Evaluation technique of pipe replacement adopting the concept of remaining value

Bureau of Waterworks, Tokyo Metropolitan Government

1. Introduction
Recently, there are some large-scale water leakage accidents caused by corrosion of the Ductile Iron Pipes installed in the Early Period (DIPEP). Therefore, the committee for diagnosing DIPEP’s degradation was established and conducted the diagnosis. As a result, it was forecasted that water leakage risk would become high caused by corrosion development in the case that pipe installation years exceeds 50 years in the soil with strong causticity. Therefore, in FY 2004, the bureau objectively conducted quantitative evaluation (QATE) and qualitative evaluation (QALE) about the replacement period and effect. As the result, it is proved that DIPEP replacement is propriety. On QATE, Cost-Benefit Analysis using new method was adopted. The new method is that “Cost” is indicated as the remaining value on fixed asset based on period of depreciation and has potential to be a useful tool to evaluate pipes replacement period and effect.

2. Characteristic of Ductile Iron Pipes in the Early Period
A definition of DIPEP is the mixed pipe route. One is the straight pipes consisted of the ductile iron, other is the special fitting pipes consisted of the cast-iron. Therefore, DIPEP has the following problem.
* Not enough strength against earthquake
* Factor of turbid water because of the no lining of special fitting pipes (Inner of pipes)
* Corrosion development because of no coating (Outer of pipes)
* Separating possibility because of A joint type on earthquake
The installation year is following:
* φ 75·200 FY 1970·1972
* φ 400·900 FY 1961·1965
* φ250·350 FY 1962·1967
* φ1000·1500 FY 1960·1964

3. The Outline of this Project
The outline of this project is following.
(1) The scale
This project decides the first priority pipe lines which has approximately 1,200km.
The select reason is follows:
* The important route (the route for hospital, refuge)
* The pipes installed under strong corrosion soil.
4. The Concept of DIPEP replacement

It is forecasted that DIPEP will cause more water leakage accident since 2018 by diagnosis for degradation. Therefore, it is necessary to replace every priority-replaced DIPEP before 2018 because the duty of waterworks keeps lifeline for urban function and urban life.

The depreciation period of this pipes is around 2018 because installation year is concentrated 1970 to 1973. Therefore, it is demanded to move up and level the replacement volume.

Then, Tokyo Waterworks Bureau systematically replaces DIPEP under the following concept to prevent water leakage, turbid water, and suspend water and to take measure the increase of pipe replacement volume.

* Priority replacement is following:
  # Route with big social effect in the case of water leakage accident
  # Older pipes
* Securing stable water supply
* Replacing simultaneously with other construction such as old pipe replacement
* Leveling the replacement volume

5. Quantitative Evaluation on this project

Tokyo Waterworks Bureau conducted the project evaluation in terms of Quantitative Evaluation and Qualitative Evaluation in FY 2004.

In this report, it is explained about the new method that “Cost” is indicated as the remaining value on fixed asset based on period of depreciation.

Quantitative Evaluation was conducted by Cost-Benefit Analysis. Cost and Benefit is defined following:

“Cost” : Remaining value on fixed asset of the pipes replaced before the end of depreciation period”.

“Benefit” : The reduction of the water suspension damage etc.

(1) Concept of “Cost”

It is necessary to replace DIPEP systematically as Fig.2 in order to replace every priority-replaced pipes until 2018.
But it is losses for the bureau to replace this type of pipes because the pipes whose installation years are less than depreciation period is replaced.

Therefore, the losses, that is to say, “Remaining value” is defined as “Cost” (show Fig. 3).

On the other hand, replacement cost such as construction cost is defined as ordinary expenditure, and not included “Cost” because pipes replacement which keeps up the stability of water supply is essential for urban life and activity.

(2) Calculation of “Cost”

“Cost” is calculated with following terms:

a) Remaining value ratio of 0 year is 100%

b) Remaining value ratio of period of depreciation is 0%

c) Remaining value decreases in the liner.

The formulation is following:

\[ Z = \sum (Y \times a \times b) \]

\( z \): Remaining Value
\( Y \): Ratio of Remaining Value
\( a \): Replacement Length
\( b \): Unit Cost of replacing pipes

\[ Y = \frac{100}{X} L + 100 \]

\( Y \): Ratio of Remaining Value
\( X \): Depreciation Year (= 50 Year)
\( L \): Laid term

As the result, “Cost” is calculated approximately 17,000 (million Yen).

(3) Concept of “Benefit”

The effect of old pipe replacement is the prevention of leakage and turbity, the reduction of water suspension damage, strengthen against earthquake and so on.

In this report, “Benefit” is defined 2 cases. One is the case of usual leakage accident, the other is the case of earthquake. “Benefit” is defined following;
a) The reduction of the water suspension damage
   
   This benefit is calculated with the population damaged, the volume of water suspension, recovery days, and the daily amount of damage per resident.
   
   As the result, “Benefit” is 70,053(Million Yen) on earthquake, 1,449(Million Yen) on leakage accident.

b) The reduction of the water leakage

   This benefit is calculated with the reduction of daily water leakage by old pipes replacement multiply unit production cost.
   
   As the result, “Benefit” is 418(Million Yen) on leakage accident.

c) The reduction of the repair cost

   This benefit is calculated with the leakage damage pipes length and earthquake damage pipes length multiplies the unit repair cost.
   
   As the result, “Benefit” is 1,340(Million Yen) on earthquake, 221(Million Yen) on leakage accident.

d) The reduction of the operation cost on water distribution adjustment

   This benefit is calculated with the leakage damage pipes length and earthquake damage pipes length multiply the unit operation cost.
   
   As the result, “Benefit” is 705(Million Yen) on earthquake, 39(Million Yen) on leakage accident.
6. The result of Quantitative Evaluation

Cost-Benefit Ratio is calculated with the result of “5. Quantitative Evaluation on this project”.

On Cost-Benefit Analysis, “Cost” and “Benefit” are converted present value. This result is reflected “Cost and Benefit (after convert)” on Table.1.

Benefit on earthquake is considered the earthquake incidence and the evaluation terms.

It is conducted Cost-Benefit Analysis with the “Cost, Benefit (after convert)”. As the result, Cost-Benefit Ratio is 1.37. Therefore, it is cleared that the project is proper.

6. Conclusion

This report proposes the technique of pipe replacement planning using Cost-Benefit Analysis. This proposal includes a new idea that the cost is defined remaining value of fixed asset.

This technique has potential to be useful tool to evaluate pipes replacement planning.

If this technique is applied to other types of pipes, it is necessary to conduct the diagnosis for degradation because the depreciation year is not known. In Tokyo, there are many soil characteristic such as strong corrosion, and the corrosion situation is different in each region. Therefore, it is necessary to promote the soil investigation.

Since then, under this report’s concept, this technique is going to be applied to other waterworks facilities’ renewal evaluation.

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<th>Table.1 Cost-Benefit Ratio</th>
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<td>Cost (C)</td>
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<td>Benefit (B)</td>
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<tr>
<td>Earthquake</td>
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<td>water suspension</td>
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<td>Leakage Accident</td>
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<td>Total</td>
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<tr>
<td>Cost-Benefit Ratio (B/C)</td>
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<td>1.37</td>
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8-1 Nishi-Shinjuku 2-chome, Shinjuku-ku, Tokyo, Japan