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Analysis on Level of Service for Asset Management in Water Supply Network

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Abstract

The level of service (LoS) analysis, although it hardly exerts a direct impact on the improvement demand calculation for the water supply network, is an essential part in setting the direction of water supply network asset management with the opinions of service users and suppliers reflected. In this study, the water supply network LoS assessment categories and performance indicators were set, which had not been carried out in the past, through AHP analysis and, using five LoS categories and 15 performance indicators, the levels of service satisfaction of users and suppliers were comparatively analyzed. The result showed that the level of users' complaints was the highest in the "water rate" category, indicating the necessity of preferential improvement of water rates. On the other hand, for the "water pressure" category, the users' satisfaction level was found to be considerably higher than that of the suppliers.

Keywords: Level of Service, Water Supply Network, Asset Management, Water rate, Water pressure

INTRODUCTION

Level of service (LoS) refers to the quality defined for a certain area of service. From the user's standpoint, LoS refers to how a customer is provided with the service and what the customer requires of the service. From the supplier's standpoint, it refers to how an organization provides the service. In asset management, LoS is a strategic goal and a declaration that is agreed on by users. It not only is a major driving engine for a business, but also affects the overall asset management decision-making process.

For the water supply network, which is part of the public infrastructure, it is necessary to select appropriate indicators and assessment categories in order to meet the user's requirements and the expected performance level. Therefore, for LoS analysis, performance indicators must be established by benchmarking LoS assessment methods of other SOC facilities and also the weights must be set for each assessment category and indicator. In this study, water supply network LoS categories and indicators were selected, which had not been carried out in the past, through AHP analysis. In addition, for the selected categories, the levels of satisfaction with the service were comparatively analyzed between users and suppliers, and thus the categories requiring preferential consideration were derived.

MATERIALS AND METHODS

LoS Classification System Establishment

The LoS of a public facility is closely relevant to the asset management of the facility. Advanced countries, such as Australia, the U.S. and the EU nations have developed and have been using various asset management procedures and criteria for efficient management of facilities as old as 100 years. Australia, especially, is known to have secured the highest level of technology for asset management. Australia places top priority on customer values when administering asset management of public facilities. Benchmarking Australia's case, a classification system was developed in this study for the purpose of setting customer-centered service satisfaction levels. First, the types of customers' satisfaction with tap water supplied through the water supply network were expressed as five assessment categories, consisting of water quality, water pressure, taste and odor, water rates and service. Then, the customer values for each assessment category and the criteria for satisfying customers values were set as of the following.

Table 1. Water Supply Network LoS Classification System

Category	Customer Value	Standard
Water Quality	Sustainability	Sustainable service through preservation of water environment and restoration of healthy water circulation
	Health	No hazard to public health
Water Pressure	Quality	Appropriate maintenance of water supply function
Taste and Odor	Quality	Appropriate maintenance of water supply function
Water Rates	Affordability	Appropriateness of the cost of water supply service use
Service	Safety	No hazard to public safety
	Accessibility	Water supply network service as required by customers
	Reliability/ Responsiveness	Predictable and continuous water supply service and immediate response
	Customer Service	Responsible facility operation, friendly response to service requirements
	Quality	Appropriate maintenance of water supply function

Selection of LoS Performance Indicators

In Korea, the Ministry of Environment has been leading the development of performance indicators (PIs) to assess LoS of water supply service operators since the latter part of the 2000s through various research projects. From the research projects, 28 indicators that were considered relevant to the water supply network LoS assessment were selected by referring to performance indicators in the "Study on a Standard Plan for Water Supply Network Improvement BTL Project Performance Requirement Standard (2013)" conducted by the Korea Development Institute (KDI) and the "Water Supply Service Performance Indicator System (2007)" suggested by the Ministry of Environment. First, considering the policy continuity, 15 indicators that are related to the water supply network LoS assessment were selected from 72 indicators for the water supply service performance indicator system (2007). Then, 13 indicators for water supply network assessment were additionally suggested by analyzing a number of domestic and foreign study papers and research outcomes. The 28 PIs selected were categorized on the basis of the criteria suggested in the water supply service performance indicator system (human resources, facilities, operation and service, water quality and water pressure).

- Human Resources: Ratio of technical personnel, No. of years of work in water supply service

- Facilities: No. of accidents in the pipeline, year of pipeline installation, pipeline improvement rate, water supply network GIS management rate, density of valve installation on pipeline, No. of leakage detection and restoration cases

- Operation and Service: Flow rate, No. of leakages per year per km, infrastructure leakage index (ILI), factors of non-revenue water (No. of non-detection water meters, water volume for waterworks business, water volume for public use, amount of leakage), No. of water quality accidents at source, leakage rate, amount of leakage per faucet, water supply rate, limited water supply hours, complaint handling hours, complaint response rate

- Water Quality: Water quality at water intake, concentration of free residual chlorine, No. of complaints on water quality

- Water Pressure: No. of complaints on water volume and pressure

- Taste and Odor: No. of complaints on taste and odor

- Water Rates: Total cost, cost of supply, No. of complaints on water rate, water rate non-payment rate

Final Selection of PIs and Indicators by Assessment Category

Of the 28 selected indicators, 15 LoS performance indicators, which satisfy the previously set customer values, were finally suggested with an exception of the indicators that were decided unnecessary on the basis of the experts' opinions as well as the result of AHP analysis. In addition, the selected indicators were categorized according to the five performance categories, consisting of water quality, water pressure, taste and odor, water rates and service. The indicators for water quality category were "No. of complaints on water quality," "water quality at water intake" and "concentration of free residual chlorine" and for the water pressure category was "No. of complaints on taste and odor." The indicators for the category of water rates were "cost of supply/ total cost" and "No. of complaints on water rate." Lastly, the indicators for the service category were "water supply rate," "flow rate," "ILI," "pipe installation years," "No. of leakages," "limited water supply hours," "complaint handling hours" and "complaint response rate".

Table 2. Water Supply Network LoS Assessment Categories and Indicators

Category	Customer Value	Indicator
Water Quality	Sustainability	Water quality at water intake (BOD)
	Health	Concentration of free residual chlorine
		No. of complaints on water quality
Water Pressure	Quality	No. of complaints on water volume/ pressure
Taste and Odor	Quality	No. of complaints on taste and odor
Water Rates	Affordability	Cost of supply/ total cost
		No. of complaints on water rate
Service	Safety	No. of leakages
	Accessibility	Water supply rate
	Reliability/ Responsiveness	Limited water supply hours
		Complaint handling hours
	Customer Service	Complaint response rate
	Quality	Flow rate
		Infrastructure leakage index (ILI)
		Conveyance, transport, distribution and supply pipe installation years

RESULTS AND DISCUSSION

Weight factor for evaluation of level of service

After determining the basic evaluation criteria to assess the level of service of water supply network, it is necessary to assign the weight factor to each criterion to indicate the degree it affects the level of service score. This study used the analytical hierarchy process (AHP) to determine each weight factor. The AHP analysis is the decision-making technique that supports the systematic assessment of mutually exclusive alternatives when the objectives or evaluation criteria of decision making are complex. First developed by "Saaty" in the early 1970s, the technique has been widely applied to multicriteria decision making. In this study, the AHP analysis takes the hierarchical index measurement model, surveys the professionals on the relative importance of studied areas, and aggregates the consistent data among the responses to calculate the weight factors. To estimate the importance, we sent the questionnaire in the form of pairwise comparison showing the relative importance of two evaluated items and then quantified the result. The AHP analysis compared all factors using the following 9-point scale.

Table 3. 9-Point Scale Comparison for AHP

Linguistic Determination (Semantical Determination)	Quantitative Scoring
Extremely preferable (absolutely important or totally preferred)	9
Between <extreme – very strong>	8
Very strongly preferable (significantly important or significantly preferred)	7
Between <very strong - strong>	6
Strongly preferable (important or preferred)	5
Between <strong - weak>	4
Slightly preferable (slightly more important or slightly preferred)	3
Between <slightly more - equally>	2
Equally (equally important or equally preferred)	1

Criteria for scoring of level of service evaluation indices

We set the scoring and weight factor for each of selected 15 evaluation indices through the AHP analysis of professionals and established the judgment criteria based on the total score of 100 points as shown below. We assessed the level of service according to scoring criteria for each index of the evaluated facility and then multiplied the level by the weight factor to calculate the score of each index. The operating entity of the waterworks pipeline network can determine the target value for the level of service based on the calculated score of each evaluation index. We suggest upgrading of the facility by determining the priority among five evaluated items (water quality, water pressure, taste and odor, price, and service) and then improving the score of the evaluated item regarded to be urgent. Th following table shows the detailed categorization, calculation method of each index, and scoring criteria.

Table 4. Evaluation Items and Indices of Level of Service in Water Supply Network

Indicator	Unit	Weighted value	Criteria
Water quality at water intake (BOD)	mg/L	3	0 : ≥ 10, 0.5 : 3-10, 1 : < 3
Concentration of free residual chlorine	mg/L	8	0 : ≥ 8, 0.5 : 4-8, 1 : < 4
No. of complaints on water quality	Cases/ 1,000 population	9	0 : ≥ 2.8, 0.5 : 0.7-2.8, 1 : < 0.7
No. of complaints on water volume/ pressure	Cases/ 1,000 population	10	0 : ≥ 2.8, 0.5 : 0.7-2.8, 1 : < 0.7
No. of complaints on taste and odor	Cases/ 1,000 population	10	0 : ≥ 2.8, 0.5 : 0.7-2.8, 1 : < 0.7
Cost of supply/ total cost	%	7	0 : ≥ 110, 0.5 : 100-110, 1 : < 100
No. of complaints on water rate	Cases/ 1,000 population	13	0 : ≥ 3, 0.5 : 1-3, 1 : < 1
No. of leakages	Cases/ km	7	0 : ≥ 2.72, 0.5 : 0.68-2.72, 1 : < 0.68
Water supply rate	%	7	0 : < 80, 0.5 : 80-95, 1 : ≥ 95
Limited water supply hours	Hours/ km	7	0 : ≥ 0.21, 0.5 : 0.05-0.21, 1 : < 0.05
Complaint handling hours	Hours/ case	4	0 : ≥ 30, 0.5 : 5-30, 1 : < 5
Complaint response rate	%	3	0 : < 80, 0.5 : 80-90, 1 : ≥ 90
Flow rate	%	3	0 : < 70, 0.5 : 70-90, 1 : ≥ 90
Infrastructure leakage index (ILI)	-	3	0 : ≥ 8, 0.5 : 2-8, 1 : < 2
Conveyance, transport, distribution and supply pipe installation years	Year	6	0 : ≥ 20, 0.5 : 10-20, 1 : < 10

Calculation method of level of service

The detailed estimation methods for the 15 PIs of five assessment categories are as described below.

- Water Quality at Water Intake (BOD) Water quality at water intake refers to the water quality in the water source conservation area at a stage before water intake and conveyance. This indicator, which is related to environmental preservation, is selected for the purpose of ensuring sustainable use of high-quality tap water for future generations.
- Concentration of Free Residual Chlorine This is the concentration of free residual chlorine in tap water supplied directly to users. Free residual chlorine concentration of a prescribed level or higher is necessary in preventing tap water contamination from external pollution sources. Assessment is carried out on water collected from a faucet.
- No. of Complaints on Water Quality This refers to the number of users' complaints about the quality of tap water. It is expressed as No. of complaints per 1,000 population of water supply per year.
- No. of Complaints on Water Volume/ Pressure This refers to the number of users' complaints about the volume and pressure of tap water. It is expressed as No. of complaints per 1,000 population of water supply per year.
- No. of Complaints on Taste and Odor This refers to the number of users' complaints about the unpleasant taste or odor of tap water. It is expressed as No. of complaints per 1,000 population of water supply per year.
- Cost of Supply/ Total Cost This is a ratio between the cost required by a supplier to produce a prescribed amount of tap water and the cost (cost of supply) paid as water rates by users (%). A ratio higher than a prescribed level can cause users' complaints.
- No. of Complaints on Water Rate This refers to the number of users' complaints about the water rates. It is expressed as No. of complaints per 1,000 population of water supply per year.
- No. of Leakages This refers to the number of leakages occurring per year per 1 km of waterworks pipeline located in a specific area. The damage and leakage of high-pressure pipelines can not only cause users' complaints as a result of suspension of the tap water supply, but also decrease the safety of pedestrians and the surrounding facilities.
- Water Supply Rate Users in an area with a waterworks system can be supplied with tap water in a quality higher than the prescribed (water quality, volume and pressure). This can be expressed as the water supply rate. The water supply rate is expressed as the percentage of population (population of water supply) that receives the benefit of waterworks system distribution to the total population in an area (%).
- Limited Water Supply Hours Limited water supply hours refer to a period of limited water supply that occurs without a notice or plan as a result of various factors including replacement of old pipelines and suspension of the water supply due to drought. The hours are expressed as the hours of unplanned limited water supply per year per 1 km of waterworks pipeline.
- Complaint Handling Hours Complaint handling hours is an indicator to assess the swift handling of complaints on waterworks service. The hours are expressed as the average time required in handling each case of complaint.
- Complaint Response Rate This indicator is used to show the level of customer service by checking if a complaint on waterworks service has been handled. It is expressed with the percentage of responses to the complaints made (%).
- Flow Rate This is the most widely used indicator in Korea for waterworks pipeline assessment. It is expressed with the percentage of water flow for which water rates are paid to the total flow of tap water produced at and supplied from water purification plants (%).
- Infrastructure Leakage Index (ILI) This is an indicator recommended by IWA to show the status of leakage in the waterworks system. ILI is calculated as a ratio between the current annual volume of real losses (CARL) and unavoidable annual real losses (UARL). CARL, in general, is calculated through water balance analysis and includes the amount of leakages in various forms (physical amount of losses) that occur in the waterworks pipeline. UARL is the amount leakages occurring when a waterworks pipeline is managed using all applicable leakage management techniques. It is calculated using the formula below.

$$UARL\ (L/day) = (18 \times Lm + 0.8 \times Nc + 25 \times Lp) \times P \quad (3.1)$$

In the formula, Lm is the length of pipeline, which is calculated by adding the length of the main pipe used in supplying water from a transport pipe to a feed pipe to the length of branch pipes (km). Nc is the number of faucets and Lp is the length of the indoor feed pipe, which is calculated as the distance between straight stops to the water meter (km). P is the system operating pressure. It is expressed with water head (mH2O).

Conveyance, Transport, Distribution and Supply Pipe Installation Years The average years of installation of water conveyance, transport, distribution and supply pipes in the assessment target section are calculated.

Table 5. Water Supply Network LoS and Performance Measuring

Survey Target	Question					Total
	Water Quality	Water Pressure	Taste and Odor	Water Rates	Service	
User	4.55	4.66	3.77	2.87	3.33	19.18
Supplier	4.90	3.58	4.76	3.89	3.79	20.92
Supplier – User	0.35	-1.08	0.99	1.02	0.46	-
Priority	4	5	2	1	3	-
Average	4.73	4.12	4.27	3.38	3.56	

Comparison of Service Satisfaction between Users and Suppliers

Water supply network operators must provide high-quality waterworks service by analyzing the LoS. To achieve this, it is necessary to investigate users' level of satisfaction for each of the five categories, find service items that require preferential improvement through comparison of satisfaction between users and suppliers and promote improvement of the related indicators. For this, the waterworks service users and suppliers were surveyed 14 times each, and thus the levels of satisfaction by assessment category were derived as in [Table 5].

The result showed the highest level of users' complaints on the assessment category of water rates, indicating the necessity of the preferential improvement of water rates. On the other hand, for the category of water pressure, users' satisfaction level was found to be considerably higher than that of suppliers. As for the category of water quality, both users and suppliers were satisfied with the service. However, it is difficult to conclude that there is little need for water quality improvement as the tap water drinking rate is low.

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