districts, etc. are on alert ■ Faucet scale between 1500 - 5000 ■ 5 to 10 small blocks are included
Small Block	■ Roads (width less than 8m), railways, rivers and streams, sewage mains, administrative districts, parks, industrial parks, and large-scale apartments are on alert ■ Elevation difference within 25m to 30m for stabilizing water pressure ■ Faucet scale between 500 – 1500

- Source: Regulations for improving the water revenue ratio (Ministry of Environment, September 2005)

2.1.3 Block system construction effect

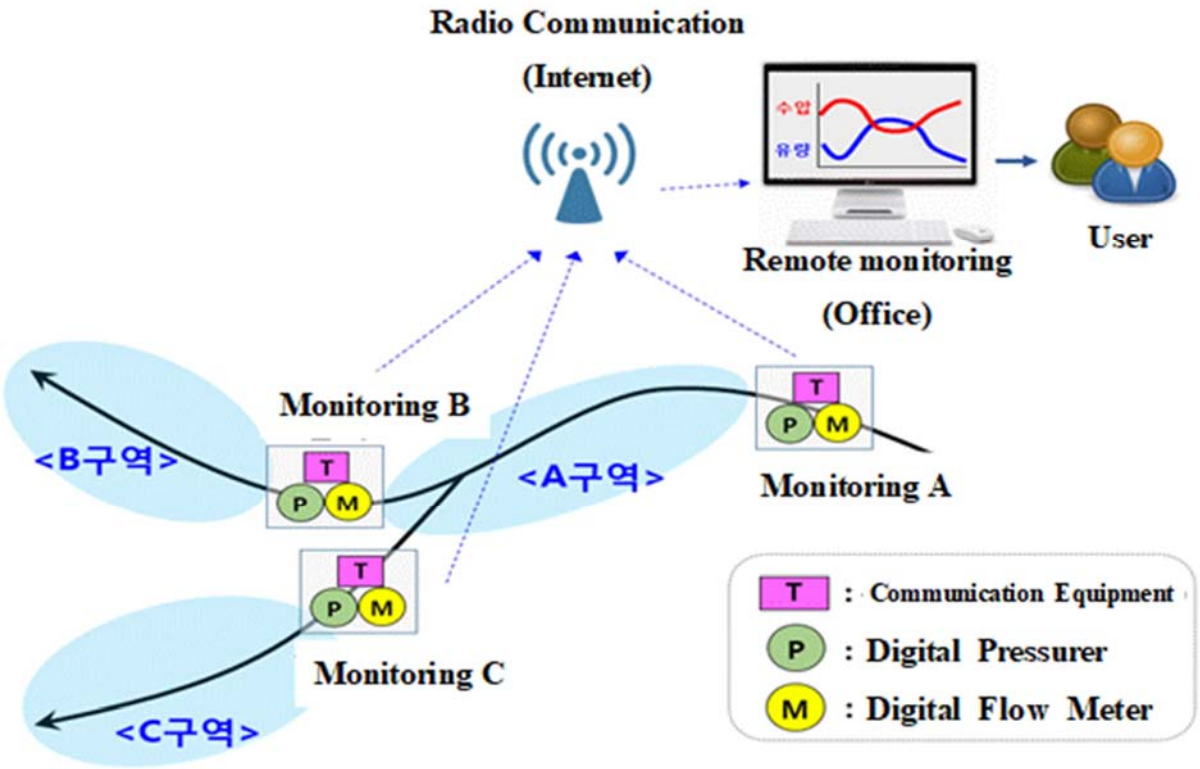
Block system construction makes it easy to identify the quantity by region and enables rational quantity allocation plan, can analyze and enhance the water revenue ratio in small blocks, it has the effect of improving responsiveness in times of crisis by securing emergency water through construction of inter-block emergency connection pipes.

2.2 Sub-small block flow monitoring system

2.2.1 Concepts

Sub-small block flow monitoring system is a technology that can be made possible by the recent rapid development of Internet of Things (IOT) technology and the implementation of low-power, high-efficiency batteries and it is mainly a technology for monitoring flow and water pressure in areas smaller than small blocks.

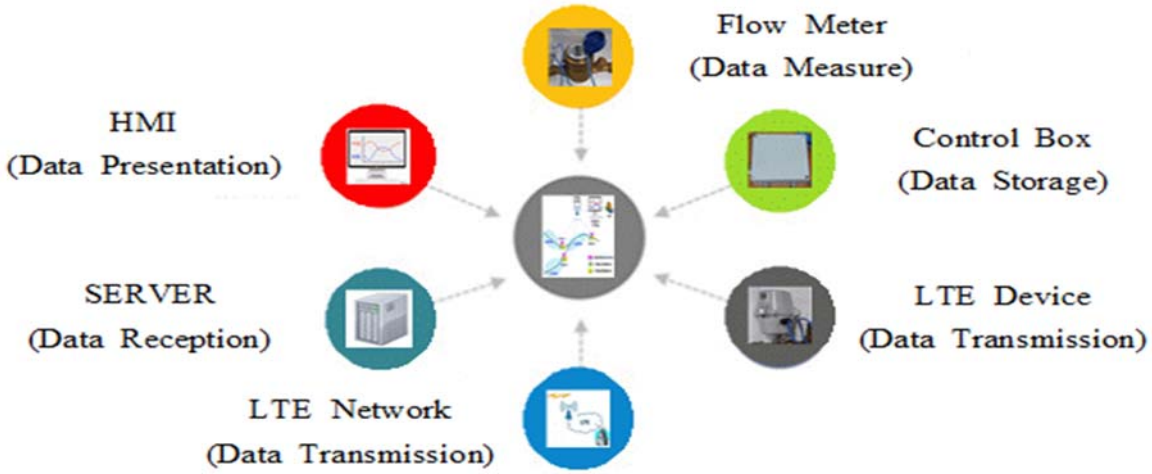
Figure 2 - Schematic diagram of Sub-small block flow monitoring system



2.2.2 Configuration of technology and data transmission

Implementing technology of sub-small block flow monitoring system requires the configuration of a digital flow meter and pressure meter, a control box for data storage, an LTE communication device with VPN for data transmission, a network (SK, KT, LGU+), a server for data reception and storage, and a HMI that can visualize data. Nevertheless, these acquisition and transmission cycles are sufficiently adjustable to meet the needs of the user, but the consumption of the battery shortens our certain expectations of the battery.

Figure 3 - Composition diagram of sub-small block flow monitoring system



2.2.3 Construction effects of sub-small block flow monitoring system

This technology can monitor flow and pressure of water supply in areas smaller than small blocks, therefore it can significantly reduce the time required for water leakage restoration activities and also has the effects of reducing leakage detection people and restoration costs for water leakage recovery less than before.

Moreover, when it is urgent to raise the water revenue ratio, the analysis results of correlation on the water revenue ratio between small block and sub-small block can be applied more efficiently on putting water leakage detector into areas with low the water revenue ratio.

3. Research methods

3.1 Current status of Goryeong local water supply

3.1.1 Goryeong local water supply and facility status

Goryeong-gun is composed of 1 town , 7 villages in the administrative district and the total population is 32,000 people, a water supply population is 31,500 people, the water supply rate is 97.2%, faucet is 13,434, and the water revenue ratio is 80.6 percent. The daily average water usage totaled 16,600㎥, which was 8,900㎥ for wide area water supply and 7.700㎥ for local water supply. (Source: Water Supply Statistical Yearbook by the Ministry of Environment, Dec. 2019)

Table 2 - Water supply and facilities of Goryeong local water supply

Classification		Main Status	Unit
Water Supply	Total Population	32,373	People
	Water Supply Population	31,460	People
	Water Supply Ratio	97.2	%
	Daily Average Supply Per Capita	515	ℓpcd
	Water Revenue Ratio	80.6	%
	Amount of Water Supply	16,600	㎥/day
Facility	Intake facility	9,000	㎥/day
	Water Treatment facility	9,000	㎥/day
	Distribution Reservoir	8,181	
	Pressure Station	56	EA
	Transmission/Distribution Pipe	516	Km
	Water Supply Pipe	288	Km

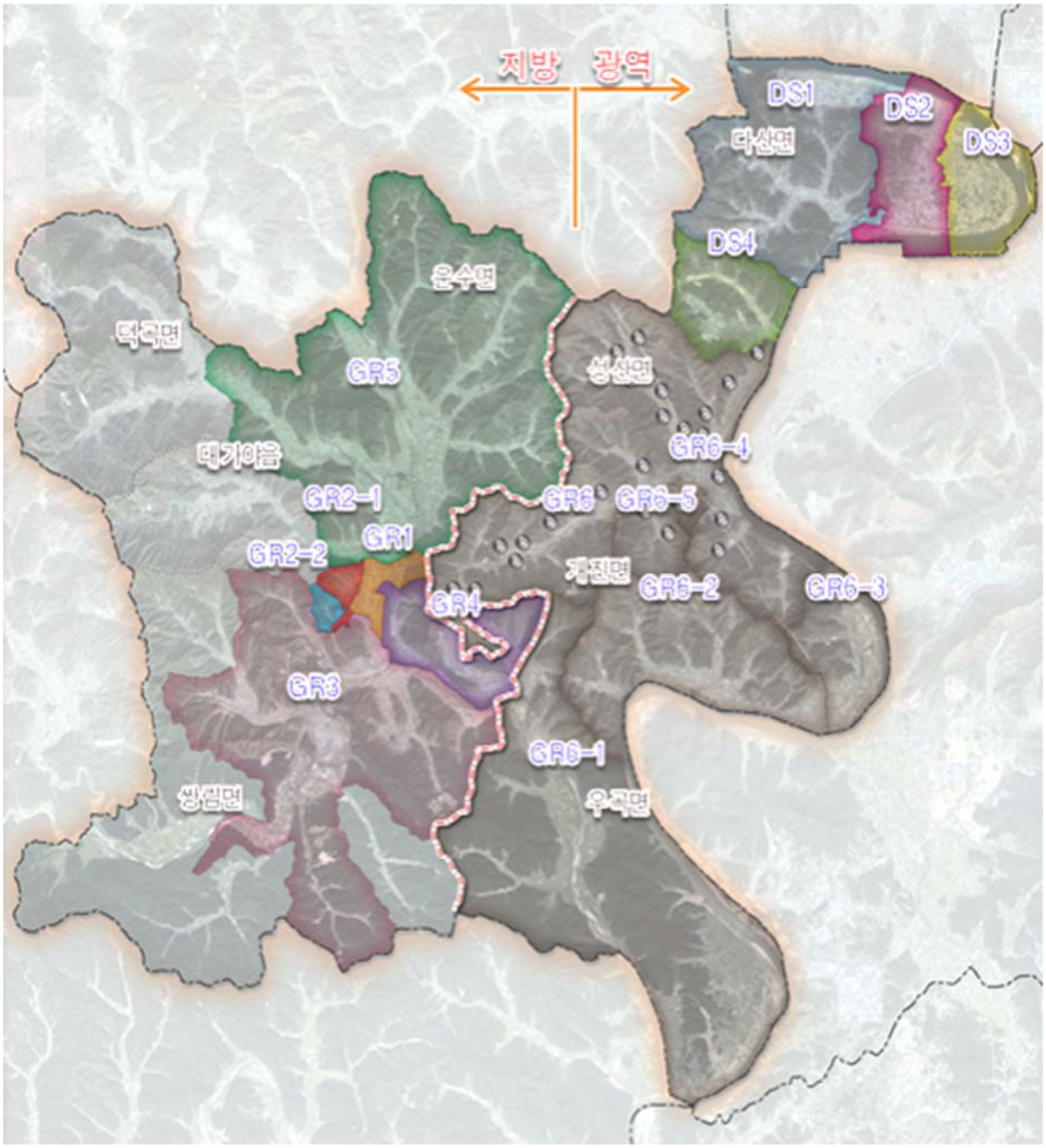
3.1.2 A block system of Goryeong local water supply

A block system of Goryeong local water supply consists of two large blocks, four medium blocks, and eleven small blocks. Large blocks are divided into wide-area water supply and local water supply systems, and the wide-area water supply system supplies the east area of mountain, the local water supply system supplies the west area of mountain. The middle block is divided by distribution reservoir which are Goryeong, Dasan, Dasan Industrial Complex, Gaepo Integration, Gaejin. The Goryeong distribution reservoir consists of GR1, GR2-1, GR2-1, GR3, GR4, GR5 small blocks and the Gaepo Integration distribution reservoir consists of GR6, the Dasan distribution reservoir consists of DS1, DS2, DS3 and lastly, the Dasan Industrial Complex distribution reservoir consists of DS4.

Table 3 - Block system construction status of Goryeong local water supply

Block System			Length of Pipe (km)	Faucet	Water Revenue Ratio (%)	NMF (m^3/hr)
Large	Middle	Small				
			807.2	13,434	82.1	26.4
Local Water Treatment Plant	Goryeong	GR1	31.1	967	77.4	23.3
		GR2-1	19.0	703	78.3	20.2
		GR2-2	9.0	151	66.6	3.5
		GR3	143.4	2,318	83.2	10.2
		GR4	26.3	509	82.4	12.3
		GR5	201.0	2,605	72.5	48.3
Wide area treatment plant	Gaepo I.g	GR6	247.1	3,825	71.1	114.3
	Dasan	DS1	52.5	882	102.9	6.8
		DS2	31.1	617	127.9	12.7
		DS3	20.8	545	67.9	7.7
	Dasan I.C	DS4	26.0	312	88.7	31.0

Figure 4 - Block system construction diagram of Goryeong local water supply



3.1.3 Sub-small block flow monitoring system in Goryeong local water supply

There are 43 sub-small block flow monitoring systems that can be monitored remotely and in detail, 12 locations are installed in GR3 Block, 10 in GR5 Block, 19 in GR6 Block, and 1 each in DS2 Block and DS3 Block.

The size of the digital flowmeter ranges from at least 25mm to up to 150mm. The faucets of sub-small blocks within GR3 blocks is at least 15, up to 285, and average 111, the faucets of sub-small blocks within GR5 blocks is at least 34, up to 357, and average 180 and the faucets of sub-small blocks within GR6 blocks is at least 42, up to 343, and average 116. However, among small blocks, Sabu and Samdae belonging to GR6 Block, Jwahak in DS2, Hochon in DS3 were excluded from this study because lack of sample and data reliability

Table 4 - Sub-small block flow monitoring system status

Small Block	Sub-Small Block Flow Monitoring System		Flow Meter Size (㎜)	Faucet
	Quantity	Name		
GR3	12	Oe-ri/Naegok, Ssanglimgongdan, Gogok, Ttalgimaeul , Anhwa, Singok2, Singok1, Songlim1ri, Sandang, Baeksan, Sinchon, Maechon	50~150	15~285
GR5	10	Junghwa P.S, Weolsan1, Huam2, Garryun1, Baekri, Weolsan2, Hwaam, Palsan, Daepyeong, Yeonbong P.S	80~150	34~357
GR6	19	Jikri, Yajeong/Sokri, Sajeon/Daegok, Yeonri samgeori, Gwangdo, Osa, Gu-gok, Ok-san2, Ok-san1, ~~Sabu~~, Kisan, Kijok, Eogok, Deukseong, ~~Samdae~~, Ogok, Buri, Yongso/Sangyong, Mugye	25~150	42~343
DS2	1	~~Jwahak~~	100	701
DS3	1	~~Hochon~~	100	617

The sub-small block flow monitoring system was first constructed and operated in 2015. Two constructed per year by 2017, and seven (17.9%) were constructed in 2018 and twenty six (66.7%) were constructed and operated in 2019.

Since most sub-small block flow monitoring systems were constructed in the first half of 2019, the data to be used in this study was used for the second half of 2019 (July-December)

Table 5 - Construction quantity of sub-small block flow monitoring system by year

Classification	Total	GR3	GR5	GR6
Total	39	12	10	17
2015	2	0	0	2
2016	2	0	0	2
2017	2	1	0	1
2018	7	3	3	1
2019	26	8	7	11

3.2 Statistical analysis

To analyze the correlation of sub-small blocks affecting the small block's the water revenue ratio, primarily correlation analysis method among the statistical technique was used.

Analysis was performed by small block unit because correlation analysis has characteristics on each small blocks, in other words, there are 12 small blocks to analysis in GR3 blocks, 10 small blocks to analysis in GR5 blocks, and 17 small blocks to analysis of GR6 blocks. Reliability analysis was conducted based on the results of the first correlation. Secondly, reliability analysis used 'F-verification: Two Groups for Variance' and a significant level of reliability analysis was applied at 5%.

Next, a correlation analysis was conducted to identify the factors affecting the sub-small block with a significant level of correlation with the water revenue ratio of the small block. The dependent and independent variables used in the correlation are as follows:

- Dependent variable = the water revenue ratio (Y)
- Independent variable = the length of distribution pipe (X1),
  the length of the water supply pipe (X2),
  the faucet (X3),
  the night minimum flow (X4)

4. Correlation analysis of the factors influencing the water revenue ratio

4.1 Correlation analysis and reliability verification of the water revenue ratio

4.1.1 Correlation analysis and reliability verification of the GR3 small block

In common, the water revenue ratio analysis period shall be six months from July to December 2019 in consideration of the period of establishment of sub-small blocks, problems of data reliability and recent COVID19.

Even though among the small blocks, the water flow rate of Oeori/Naegok, Ssangnim Industrial Complex, and Baeksan exceeds 100%, the purpose of this study is not to analyze the adequacy of the water revenue ratio, but to identify the affecting factors of the water revenue ratio, so the flow data of the small block is to be utilized as it is

Table 6 - The water revenue ratio of GR3 small block and 12 sub-small blocks

Classification	2019					
	July	Aug.	Sep.	Oct.	Nov.	Dec.
GR3	86.10	91.31	89.77	72.50	91.45	86.91
Oeri/Naegok	121.96	124.15	140.56	107.41	127.59	129.95
Ssanglimgongdan	101.80	95.10	104.23	96.29	95.57	105.71
Gogok	78.25	66.92	50.94	53.85	46.32	63.79
Ttalgimaeul	60.09	58.34	60.03	55.22	52.32	52.14
Anhwa	86.33	68.92	68.13	50.55	54.49	60.03
Singok2	43.53	49.52	50.41	49.12	41.61	47.94
Singok1	65.62	47.76	31.43	24.33	30.94	66.57
Songlim1ri	64.74	66.56	69.28	61.29	63.34	54.86
Sandang	81.64	80.01	107.86	93.27	95.54	78.15
Baeksan	254.25	244.15	268.35	200.95	217.29	269.07
Sinchon	31.41	32.53	36.76	30.10	30.73	36.20
Maechon	36.79	43.76	42.30	30.38	31.30	35.70

Result of correlation analysis between GR3 and 12 small blocks, Oeori/Naegok, Anhwa, Songlim1ri, Baeksan, Sinchon, and Maechon has a significant correlation of more than 30% with GR Block. In particular, it was analyzed that Oeri/Naegok had more than 70% correlation, and that the Baeksan and Maechon had more than 50% correlation.

Table 7 - Correlation analysis results between GR3 small block and 12 sub-small blocks

Classification	GR3	Oeri/Naegok	Ssanglimgongdan	Gogok	Ttalgimaeul	Anhwa	Singok2	Singok1	Songlim1ri	Sandang	Baeksan	Sinchon	Maechon
GR3	1.0000												
Oeri/Naegok	0.7969	1.0000											
Ssanglimgongdan	0.1284	0.5729	1.0000										
Gogok	0.0384	-0.1718	0.2354	1.0000									
Ttalgimaeul	0.1095	0.1649	0.1227	0.4382	1.0000								
Anhwa	0.3680	0.2623	0.3432	0.7913	0.7625	1.0000							
Singok2	-0.2446	0.0758	0.2043	-0.0586	0.3050	-0.1388	1.0000						
Singok1	0.2864	0.1579	0.5233	0.8403	0.0654	0.6299	-0.1768	1.0000					
Songlim1ri	0.3356	0.2934	-0.2474	-0.0862	0.7872	0.4166	0.1259	-0.3989	1.0000				
Sandang	-0.0246	0.3350	0.0160	-0.7651	0.1818	-0.2818	0.1487	-0.7919	0.5423	1.0000			
Baeksan	0.5591	0.7671	0.8231	0.4199	0.3523	0.5993	0.2487	0.6542	0.0508	-0.1517	1.0000		
Sinchon	0.4056	0.8035	0.8093	-0.0317	0.1126	0.1399	0.5129	0.2871	-0.0376	0.1511	0.8569	1.0000	
Maechon	0.5788	0.5785	0.2389	0.3334	0.6778	0.5670	0.5201	0.2569	0.5666	-0.0313	0.6919	0.5735	1.0000

The reliability analysis between the GR3 and twelve sub-small blocks was conducted performed as follows. This is the result of reliability analysis between GR3 block and Oeri/Naegok Sub-small block. It can be concluded that GR3 block and Oeri/Naegok sub-small block are not correlated to the water revenue ratio.

- P-value: 0.187626 > 0.05 (significance level)

Table 8 - Reliability analysis results GR3 small block and Oeri/Naegok

	GR3	Oeri/Naegok
Average	0.863424	1.252709
Dispersion	0.005089	0.011846
observation count	6	6
degree of freedom	5	5
F ratio	0.4296	
P(F<=f) one-sided test	0.187626	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR3 block and Ssanglimgongdan sub-small block. It can be concluded that GR3 block and Ssanglimgongdan sub-small block are not correlated with the water revenue ratio

- P-value: 0.191361 > 0.05 (significance level)

Table 9 - Reliability analysis results GR3 small block and Ssanglimgongdan

	GR3	Ssanglimgongdan
Average	0.863424	0.997806
Dispersion	0.005089	0.002216
observation count	6	6
degree of freedom	5	5
F ratio	2.296567	
P(F<=f) one-sided test	0.191361	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR3 block and Gogok sub-small block. It can be concluded that GR3 block and Gogok sub-small block are not correlated with the water revenue ratio.

- P-value: 0.144784 > 0.05 (significance level)

Table 10 - Reliability analysis results GR3 small block and Gogok

	GR3	Gogok
Average	0.863424	0.600118
Dispersion	0.005089	0.014043
observation count	6	6
degree of freedom	5	5
F ratio	0.362398	
P(F<=f) one-sided test	0.144784	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR3 block and Ttalgimaeul sub-small block. It can be concluded that GR3 block and Ttalgimaeul sub-small block are not correlated with the water revenue ratio

- P-value: 0.084159 > 0.05 (significance level)

Table 11 - Reliability analysis results GR3 small block and Ttalgimaeul

	GR3	Ttalgimaeul
Average	0.863424	0.563594
Dispersion	0.005089	0.001335
observation count	6	6
degree of freedom	5	5
F ratio	3.81123	
P(F<=f) one-sided test	0.084159	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR3 block and Anhwa sub-small block. It can be concluded that GR3 block and Anhwa sub-small block are not correlated with the water revenue ratio.

- P-value: 0.111633 > 0.05 (significance level)

Table 12 - Reliability analysis results GR3 small block and Anhwa

	GR3	Anhwa
Average	0.863424	0.647418
Dispersion	0.005089	0.016471
observation count	6	6
degree of freedom	5	5
F ratio	0.30898	
P(F<=f) one-sided test	0.111633	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR3 block and Singok2 sub-small block. It can be concluded that GR3 block and Singok2 sub-small block are not correlated with the water revenue ratio.

- P-value: 0.079121 > 0.05 (significance level)

Table 13 - Reliability analysis results GR3 small block and Singok2

	GR3	Singok2
Average	0.863424	0.470223
Dispersion	0.005089	0.00129
observation count	6	6
degree of freedom	5	5
F ratio	3.945379	
P(F<=f) one-sided test	0.079121	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR3 block and Singok1 sub-small block. It can be concluded that GR3 block and Singok1 sub-small block are correlated with the water revenue ratio.

- P-value: 0.038232 < 0.05 (significance level)

Table 14 - Reliability analysis results GR3 small block and Singok1

	GR3	Singok1
Average	0.863424	0.436517
Dispersion	0.005089	0.028857
observation count	6	7
degree of freedom	5	6
F ratio	0.176359	
P(F<=f) one-sided test	0.038232	
F reject: one-sided test	0.202008	

This is the result of reliability analysis between GR3 block and Songlim1ri Sub-small block. It can be concluded that GR3 block and Songlim1ri sub-small block are not correlated with the water revenue ratio.

- P-value: 0.223859 > 0.05 (significance level)

Table 15 - Reliability analysis results GR3 small block and Songlim1ri

	GR3	Songlim1ri
Average	0.863424	0.633445
Dispersion	0.005089	0.002475
observation count	6	6
degree of freedom	5	5
F ratio	2.056152	
P(F<=f) one-sided test	0.223859	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR3 block and Sandang sub-small block. It can be concluded that GR3 block and Sandang sub-small block are not correlated with the water revenue ratio.

- P-value: 0.156383 > 0.05 (significance level)

Table 16 - Reliability analysis results GR3 small block and Sandang

	GR3	Sandang
Average	0.863424	0.894108
Dispersion	0.005089	0.013368
observation count	6	6
degree of freedom	5	5
F ratio	0.380703	
P(F<=f) one-sided test	0.156383	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR3 block and Baeksan sub-small block. It can be concluded that GR3 block and Baeksan sub-small block are correlated with the water revenue ratio.

- P-value: 0.004781 < 0.05 (significance level)

Table 17 - Reliability analysis results GR3 small block and Baeksan

	GR3	Baeksan
Average	0.863424	2.423425
Dispersion	0.005089	0.077538
observation count	6	6
degree of freedom	5	5
F ratio	0.065635	
P(F<=f) one-sided test	0.004781	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR3 block and Sinchon sub-small

block. It can be concluded that GR3 block and Sinchon sub-small block are correlated with the water revenue ratio.

- P-value: 0.03276 < 0.05 (significance level)

Table 18 - Reliability analysis results GR3 small block and Sinchon

	GR3	Sinchon
Average	0.863424	0.329546
Dispersion	0.005089	0.000813
observation count	6	6
degree of freedom	5	5
F ratio	6.259674	
P(F<=f) one-sided test	0.032765	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR3 block and Maechon sub-small block. It can be concluded that GR3 block and Maechon sub-small block are correlated with the water revenue ratio.

- P-value: 0.291092 > 0.05 (significance level)

Table 19 - Reliability analysis results GR3 small block and Maechon

	GR3	Maechon
Average	0.863424	0.367051
Dispersion	0.005089	0.003026
observation count	6	6
degree of freedom	5	5
F ratio	1.681867	
P(F<=f) one-sided test	0.291092	
F reject: one-sided test	5.050329	

Correlation and reliability analysis of the water revenue ratio, sub-small blocks with significant correlation are Singok1, Baeksan, and Sinchon.

Table 20 - Correlation and reliability analysis result of 12 sub-small blocks in GR3

Classification	Correlation Analysis	Reliability (P<0.05)
Oeri/Naegok	0.797	0.188
Ssanglim I.C	0.128	0.191
Gogok	0.038	0.145
Strawberry village	0.110	0.084
Anhwa	0.368	0.112
Singok2	- 0.245	0.079
Singok1	0.286	0.038
Songlim1ri	0.336	0.224
Sandang	- 0.025	0.156
Baeksan	0.559	0.005
Sinchon	0.406	0.033
Maechon	0.579	0.291

Factors affecting the water revenue ratio of Singok1, Baeksan, and Sinchon sub-small block are as follows.

Table 21 - Factors affecting the water revenue ratio of sub-small blocks in GR3

Classification	Length of Distribution Pipe(M)	Length of Water Supply Pipe(M)	Faucet	Night Minimum Flow(㎥/hr)	Water Revenue Flow(%)
Singok1	1,270	1,373	69	0.7	71.1
Baeksan	692	1,376	66	1.0	27.1
Sinchon	2,006	1,179	66	0.5	88.5

4.1.2 Correlation analysis and reliability verification of the GR5 small block

Ten sub-small blocks are operated within GR5 blocks and the water revenue ratio is exceeded 100 percent in Jung-hwa pressure station, Weol-san1, Yeon-bong pressure station sub-small blocks.

As mentioned earlier, the data are used as it is and the water revenue ratio of GR5 block and ten sub-small blocks are as follows.

Table 22 - The water revenue ratio of GR5 small block and 10 sub-small blocks

water revenue flow	2019년					
	July	Aug.	Sep.	Oct.	Nov.	Dec.
GR5	74.06	74.66	75.96	86.30	66.74	68.78
Junghwa P.S	121.96	124.15	140.56	107.41	127.59	129.95
Weolsan1	101.80	95.10	104.23	96.29	95.57	105.71
Huam2	78.25	66.92	50.94	53.85	46.32	63.79
Garryun1	60.09	58.34	60.03	55.22	52.32	52.14
Baekri	86.33	68.92	68.13	50.55	54.49	60.03
Weolsan2	43.53	49.52	50.41	49.12	41.61	47.94
Hwaam	65.62	47.76	31.43	24.33	30.94	66.57
Palsan	64.74	66.56	69.28	61.29	63.34	54.86
Daepyeong	81.64	80.01	107.86	93.27	95.54	78.15
Yeonbong P.S	254.25	244.15	268.35	200.95	217.29	269.07

According to the correlation analysis, sub-small blocks with more than 30% correlation are Junghwa pressure station, Garryun1, Wolsan2, Hwaam, Yeonbong pressure station and there was a negative correlation in the case of Junghwa pressure station, Hwaam, and Yeonbong pressure station sub-small blocks

Table 23 - Correlation n analysis results between GR5 small block and 10 sub-small blocks

	GR5	Junghwa P.S	Weolsan1	Huam2	Garryun1	Baekri	Weolsan2	Hwaam	Palsan	Daepyeong	Yeonbong P.S
GR5	1										
Junghwa P.S	-0.62258	1									
Weolsan1	-0.23257	0.572853	1								
Huam2	-0.02015	-0.17183	0.235441	1							
Garryun1	0.367942	0.164858	0.122699	0.438243	1						
Baekri	-0.14759	0.262312	0.343211	0.791276	0.762505	1					
Weolsan2	0.556873	0.07575	0.20428	-0.05861	0.304977	-0.1388	1				
Hwaam	-0.45356	0.157931	0.52326	0.840335	0.065351	0.629861	-0.17678	1			
Palsan	0.193036	0.293432	-0.24735	-0.08624	0.787212	0.416599	0.125861	-0.39894	1		
Daepyeong	0.230422	0.334994	0.015973	-0.76513	0.181838	-0.28181	0.148662	-0.7919	0.542343	1	
Yeonbong P.S	-0.43409	0.767105	0.823068	0.419939	0.352251	0.599281	0.248679	0.65419	0.050809	-0.15166	1

The reliability analysis between the GR5 and ten sub-small blocks was conducted performed as follows. This is the result of reliability analysis between GR5 block and Junghwa pressure station sub-small block. It can be concluded that GR5 block and Junghwa pressure station sub-small block are not correlated to the water revenue ratio.

- P-value: 0.166137 > 0.05 (significance level)

Table 24 - Reliability analysis results GR5 small block and Junghwa pressure station

	GR5	Junghwa P.S
Average	0.744179	1.252709
Dispersion	0.004691	0.011846
observation count	6	6
degree of freedom	5	5
F ratio	0.396012	
P(F<=f) one-sided test	0.166137	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR5 block and Weolsan1 sub-small block. It can be concluded that GR5 block and Weolsan1 sub-small block are not correlated to the water revenue ratio.

- P-value: 0.214965 > 0.05 (significance level)

Table 25 - Reliability analysis results GR5 small block and Weolsan1

	GR5	Weolsan1
Average	0.744179	0.997806
Dispersion	0.004691	0.002216
observation count	6	6
degree of freedom	5	5
F ratio	2.117011	
P(F<=f) one-sided test	0.214965	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR5 block and Huam2 sub-small block. It can be concluded that GR5 block and Huam2 sub-small block are not correlated to the water revenue ratio.

- P-value: 0.127038 > 0.05 (significance level)

Table 26 - Reliability analysis results GR5 small block and Huam2

	GR5	Huam2
Average	0.744179	0.600118
Dispersion	0.004691	0.014043
observation count	6	6
degree of freedom	5	5
F ratio	0.334064	
P(F<=f) one-sided test	0.127038	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR5 block and Garryun1 sub-small block. It can be concluded that GR5 block and Garryun1 sub-small block are not correlated to the water revenue ratio.

- P-value: 0.097062 > 0.05 (significance level)

Table 27 - Reliability analysis results GR5 small block and Garryun1

	GR5	Garryun1
Average	0.744179	0.563594
Dispersion	0.004691	0.001335
observation count	6	6
degree of freedom	5	5
F ratio	3.51325	
P(F<=f) one-sided test	0.097062	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR5 block and Baekri sub-small block. It can be concluded that GR5 block and Baekri sub-small block are not correlated to the water revenue ratio.

- P-value: 0.097171 > 0.05 (significance level)

Table 28 - Reliability analysis results GR5 small block and Baekri

	GR5	Baekri
Average	0.744179	0.647418
Dispersion	0.004691	0.016471
observation count	6	6
degree of freedom	5	5
F ratio	0.284822	
P(F<=f) one-sided test	0.097171	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR5 block and Weolsan2 sub-small block. It can be concluded that GR5 block and Weolsan2 sub-small block are not correlated to the water revenue ratio.

- P-value: 0.091396 > 0.05 (significance level)

Table 29 - Reliability analysis results GR5 small block and Weolsan2

	GR5	Weolsan2
Average	0.744179	0.470223
Dispersion	0.004691	0.00129
observation count	6	6
degree of freedom	5	5
F ratio	3.636911	
P(F<=f) one-sided test	0.091396	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR5 block and Hwaam sub-small block. It can be concluded that GR5 block and Hwaam sub-small block are not correlated to the water revenue ratio.

- P-value: 0.024128 > 0.05 (significance level)

Table 30 - Reliability analysis results GR5 small block and Hwaam

	GR5	Hwaam
Average	0.744179	0.444407
Dispersion	0.004691	0.034105
observation count	6	6
degree of freedom	5	5
F ratio	0.137552	
P(F<=f) one-sided test	0.024128	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR5 block and Palsan sub-small block. It can be concluded that GR5 block and Palsan sub-small block are not correlated to the water revenue ratio.

- P-value: 0.249872 > 0.05 (significance level)

Table 31 - Reliability analysis results GR5 small block and Palsan

	GR5	Palsan
Average	0.744179	0.633445
Dispersion	0.004691	0.002475
observation count	6	6
degree of freedom	5	5
F ratio	1.895392	
P(F<=f) one-sided test	0.249872	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR5 block and Daepyeong sub-small block. It can be concluded that GR5 block and Daepyeong sub-small block are not correlated to the water revenue ratio.

- P-value: 0.137571 > 0.05 (significance level)

Table 32 - Reliability analysis results GR5 small block and Daepyeong

	GR5	Daepyeong
Average	0.744179	0.894108
Dispersion	0.004691	0.013368
observation count	6	6
degree of freedom	5	5
F ratio	0.350938	
P(F<=f) one-sided test	0.137571	
F reject: one-sided test	0.198007	

This is the result of reliability analysis between GR5 block and Yeonbong pressure station sub-small block. It can be concluded that GR5 block and Yeonbong pressure station sub-small block are correlated to the water revenue ratio.

- P-value: 0.003968 < 0.05 (significance level)

Table 33 - Reliability analysis results GR5 small block and Yeonbong pressure station

	GR5	Yeonbong P.S
Average	0.744179	2.423425
Dispersion	0.004691	0.077538
observation count	6	6
degree of freedom	5	5
F ratio	0.060503	
P(F<=f) one-sided test	0.003968	
F reject: one-sided test	0.198007	

Correlation and reliability analysis of the water revenue ratio, sub-small blocks with significant correlation are Hwaam and Yeonbong pressure station

Table 34 - Correlation and reliability analysis result of 10 sub-small blocks in GR5

Classification	Correlation Analysis	Reliability (P<0.05)
Junghwa P.S	- 0.623	0.166
Weolsan1	- 0.233	0.215
Huam2	- 0.020	0.127
Garryun1	0.368	0.097
Baekri	- 0.148	0.097
Weolsan2	0.557	0.091
Hwaam	- 0.454	0.024
Palsan	0.193	0.250
Daepyeong	0.230	0.138
Yeonbong P.S	- 0.434	0.004

Factors affecting the water revenue ratio of Hwaam and Yeonbong pressure station sub-small block are as follows.

Table 35 - Factors affecting the water revenue ratio of sub-small blocks in GR5

Classification	Length of Distribution Pipe(M)	Length of Water Supply Pipe(M)	Faucet	Night Minimum Flow(㎥/hr)	Water Revenue Flow(%)
Hwaam	6,968	4,440	186	1.8	57.0
YeonbongP.S	11,496	4,968	247	2.7	59.1

4.1.3 Correlation analysis and reliability verification of the GR6 small block

Seventeen sub-small blocks are operated within GR6 blocks and the water revenue ratio is exceeded 100 percent in Buri sub-small blocks. As mentioned earlier, the data are used as it is and the water revenue ratio of GR6 block and seventeen sub-small blocks are as follows

Table 36 - The water revenue ratio of GR6 small block and 17 sub-small blocks

water revenue flow	2019년					
	July	Aug.	Sep.	Oct.	Nov.	Dec.
GR6	84.55	74.12	84.25	58.20	83.34	75.22
Jikri	76.36	71.10	72.39	67.01	59.10	60.62
Yajeong/Sokri	133.24	98.21	113.32	92.69	89.05	94.28
Sajeon/Daegok	94.04	69.98	77.60	54.49	68.05	67.32
Yeonri samgeori	94.47	89.92	111.10	95.79	84.04	88.84
Gwangdo	80.95	77.45	85.03	74.91	76.97	77.94
Osa	136.79	84.31	91.51	90.88	78.56	85.56
Gugok	93.71	93.68	100.91	207.99	57.33	92.62
Oksan2	96.33	96.64	103.11	98.59	90.47	86.56
Oksan1	92.26	89.41	95.33	95.29	88.54	83.81

water revenue flow	2019년					
	July	Aug.	Sep.	Oct.	Nov.	Dec.
Kisan	60.14	20.00	36.15	25.60	22.64	28.22
Kijok	45.18	39.65	45.41	42.57	40.09	43.56
Eogok	82.28	79.46	74.41	79.02	88.96	97.39
Deukseong	162.28	52.12	86.99	51.69	157.28	78.77
Ogok	67.88	67.40	71.44	62.45	41.44	53.38
Buri	104.44	101.13	113.49	104.09	99.01	102.35
Yongso/Sangyong	89.60	65.73	57.47	36.33	102.15	39.04
Mugyeo	64.91	70.83	65.64	85.97	48.02	47.67

According to the correlation analysis, sub-small blocks with more than 30% correlation are Yajeong/Sokri, Sajeon/Daegok, Gwangdo, Kisan, Kijok, Deukseong, Yongso/Sangyong and the remaining small blocks except for the Sajeon/Daegok, Kisan and Kijok showed a high correlation of more than 70%, and in the case of the Gugok, it had a correlation of more than negative 80%.

Table 37 - Correlation analysis results between GR5 small block and 10 sub-small blocks

	GR6	Jikri	Yajeong/Sok-i	Sajeon/Daegok	Yeonri samgeori	Gwangdo	Osa	Gugok	Oksan2	Oksan1	Kisan	Kijok	Eogok	Deukseong	Ogok	Buri	Yongso/Sangyong	Mugyeo
GR6	1																	
Jikri	0.175545	1																
Yajeong/Sokri	0.513935	0.839084	1															
Sajeon/Daegok	0.787525	0.644605	0.911896	1														
Yeonri samgeori	0.108765	0.598619	0.47613	0.237703	1													
Gwangdo	0.706283	0.553012	0.690452	0.696493	0.765892	1												
Osa	0.288660	0.718959	0.914775	0.791729	0.210277	0.360444	1											
Gugok	-0.878278	0.153705	-0.14426	-0.53275	0.28779	-0.366	0.026695	1										
Oksan2	-0.054679	0.750251	0.432231	0.170286	0.82347	0.496709	0.239172	0.406626	1									
Oksan1	-0.170872	0.626756	0.384476	0.080233	0.723377	0.32549	0.307277	0.557397	0.928403	1								
Kisan	0.459942	0.660825	0.946388	0.856926	0.33805	0.556433	0.959499	-0.09628	0.23444	0.290332	1							
Kijok	0.252796	0.478073	0.710912	0.521019	0.704915	0.697719	0.620315	0.150382	0.334102	0.355637	0.764841	1						
Eogok	0.073422	-0.7396	-0.37631	-0.14271	-0.70534	-0.3925	-0.20289	-0.37397	-0.98164	-0.90662	-0.16057	-0.16725	1					
Deukseong	0.721033	0.004413	0.445387	0.645981	-0.23409	0.246029	0.495295	-0.58691	-0.23922	-0.09022	0.577631	0.169386	0.228381	1				
Ogok	-0.051290	0.910702	0.64069	0.382402	0.741399	0.532535	0.474854	0.33968	0.787662	0.60696	0.433467	0.503967	-0.7432	-0.37175	1			
Buri	0.197446	0.542829	0.491271	0.286271	0.989243	0.822236	0.213007	0.196794	0.73872	0.635002	0.372529	0.762238	-0.6046	-0.1703	0.684032	1		
Yongso/Sangyong	0.704520	0.070936	0.297342	0.557561	-0.32736	0.148561	0.283386	-0.68005	-0.10068	-0.05141	0.29775	-0.23613	0.005315	0.854926	-0.31573	-0.31106	1	
Mugyeo	-0.660954	0.558364	0.123596	-0.2403	0.416999	-0.14976	0.185366	0.838208	0.734511	0.769159	0.019956	0.060274	-0.75789	-0.53207	0.652521	0.288082	-0.40603	1

The reliability analysis between the GR6 and seventeen sub-small blocks was conducted performed as follows. This is the result of reliability analysis between GR6 block and Jikri sub-small block. It can be concluded that GR6 block and Jikri sub-small block are not correlated to the water revenue ratio.

- P-value: 0.202950992 > 0.05 (significance level)

Table 38 - Reliability analysis results GR6 small block and and Jikri

	GR6	Jikri
Average	0.766126864	0.677659
Dispersion	0.010279524	0.004662
observation count	6	6
degree of freedom	5	5
F ratio	2.204855581	
P(F<=f) one-sided test	0.202950992	
F reject: one-sided test	5.050329058	

This is the result of reliability analysis between GR6 block and Yajeong/Sokri sub-small block. It can be concluded that GR6 block and Yajeong/Sokri sub-small block are not correlated to the water revenue ratio.

- P-value: 0.144592301 > 0.05 (significance level)

Table 39 - Reliability analysis results GR6 small block and Yajeong/Sokri

	GR6	Yajeong/Sokri
Average	0.766126864	1.034661
Dispersion	0.010279524	0.028389
observation count	6	6
degree of freedom	5	5
F ratio	0.362094361	
P(F<=f) one-sided test	0.144592301	
F reject: one-sided test	0.1980069	

This is the result of reliability analysis between GR6 block and Sajeon/Daegok sub-

small block. It can be concluded that GR6 block and Sajeon/Daegok sub-small block are not correlated to the water revenue ratio.

- P-value: 0.290679508 > 0.05 (significance level)

Table 40 - Reliability analysis results GR6 small block and Sajeon/Daegok

	GR6	Sajeon/Daegok
Average	0.766126864	0.71913
Dispersion	0.010279524	0.017309
observation count	6	6
degree of freedom	5	5
F ratio	0.593893681	
P(F<=f) one-sided test	0.290679508	
F reject: one-sided test	0.1980069	

This is the result of reliability analysis between GR6 block and Yeonri samgeori sub-small block. It can be concluded that GR6 block and Yeonri samgeori sub-small block are not correlated to the water revenue ratio.

- P-value: 0.097062 > 0.05 (significance level)

Table 41 - Reliability analysis results GR6 small block and Yeonri samgeori

	GR6	Yeonri samgeori
Average	0.766126864	0.940257
Dispersion	0.010279524	0.008764
observation count	6	6
degree of freedom	5	5
F ratio	1.172877222	
P(F<=f) one-sided test	0.432679702	
F reject: one-sided test	5.050329058	

This is the result of reliability analysis between GR6 block and Gwangdo sub-small block. It can be concluded that GR6 block and Gwangdo sub-small block are correlated to the water revenue ratio.

- P-value: 0.01992 < 0.05 (significance level)

Table 42 - Reliability analysis results GR6 small block and Gwangdo

	GR6	Gwangdo
Average	0.766127	0.788729
Dispersion	0.01028	0.00129
observation count	6	6
degree of freedom	5	5
F ratio	7.96817	
P(F<=f) one-sided test	0.01992	
F reject: one-sided test	5.050329	

This is the result of reliability analysis between GR6 block and Osa sub-small block. Therefore, it can be concluded that GR6 block and Osa sub-small block are not correlated to the water revenue ratio.

- P-value: 0.065581471 > 0.05 (significance level)

Table 43 - Reliability analysis results GR6 small block and Osa

	GR6	Osa
Average	0.766126864	0.946009
Dispersion	0.010279524	0.044957
observation count	6	6
degree of freedom	5	5
F ratio	0.228650956	
P(F<=f) one-sided test	0.065581471	
F reject: one-sided test	0.1980069	

This is the result of reliability analysis between GR6 block and Gugok sub-small block. Therefore, it can be concluded that GR6 block and Gugok sub-small block are not correlated to the water revenue ratio.

- P-value: 0.001402975 > 0.05 (significance level)

Table 44 - Reliability analysis results GR6 small block and Gugok

	GR6	Gugok
Average	0.766126864	1.07707
Dispersion	0.010279524	0.265218
observation count	6	6
degree of freedom	5	5
F ratio	0.038758765	
P(F<=f) one-sided test	0.001402975	
F reject: one-sided test	0.1980069	

This is the result of reliability analysis between GR6 block and Oksan2 sub-small block. It can be concluded that GR6 block and Oksan2 sub-small block are not correlated to the water revenue ratio.

- P-value: 0.130249493 > 0.05 (significance level)

Table 45 - Reliability analysis results GR6 small block and Oksan2

	GR6	Oksan2
Average	0.766126864	0.952847
Dispersion	0.010279524	0.003487
observation count	6	6
degree of freedom	5	5
F ratio	2.947863046	
P(F<=f) one-sided test	0.130249493	
F reject: one-sided test	5.050329058	

This is the result of reliability analysis between GR6 block and Oksan1 sub-small block. It can be concluded that GR6 block and Oksan1 sub-small block are correlated to the water revenue ratio.

- P-value: 0.047208098 < 0.05 (significance level)

Table 46 - Reliability analysis results GR6 small block and Oksan1

	GR6	Oksan1
Average	0.766126864	0.907751
Dispersion	0.010279524	0.001976
observation count	6	6
degree of freedom	5	5
F ratio	5.203155732	
P(F<=f) one-sided test	0.047208098	
F reject: one-sided test	5.050329058	

This is the result of reliability analysis between GR6 block and Kisan sub-small block. It can be concluded that GR6 block and Kisan sub-small block are not correlated to the water revenue ratio.

- P-value: 0.212849782 > 0.05 (significance level)

Table 47 - Reliability analysis results GR6 small block and Kisan

	GR6	Kisan
Average	0.766126864	0.321234
Dispersion	0.010279524	0.021916
observation count	6	6
degree of freedom	5	5
F ratio	0.469046348	
P(F<=f) one-sided test	0.212849782	
F reject: one-sided test	0.1980069	

This is the result of reliability analysis between GR6 block and Kijok sub-small block. It can be concluded that GR6 block and Kijok sub-small block are correlated to the water revenue ratio.

- P-value: 0.003741666 < 0.05 (significance level)

Table 48 - Reliability analysis results GR6 small block and Kijok

	GR6	Kijok
Average	0.766126864	0.427451
Dispersion	0.010279524	0.000606
observation count	6	6
degree of freedom	5	5
F ratio	16.9558466	
P(F<=f) one-sided test	0.003741666	
F reject: one-sided test	5.050329058	

This is the result of reliability analysis between GR6 block and Eogok sub-small block. It can be concluded that GR6 block and Eogok sub-small block are not correlated to the water revenue ratio.

- P-value: 0.334263155 > 0.05 (significance level)

Table 49 - Reliability analysis results GR6 small block and Eogok

	GR6	Eogok
Average	0.766126864	0.835864
Dispersion	0.010279524	0.006865
observation count	6	6
degree of freedom	5	5
F ratio	1.497445086	
P(F<=f) one-sided test	0.334263155	
F reject: one-sided test	5.050329058	

This is the result of reliability analysis between GR6 block and Deukseong sub-small block. It can be concluded that GR6 block and Deukseong sub-small block are correlated to the water revenue ratio.

- P-value: 0.001648329 < 0.05 (significance level)

Table 50 - Reliability analysis results GR6 small block and Deukseong

	GR6	Deukseong
Average	0.766126864	0.981858
Dispersion	0.010279524	0.247731
observation count	6	6
degree of freedom	5	5
F ratio	0.04149476	
P(F<=f) one-sided test	0.001648329	
F reject: one-sided test	0.1980069	

This is the result of reliability analysis between GR6 block and Ogok sub-small block. Therefore, it can be concluded that GR6 block and Ogok sub-small block are not correlated to the water revenue ratio.

- P-value: 0.408059702 > 0.05 (significance level)

Table 51 - Reliability analysis results GR6 small block and Ogok

	GR6	Ogok
Average	0.766126864	0.606659
Dispersion	0.010279524	0.012794
observation count	6	6
degree of freedom	5	5
F ratio	0.803491128	
P(F<=f) one-sided test	0.408059702	
F reject: one-sided test	0.1980069	

This is the result of reliability analysis between GR6 block and Buri sub-small block. Therefore, it can be concluded that GR6 block and Buri sub-small block are not correlated to the water revenue ratio.

- P-value: 0.074620101 > 0.05 (significance level)

Table 52 - Reliability analysis results GR6 small block and Buri

	GR6	Buri
Average	0.766126864	1.04085
Dispersion	0.010279524	0.002522
observation count	6	6
degree of freedom	5	5
F ratio	4.075628451	
P(F<=f) one-sided test	0.074620101	
F reject: one-sided test	5.050329058	

This is the result of reliability analysis between GR6 block and Yongso/Sangyong sub-small block. Therefore, it can be concluded that GR6 block and Yongso/Sangyong sub-small block are correlated to the water revenue ratio.

- P-value: 0.026995778 < 0.05 (significance level)

Table 53 - Reliability analysis results GR6 small block and Yongso/Sangyong

	GR6	Yongso/Sangyong
Average	0.766126864	0.650525
Dispersion	0.010279524	0.070773
observation count	6	6
degree of freedom	5	5
F ratio	0.145246062	
P(F<=f) one-sided test	0.026995778	
F reject: one-sided test	0.1980069	

This is the result of reliability analysis between GR6 block and Mugyeo sub-small block. It can be concluded that GR6 block and Mugyeo sub-small block are correlated to the water revenue ratio.

- P-value: 0.224484506 < 0.05 (significance level)

Table 54 - Reliability analysis results GR6 small block and Mugyeo

	GR6	Mugyeo
Average	0.766126864	0.638396
Dispersion	0.010279524	0.021094
observation count	6	6
degree of freedom	5	5
F ratio	0.487331273	
P(F<=f) one-sided test	0.224484506	
F reject: one-sided test	0.1980069	

Correlation and reliability analysis of the water revenue ratio, sub-small blocks with significant correlation are Gwangdo, Gugok, Oksan1, Kijok, Deukseong, Yongso/Sangyong. Gugok and Oksan1 has a negative correlation

Table 55 - Correlation and reliability analysis result of 17 sub-small blocks in GR6

Classification	Correlation Analysis	Reliability (P<0.05)
Jikri	0.176	0.203
Yajeong/Sokri	0.514	0.145
Sajeon/Daegok	0.788	0.291
Yeonri samgeori	0.109	0.433
Gwangdo	0.706	0.020
Osa	0.289	0.066
Gugok	- 0.878	0.001
Oksan2	- 0.055	0.130
Oksan1	- 0.171	0.047

Classification	Correlation Analysis	Reliability (P<0.05)
Kisan	0.460	0.213
Kijok	0.253	0.004
Eogok	0.073	0.334
Deukseong	0.721	0.002
Ogok	- 0.051	0.408
Buri	0.197	0.075
Yongso/Sangyong	0.705	0.027
Mugyeo	- 0.661	0.224

Factors affecting the water revenue ratio of Gwangdo, Gugok, Oksan1, Kijok, Deukseong, Yongso/Sangyong sub-small blocks are as follows.

Table 56 - Factors affecting the water revenue ratio of sub-small blocks in GR6

Classification	Length of Distribution Pipe(M)	Length of Water Supply Pipe(M)	Faucet	Night Minimum Flow(㎥/hr)	Water Revenue Flow(%)
Gwangdo	1,928	1,237	42	0.1	58.5
Gugok	2,433	1,780	60	0.3	82.1
Oksan1	2,080	1,528	46	0.1	86.2
Kijok	2,085	2,095	125	2.0	39.5
Deukseong	3,082	3,943	164	8.9	67.8
Yongso/ Sangyong	7,630	6,673	293	6.0	51.9

4.2 Correlation analysis of the factors influencing the water revenue ratio

The correlation and influencing factors of the water revenue ratio of the three small blocks and 39 sub-small blocks are shown in Table 21, Table 35, and Table 56.

However, the factors that affect the water revenue ratio are shown differently depending on the region, the surrounding environment, and the characteristics of the block, and the correlation also varies. Nevertheless, the main factors in this study were analyzed only by length of distribution pipe, length of water supply pipe, faucet, and night minimum flow. Table 57 shows the affecting factors of sub-small blocks with a water revenue ratio correlation.

Table 57 - Factors affecting the water revenue ratio of 3 small blocks(GR3, GR5, GR6)

Classification		Distribution Pipe(M)	Length of Water Supply Pipe(M)	Faucet	Night Minimum Flow(㎥/hr)	Water Revenue Flow(%)
GR3	Singok1	1,270	1,373	69	0.7	71.1
	Baeksan	692	1,376	66	1.0	27.1
	Sinchon	2,006	1,179	66	0.5	88.5
GR5	Hwaam	6,968	4,440	186	1.8	57.0
	Yeonbong P.S	11,496	4,968	247	2.7	59.1
GR6	Gwangdo	1,928	1,237	42	0.1	58.5
	Gugok	2,433	1,780	60	0.3	82.1
	Oksan1	2,080	1,528	46	0.1	86.2
	Kijok	2,085	2,095	125	2.0	39.5
	Deukseong	3,082	3,943	164	8.9	67.8
	YongsoSangyong	7,630	6,673	293	6.0	51.9

The independent variables are length of distribution pipe (X1), length of water supply pipe (X2), faucet (X3), night minimum flow (X4) and the dependent variable is set to the water revenue flow (Y).

The correlation analysis results are as follows:

Table 58 - Correlation analysis results between the factors affecting the water revenue ratio

	Length of Distribution Pipe(M)	Length of Water Supply Pipe(M)	Faucet	Night Minimum Flow(㎥/hr)	Water Revenue Flow(%)
Length of Distribution Pipe(M)	1				
Length of Water Supply Pipe(M)	0.848055706	1			
Faucet	0.866598877	0.978343309	1		
Night Minimum Flow(㎥/hr)	0.345259623	0.699240674	0.672965598	1	
Water Revenue Flow(%)	-0.103308756	-0.228230242	-0.303512662	-0.17121355	1

5. Conclusion

5.1 Research result

To study the factors of sub-small blocks in small blocks affecting the water revenue ratio, it was selected GR3, GR5 and GR6 small blocks in Goryeong local water supply.

First, correlation analysis of 3 small blocks and 39 sub-small blocks, and 'F-verification: Dispersion of two groups with a 5% significance level were performed. The results showed that eleven sub-small blocks had a significant level of correlation with the water revenue ratio of the three small blocks. In detail, GR3 small block have 3 sub-small blocks(Singok1, Baeksan, Sinchon) out of total 12 sub-small blocks, GR5 small block have 2 sub-small blocks (Hwaam, Yeonbong Pressure Station) out of total 10 sub-small blocks and GR6 small block have 6 sub-small blocks (Gwangdo, Gugok, Oksan1, Kijok, Deukseong, Yongso/Sangyong) out of total 17 sub-small blocks

Table 59 - Correlation block and ratio in 3 small blocks

Classification	Total sub-small block (A)	sub-small block with correlation (개소, B)	correlation ratio (%, C=B/A)	name of sub-small block
Total	29	11	37.9	
GR3	12	3	25.0	Singok1, Baeksan, Sinchon
GR5	10	2	20.0	Hwaam, Yeonbong P.S
GR6	17	6	35.3	Gwangdo,Gugok, Oksan1,Kijok, Deukseong, Yongso/Sangyong

Secondly, 11 small blocks were analyzed for the correlation between the factors affecting the water revenue ratio. The independent variables are length of distribution pipe (X1), length of water supply pipe (X2), faucet (X3), night minimum flow (X4) and the dependent variable is set to the water revenue flow (Y)

As a result of the correlation analysis between the factors influencing the water revenue ratio, all of the factors negatively related to the water revenue ratio.

Faucet was the highest correlation with negative 0.3, length of water supply pipe is negative 0.23, night minimum flow is negative 0.17, and lastly length of distribution pipe extensions was corelated with negative 0.10.

Table 60 - Correlation ratio between the water revenue ration and factors

classification	length of distribution pipe(M)	length of water supply pipe(M)	faucet	night minimum flow(㎥/hr)
water revenue flow(%)	0.10	- 0.23	- 0.30	- 0.17

5.2 Limitations of research and future research direction

In order to enhance the water revenue ratio of local water supply in Korea, it is becoming common to construct sub-small block flow monitoring system when constructing a block system. This also proves that the current block system centered on small block is not easy to increase and maintain the water revenue ratio of high level over 80 percent. This study is significant in that the correlation analysis targets of the factors affecting the improvement of the water revenue ratio were not small block but sub-small block.

There are two main things that are somewhat desired in this study. The first was the lack of samples. The sub-small block flow monitoring system was limited to the Goryeong local water supply, so sufficient samples were not secured. The total number of samples used in this study is not so small as 39; however, only 11 samples have been proven to be of the water revenue ratio, which has limited analysis. Therefore, in future studies, securing more proven samples is a way to increase the reliability of the study.

Another is about the diversity of factors affecting the water revenue ratio. As mentioned earlier, the factors that affect the water revenue ratio are very variable depending on the conditions of the site and diverse environments. The four influencing factors used in this study; length of distribution pipe, length of water supply pipe, faucet and night minimum flow are rather basic factors but considered to be somewhat lacking in diversity.

Therefore, in addition to the four affecting factors of this study, it is deemed necessary to analyze factors such as replacement ratio of old pipes, number of pipe accidents and emergency restoration, and water pressure management of blocks.

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