Statistical Analysis and Effective Use of Performance Indicators (PI) for Water Supply Services

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Abstract
Drinking-water utilities in Japan had little experience to evaluate their performance of services, due to lack of defined numeric indexes for that purpose. However, since 137 PIs (performance indicators) for water supply services were indicated in 2005, water utilities have been able to do it using the PIs.

The Japan Water Research Center performed an analysis of PIs in water utilities nationwide for the first time, in order to make easier to evaluate a utility’s position in the nationwide framework of the utilities. Using statistical data for the approximately 1,800 water utilities, the value for 49 PIs were calculated. Furthermore, the utilities were categorized into several groups according to size (e.g. population served), and PI histograms were drawn up. An attempt was also made to analyze the correlation among certain indicators.

Keywords
Histogram; ISO/TC224; performance indicators

INTRODUCTION
It was not easy to evaluate or quantify their own performance of services for drinking-water utilities in Japan, due to lack of defined numeric indexes for that purpose. However, since 137 PIs (performance indicators) for water supply services were introduced in 2005, water utilities have been able to objectively evaluate or quantify their own performance by calculating the PIs.

The PI figures make it easier to understand current performance, identify and analyze problems, set out future goals and policies, and meet accountability requirements. Thus, PIs greatly contribute to the evolvement of the water industry in Japan.

A nationwide analysis of PIs for water utilities was performed by JWRC (the Japan Water Research Center) for the first time in Japan. Using statistical data for the approximately 1,800 water utilities (almost all utilities in Japan which each serve water to more than 5,001 people), the value for 49 PIs were calculated, and PI histograms were created for the entire water utilities, with the aim of developing tools that allow water utilities to identify and analyze problems and formulate management targets. Furthermore, categorizing the utilities according to the size of utility as defined by the population served which is one of background information (i.e. context), PI histograms for categorized utilities were created. The correlation among several PIs was also studied using correlation diagrams.

The current paper reports on results that were obtained while compiling PI histograms and analyzing the correlation among PIs.
METHODS
How the PIs were established in Japan
In January 2005, JWWA (the Japan Water Works Association) established the “Guidelines for the management and assessment of a drinking water supply service” as a JWWA standard Q 100 which comprise 137 clearly defined PIs.

The background for formulating the guidelines was activities according to ISO/TC224, the international standardization for service activities relating to drinking water and wastewater. In Japan, the Water Supply Control Panel was established to deal with these issues. JWWA and JWRC jointly are in charge of a secretariat of the panel. In September 2004, the panel formed a working group for the domestic standardization of water supply services. Based on the draft which was made by the group, the actual guidelines which defined the PIs were promulgated by JWWA in January 2005. The title of the guidelines was listed on bibliography of the committee draft of ISO/TC224 and therefore became known internationally. They represented the first standard established according to ISO/TC224 and consequently attracted interest of those who concerned.

Guidelines and Performance Indicators
The guidelines are based on the following basic principles.
• The application scope of the guidelines is to cover all activities of drinking-water utilities in Japan.
• In keeping with the long-term targets as announced in June 2004 by the Ministry of Health, Labor and Welfare, the guidelines are to be matched to domestic requirements and characteristics, in order to allow maintaining a level of service that is suitable for Japanese water utilities.
• Performance Indicators must have clear targets, be easy to calculate, and be defined unambiguously.
• No benchmarks are to be set for Performance Indicators.
• The guidelines must be easy to understand not only for those who are in water industry but also for consumers of water supply services.

The guidelines include PIs, variables for calculating PIs, and background information (context). Figure 1 represents PIs and their related elements. A fact that PIs are closely related to their context must be taken into consideration when deciding how to apply them. If the context is different, comparing PIs among utilities is difficult. If the conditions as laid out in the guidelines are not fulfilled, the respective PI cannot be calculated. Although all PIs in the guidelines should be calculated as far as possible, a reasonable selection of PIs is also possible. The context must be taken into consideration in case of selection and application of PIs.

Because PIs are intended to express various aspects of water supply services in an adequate and fair manner, PIs must be:
• Unambiguously defined, to avoid arriving at different results according to calculation method,
• Verifiable and documented,
• Easy to understand, and
• Objective and defined in such a way as to avoid the influence of subjective or personal opinions.
Variables must be:
- Suitable for defining the PI or context,
- Obtained in the same geographic area/time period of the respective PI or context, and
- Reliable and accurate.

Context defines the specific characteristics of a water system. There are two kinds of context:
- Information about natural conditions (e.g. geography, climate, frequency of natural disasters), and
- Information about social and cultural conditions (e.g. population, aging degree of people, economic condition, consumer needs, customs)

The guidelines specify the 137 PIs which are divided into six categories, namely Reliability, Stability, Sustainability, Environment, Management, and International cooperation. These six categories are explained in the following, with a PI example given for each.

Reliability (22 PIs): Supply of safe and comfortable water to every user

- Resources availability ratio = (Average daily transmission input / Resource capacity) x 100 (unit: %)

This indicates the ratio of average daily transmission input to resource capacity. The PI is intricately related to the surplus capacity of resources. The higher the ratio, the more effectively is the resource being used. However, this results in increased risk, because source water will not be possible to be taken 100 percent during drought periods.

Stability (33 PIs): Stable supply of water at anytime anywhere

- Ratio of earthquake-resistant pipeline = (Length of earthquake-resistant pipelines / Total pipeline length) x 100 (unit: %)

This indicates the ratio of pipelines with earthquake-resistant pipes/joints to the total length of pipelines in the system. A higher value is desirable.

Sustainability (49 PIs): Sustainable and stable supply of safe water

- Cost to water supply = [Ordinary expenses – (Commissioned work cost + Unused material and article costs + Auxiliary service cost)] / Revenue water volume (unit: yen/ m³)

This indicates the cost required to supply 1 m³ of revenue amount water. From a view point of the tariff level, a low “Cost to water supply” PI is desirable both for the water utility and for the water consumer. However, the PI is affected by environmental aspects of the water utility such as water quality of the water sources and raw water. Therefore the superiority/inferiority of a management cannot be judged on the basis of the “Cost to water supply” PI alone.

Environment (7 PIs) : Contribution to environmental protection

- Electric power consumption per 1 m³ transmission input = Total power consumption / Annual transmission input (unit: kWh/ m³)

This indicates the electric power consumption that is required to deal with 1 m³ of water from the intake to the tap. It includes all electric power consumption items in the water utility. Because most of the power is required for transmission and distribution, this PI particularly depends on geographical factors.

Management (24 PIs): Appropriate Operation and Maintenance of drinking water supply system

- Ratio of ductile iron and steel mains = [(Length of ductile cast iron pipes + Length of steel pipes) / Total pipeline length] x 100 (unit: %)

This indicates the ratio of ductile cast iron and steel pipes in the overall pipeline length. Iron
pipeline are commonly considered as more reliable.

**International cooperation** (2 PIs): International contribution by overseas transfer of experiences

- Degree of international technical cooperation = Number of dispatched staff members × Number of residence weeks (unit: members × week)

This is the product of the number of staff members dispatched overseas and the number of weeks that were spent overseas. The dispatched staff members do not include visitors for business or social exchange.

No benchmarks are specified in the guidelines for the PI values. Some PIs should not be used in a simple manner to judge the performance of a water utility. The evaluation requires a comprehensive view that takes the context of the water utility into consideration and also allows for factors such as the level of required quality of the water services.

**Quantification of Water Supply Management**

Performance indicators are useful for providing numeric index data that allow quantification of a water supply management. Although variables used for calculating the 137 PIs are more than 200, many of them can be obtained from statistical data in a couple of annual fact-sheets for water utility which are respectively published by JWWA and the Ministry of Internal Affairs and Communications.

When calculating PIs for water utilities all over Japan, the use of such statistical data was explored and it was found that 49 out of the 137 PIs can be calculated using the data mentioned above. The targets of this assessment were water utilities with a population served of over 5,000.

**RESULTS AND DISCUSSION**

**Frequency Histograms for Entire Water Utilities**

Using variables obtained from the statistical data, 49 PIs for entire water utilities in Japan were calculated. As an example, Figure 2 shows a frequency histogram for the “Ratio of ductile iron and steel mains.” In this histogram, the class interval is set to 5 percent, resulting in 20 classes for the PI, and the number of utilities in each class (in other words, the frequency) is plotted. As described previously, this PI is defined as the ratio of “Length of ductile cast iron pipes and Length of steel pipes” to “Total pipeline length”.

To assess nationwide trends regarding this PI, percentiles were examined (Lafferty et al. 2005). Percentiles are a highly useful tool for judging where PIs calculated by each water utility fit in the framework for all water utilities in Japan. Several percentiles are shown in the tables below each histogram. To obtain a percentile of a group of data values, the data are first sorted in order of value from lowest to highest. If there are 100 data values, the 5th percentile is the 5th value in order, the 20th percentile is the 20th value in order, and any other percentiles can be found by the same procedure. The 50th percentile is the median.

Another example is the frequency histogram for “Revenue on water sales per personnel” shown in Figure 3. This PI is calculated by dividing “Water supply revenue” by “Number of staff members on profit and loss account.” The PI is an indicator of productivity per staff member on profit and loss account in terms of revenue basis. Higher values are desirable. The class interval in the histogram is set to 5 million yen (40,000 USD). The figure shows that it is based on data from 1,632 water utilities (almost all in Japan) for the fiscal year 2004. The median (50th percentile) is 48 million yen (384,000 USD), the 25th percentile is 36 million yen (288,000 USD), and the 75th percentile is 66 million yen (528,000 USD). Figures were calculated at 1 USD = 125 JPY.
As indicated in the guidelines, when calculating PIs, taking the context into consideration is very important. Especially, the size of a water utility is an important context element. Water utilities were therefore divided into size categories according to their population served: less than 50,000, 50,000 and more, and metropolitan water utilities, etc (Table 1). Histograms for PIs in the various size categories were then compiled. By viewing histograms for their respective size category, a water utility can check its own position relative to the other similar-scale water utilities in Japan.

Two examples for “Ratio of ductile iron and steel mains” are shown in Figure 4, for water utilities with population served of less than 5,000, and between 50,000 and 100,000.

Correlation among PIs

The correlation among several PIs of different characteristics, as obtained for the entire water utilities was examined. As an example, Figure 5 shows the correlation between “Cost to water supply” and “Transmission input per employee.” This three-dimensional graph uses “Transmission input per employee” and “Cost to water supply” as horizontal left/right axes, and indicates the 25th, 50th, and 75th percentile values on each axis, resulting in four divisions. The surface area of the graph is divided into sixteen squares. The vertical axis shows the number of water utilities.

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**Table 1** Size categories

<table>
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<tr>
<th>Population served</th>
<th>Less than 5,000</th>
<th>5,000 &amp; more</th>
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<td>Less than 5,000</td>
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<tr>
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<td>15,000 ≤ &amp; &lt; 30,000</td>
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<tr>
<td>150,000 ≤ &amp; &lt; 300,000</td>
<td>300,000 &amp; more</td>
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<tr>
<td>Metropolitan utilities</td>
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Based on the PI values of “Cost to water supply” and “Transmission input per employee” for a water utility, the square occupied by this water utility is determined. For example, a water utility with a “Cost to water supply” of 82 yen/m$^3$ and “Transmission input per employee” of 550,000m$^3$/person will fit into the leftmost front square. Using this procedure for the entire water utilities, the resulting count for each square in the graph is indicated in Figure 5. The higher the bar, the higher the number of water utilities.

In the example of Figure 5, the two PIs have a largely negative correlation. In other words, the higher the “Transmission input per employee” is, the lower the “Cost to water supply.” This relationship could be expected from the characteristics of the two PIs. However, in other cases correlations were found to run counter to expectations, and sometimes an unexpected correlation could be established. This is probably due to the influence of many context elements for water utilities.

**Effective Use of Performance Indicators**

Drinking-water utilities are charged with providing palatable water for their customers. To properly realize their responsibility, the 137 PIs must be used for a thorough evaluation of the water utility management from various angles. As PIs are to be a kind of scorecard for the water supply services, PIs should provide an impetus for working towards improvements in the level of service. It is therefore of vital importance that a water utility calculates its own PI values and uses the results to evaluate its position in the nationwide framework of water utilities. PIs should also be widely...
publicized and explained to third parties such as consumers and local diets. This will increase the transparency of water utility management and will foster the public’s understanding for service improvements. Clarifying the current situation with regard to management and technical status is an essential step when planning for the future projects such as the renewal of decrepit plant.

**CONCLUSIONS**

Drinking-water utilities in Japan had little experience to evaluate their performance of services, due to lack of defined numeric indexes for that purpose. However, since 137 PIs for water supply services were indicated in 2005, water utilities have been able to do it using the PIs.
JWRC calculated 49 PIs for drinking-water utilities nationwide, using available variables from statistical data for water utilities. “Frequency histograms for entire water utilities” and “frequency histograms for categorized water utilities” were also created. A water utility can use these histograms to compare its own PIs to those of the other water utilities, in order to objectively assess its own position within a nationwide framework. The correlation among PIs of different characteristics was also examined.

JWRC will continue the study of PIs, with the aim of providing useful information to water utilities and promoting the effective use of PIs for improving the level of water services.

REFERENCES

