Ex-post Evaluation (Case Study Research) of Advanced Water Treatment Facilities and Their Expansion to Water Utilities Overseas

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INTRODUCTION

Tokyo depends on rivers for most of its water. The Tone River and Arakawa River systems account for the largest share at 78%, followed by the Tama River System which accounts for 19%.

The Tokyo Waterworks operates 5 water purification plants that utilize water from the Tone River and Arakawa River systems (WPP A to E). However, these plants used to be afflicted with quality problem of raw water in their river systems. In the 1970s, complaints of a musty odor were filed frequently, with over 1,000 filed in a certain year. These purification plants had long utilized powdered activated carbon treatment to deal with the musty odor. However, this method was not efficient, since it could not adequately respond to sudden and complicated concentration changes in water quality. In addition, fine powdered activated carbon particles spilled into the sand filter basin, revealing limitations of the powdered activated carbon treatment, and a lasting measure was required immediately.

Therefore, the Tokyo Waterworks launched projects from 1989 to 2014 to develop facilities with advanced water treatment that incorporated ozonation and biological activated carbon absorption (BAC) treatment, as permanent measures. Afterwards the Tokyo Waterworks steadily installed advanced water treatment facilities at its 5 water purification plants over the course of 25 years, spending approximately ¥230 billion in total. Advanced water treatment facilities have achieved a treatment capacity of 5.48 million m3 per day.

To obtain the understanding of customers, it is necessary to appropriately evaluate a project before it is officially started. In Japan, there are many cases of ex-ante evaluation, yet the number of ex-post evaluation is still small. As this case study research shows, the Tokyo Waterworks considers the results of ex-post evaluation of projects for advanced water treatment facilities for which construction was started in or after 2001.

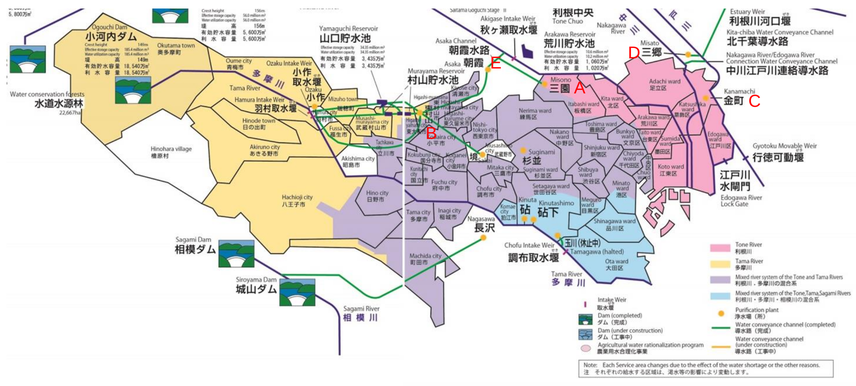

Figure 1. Overview of Tokyo Waterworks

Ex-ante Evaluation of Advanced Water Treatment Facilities

The Tokyo Waterworks conducted ex-ante evaluation using cost-effectiveness analysis based on conversion factor method, for projects yet to be adopted at advanced water treatment facilities built since 2001. C (cost) = project cost and B (benefit) = reduction of costs were totaled and used to calculate the cost benefit ratio (abbreviated as B/C), which was evaluated as reasonable if equal to 1 or higher.

C = project costs (including ozonation facilities, biological activated carbon absorption treatment facilities, distribution pipes) + maintenance and management costs

B= Reduction of costs (Reduction of costs for water quality improvement by customers themselves + Reduction of costs for powdered activated carbon injection)

1. Explanation of ex-ante project evaluation of WPP B advanced water treatment facilities (as an example)

- Specifications of WPP B
  - Located in west part of Tokyo (water supplied to 670,000 households with population of 1.44 million)
  - WPP with daily volume of 126,500 m3, including 8,800 m3 of raw water from Tone River System
  - 35% of monitors living in the water supply area is dissatisfied with drinking water, 94% want the introduction of advanced treatment
- Principles of Costs and Benefits [Reduction of Costs]
  - Costs: Costs associated with maintenance and maintenance of advanced water purification facilities
  - Benefits [Cost Reductions]: The reduction of “costs associated with water quality improvements made by customers themselves” and “costs related to powdered activated carbon injection”

Table 1. Ex-ante project evaluation of WPP B advanced water treatment facilities

Item			B/C [Cost Reduction] a	Conversion Factor b	B/C [Cost Reduction] a×b (¥1,000,000)
Costs	Project Costs	Ozonization	¥6,000 mil.	0.98	5,880
		Biological Activated Carbon	¥13,000 mil.	0.98	12,740
		Piping	¥1,000 mil.	1.13	1,130
		Electrical Equipment, etc.	¥10,000 mil.	1.85	18,500
		Total	¥30,000 mil.	—	38,250
	Maintenance Costs		¥1,220 mil./year	21.48	26,206
	Total Cost (C)		—	—	64,456
Cost Reductions	Pasteurization of tap water		¥336 mil./year	21.48	7,217
	Installation of water purifiers		¥1,703 mil.	4.61	7,851
	Replacement of filters		¥2,293 mil./year	21.48	49,254
	Purchase of bottled water		¥5,940 mil./year	21.48	127,591
	Powdered Activated Carbon		¥53 mil./year	21.48	1,138
	Total Cost Reductions (B)		—	—	193,051
Cost-Benefit Ratio (B/C)				2.995	

2. Ex-ante project evaluation of 5 advanced water treatment facilities

Table 2-5. Evaluation of advanced water treatment facilities

WPP	Ex-ante Evaluation (Year)	Facility Completion (Year)	Facility Output (10,000 m3/day)	Supply Population (10,000 people)	Total Cost (C = ¥1,000,000)	Total Benefit (B = ¥1,000,000)	Cost/ Benefit Ratio (B/C)
A	2001	2007	30	63	30,731	108,479	3.530
B	2005	2010	88	144	64,456	193,051	2.995
C	2005	2013	88	146	72,959	193,545	2.653
D	2006	2014	55	79	33,148	99,865	3.013
E	2007	2014	85	96	51,930	128,780	2.480

- All 5 WPP have B/C of 1 or greater, and sufficient evaluation was made to start the projects

Ex-post Evaluation of Advanced Water Treatment Facilities

Three years have passed since advanced water treatment was applied to 100 percent of Tokyo’s tap water. Thus, ex-post evaluation of the projects were made based upon the results of ex-ante evaluation by reviewing increased costs from operating advanced water treatment facilities, effectiveness of water purification, changes of the evaluation from customers, and others.

1. Ex-post evaluation of WPP B advanced water treatment facilities (case study)

- Factors changed before and after the project (Main items, red letters show change)
  - Improvement target: 1,440,000 people, 670,000 households → 1,640,000 people, 820,000 households
  - Purifier installation rate, unit price 39.5%, ¥6,550/household/5 years → 31.7%, ¥10,000/household/5years
  - Bottled water purchase ratio, unit price: 12.8%, ¥33,000/person/year → 16.1%, ¥16,900/person/year

Table 3 – Ex-post evaluation of advanced water treatment facilities at WPP B (red characters show change)

Item			B/C [Cost Reduction] a	Conversion Factor b	B/C [Cost Reduction] a×b (¥1 mil.)
Costs	Project Costs	Ozonization	¥5,731 mil.	0.98	5,616
		Biological Activated Carbon	¥12,685 mil.	0.98	12,431
		Piping	¥799 mil.	1.13	903
		Electrical Equipment, etc.	¥6,538 mil.	1.85	12,095
		Total	¥25,753 mil.	-	31,046
	Maintenance Costs		¥1,220 mil.	21.48	26,206
	Total Cost (C)		-	-	57,251
Cost Reductions	Pasteurization of tap water		¥0 mil./ year	21.48	0
	Installation of water purifiers		¥2,600 mil./ year	4.61	11,986
	Replacement of filters		¥3,562 mil./ year	21.48	76,512
	Purchase of bottled water		¥4,394 mil./ year	21.48	94,383
	Powdered Activated Carbon		¥31 mil./ year	21.48	660
	Total Cost Reductions (B)		-	-	183,541
Cost-Benefit Ratio (B/C)				3.206	

- Purchase cost of bottled water decreased significantly (¥183/2 L at the time of initial evaluation → ¥93/L at present, Benefits decreased by ¥30 billion), and as a result, the total benefits decreased by ¥10 billion.
- Various cost reduction construction contributed to the reduction of project costs, as costs were reduced by ¥7 billion from the time of the initial evaluation.
- As a result, the B/C reached 3.206, a great improvement from the time of the initial evaluation.

2. Ex-post evaluation of the 5 advanced water treatment facilities

Table 4. Ex-post evaluation of the 5 advanced water treatment facilities (red characters show changes)

WPP	Ex-post project					Ex-ante project
	Facility Output (10,000 m3/day)	Supply Population (10,000 people)	Total Cost (C = ¥1,000,000)	Total Benefit (B= ¥1,000,000)	Cost/ Benefit Ratio (B/C)	Cost/ Benefit Ratio (B/C)
A	30	83	26,863	92,896	3.458	3.530
B	88	164	57,251	183,541	3.206	2.995
C	88	147	78,375	162,695	2.076	2.653
D	55	86	30,832	97,238	3.154	3.013
E	85	100	53,710	114,440	2.131	2.480

- Changes in social conditions that occurred between 2001, the first year of evaluation, and 2018
  - The consumption tax rose from 5% to 8% in 2014, but consumer prices have not risen much (With 2015 as 100, 2001 was 98.4).
  - The average wage index of workers also remained flat from 2001 to 2015
  - Therefore, there has not been any change in socioeconomic conditions that should be taken into consideration in particular for this ex-post evaluation
- In WPPs A, C, and E, construction costs of the facilities remained largely unchanged from initial estimates, and the unit price of bottled water dropped drastically, so the benefits brought were decreased, and B/C fell below the initial level.

CONCLUSIONS

- Necessity of future ex-post evaluation
  - Because there is possibility of price fluctuations and changes of answer trends in questionnaire results, it is necessary to conduct ex-post evaluation cyclically for a certain period.
- Necessity of improvement measures
  - Because the questions on customer questionnaires, which are important for business evaluation, are different from those in the past, it was not possible to completely match the project evaluation. It is necessary to evaluate projects in a unified manner.
- Necessity to conduct ex-post evaluation
  - For advanced water treatment facilities started since 2001, B/C is 1 or more before and after the project, and the effect after introduction can quantitatively be shown. It is possible to make proper explanations to the customers.
- Secondary effects due to advanced treatment introduction
  - In 2012, formaldehyde was detected at a WPP in the upper part of the Tone River at values close to the water quality standard value. Yet, in Tokyo WPPs where advanced water treatment facilities were in operation, it was possible to continue water treatment without problems.
  - With conventional water purification treatment, it was possible for large water suspension damage to occur, but because it is now possible to prevent it beforehand, so a large secondary effect was achieved due to the introduction of advanced water purification treatment.
- Introduction to other waterworks utilities
  - Advanced water treatment facilities capable of oxidation treatment with ozone, adsorption treatment with granular activated carbon, and decomposition by microorganism, can support not only chronic but also sudden water quality deterioration.
  - It is expected that there will be more chances for users to drink safer, better tasting water by introducing advanced water treatment facilities to water business utilities around the world suffering from deterioration of water quality.

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