A Study on the Efficiency Analysis of Local water and Sewage in Gyeongbuk province by using the DEA

By

KIM, Jin Kab

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF PUBLIC MANAGEMENT

2020

A Study on the Efficiency Analysis of Local water and Sewage in Gyeongbuk province by using the DEA

By

KIM, Jin Kab

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF PUBLIC MANAGEMENT

2020

Professor Lee, Junesoo

A Study on the Efficiency Analysis of Local water and Sewage in Gyeongbuk province by using the DEA

By

KIM, Jin Kab

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF PUBLIC MANAGEMENT

Committee in charge:

Junesoo Lee

Professor Lee, Junesoo, Supervisor ______________________

Professor Park, Jae Young ______________________

Approval as of May, 2020

Executive summary

Local water and sewage in Korea are operated by 161 local governments, so the rates and service levels are different for each region. The difference in water rates by region is up to 3.9 times. The national average water realization is 80.1%, but the realization rate of 96 municipalities with a population of less than 100,000 is only 47.2%. In addition, while the national average water supply rate exceeds 97%, the water service rate in rural areas is less than 60%.

This study aims to suggest ways to improve productivity by comparing and evaluating the efficiency of local water and sewage in Gyeongbuk province. The technique used in the analysis was applied to Data Envelopment Analysis (DEA), which is mainly used for efficiency evaluation. DEA is a type of linear programming used to assess the relative efficiency between Decision-Making units (DMUs) organized for similar purposes, using different types of inputs to produce different types of outputs. By evaluating the relative efficiencies of Gyeongbuk province water and sewage system, it will be examined whether the system is efficient or not. I further analyzed the factors affecting the efficiency of water and sewage systems and suggested implications for efficient water and sewage management.

The number of employees and operating costs was used as input factors for the efficiency of water supply, and the analysis was conducted using the water population, revenue water rate, and water fee income. The analysis results of this study are as follows. The results of the CCR analysis by DEA showed that the average efficiency score was 0.80 and there were 5 effective local governments. According to the BCC analysis, the average efficiency score is 0.87 points and 12 effective local governments account for 54.5% of the total.

The number of employees and operating costs was used as input factors for local sewage efficiency measurement, and the results were analyzed using sewage population, amount of wastewater, and sewage fee income.

The analysis results of this study are as follows. The results of the CCR analysis by DEA showed that the average efficiency score was 0.406, and there were 2 effective local governments. As a result of BCC analysis, the average efficiency score was 0.736 points and 5 effective local governments accounted for 22.7% of the total.

Factors that determine actual efficiency are variables that cannot be quantified, such as geographic location, facility ageing, employee abilities, and job satisfaction. In the future, it is necessary to develop a formula for evaluating the efficiency of local water and sewage, and further empirical analysis studies to verify reliability.

In addition, further research is needed to implement the integrated operation system, including the dam, river, and water and sewage information linkage. And, Further research is deemed necessary to realize the sequential integration of local sewage systems, such as the establishment of an integrated operation system, the linkage of the dam, stream and water supply information, the survey of staff for the integration of water supply and sewage organization and facility management work.

TABLE OF CONTENTS

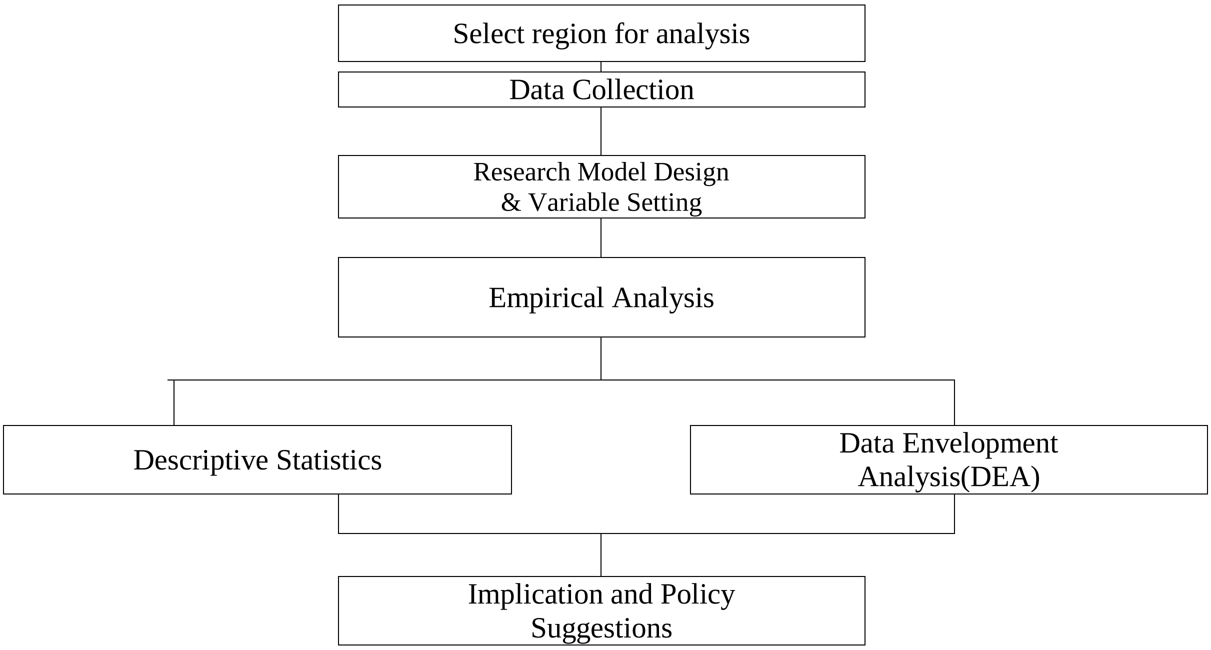
List of Table

1. Introduction

Water and sewage is a representative public good that is essential for the quality of life of citizens and industrial activities. The water supply rate in Korea has increased from 55% in 1980 to 98.1% in 2017 and the sewage treatment rate had also risen from 8.3% in 1980 to 93.6% in 2017. Even though the water supply and sewage, treatment sector has seen expanded coverage, there remain needed improvements in the quality of water and sewage operations and management in Korea. Local water supply systems are regarded as a local government's administrative services and are operated mainly by direct management. In terms of the local water and sewage business, there are severe imbalances in water and sewage services between regions, and its operation faces challenges with the financing and continuous improvement of facilities chronic operational-financial deficit. Needless to say that existing facilities are ageing, and employee capacities are not up-to-date.

Local water and sewage in Korea are operated by 161 local governments, so the rates and service levels are different for each region. Pyeongchang's water rate is 1,466.56 won/ton, but Gunwi's water rate is 376.09 won/ton, which is up to 3.9 times. The national water rate is 80.1%, while 96 municipalities with a population of less than 100,000 are 47.2% (Waterworks Statistics, 2017). In addition, while the national average water supply rate exceeds 97%, the water service rate in rural areas is less than 60%. For example, Cheongsong-gun has an 18,32 5 water service population and 11,438 sewage service population out of 26,201, respectively. The water rate is 426 won per ton, the production cost is 1,368 won per ton, and the price real ization rate is only 31.2% won (Waterworks Statistics, 2017). In Cheongsong, the sewage rate is 346 won per ton, the treatment cost is 1,269 won per ton, and the rate of sewage price realiz ation is 27.3% won (Sewage Statistics, 2017). Also, the non-revenue water rate is 59.7%. Thi s means 1,309,458 tons of water leakage and annual losses of 1.8billion won. Therefore, this study aims to suggest a way to improve productivity by comparing and evaluating the efficiency of local water and sewage system in Gyeongbuk province. The technique used for analysis is the data envelopment analysis (DEA), one of the techniques used primarily for efficiency evaluation. DEA is a type of linear programming used to assess the relative efficiency between decision-making units (DMUs) organized for similar purposes, using different types of inputs to produce different kinds of outputs. By evaluating the relative efficiencies of Gyeongbuk province water and sewage system, this will investigate the degree of inefficiency, further analyze the factors that affect the efficiency of water and sewage system, and draw implications for efficient water and sewage management in the future.

2. Research Procedure



3. Literature review

3.1 Concept of Efficiency

. The concept of efficiency in this paper refers to the effectiveness of a whole organization, that of local governments, the state, the businesses, and the efficiency of specific policies, such as the efficiency of economic policies. Since the 70s, there continues to be a strong interest in efficiency in the public sector of most governments. According to Rubin

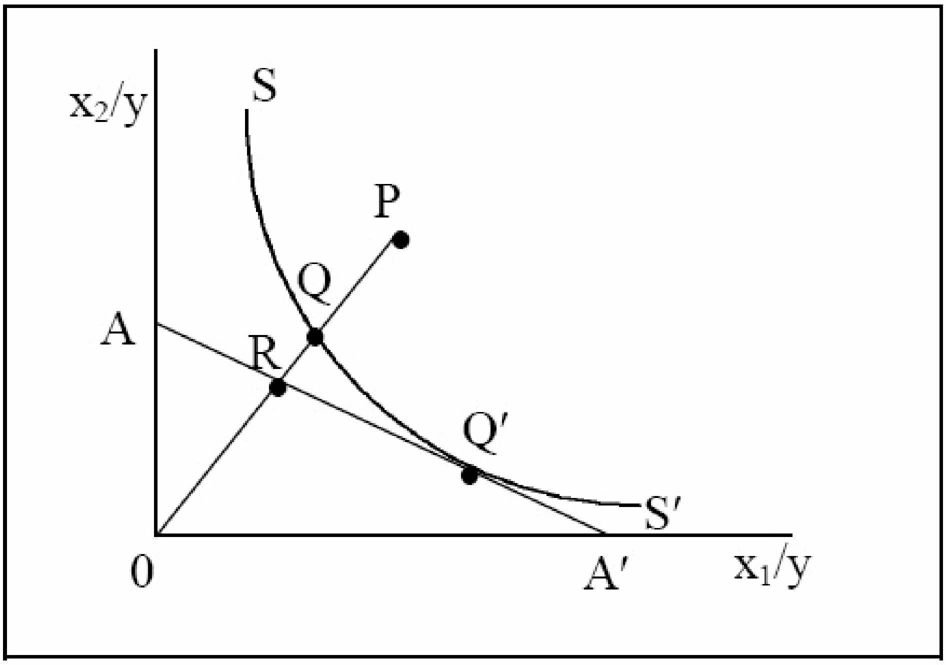
(1985), economic growth in the United Kingdom, and the United States have been slowing, and the competitiveness of the public sector has also waned; consequently, in the 80s, during the Thatcher, and Reagan's government in the UK and US respectively, performance-oriented strategies became more pronounced in the public sector. In the 1990s, management practices that emphasize economic efficiency worldwide became popular, and efficiency became a crucial value in organizational management.

In Korea,, the government of Kim Dae-jung and Roh Moo-hyun institutionalized a performance management system extensively to meet the demand for transparent disclosure of government activities and management of performance through performance evaluation (Lee, 2010).

Efficiency is defined as the ratio of output to input used by the production organization. Farrell (1957), proposed a method of measuring the efficiency of the distance concept; that the efficiency of a production organization can be measured as the distance away from the efficient set. The ability of a firm or public service provider to produce the maximum output at a given input is called technical efficiency, and the ability to determine the optimal input combination in terms of production factor prices is called allocation efficiency. For example, a production organization is considered to be technically efficient if, it has to reduce the output or increase its inputs in order to increase the output of a product. Allocative efficiency reflects the ability to increase the imports of production units using output factors at optimal rates given output price and production technology. Multiplying these two indicators yields an indicator of the overall (Yoo, 2008).

As shown in the figure below, the concept of efficiency in the input space representing the quantity of the two production elements x1 and x2 inputted to produce one unit of output y is as follows. The upper right portion of the curve SS' is a production possibility set with a fixed output level of 1 unit, and the curve SS' is the frontier which forms the boundaries of the productivity set. The straight-line AA' is an isocline that reflects the price of the factor of production. The production organization Q produces the same amount of output y as P, using only two OQ / OP levels used by the production organization P for the two production elements, x1 and x2, and defines this ratio as the technical efficiency of P. Is between 0 and 1. In addition, Q' produces the same amount as Q, so it has the same technical efficiency. At the same time, Q' can produce the same amount at the cost of OR / OQ lower than Q2.

Figure 1 Equivalence Curve and Efficiency under Input Constraints (Farrell)



Companies or organizations that are subject to efficiency evaluations are called Decision Making Units (DMUs). In Data Envelopment Analysis (DEA), independent decision-making capabilities are developed in the process of creating inputs by combining inputs. The DMU can be a department of a particular company or a whole company, and can also be a local government representing a local government, a social welfare function, a regional development function, a firefighting function, or a security function (Lim, 2000).

In this study, the DMU is the local government because the assessment of water and sewage efficiency is conducted by the local government, which is a water and sewage operator. In general, the concept of efficiency is defined as the ratio of the output factors to the input element, the most efficient value in the data is considered relative, and all values less than 1 are evaluated as inefficient.

3.2 Status of Water and Sewage in Gyeongbuk province

The local water and sewage system mean that local governments provide water and sewage services to local residents as the main supplier. In 2017, the water supply population in Gyeongbuk province was 2,511 thousand, with a water supply rate of 91.5%. There was a 5% difference from the national average water supply rate of 96.80%, indicating that there are still more people in Gyeongbuk than in other regions. Revenue water, which means the amount of water supplied for a fee, is also below the national average. If revenue water is high, it could reduce the water production, which means that the operating efficiency of water supply is good by reducing various operating costs such as raw water purchase cost, chemical cost, and power cost. Therefore, the Gyeongbuk province was administered economically in terms of revenue water compared to the national average. In the case of the realization rate, which means the ratio of average rate to the overall cost, the average value of Gyeongbuk province is much lower than the national average. Water rate does not cover the cost of production, which has led to reduced investment in the supply of safe and clean water and decreased services to the residents. For example, old facilities, such as rusty water pipes, are more likely to stop tap water supply, and rust can come from tap water. If the scale of the water supply system is small, the cost of tap water production is much higher. In Uiseong-gun, the cost of producing 1 ton of tap water is 5,245 won, 4,347 won higher than the national average of 898 won. Bonghwa-gun, Yeongcheon-si, and Uljin-gun also have higher production costs than the national average. In

Gimcheon-si, the production cost is 860 won per ton, which is the lowest among the Gyeongbuk province.

Table 1: Status of water in Gyeoungbuk province.

Municipality	Water Population	Distribution Rate(%)	Average Price (won/ton)	Overall Cost (won/ton)	Realization rate(%)
Pohang	494,823	95.3	860	1,060	81.1%
Gyeongju	246,142	91.8	1,160	1,593	72.8%
Gimcheon	127,177	87.7	633	866	73.1%
Andong	153,561	91.5	785	1,630	48.2%
Gumi	425,886	99.7	604	595	101.6%
Yeongju	96,441	88.1	1,020	1,345	75.9%
Yeongcheon	98,952	95.0	953	2,379	40.0%
Sangju	73,861	72.5	1,030	1,957	52.6%
Mungyeong	68,942	93.3	833	1,377	60.5%
Gyeongsan	266,494	99.2	875	1,080	81.0%
Gunwi	18,206	73.5	376	1,190	31.6%
Uiseong	46,567	86.1	784	5,245	14.9%
Cheongsong	18,325	69.9	426	1,368	31.2%
Yeongyang	15,480	87.5	710	2,178	32.6%
Yeongdeok	35,494	89.9	902	2,275	39.6%
Cheongdo	34,405	77.5	804	1,001	80.4%
Goryeong	33,246	93.6	593	1,120	52.9%
Seongju	33,992	72.6	727	1,292	56.3%
Chilgok	114,852	92.0	769	1,192	64.5%
Yecheon	41,585	83.5	741	1,715	43.2%
Bonghwa	22,114	65.9	496	3,193	15.5%
Uljin	36,372	69.5	796	2,911	27.3%
Ulleung	8,540	84.3	848	2,583	32.8%

In 2017, the total sewage population in Gyeongbuk province was 2,239 thousand, which cover 81.5% of the population. The number of people who have yet to receive sewage services is more significant than that of other regions, which showed that there is a 12 per cent gap between the average rates of 93.6 per cent in the country's public sewage service. Sewage realization rate, which means the ratio of average rate to the overall cost, Gyeongbuk province's rate is much lower than the national average. Sewage fees, which does not cover production costs, causes delay in the expansion of sewage treatment facilities and limit the investment in facility improvement. For example, in Yeongdeok-gun, the cost of treating 1ton of sewage is 5,212 won, 4,078 won higher than the national average of 1,134 won. Yeongcheon-city, and Sangju-county, where production costs are higher than the national average. Local water and sewage management in most parts of Gyeongbuk province have poor financial and facilities capabilities.

Table 2: Status of sewage in Gyeoungbuk.

Municipality	Sewage Population	Distribution Rate(%)	Average Price (won/ton)	Overall Cost (won/ton)	Realization rate(%)
Pohang	433,350	83.4	359	2,141	16.8%
Gyeongju	244,087	93.1	604	2,786	21.7%
Gimcheon	116,197	80.0	377	617	61.0%
Andong	132,296	78.9	336	2,662	12.6%
Gumi	418,620	97.9	348	801	43.4%
Yeongju	95,117	86.8	277	3,218	8.6%
Yeongcheon	75,769	72.7	420	4,020	10.5%
Sangju	68,259	72.6	284	3,700	7.7%
Mungyeong	60,908	82.3	259	2,560	10.1%
Gyeongsan	210,992	93.2	379	1,143	33.1%
Gunwi	9,444	38.1	330	2,909	11.3%
Uiseong	23,956	44.2	251	1,742	14.4%
Cheongsong	11,438	43.6	347	1,269	27.3%
Yeongyang	8,826	54.7	313	5,080	6.2%
Yeongdeok	29,444	74.7	438	5,212	8.4%
Cheongdo	24,853	56.0	134	610	21.9%
Goryeong	21,544	62.3	269	989	27.2%

Seongju	17,647	38.1	277	1,438	19.3%
Chilgok	92,057	77.3	459	2,647	17.3%
Yecheon	28,836	57.9	271	990	27.4%
Bonghwa	20,564	61.9	206	756	27.3%
Uljin	37,067	70.8	383	1,045	36.7%
Ulleung	168	1.6	0	0	#DIV/0!

3.3 Review of Previous Research

A number of studies were conducted using the Data Envelopment Analysis (DEA) on the efficiency of water supply and sewage services. The study of water utility by Won (1996), used the DEA research method for the operation efficiency of local water supply projects. Efficiency in public service delivery was estimated through the DEA model, which consisted of four inputs (personality, property, other operating and non-operating expenses) and three outputs (person-to-person, daily water supply, reliability, and profitability ratios). Yoo (2002), said that productivity changes are measured by considering manpower and capital input factors, water pipe extension, water supply transfer, and adjustment factors for the operation of 89 local water supply companies, and productivity is achieved by technological advancement rather than efficiency improvement. Lee (2004), analyzed the relationship between the two criteria by digitizing efficiency and equity through the DEA study on the theory that public services cannot take both equity and efficiency. Go et al. (2008), analyzed the efficiency of 160 water supply projects (local and non-local public enterprises) between 2001 and 2005 using the DEA. They explained that the larger the scale, the more efficient the water supply project, the lower the production cost, and the higher the efficiency of the production cost, after estimating the efficiency of the water rate revenue and the total production cost by the input variables. The study by Go et al. (2008), was meaningful in eliciting policy implications for improving efficiency by analyzing the relationship between the efficiency estimates measured through the

DEA and the characteristics of the entity. Won (2010), analyzed the methods of local water supply projects through the DEA analysis to derive good efficiency in consignment operation and sought efficient operation of local water supply projects at the same time. Yoo (2013), used the DEA to estimate the economies of scale of 105 water supply and water supply utilities in 2009 with labour (number of employees) and capital and output as water pipe extension, water supply transfer, adjustment and rate reality rates. Yoo (2014), used the DEA to measure cost efficiency of 91 local public enterprises between 2008 and 2011 to compare the consignee and the direct operating institutions of the water supply project. The analysis of labour and capital as input elements and the water pipe extension, water supply and water supply adjustment as output elements showed that consignment operation did not affect cost efficiency.

For the analysis of sewage utility, Yu (2001), measured the efficiency of the project by applying the input and output factors to the first 17 provincial sewage projects through the transcendental probability cost change function model. This study analyzed the efficiency and scale profits of 75 local sewage companies by applying the function model and analyzed the effectiveness of scale of local sewage companies by using non-radial Malmquist productivity index to supplement the limitations of previous studies. Choi (2002), derived the efficiency of the private consignment method by comparing the before and after private consignment operation of the Tancheon sewage treatment facility in Seoul. According to a study by Lee et al. (2003), the sewage treatment plants of 53 local governments and public parking lots of 48 cities nationwide were analyzed by the DEA method to investigate the difference in efficiency between local direct management and private consignment operations. The public parking lot found that private management was relatively efficient. In the study of Cho et al. (2007), DEA analysis was conducted on 39 sewage projects due to the continuous deficit management of local company-owned sewage projects, and the manpower and budget were input factors. The effective group was derived by considering as a factor and the benchmarking group was obtained through tier analysis.

Table 3: Previous researches

Field of Research	Researcher	Title	method	implication
Water	Kyung-Joon Yoon et al(1996)	Evaluation of Relative Efficiency of Local Government	DEA	Estimation of Efficiency of Waterworks Local waterworks
Water	Yoo Geum Rok(2002)	Analysis of productivity in Local Waterworks after the Foreign Exchange Crisis	Probability analysis	Local government productivity is driven by technological advances
Water	Lee Young Bum(2004)	An Empirical Study on the Relationship between Efficiency and Equity in Public Service Provision: Focused on Water Supply Projects.	DEA	Two Value Analysis of Efficiency and Equity for Waterworks Local Public Enterprises waterworks
Water	Go Kwang-hong et al.(2008)	Analyze the efficiency of 160 waterworks	DEA	Identify policy implications for improving efficiency
Water	Won Koo Hwan(2010)	An Analysis on the Consignment Efficiency of Local Waterworks	DEA	A Comparative Analysis on the Efficiency of Local government
Water	Choi Han Joo et al(2013)	A Study on the Efficiency Analysis of Local Water Supply in Chungbuk Province	DEA	Efficiency Analysis of 12 Local waterworks
Water	Yoo Geum Rok(2013)	The economies of scale of 105 waterworks	DEA	Proper scale of waterworks
Water	Yoo jiyoen (2014)	Cost-effectiveness measurement for local waterworks	DEA	Comparison of outsourcing and direct management
Sewage	Yoo Geum Rok(2001)	Efficiency of Local Sewage Projects	DEA	Operational Cost Effectiveness Analysis of 17 Sewage Projects
Sewage	Choi Byeongdae(2002)	Evaluation of the Performance of Private Entrustment of Environmental Base Facilities for Local Governments	Pre and post comparison	As a result of private consignment evaluation of sewage facilities
Sewage	Lee Sam-joo, Ko Seung-hee(2003)	private consignment assessment of sewage facilities	DEA	Efficiency of 53 municipal sewage treatment plants in DEA
Sewage	Cho Hyung Suk et al(2007)	Efficiency of Local Sewage Project Evaluation: Focusing on DEA and Tier Analysis	DEA	Analysis of the Efficiency of Sewage Projects in DEA Sewage
Sewage	Yoo Geum Rok(2012)	Evaluation of Efficiency and Scale Revenues of Local sewage	DEA	Analysis of 69 local sewage companies using the non-radical Malmquist productivity index

4. Research model

4.1 Research Methodology

The methodology of measuring efficiency in a sector can be distinguished mainly by the Frontier approach and the Non-Frontier approach. The Frontier approach is described as achieving maximum production with constant input under given technical conditions (Oh, 2000). For example, if a firm A produces more output than firm B in its maximum condition, firm A achieves Frontier Production (Lee et al, 2003). The most efficient enterprise is the organization on the production frontier curve, and the more inefficient the organization, the lower the production frontier curve. The non-frontier approach is a method of measuring efficiency without assuming a frontier, such as cost-benefit analysis, proportion analysis, and regression analysis. For example, the cost-benefit analysis used in preliminary feasibility studies in the public sector is used as a ratio of output to input, as a basis for determining the priorities of investment between the public sectors or for assessing the value of an investment. The frontier approaches include Stochastic Frontier Analysis (SFA) based on econometric methods and DEA, which measures relative efficiency based on linear programming. In this study, the DEA will be used to analyze the efficiency of local water and sewage in Gyeongbuk province.

4.2 Research Analysis Model

One of the frontier approaches, DEA is one of the linear programming methods developed by Charnes, Cooper, & Rhodes (1978) to measure the relative effectiveness of individual decision-making units such as non-profit organizations. Their work, called the CCR model, is based on a study of the technical efficiency performed by Farrell (1957), he used productive efficiency as the allocation and technical efficiency. He divided by technical efficiency and proposed a measure of effectiveness using a nonparametric approach.

DEA is a method of evaluating the relative efficiency of other decision units based on the productivity of the most efficient decision making unit (DMU). Unlike other methods of measuring efficiency, the effective frontier is derived from the data between the empirical inputs and outputs of the subjects based on the linear programming method, and then the inefficiency is measured by how far the subjects are from the effective frontiers. (Park, 2008).

It is not necessary to unite the unit of measurement of input and output into one unit like a monetary unit, so it is possible to measure relative efficiency even if the unit of measurement of each factor is different, so it is useful even in organizations where there is no fair market price for input and output. It has the advantage of being used in a way. It is easy to measure the efficiency of the public sector where non-quantitative value exists, such as water and sewage service.

The advantages of the DEA model are as follows.

First, it does not require a dictionary function form between input and output variables. In other words, unlike the econometric model, which assumes a specific production function and estimates efficiency through a statistically accurate production function, efficiency is analyzed by considering only the production possible set defined by a simple normal distribution.

Second, it is useful for producing multiple outputs using multiple inputs. Since the DEA directly estimates the weights of inputs and outputs that maximize the efficiency of the assessment target, there is no need to subjectively determine the weights in advance. It is also applicable when the unit of measure of input and output variables is different, and even when input and output cannot be converted into monetary units, as in the public sector.

Third, in the DEA, efficient DMUs are selected, and the relative group is measured as a reference group, which suggests how inefficient compared to efficient DMUs. Therefore, information can be obtained on which inputs should be reduced or which outputs should be increased to achieve efficiency. In addition, it shows whether the cause of inefficiency is due to purely technical or scale efficiency.

The CCR model was proposed by Charnes, Cooper, & Rhodes (1978). The output weighting sum for the input weighting sum of the DMU under the simple constraint that the ratio of the weighted sum of the output to the weighted sum of the inputs of the DMUs must not exceed 1, and that the weights of each input and output are greater than zero. It is a linear programming method to maximize the ratio of the output weighting sum to the input weighting sum of the DMU under simple constraints. Therefore, the CCR model represents performance as the ratio of input and output weights.

Since the CCR model assumes a Constant Retune Scale (CRS) of the output that scales up in proportion to the expansion of the DMU's input size, the efficiency score is limited to the combination of scale and technical efficiency.

On the other hand, the BCC model developed by Banker, Charnes & Cooper et al. is a modified DEA model to distinguish between scale efficiency and technical efficiency assuming Variable Returns Scale (VRS) . After all, the efficiency score of the BCC model represents pure technological efficiency excluding the effect of scale. The scale efficiency is less than or equal to 1 because the CCR efficiency is always less than or equal to the BCC efficiency. As mentioned earlier, CCR efficiency is called Technical Efficiency (TE) and BCC efficiency is called Pure Technical Efficiency (PTE) because it assumes VRS. Using this concept to decompose efficiency, we get

Scale Efficiency (SE) = CCR / BCC = Technology Efficiency (TE) / Pure Technology Efficiency (PTE)

This study aims to derive relative efficiency index through the DEA method linear planning model to measure local water and sewage efficiency. Detailed equations for the CCR model and BCC model are given in Appendix 1.

4.3 Analysis Data and Variable Setting

In this study, local governments were excluded from the 23 local governments in Gyeongbuk except for Ulleung-gun, which has different regional characteristics. The data was analyzed by comparing the efficiency of local water and sewage using 2017 water and sewage statistics.

Table 4: Local government of Gyeongbuk

Municipality (22)	Pohang City, Gyeongju City, Gimcheon City, Andong City, Gumi City, Yeongju, Yeongcheon City, Sangju City, Mungyeong City, Gyeongsan City, Gunwi County, Uiseong County, Cheongsong County, Yeongdeok County, Cheongdo County, Sungju County, Chilgok County, Yechon County, Bonghwa County, Uljin County

DEA analysis programs for efficiency analysis have been developed in various ways, including Frontier Analyst (Banxia Software Ltd), DEA-Solver-Pro (SAITECH Inc), EMS (Sheel), and B-BoxTM DEA (CalebABC Co. Ltd). Data was analyzed using the free software, which are EMS and B-Box DEA programs.

The inputs and outputs used for the relative efficiency analysis in the existing studies are shown in various ways such as labour cost, facility capacity, and the number of employees, capital cost, pipeline extension, water supply population, production volume, flow rate, and operating profit.

Table 5: Measurement variables

Item	Measurement variables
Input variables	Labour cost, goods cost, depreciation cost, capital cost, operating cost, non-operating cost, facility capacity, number of employees, net operating facility assets, total expenditure, water pipe extension
Output variables	Water supply population, production volume, water supply volume, adjustment amount, stability ratio, flow rate, profitability ratio, facility utilization rate, operating profit, gross revenue, water supply, water supply extension

The setting of variables for this study was determined by reference to existing studies. Costs, budgets and employees can be taken into account as input factors to measure the efficiency of local sewage the input element used the number of employees and operating expenses, considering that labour and facility operating costs accounted for the most significant portion. The elements used the flow rate, which stands for direct project execution, tap water production, and water supply rate revenue, the utilization rate of sewage treatment plant, sewage treatment volume, and sewage treatment rate revenue. Since the DEA assesses efficiency in terms of maximizing the percentage of output to inputs, input and output variables should be causative.

In addition, Copper (2000), proposes that the relationship between the number of decision units (n), the number of inputs (m), and the number of computed variables (s) should follow $n \geq \max(m \times s, 3(m+s))$ in order to secure the degree of freedom. With two inputs and three outputs, the number of decision-making units (n) is 22 in the number of local governments in Gyeongbuk Province, and two inputs and three outputs are valid.

Table 6: Input and output variable

Item	Input variables	Output variables
water	Number of employees, operating costs	Water population, flow rate, fee income
sewage	Number of employees, operating costs	Sewage Treatment Population, Sewage Treatment Volume, Fee Revenue

5. Water Supply Analysis Results

5.1 Water Supply Analysis Data

The number of employees in 22 cities and counties in Gyeongbuk, operating expenses, water supply population, flow rate, and fee income per cent as follows.

Table 7 Water analysis data

Municipality	Number of employees	Operating cost (one million won)	Water population	Revenue water (%)	Fee income (one million won)
Pohang	150	40,575	494,823	67.3	10,889
Gyeongju	62	28,172	246,142	55.3	18,319
Gimcheon	36	9,572	127,177	78.2	10,432
Andong	62	18,698	153,561	90.4	14,855
Gumi	84	44,453	425,886	88.8	14,353
Yeongju	42	17,123	96,441	62.1	8,098
Yeongcheon	46	14,168	98,952	55.6	17,139
Sangju	38	2,118	73,861	67.6	23,912
Mungyeong	52	7,267	68,942	48.8	6,570
Gyeongsan	57	25,391	266,494	73.7	15,712
Gunwi	15	959	18,206	52.9	299
Uiseong	31	8,187	46,567	52.7	25,528
Cheongsong	15	2,039	18,325	59.7	4,679
Yeongyang	28	2,707	15,480	68.8	8,023
Yeongdeok	41	3,812	35,494	55.8	4,989
Cheongdo	13	4,498	34,405	58.6	1,570
Goryeong	4	3,373	33,246	78.2	5,766
Seongju	18	4,030	33,992	66.7	15,351
Chilgok	40	10,442	114,852	78.7	10,276
Yecheon	9	6,156	41,585	81.2	11,618
Bonghwa	28	2,107	22,114	70.2	5,030
Uljin	28	3,029	36,372	68.5	16,810

5.2 Descriptive Statistics Analysis

As a result of descriptive statistical analysis of input factors, the average number of employees in local waterworks offices averages 40.2, and the operating costs average 11,293 million won. As a result of descriptive statistical analysis on output factors, the water supply population is 113,769, the flow rate is 67.3%, and the income is 11,373 million won.

Table 8: Descriptive statistics of water data

Item	Number of employees	Operating cost (one million won)	Water population	Revenue water (%)	Fee income (one million won)
Sum	899	258,874	2,502,917	1,480	250,219
Average	40.9	11,767.0	113,769.0	67.3	11,373.6
Dispersion	986	157,589,267	17,459,383,797	140	45,127,622
Standard Deviation	31.4	12,553.5	132,134.0	11.8	6,717.7
median	37	6,711.3	57,754.5	67.5	10,660.5
Mode	28			78.2	
Maximum	150	44,452.7	494,823.0	90.4	25,528.4
Minimum	4	959.2	15,480	48.8	299.3
Count	22	22	22	22	22
Standard error	6.7	2,676.4	28,171.1	2.5	1,432.2
Dwarf	2.1	1.6	1.9	0.4	0.4
Kurtosis	6.3	1.6	3.2	-0.7	-0.3

5.3 Efficiency Analysis by CCR Model

The CCR model is an analysis method that assumes revenue invariance (Constant Scale Return). The results of the efficiency analysis are shown in Table 9. As a result of measuring the efficiency score, Sangju-si, Gunwi-gun, Goryeong-gun, Seongju-gun, and Yecheon-gun were efficiently evaluated, accounting for 22.7% of the total 22 areas. In comparison, the efficiency of the Yeongdeok-gun local waterworks project was 0.436 and 0.479 in Yeongju-si, indicating that they are operating relatively inefficiently. The mean CCR efficiency score is 0.800, the standard deviation is 0.189, the maximum is 1.000, and the minimum is 0.436. The relative degree of inefficiency can be grasped compared to the area that is the efficiency reference group of each region. The reference group that can serve as a model for benchmarking is the one-efficiency group, and the analysis of the reference count in the efficiency analysis is also an essential criterion for grasping the qualitative aspect of efficiency. In the case of Yeongdeok, which has the lowest efficiency, the reference group is Sangju, Army-level Army, and Senior Citizens. The level of efficiency is lower than these reference groups. In order to improve the efficiency of the Yeongdeok, it is necessary to refer to the operation of the Sangju, Yeongyang, and Goryeong. The reference count is the reference count of the efficient regions used to evaluate the inefficient regions. The higher the number of references, the more frequently used to evaluate other inefficient regions. In Yecheon, the frequency of reference was only 1, whereas in Sangju and Goryeong, the frequency of reference was 16 times.

Table 9: CCR Efficiency score of water data

DMU		Score	Benchmarks	# of Reference
1	Pohang	0.896	8 (2.57) 17 (9.17)	
2	Gyeongju	0.768	8 (0.62) 17 (6.03)	
3	Gimcheon	0.970	8 (0.67) 17 (2.33)	
4	Andong	0.630	8 (0.71) 17 (3.05)	
5	Gumi	0.878	8 (0.77) 17 (11.09)	
6	Yeongju	0.479	8 (0.29) 17 (2.25)	
7	Yeongcheon	0.540	8 (0.44) 17 (1.99)	
8	Sangju	1.000		16
9	Mungyeong	0.505	8 (0.62) 17 (0.70)	
10	Gyeongsan	0.918	8 (0.70) 17 (6.47)	
11	Gunwi	1.000		4
12	Uiseong	0.924	18 (1.45) 20 (0.28)	
13	Cheongsong	0.885	8 (0.11) 11 (0.51) 17 (0.32)	
14	Yeongyang	0.723	8 (0.27) 11 (0.60) 17 (0.24)	
15	Yeongdeok	0.436	8 (0.30) 11 (0.38) 17 (0.20)	
16	Cheongdo	0.617	8 (0.13) 17 (0.74)	
17	Goryeong	1.000		16
18	Seongju	1.000		2
19	Chilgok	0.797	8 (0.62) 17 (2.08)	
20	Yecheon	1.000		1
21	Bonghwa	0.767	8 (0.18) 11 (0.96) 17 (0.10)	

22	Uljin	0.873	8 (0.56) 17 (0.29) 18 (0.12)	
Average		0.800		
Standard Deviation		0.189		
Maximum		1.000	Number of Efficiency 1	5
Minimum		0.436	Rate of Efficiency 1	21.7%

5.4 Efficiency Analysis by BCC Model

The BCC model is characterized by allowing variable returns to scale. In other words, it is effective to derive an inefficient place because of the size. According to the results of measuring the efficiency score, the efficiency scores of Pohang, Gimcheon, Andong, Gumi, Sangju, Gyeongsan, Gunwi, Uiseong, Goryeong, Seongju, Yecheon, and Bonghwa are measured as 1. Twelve out of twenty-two municipal efficiency scores were 1, representing 54.5% of the total. These results indicate that the efficiency of the whole is increased when the change of scale is recognized. The mean of the efficiency scores of the BCC model was 0.871, the standard deviation was 0.189, the maximum was 1.000, and the minimum was 0.456.

Looking at the reference frequency of the municipality with 1 efficiency, Goryeong had the most 8 times, followed by the Sangju city with the most 7 times.

Table 10: BCC Efficiency score of water data

DMU		Score	Benchmarks	# of Reference
1	Pohang	1.000		
2	Gyeongju	0.919	5 (0.32) 10 (0.36) 12 (0.31) 20 (0.01)	
3	Gimcheon	1.000		3
4	Andong	1.000		1
5	Gumi	1.000		1
6	Yeongju	0.504	3 (0.26) 10 (0.16) 17 (0.57)	
7	Yeongcheon	0.639	8 (0.31) 10 (0.21) 12 (0.06) 20 (0.42)	
8	Sangju	1.000		7
9	Mungyeong	0.510	3 (0.16) 8 (0.51) 17 (0.33)	
10	Gyeongsan	1.000		3

11	Gunwi	1.000		3
12	Uiseong	1.000		2
13	Cheongsong	0.924	8 (0.11) 11 (0.56) 17 (0.33)	
14	Yeongyang	0.815	8 (0.22) 17 (0.35) 21 (0.05) 23 (0.38)	
15	Yeongdeok	0.456	8 (0.26) 11 (0.54) 17 (0.20)	
16	Cheongdo	0.648	8 (0.08) 11 (0.15) 17 (0.77)	
17	Goryeong	1.000		8
18	Seongju	1.000		1
19	Chilgok	0.871	3 (0.83) 4 (0.02) 17 (0.07) 20 (0.07)	
20	Yecheon	1.000		3
21	Bonghwa	1.000		1
22	Uljin	0.877	8 (0.59) 17 (0.37) 18 (0.04)	
Average		0.871		
Standard Deviation		0.189		
Maximum		1.000	Number of Efficiency 1	12
Minimum		0.456	Rate of Efficiency 1	54.5%

Scale efficiency (SE) is the efficiency figure of the CCR model divided by the efficiency figure of the BCC model. The efficiency score of the CCR model is called technical efficiency (TE) because it does not take the effect of scale into account. The BCC model, on the other hand, shows the pure technical efficiency (PTE) in part under variable returns on scale. Areas with an efficiency scale of 1 and a pure technology efficiency score of 1 are all in Sangju, County, Goryeong, Seongju, and Yecheon, the same as the results of the CCR model.

However, Kimcheon, Uiseong, Gyeongsan, Pohang, Gumi, Bonghwa, Andongsi showed that the efficiency was 1 only in the BCC model, indicating that the cause of inefficiency was due to scale inefficiency. In other words, these seven regions had a pure technical efficiency of 1 point in the BCC model, but the efficiency score of the CCR model was less than 1, so the overall efficiency was evaluated as inefficiency. The overall efficiency of the CCR model is 80%, and the efficiency of pure technology is about 87.1%, which is 7.1%

higher than the efficiency of the CCR model. These results mean that the inefficiency of scale is about 7.1%.

Table 11: Scale Efficiency score of water data

DMU		CCR Technology Efficiency	BCC Pure Technology Efficiency	Scale Efficiency (SE)
1	Pohang	0.896	1.000	0.896
2	Gyeongju	0.768	0.919	0.836
3	Gimcheon	0.970	1.000	0.970
4	Andong	0.630	1.000	0.630
5	Gumi	0.878	1.000	0.878
6	Yeongju	0.479	0.504	0.951
7	Yeongcheon	0.540	0.639	0.845
8	Sangju	1.000	1.000	1.000
9	Mungyeong	0.505	0.510	0.991
10	Gyeongsan	0.918	1.000	0.918
11	Gunwi	1.000	1.000	1.000
12	Uiseong	0.924	1.000	0.924
13	Cheongsong	0.885	0.924	0.957
14	Yeongyang	0.723	0.815	0.887
15	Yeongdeok	0.436	0.456	0.955
16	Cheongdo	0.617	0.648	0.952
17	Goryeong	1.000	1.000	1.000
18	Seongju	1.000	1.000	1.000
19	Chilgok	0.797	0.871	0.915
20	Yecheon	1.000	1.000	1.000
21	Bonghwa	0.767	1.000	0.767
22	Uljin	0.873	0.877	0.996
Average		0.800	0.871	0.921
Standard Deviation		0.189	0.189	0.091
Maximum		1.000	1.000	1.000
Minimum		0.436	0.456	0.630

In areas where inefficiency has been shown, efficiency should be enhanced by a reduction in input or an increase in output components. Yeongdeok, Yeongju, and Mungyeong which are the least efficient as a result of the DEA analysis, the number of employees input and operating expenses shall be reduced, and the revenue water ratio and water fee income should be increased. Given the fact that the number of employees cannot be reduced, however, it is necessary to reduce operating costs through staff training and operational efficiency and to increase the realization rate.

Table 12: Efficiency improvement method in waterworks

Item	Number of employees			Operating costs (million won)		
	Present	Target	Reduction	Present	Target	Reduction
Youngduk	41	17.8	23.1	3,188	1,660	1,528
Yoeungju	42	20.1	21.8	17,122	8,208	8,914
Mungyeong	52	26.2	25.7	7,266	3,672	3,594

Item	Water population			Revenue Water Rate(%)			Fee income (million won)		
	Present	Target	increase	Present	Target	increase	Present	Target	increase
Youngduk	35,494	35,494	0	55.8	61.7	5.9	4,988	7,451	2,463
Yoeungju	96,441	96,441	0	62.1	77.4	15.3	8,097	8,635	538
Mungyeong	68,942	68,942	0	48.8	72.7	23.9	6,569	15,827	9,258

6. Sewage Analysis Results

6.1 Sewage Analysis Data

The number of local municipal sewage staff, operating costs, sewage treatment population, throughput, and sewage fee income in Gyeongbuk are as follows.

Table 13: Sewage analysis data

Municipality	Number of employees	Operating cost (one million won)	Sewage Treatment Population	Sewage treatment (㎥ / day)	Sewage rate income (one million won)
Pohang	152	158,207	433,350	223,833	21,588
Gyeongju	103	92,765	244,087	117,708	14,253
Gimcheon	63	38,831	116,197	65,940	6,548
Andong	68	76,998	132,296	53,548	4,979
Gumi	112	112,365	418,620	385,481	38,616
Yeongju	31	28,121	95,117	38,377	2,652
Yeongcheon	69	54,805	75,769	41,349	3,051
Sangju	58	28,629	68,259	21,708	1,667
Mungyeong	74	33,046	60,908	38,121	2,059

Gyeongsan	21	38,764	210,992	33,817	9,318
Gunwi	14	12,597	9,444	2,573	181
Uiseong	30	33,203	23,956	10,492	538
Cheongsong	18	23,131	11,438	8,022	713
Yeongyang	19	9,233	8,826	2,685	275
Yeongdeok	39	23,824	29,444	13,951	1,255
Cheongdo	22	15,445	24,853	13,698	273
Goryeong	18	19,372	21,544	7,213	575
Seongju	21	41,520	17,647	6,080	466
Chilgok	49	60,664	92,057	44,553	6,269
Yecheon	44	14,583	28,836	7,693	571
Bonghwa	32	22,447	20,564	5,396	135
Uljin	34	33,286	37,067	16,743	1,476

6.2 Descriptive Statistics Analysis

As a result of descriptive statistical analysis of input and output factors, the average number of local sewage employees was 9.6, and the operating cost averaged 44,174 million won. The result of descriptive statistical analysis on the output factor is 99,149 sewage treatment population, 52,661 ㎥ / day of sewage treatment, and KRW 5,339 million of revenue.

Table 14: Descriptive statistics of sewage data

Item	Number of employees	Operating cost (one million won)	Sewage Treatment Population	Sewage treatment (㎥ / day)	Sewage rate income (one million won)
Sum	1,091	971,835	2,181,271	1,158,981	117,458
Average	49.6	44,174	99,149	52,681	5,339
Dispersion	1,277	1,346,055,517	15,202,711,354	7,998,786,189	83,621,515
Standard Deviation	35.7	36,688.6	123,299.3	89,435.9	9,144.5
median	36.5	33,124.6	48,987.5	19,225.7	1,571.5
Mode	21.0				
Maximum	152	158,207	433,350	385,481	38,616
Minimum	14	9,233	8,826	2,573	135
Count	22	22	22	22	22

Standard error	8	7,822	26,287	19,068	1,950
Dwarf	1.46	1.88	1.93	3.01	2.78
Kurtosis	1.99	3.61	3.08	9.59	8.39

6.3 Efficiency Analysis by CCR Model

As a result of efficiency scores, Gumi and Gyeongsan were evaluated efficiently among 22 regions. In comparison, the efficiency of Seongju local sewage projects is 0.118 and 0.139, which is relatively inefficient. The mean CCR efficiency score was 0.406, the standard deviation was 0.262, the maximum was 1.000, and the minimum was 0.118.

Table 15 CCR Efficiency score of sewage

DMU		Score	Benchmarks	# of Reference
1	Pohang	0.612	5 (0.48) 10 (1.09)	
2	Gyeongju	0.578	5 (0.25) 10 (0.67)	
3	Gimcheon	0.686	5 (0.15) 10 (0.26)	
4	Andong	0.362	5 (0.10) 10 (0.43)	
5	Gumi	1.000		20
6	Yeongju	0.713	5 (0.07) 10 (0.31)	
7	Yeongcheon	0.313	5 (0.09) 10 (0.18)	
8	Sangju	0.480	5 (0.03) 10 (0.26)	
9	Mungyeong	0.434	5 (0.09) 10 (0.11)	
10	Gyeongsan	1.000		20
11	Gunwi	0.147	5 (0.00) 10 (0.04)	
12	Uiseong	0.155	5 (0.02) 10 (0.07)	
13	Cheongsong	0.139	5 (0.02) 10 (0.02)	
14	Yeongyang	0.191	5 (0.00) 10 (0.03)	
15	Yeongdeok	0.270	5 (0.03) 10 (0.08)	
16	Cheongdo	0.366	5 (0.03) 10 (0.06)	
17	Goryeong	0.226	5 (0.01) 10 (0.08)	
18	Seongju	0.118	5 (0.01) 10 (0.06)	
19	Chilgok	0.344	5 (0.11) 10 (0.22)	
20	Yecheon	0.387	5 (0.01) 10 (0.12)	
21	Bonghwa	0.179	5 (0.01) 10 (0.08)	
22	Uljin	0.241	5 (0.03) 10 (0.11)	

Average	0.406		
Standard Deviation	0.261		
Maximum	1.000	Number of Efficiency 1	2
Minimum	0.118	Rate of Efficiency 1	9.1%

6.4 Efficiency Analysis by BCC Model

According to the BCC model efficiency score, the Pohang, Gumi, Gyeongsan, Gunwi, and Yeongyang scored 1. 5 of the 22 municipality efficiency scores were measured at 1, representing 22.7% of the total. These results indicate that the efficiency of the whole is increased when the change of scale is recognized. The mean of the efficiency scores of the BCC model was 0.736, standard deviation 0.206, maximum 1.000, and minimum 0.220, respectively. As for the reference number of municipalities with 1 efficiency, there were 17 in Gyeongsan and 15 in Gumi.

Table 16 BCC efficiency score of sewage

DMU		Score	Benchmarks	# of Reference
1	Pohang	1.000		0
2	Gyeongju	0.585	5 (0.25) 10 (0.66) 14 (0.09)	
3	Gimcheon	0.805	5 (0.15) 10 (0.23) 14 (0.62)	
4	Andong	0.417	5 (0.10) 10 (0.41) 11 (0.15) 14 (0.34)	
5	Gumi	1.000		15
6	Yeongju	0.884	5 (0.07) 10 (0.28) 14 (0.65)	
7	Yeongcheon	0.417	5 (0.09) 10 (0.15) 14 (0.76)	
8	Sangju	0.672	5 (0.03) 10 (0.23) 14 (0.74)	
9	Mungyeong	0.622	5 (0.09) 10 (0.08) 14 (0.83)	
10	Gyeongsan	1.000		17
11	Gunwi	1.000		9
12	Uiseong	0.529	5 (0.01) 10 (0.16) 11 (0.83)	
13	Cheongsong	0.846	10 (0.17) 11 (0.83)	
14	Yeongyang	1.000		12

15	Yeongdeok	0.560	5 (0.03) 10 (0.05) 14 (0.92)	
16	Cheongdo	0.900	5 (0.03) 10 (0.02) 11 (0.35) 14 (0.60)	
17	Goryeong	0.836	5 (0.00) 10 (0.13) 11 (0.87)	
18	Seongju	0.704	10 (0.11) 11 (0.89)	
19	Chilgok	0.498	5 (0.08) 10 (0.37) 11 (0.55)	
20	Yecheon	0.851	5 (0.01) 10 (0.09) 14 (0.91)	
21	Bonghwa	0.548	5 (0.00) 10 (0.05) 11 (0.37) 14 (0.57)	
22	Uljin	0.524	5 (0.03) 10 (0.07) 11 (0.84) 14 (0.05)	
Average		0.736		
Standard Deviation		0.206		
Maximum		1.000	Number of Efficiency 1	5
Minimum		0.417	Rate of Efficiency 1	22.7%

An efficiency scale of 1 and a pure technology efficiency score of 1 are both Gumi and Gyeongsan, which are the same as the results of the CCR model. However, Pohang, Yeongyang, and Gunwi showed that the efficiency was 1 only in the BCC model, indicating that the cause of inefficiency was due to scale inefficiency. In other words, these three regions had one point of pure technical efficiency of the BCC model, but the efficiency score of the CCR model was less than one, so the overall efficiency was evaluated as inefficiency. The overall efficiency of the CCR model is 40.6%, and the efficiency of pure technology is about 73.6%, 33% p higher than the efficiency of the CCR model. This means that the inefficiency of scale is about 33%.

Table 17: Scale efficiency score of sewage

DMU		CCR Technology Efficiency	BCC Pure Technology Efficiency	Scale Efficiency (SE)
1	Pohang	0.612	1.000	0.612
2	Gyeongju	0.578	0.585	0.988
3	Gimcheon	0.686	0.805	0.852
4	Andong	0.362	0.417	0.870
5	Gumi	1.000	1.000	1.000
6	Yeongju	0.713	0.884	0.806

7	Yeongcheon	0.313	0.417	0.751
8	Sangju	0.480	0.672	0.714
9	Mungyeong	0.434	0.622	0.698
10	Gyeongsan	1.000	1.000	1.000
11	Gunwi	0.147	1.000	0.147
12	Uiseong	0.155	0.529	0.293
13	Cheongsong	0.139	0.846	0.165
14	Yeongyang	0.191	1.000	0.191
15	Yeongdeok	0.270	0.560	0.483
16	Cheongdo	0.366	0.900	0.407
17	Goryeong	0.226	0.836	0.270
18	Seongju	0.118	0.704	0.167
19	Chilgok	0.344	0.498	0.691
20	Yecheon	0.387	0.851	0.454
21	Bonghwa	0.179	0.548	0.326
22	Uljin	0.241	0.524	0.459
Average		0.406	0.736	0.561
Standard Deviation		0.261	0.206	0.292
Maximum		1.000	1.000	1.000
Minimum		0.118	0.417	0.147

Efficiency should be improved by reducing inputs or increasing outputs. As a result of DEA analysis, the least efficient Gunwi, Cheongsong and Seongju should significantly reduce the number of employees and operating costs as inputs, and increase sewage treatment population and fee income. However, the number of employees cannot be reduced; it is necessary to increase revenue and reduce the operating cost through the efficiency of staff training and operational efficiency.

Table 18: Efficiency improvement method in the sewage system

Item	Number of employees			Operating costs (million won)		
	Present	Target	Reduction	Present	Target	Reduction
Youngduk	14	1.2	12.8	12,597	1,853	10,744
Yoeungju	18	2.5	15.5	23,131	2,790	20,341
Mungyeong	21	2.5	18.5	41,519	3,604	37,915

Item	Sewage Treatment	Sewage treatment(㎡ / day)	Sewage rate income

	Population						(one million won)		
	Present	Target	increase	Present	Target	increase	Present	Target	increase
Youngduk	9,444	9,444	0	2,572.0	2,572.0	0.0	181	181	0
Yoeungju	11,438	44,596	33,158	8,022.0	8,022.0	0.0	713	1,774	1,061
Mungyeong	17,647	32,066	14,419	6,079.0	6,079.0	0.0	466	1,206	740

7. Conclusion

Water and sewage are public goods that are essential for people's lives and are in charge of expanding tap water supply, ensuring safe water quality, and preserving the. Therefore, this study attempted to derive useful management information of water and sewage operation by measuring the efficiency of local water and sewage and analyzing the factors influencing the efficiency according to the demand. This study used Data Envelope Analysis (DEA) as an analytical method which is CCR and BCC model.

The employees and operating costs were used as input factors for the efficiency of local water supply, and the analysis was conducted using the water supply population, revenue water ration, and water supply rate.

The analysis results of this study are as follows: the results of the CCR analysis by DEA showed that the average efficiency score was 0.80 and 5 effective local governments were 21.7%. According to the BCC analysis, the average efficiency score is 0.87 points and 12 effective local governments account for 54.5% of the total.

Employees and operating costs were used as input factors for local sewage efficiency measurement, and the results were analyzed using sewage treatment population, sewage treatment volume, and sewage fee income.

The analysis results of this study are as follows: the results of the CCR analysis by DEA showed that the average efficiency score was 0.406 and 2 effective local governments were 9.1% of the total. As a result of BCC analysis, the average efficiency score was 0.736 points and 5 effective local governments accounted for 22.7% of the total. Looking at the number of times each efficient municipality is used as a reference group, Gyeongsan was the most used 17 times.

8. Recommendation and Limitation

8.1 Recommendation

Both water and sewage system, which has similarities in the management sector makes it possible to pursue a scale of economies responsible for the entire process from tap water supply to sewage treatment rather than operating separately. In other words, by linking and expanding the operation mechanisms of water and sewage, the effect is to reduce the overall cost of the operation. In particular, it could save money by eliminating overlapping functions through the integration of the water and sewage management sectors. The comprehensive implementation of water and sewage system, including the water and sewage basic plan, will realize the integration of water management considering the entire water cycle, and reduce the financial burden by unifying fiscal management. It is also necessary to strengthen job training for employees to improve their expertise so that water and sewage facilities can be operated more effectively.

For example, if the construction of a water supply pipe is carried out simultaneously in the sewage pipe, the construction period and cost of the water supply can be reduced, and residents' inconvenience can be minimized. In addition, integrating the inspection and maintenance of water and sewage facilities can reduce time and cost. And while complaints about water and sewage services are divided into water and sewage services, there is a high possibility that the integration of water and sewage services will lead to a one-stop solution of various complaints about water and sewage through the operation of the integrated service center in the water supply and sewage system. Since K-water is operating the local sewage system in Cheongsong for the first time in Korea, it is expected that K-water will be able to secure competitiveness in the global water market and be used as a new growth opportunity along with its existing businesses by presenting integrated water and sewage management model.

8.2 Limitation

The DEA analysis is a measure of how efficient the DMU is, so the efficiency score itself is the result of a relative evaluation. Therefore, the degree of efficiency may be comparable, but there is a limit in explaining the actual difference value of efficiency. And there are various factors in assessing local water and sewage system efficiency. This study analyzed efficiency by using two inputs and three variables. However, factors that determine actual efficiency also exist that cannot be quantified, such as geographical location, facility condition, employee expertise, and work satisfaction. In the future, it is necessary to develop a formula for evaluating the efficiency of local water and sewage, and further empirical analysis studies to verify reliability.

In addition, further research is needed to implement the integrated operation system including dam, river, and water and sewage information linkage. And, further research is necessary to realize the sequential integration of local sewage systems, such as the establishment of an integrated operation system, the linkage of dam, stream and water supply information, the survey of staff for the integration of water supply and sewage organization and facility management work.

References

Banker, R. D., Charnes, A. and Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science, 30(9): Pages1078-1092.

Charnes, A., Cooper, W. W. and Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units, European Journal of Operational Research, Vol. 2: Pages429-444.

Cho, Hyung-Seok, Moon-Ho Moon, (2007) Korea Institute of Local Administration, 12-151 Evaluating Relative Efficiency of Local Sewage Systems -Evidence from DEA and Tier Analysis-

Choi (2014). Case Study on the Efficiency of Local Water Supply in Jeollabuk-do using DEA and Mamquist Index. Digital Convergence Research, 12 (12): 571-580.Banker, R. D.,

Charnes, A. & Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science, Vol.30 No.9, pp. 1,078-1,092.

Choi, Byung-Dae (2002), Performance Evaluation of Private Entrustment of Environmental Basic Facilities of Local Governments-Focusing on Tancheon Sewage Treatment Plant in Seoul City, Korea Local Government Association

Choi, Han-Joo and Seol-Young Hoon (2013), “A Study on the Analysis of Local Waterworks Efficiency in Chungbuk Province.“ Regional Policy Research, 24 (2): 57-77.

Farrell, M.J. (1957). The Measurement of Productive Efficiency. Journal of Royal Statistical Society. Series A, 120(3), 253-290.

Go Kwang-hong et al (2008). For efficient operation management plan of water supply business DEA performance analysis. Accounting Research 13 (1), 123-150.

Lee Eun-kuk, Won-gu Won and Oh Seung-eun (2003) Theory and Practice of Local Government Productivity Measurements. Seoul: House Moon.

Lee, Jung-dong and Oh Dong-hyun (2012). Efficiency Analysis Theory: DEA Data Envelope Analysis. Gifil Media Co., Ltd.

Lee, Sam-joo, Ko Seung-hee (2003), Relative Efficiency Analysis of Private Consignment for Local Governments, Local Administrative Studies

Lee, Soung-Beom (2004), An Empirical Study on the Relationship between Efficiency and Equity in Public Service Delivery Research: A Study on Korean Administration, Focusing on Water Supply Projects

Lee, Young-Beom (2003), A Method of Adjusting Differential Operating Conditions in Measuring Organizational Efficiency Using DEA, Korean Policy Studies Review 12 (3).

Ministry of Environment (2017), Water works statistics

Oh, Seung-eun (2000). Efficiency Analysis of Corporate Activities in Local Governments-Focused on Local Public Development Projects, Yonsei University.

Park, Man Hee (2008), Efficiency and Productivity Analysis-Data Envelope and Malmquist Productivity Analysis Mainly, Academic Information of Korea

Rubin, I. (1985), Shrinking the federal government: the effect of cutbacks of five federal agencies, Longman.

Won (2010). Analysis of Commissioning Efficiency of Professional Institutions in Local Waterworks Projects. Korean Local Government Research, 12 (3): 91-110.

Yoo Geum-rok (2002), Analysis of Changes in Productivity of Local Waterworks Projects after the Foreign Exchange Crisis, Korean Journal of Public Administration, Vol. 36, No. 4, p.281 ~ 301.

Yoo, Geum-rok (2008), An empirical evaluation of the efficiency and its determinants of the public sector using a boostrapped data envelopment analysis: An application to public health centers in Seoul metropolitan city, The Korea Association for Policy Studies, Vol.17 No.2 page 291-322.

Yoo, Geum-rok (2013). Evaluation of Operational Efficiency, Scale Efficiency, and Scale Economy of Local Waterworks Coating Company Using Directional Distance Function Model. Korean Journal of Public Administration, 47 (2): 275-311.

Yoo, Jiyeon (2014). A Study on the Effect of Consignment Operation of Local Waterworks Companies on Cost Efficiency. Korean Journal of Finance, 19 (2), 101-130.

Yoon and Won (1996). Evaluation of Relative Efficiency of Local Enterprises: Data Envelopment Analysis of Urban Water works Projects. Korean Administrative Studies, 5 (4), 119-139.

Appendix 1 Equation of CCR and BCC model

1. CCR model

The CCR model is an efficiency measurement model that derives the ratio that can reduce the input as much as possible while fixing the level of output from the feasible set that satisfies the constant return. Where *n* is the output factor, *m* is the input factor, and *j* is the subscript representing the DMU, the local government to be analyzed. The objective function *k* is the rate at which the inputs of the kth DMU of interest are reduced. If the inputs are reduced equally by all inputs, then the kth DMU will reach production change. On the other hand, and are margins for input and output respectively.

$$\theta^{k^*} = \min_{\theta,\lambda,s^-,s^+} + [\theta^k - \epsilon(\sum_{m=1}^{M} s_m^- + \sum_{n=1}^{N} s_m^+)]$$

Subject to $\theta^k x_m^k = \sum_{j=1}^{J} x_m^j \lambda^j + s_m^-$ $(m = 1,2,3,\ldots, M)$

$y_n^k = \sum_{j=1}^{J} y_n^j \lambda^j - s_n^+$ $(n = 1,2,3, \ldots, N)$

$\lambda^j \geq 0$ $(j = 1,2,3, \ldots, J)$

$s_m^- \geq 0$ $(m = 1,2,3, \ldots, M)$

$s_n^+ \geq 0$ $(n = 1,2,3, \ldots, N)$

2. BCC model

Next, if the unsatisfactory assumptions of unprofitable income are not satisfied among the axioms of the producible sets, a producible set that satisfies variable scale returns is obtained.

$$\theta^{k*} = \min_{\theta,\lambda} \theta^{k}$$

Subject to $\theta^{k} x_m^k \geq \sum_{j=1}^{J} x_m^j \lambda^j$ $(m = 1,2,3,. \ldots, M)$

$$y_n^k \leq \sum_{j=1}^{J} y_n^j \lambda^j \quad (n= 1,2,3, \ldots, N)$$

$$\sum_{j=1}^{J} \lambda^j = 1$$

$$\lambda^j \geq 0 \quad (j = 1,2,3, \ldots, J)$$

On the other hand, the efficiency value derived from the CCR model is divided by the efficiency value derived from the BCC model to obtain Scale Efficiency. This is called pure scale efficiency.

$$SE = \frac{\theta^{k*}(CCR)}{\theta^{k*}(BCC)}$$

Appendix 2 Verification by Regression Analysis

1. Efficiency Determinant Analysis

Based on the DEA analysis results, a regression analysis was conducted to more clearly identify the factors causing differences in the efficiency of local water and sewage. This method is also known as post-DEA. The average of the sewage efficiency index measured in the CCR model and the BCC model was set as the dependent variable, and the regression analysis was performed using the input and output variables used as the independent variables.

2. Water supply system

Looking at the explanatory of the regression model and the suitability of the model, the ability to explain the variation in the efficiency score, where the variation of the input and output factors as independent variables is the dependent variable, was 68.3% (corrected R-squared = 0.585).

모형 요약

모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.827[a]	.683	.585	.118102

a. 예측값: (상수), 급수수익백만원, 유수율, 직원수, 운영비용백만원, 급수인구

In addition, the regression model established in the study was found to be statistically appropriate (F = 6.909, p = 0.001).

분산분석 [a]

모형		제곱합	자유도	평균 제곱	F	유의확률
1	회귀 모형	.482	5	.096	6.909	.001[b]
	잔차	.223	16	.014		
	합계	.705	21			

a. 종속변수: 효율성점수평균

b. 예측값: (상수), 급수수익백만원, 유수율, 직원수, 운영비용백만원, 급수인구

The variables that have a significant effect on the efficiency score among the input and output factors of local water supply are the number of employees, operating costs, water supply population, and salary income.

계수 a

모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	.704	.188		3.746	.002
	직원수	-.007	.002	-1.277	-3.383	.004
	운영비용백만원	-3.254E-005	.000	-2.229	-3.865	.001
	급수인구	4.636E-006	.000	3.343	4.453	.000
	유수율	.003	.003	.173	1.048	.310
	급수수익백만원	9.829E-006	.000	.360	2.446	.026

a. 종속변수: 효율성점수평균

3. Sewage system

Looking at the explanatory of the regression model and the suitability of the model, the ability to explain the variation in the efficiency score, where the variation of the input and output factors as independent variables is the dependent variable, was 92.4% (corrected R square = 0.900).

모형 요약

모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.961[a]	.924	.900	.061607

a. 예측값: (상수), 하수도요금수입백만원, 직원수, 운영비용백만원, 하수처리인구, 처리량일

In addition, the regression model established in the study was found to be statistically appropriate (F = 39.008, p = 0.000).

분산분석 [a]

모형		제곱합	자유도	평균 제곱	F	유의확률
1	회귀 모형	.740	5	.148	39.008	.000[b]
	잔차	.061	16	.004		
	합계	.801	21			

a. 종속변수: 효율성점수평균

b. 예측값: (상수), 하수도요금수입백만원, 직원수, 운영비용백만원, 하수처리인구, 처리량일

The variables that have a significant effect on the efficiency score among the input and output factors of local sewage are the number of employees, operating costs, sewage treatment population, amount of production, and sewage fee income.

계수 [a]

모형	비표준화 계수		표준화 계수	t	유의확률
	B	표준 오차	베타		
(상수)	.642	.028		23.313	.000
직원수	-.002	.001	-.353	-1.801	.091
운영비용	-8.515E-006	.000	-1.600	-7.362	.000
하수처리인구	4.564E-006	.000	2.881	8.515	.000
처리량일	2.081E-006	.000	.953	1.809	.089
하수도요금	-3.015E-005	.000	-1.411	-2.233	.040

a. 종속변수: 효율성점수평균