# Evaluation of water supply project by performance indicators

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## ABSTRACT

The performance indicators defined in *Guidelines for the management and assessment of a drinking water supply service*, which was published in 2005 by the JWWA Technical Committee in Japan, are often applied to compare ones of different water supply utilities. On the other hand, the PIs are useful to estimate results of a new project which a water supply utility will plan.

This paper shows results of the evaluation of an imaginary project which the authors intend to promote concerning replacement of old pipelines using the numerical model of PIs on condition that any factors of the existing water supply utility are not changeable. The authors can estimate numerical variation of the other PIs caused by pipeline replacement, which are water charge, leakage ratio, pipeline burst ratio, redundancy of water resource and so on. This study shows that PIs make it easy to evaluate a new project.


**Key words** | cost to water supply, earthquake-resistant pipeline, evaluation of water supply project, leakage rate, performance indicator (PI), pipeline replacement

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## INTRODUCTION

### Evaluation process of water supply project by PIs

*Guidelines for the management and assessment of a drinking water supply service* (JWWA 2005), published in January 2005, is the standard based on ISO/TC224 for water supply utilities. This standard advances the cause of numerical evaluation for water supply performance from the various viewpoints of public service. Therefore it is called "a SCALE for water supply performance".

In June 2006 approximately forty water supply utilities released official announcements of their PIs calculated on this guideline. This means that many water supply utilities realize the importance of the guidelines in order to clarify activities and performance of their management. The Welfare and Labor Ministry recommends usage of these guidelines to develop "Regional Water Supply Vision" to make its numerical goals clear instead of the usual vague expressions. This fact shows that the guidelines play an important role in making water supply services determine the numerical factors.

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But the announcement of PIs of a water supply utility does not mean evaluation of its management. This paper states how to make full use of the guideline to evaluate the outcome of the water supply service to take a simple case study which makes it easy to compare the results before and after a project. However, a decision of right or wrong in employment of a project is another issue which this paper does not deal with.

## METHODS

### Mutual organic relation among PIs

There are defined 137 items of PIs in the guidelines. Now only a couple of years have passed since the guidelines were published. Most of the water supply utilities are apt to compare their PIs to the other utilities' PIs without consideration of the different context of the utilities. Comparison of each PI among water supply utilities is also natural and important but does not bring a solution in face of a difficult problem. And it is not sufficient to analyze the problem. This is why PIs are not independent of each other and one PI affects the other PIs. For instance 6101 degree of international exchange, 3111 ratio of accidents in the line of duty and the like are fully independent from the other PIs but we know that 2103 aging of mains is considerably subjected to 2202 trunk main failures, 5107 leakage rate, 3206 complaints for water quality, 5109 hours of water interruption or water turbidity and so on. Strictly speaking, most of the PIs have a large mutual correlation coefficient in mathematics. One PI should not be used to clarify distinctive features of the whole performance of a water supply utility but a set of PIs should be applied to the evaluation process. We have to understand that a PI is affected by various factors of performance and the other PIs. For instance, in the case of 2104 mains rehabilitation is a high value, 5107 leakage rate may be kept at a small value and 3017 charge for one month per 20 $m^3$ for domestic has little relation to it. Now it is suitable to consider a set of PIs that are connected with each other.

As this study is confined in scope to the performance of only one water supply utility, we do not discuss the context of the other utility.

**Table 1** | Basic conditions of S city

| Terms | Units | Values |
|---|---|---|
| Water supply inaugural date | – | 1935/Apr. |
| Population served by water supply | % | 99.8 |
| Population served | person | 57,180 |
| Number of service connections | No. | 24,310 |
| Water supply area | $km^2$ | 91.4 |
| Density of population served | person/$km^2$ | 625.7 |
| Ratio of employed populations | % | Primary industry 6.3 |
| | | Secondary industry 31.9 |
| | | Tertiary industry 61.6 |
| Annual amount of water intake | 1,000 $m^3$ | Groundwater 4,052 |
| | | Receiving of water 5,282 |
| | | Total 9,334 |
| Annual amount of water supply | 1,000 $m^3$ | 9,289 |
| Annual revenue on water sales | billion ¥ | 1.42 |
| Maximum daily supply | $m^3$/day | 29,579 |
| Average daily supply | $m^3$/day | 25,380 |
| Capacity of daily supply | $m^3$/day | 45,000 |
| Mains length | km | 421.3 |
| Number of employees | person | 41 |

## Effect of improving only one PI

As the authors stated before, it is the most important point of this paper that improvement of only one PI makes a chain reaction with the other PIs under certain conditions. This paper shows a feasiblity study in the existing S city of middle size.

## Model of water supply utility

In Japan most of the small and medium cities are facing the most important and urgent problem which is pipeline replacement and earthquake-resistance. This paper deals with the problem to be solved immediately. Our feasiblity study uses the data of the existing S city, which is available to the public. Its basic conditions are shown in Table 1, and related PIs in Table 2.

## Assumptions

The study was conducted on the assumptions described as follows:

1. Current internal and external conditions relating to water utility, e.g. population served, number of employees etc., will not change.
2. A project is supposed, in which only mains rehabilitation in all PIs is changed from 1.7% to 3.0% for 15 years. This means that aged pipeline replacement is accelerated. Aged pipeline replacement is done under the policy described below which is generally accepted and probably applied now. Cast-iron pipe, steel pipe with screwed joint, asbestos cement pipe and hard PVC pipe are replaced by ductile iron pipe with earthquake-resistant joints, which enhance the earthquake safety of pipelines.

**Table 2** | PIs related to pipeline replacement and earthquake-resistant

| No. | Pis | Units | Values |
|---|---|---|---|
| 2103 | Aging of mains | % | 19.8 |
| 2104 | Mains rehabilitation | % | 1.7 |
| 2210 | Ratio of earthquake-resistant pipeline | % | 0.1 |
| 1001 | Resources availability ratio | % | 77.9 |
| 1002 | Surplus capacity of resources | % | 10.9 |
| 1117 | Ratio of lead service lines | % | 86.0 |
| 3009 | Ratio of income bond interest for revenue on water sales | % | 11.4 |
| 3015 | Cost to water supply | ¥/$m^3$ | 181.2 |
| 3017 | Charge for one month per 20 $m^3$ for domestic | ¥ | 3,150 |
| 3018 | Revenue water ratio | % | 82.5 |
| 3206 | Complaints for water quality | No./1,000 No. | 0.368 |
| 5102 | Ratio of ductile iron and steel mains | % | 44.1 |
| 5103 | Number of pipeline failures | No./100 km | 25.7 |
| 5107 | Leakage rate | % | 10.0 |
| 5108 | Leakage volume per contracted service connection | $m^3$/year/No. | 38.2 |
| 5109 | Hour of water interruption or water turbidity | hour | 0.24 |

3. PIs influenced by the project are considered. For instance, PIs relating to finance and water charge change because of fundraise. In this paper, it was assumed that the cost of the replacement is ¥70,700 per metre for diameter 75mm–250 mm and ¥100,000 m per metre for diameter larger than 250 mm, respectively (JWWA 2002).
4. The existing accounting system of a publicly owned utility is applied. For example, aged pipeline replacement is conducted not by bond floatation but by O&M cost. It was assumed that all the present costs for the improvement of facilities are devoted to the aged pipeline replacement (current rate: 1.7%), and the difference between this cost and the cost in the case where the replacement rate is increased to 3.0% is the cost for this project.
5. When aged distribution pipes are replaced, service pipes under public roads are replaced at the same time within the expenditure of the water utility. Hence this cost was included in this study.
6. The leakage rate turns lowered when aged pipes are replaced. The lowered leakage rate was estimated from Figure 1, which was obtained based on PIs announced officially by water utilities. The estimation for other PIs was done with the same method.

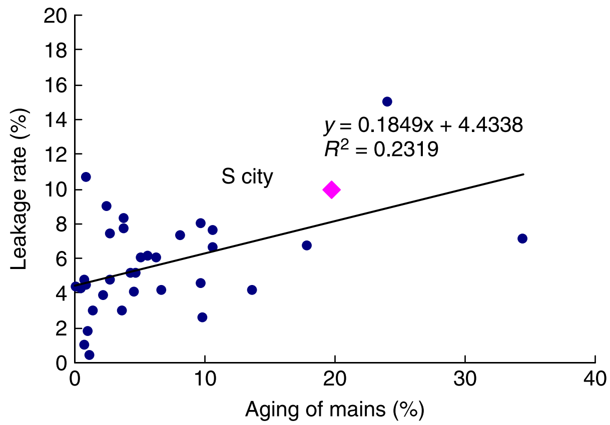


**Figure 1** | Correlation between aging of mains and leakage rate.

As this investigation is a model case, conditions are also simplified. In reality, what should be considered is much more than in this study. However, the method described in this paper is effective to analyze how related PIs are influenced.

## RESULTS AND DISCUSSION

Table 3 shows the affected PIs by the project where the aged pipeline replacement rate is increased.

PIs that are not indicated in Table 3 are affected. For instance, complaints for water quality including water

**Table 3** | PIs affected by the promotion of pipeline replacement and earthquake-resistance

| No. | Pis | Units | At present | 15 years later |
|---|---|---|---|---|
| 2103 | Aging of mains | % | 19.8 | 7.3 |
| 2210 | Ratio of earthquake-resistant pipeline | % | 0.1 | 45.1 |
| 1001 | Resources availability ratio | % | 77.9 | 74.6 |
| 1002 | Surplus capacity of resources | % | 10.9 | 15.0 |
| 1117 | Ratio of lead service lines | % | 86.0 | 38.7 |
| 3015 | Cost to water supply | ¥/m$^3$ | 181.2 | 238.4 |
| 3018 | Revenue water ratio | % | 82.5 | 86.7 |
| 5102 | Ratio of ductile iron and steel mains | % | 44.1 | 72.5 |
| 5103 | Number of pipeline failures | No./100 km | 25.7 | 7.6 |
| 5107 | Leakage rate | % | 10.0 | 5.8 |
| 5108 | Leakage volume per contracted service connection | m$^3$/year/No. | 38.2 | 21.2 |

turbidity may decrease. However, the changes of such PIs are not estimated due to the unavailability of data.

Implementation of aged pipeline replacement results in the change of many PIs. In this paper, all changed PIs are not dealt with. The improvement of leakage rate, surplus capacity of resources, effectiveness of earthquake-resistance and increase of revenue water ratio will be discussed.

1. It is generally understood that leakage from service pipes accounts for 90% of all leakage. In this study, service pipes under public roads are replaced when aged distribution pipes are replaced. As a result, the leakage rate was improved by 4.2%. This kind of estimation procedure is reasonable when looking at coefficient of correlation.

   The decrease of leakage results in the improvement of surplus capacity of resources which increases by 4.1%. It was impossible to give thought to such a point in a traditional way of consideration. Furthermore, the cost for water resources development to raise surplus capacity of resources by 4.1% can be calculated.
2. The ratio of earthquake-resistant pipeline increased by 45% as a result of replacing aged pipes with earthquake-resistant pipes. This means that the number of pipeline failures due to earthquakes with seismic intensity of 6 and lower (peak ground acceleration 520 gal) is estimated to decrease from 173 to 80 by 54% according to JWWA (1998). Further, the water interruption rate just after the earthquakes with seismic intensity of 6 and lower (peak ground acceleration 520 gal) is calculated to decrease from 83% to 59% by 24% according to Kawakami (1999). From this, the project promotes the enhancement of earthquake safety of pipelines.
3. It is acknowledged that the reason why pipeline replacement does not proceed is the shortage of expenditures in spite of the understanding of the necessity of the replacement. This is a matter of high concern in Japan. Assuming that the cost for the replacement is covered with only water charges, not covered with subsidy and bond floatation, the added burden on the water charge for consumers is ¥57 per $m^3$ for 15 years. In this way, the cost for the replacement of aged pipelines is clarified, although rationalization effort and subsidy are not taken into account in this case. Traditionally, a lot of factors including replacement of facilities, boost in prices, staff cutbacks and rationalization effort were taken into consideration altogether at the same time. Hence, it was not easy for consumers to realize the reason for an increase of the water charge. However, advantageous cost and effect are clarified and easily understood by the evaluation of the project using PIs.

As described above, it is possible to grasp the project planned by looking at the change of PIs. In this respect, PIs are useful, and provide quantitative and rational information for making a decision. However, the implementation of this project with the added burden on the water charge (¥57 per $m^3$ for 15 years) should be dependent on judgment by consumers.

## CONCLUSIONS

In the management of a drinking water supply service, it is difficult to estimate quantitatively from various points of view the effects of a newly planned project. The explanation for the project tended to be done so far without numerical value, which may have complicated the evaluation of the pros and cons of the project. Meanwhile, the PI system is useful as a tool for the judgment and evaluation of the project. It is possible to obtain a clear picture of the effects of the project by simulating PIs in consideration of the relationship of PIs. PIs are of great use for the evaluation of your own water supply project as well as the comparison of performance with other utilities.

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