Lessons & Practices

OPERATIONS EVALUATION DEPARTMENT

MANAGING URBAN WATER SUPPLY AND SANITATION: OPERATION AND MAINTENANCE

Introduction

In the 1980s more than 1.6 billion people gained access to water of reasonable quality, and sanitation services expanded substantially. Yet data from the World Health Organization suggest that at least 170 million people in urban and 855 million in rural areas still lack a source of potable water, and more than 1.7 billion people still lack adequate sanitation.

To provide a continuous safe water supply service calls for ample and reliable water sources and adequate capacity for treatment, transmission, and distribution, as well as properly functioning pumps, reservoirs, and networks. (Box 1.) The way these facilities are operated and maintained can greatly affect the health of the population, the quality of the environment, the benefits to the poor, and the resources available for investment in expansion.

Health: The recent outbreak of cholera in Peru is a stark reminder that poor service can adversely affect health. And a review (Lindstrom, 1981) of about 100 health impact studies shows that among an estimated 900 million people afflicted by diarrhea, reductions in disease occurrence attributable to improvements in the quality or availability of water and/or sanitation exceeded 22 percent in half the cases. Similar improvements are reported for other water-borne diseases.

Environment: Excessive pumping of aquifers lowers groundwater levels in coastal areas. This can cause saline infusion, rendering the water permanently unfit for human consumption. Inappropriate waste water disposal pollutes the receiving waters and may render them unfit for abstraction and treatment.

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Effects of water supply and sanitation improvements on morbidity from diarrhea

Type of improvement	*Median reduction in morbidity (percent)*
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Source World Bank, *World Development Report 1992*

Water for the poor: The poor suffer disproportionately when water supply is unreliable. Wealthier households, like industrial firms, can install private facilities such as reservoirs, recycling equipment, and private wells, though at additional cost to the economy. These options are beyond the reach of poor consumers. Intermittent service jeopardizes the social emphasis of many water supply projects supported by the Bank.

Financial performance: Good operation and maintenance (O&M) can enhance the quality of service and extend the useful lives of facilities. This affects the financial performance of water utilities, and hence the resources available for investment in new services. To minimize the costs of operating a water-supply system, competent management of capital and current expenditures, assets, and liabilities are just as important as preventing losses of water from the system. Adequate cost recovery ensures that enough funds are available to pay for operation, maintenance, and debt service.

The cost imposed on economies by poorly-run and maintained water supply and sanitation systems is not well documented but is clearly very large. There is ample evidence of poor quality water, unnecessarily sporadic service, large volumes of unaccounted-for water, and inadequate collection, treatment, and disposal of effluent.

World Bank assistance

The Bank routinely reviews the operating and maintenance performance of its borrowers. In many of the water utilities that the Bank has supported through projects, a serious lack of maintenance was already apparent during project preparation and implementation (OED 1992). Its root cause was usually lack of funds, which led to shortages of managers qualified to organize O&M, shortages of skilled staff and training, and shortages of spare parts. The Bank's lending for water supply and sanitation has been mainly for new infrastructure and related studies. Recent projects give more prominence to institutional development and the rehabilitation of facilities, and often include actions to improve organizational structures, institutional performance, operating procedures, and staff qualifications through training or recruitment. Loan and credit agreements regularly include conditions related to various aspects of operating performance. Indicators for monitoring performance are almost always used.

Lessons of experience

Immediate causes of neglect

A prime cause of poor operation and maintenance is poor management. But studies, reorganizations, and technical assistance to water and sanitation utilities have typically focused on expansion and on increasing service levels, and only pay lip-service to problems in the management of existing facilities. The pressure to provide services to more people is particularly intense in the water supply sector. As a result, new facilities receive higher priority,

Box 1: Definitions

Operation and maintenance (O&M) refers to all activities needed to run a water supply and sanitation entity, except for construction of new facilities.

Operation includes the planning and control of the extraction/collection, treatment, conveyance, and delivery of water, and/or the collection, treatment, and disposal of effluent. It also covers the management of client and public relations, legal, personnel, commercial, and accounting functions.

Maintenance may be preventive or reactive. Preventive maintenance—including inspection, cleaning, lubrication—consists of the systematic routine actions needed to keep the utility plant in good condition. It sometimes also includes minor repairs and replacement as dictated by the routine examination. Reactive maintenance normally occurs as a result of reported pipe breaks and the malfunctioning or breakdown of equipment.

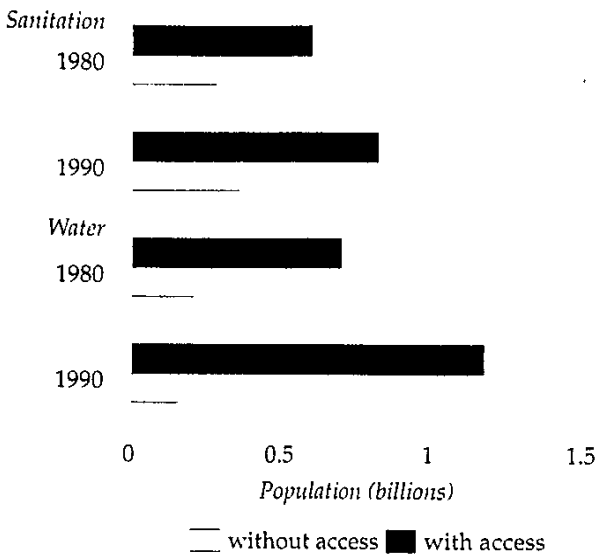
Unaccounted-for water (UfW) is the difference between the amount of water put into a supply system and that which is billed to consumers. UfW has two aspects:

- "Physical losses", or water actually lost through leaks. Leaks may stem from poorly constructed plants, reservoirs, and networks, aging systems and house connections, accidents, and poor maintenance.
- "Administrative losses", or revenue lost through unbilled or underbilled consumption. This can result from administrative failures such as inaccurate or faulty metering, incorrect billing, and theft.

in terms of budgets and staffing, than operation and maintenance. And, in a financial crisis, O&M budgets are the first to be cut, with consequent deterioration of pipes, machinery, and service. Maintenance equipment, vehicles, and spare parts are often in short supply and requests for their acquisition are often "postponed". However motivated the O&M staff may be, they cannot react promptly to emergencies without the right equipment.

To be sustainable, an operation must be financially viable. Because of the pressure to expand the area served, viability generally implies the recovery of the costs of operation and maintenance, as well as capital costs. Public utilities often have difficulty getting approval for increasing their charges to levels that are financially and economically adequate. Sometimes this is for political reasons but often it is also because the requests are poorly prepared and their urgency is not well perceived. Higher charges must be justified not only to the parent entity but also to consumers. Public relations campaigns can be helpful here, but quality service is often

Urban access to safe water and adequate sanitation in developing countries, 1980 and 1990



Source World Bank, *World Development Report, 1992.*

crucial to securing consumers' acceptance of increases.

OED assessments show that day-to-day management of water utilities is often complicated by problems at the national level: inadequate or ambiguous legislation, poor allocation and/or duplication of responsibilities among ministries and different levels of government, and excessive numbers of poorly-paid and incompetent civil servants.

Importance of "arms length" regulation

Most of the water supply and sanitation entities in developing countries are public. Some of the public companies, such as those in Singapore or Santiago de Chile, are highly successful. But many suffer from weaknesses often associated with public entities—for example political interference in management decisions, overstaffing, inadequate incentives for staff, and poor standards of service.

The most successful water and sanitation utilities are in countries with strong but "arms-length" regulation of the sector. This allows government-owned utilities to operate under commercial rules and with the greatest possible exposure to the discipline of the market, while meeting essential economic and social criteria. Where managers are free to set tariffs, select staff, and set competitive salaries, utilities are more successful and so are their projects. Experience in Botswana and Singapore shows the value of giving water utilities substantial operational and financial freedom, with regulatory oversight by parent ministries to ensure appropriate policy direction.

OED reviews show that the Bank has consistently supported the granting of autonomy to water utilities in countries where the water supply sector is appropriately regulated. Where autonomy was achieved, it was crucial to good performance.

For regulators to exercise control, the standards of service and the framework for setting tariffs and for monitoring performance must be clearly stated in the law (typically a "Water Act"), ordinances, or operating contracts, together with the rights and obligations of the utility. This has not always been the case, perhaps because the public ownership of the utilities has clouded the need to separate the regulatory function from management by or for the owner.

Because, in most countries and sectors, public entities are likely to retain primary responsibility for infrastructure in the foreseeable future, efforts to improve their effectiveness

are crucial. Three instruments have often proved useful in instilling commercial discipline in public agencies:

- corporatization, which gives the agency a degree of autonomy, insulating it from noncommercial pressures and constraints;
- explicit contracts and regulatory procedures between the government and the agency, which specify the services to be delivered but leave discretion over planning and management;
- pricing policies designed to ensure cost recovery, and hence a desirable form of financial independence for the agency.

Private sector development

Even where private companies are not allowed to or do not wish to own assets, they can play an important role

For private providers of services, the desire to raise net earnings normally provides enough motivation to maximize the use of capacity along with revenues, and keep expenditures at a minimum. These agencies can adopt pay scales that attract competent personnel. Normally, their books are kept on a commercial basis and thus offer many of the benefits of management information systems rarely available to government entities.

Private companies may be reluctant to extend their operations into poor neighborhoods where individual water consumption may be too low to bring a return on investment, and/or where it is difficult to bill consumers and collect the payments they owe.

Even where private companies are not allowed to or do not wish to own assets, they can play an important role. In Côte d'Ivoire, for example, a private company competently operates and maintains the water supply and sanitation facilities under contract to the government. Arrangements such as this work well when the private contractor is capably supervised by the public utility or government department responsible. Full-fledged concession contracts are not the only way to take advantage of the private sector's flexibility, accountability, and ability to hire and retain strong staff. Santiago de Chile successfully uses private contractors for O&M; in 1989, some 34 O&M contracts were signed with private operators.

Yepes (1992) indicates several areas where the participation of the private sector has proved cost-effective: maintenance and repair of equipment, water and sewerage networks, and pumping stations; meter installation and maintenance; collection of service payments; and data processing.

To yield their full benefits, contracts with private operators should be subject to competitive bidding. Mutual responsibilities and monitoring criteria must be clearly defined. The entity awarding the contracts must be able to administer them. No O&M system will work optimally without a planning and control scheme and a detailed monitoring and feedback system.

Types of maintenance

Preventive or routine maintenance, including leak detection, should be carried out continuously according to pre-established schedules, according to rational considerations such as the manufacturer's recommendations for servicing the equipment. Once agreed upon, these schedules need to be kept to and the results recorded. Special programs such as intensive leak detection, surveys to detect illegal connections, or distribution network analysis, may be scheduled on an annual or one-time basis.

An important aspect of routine maintenance is the systematic inspection and replacement

of consumption meters. This usually requires a meter repair shop for cleaning, repair, and testing. Information on the condition of meters is vital for future protective and procurement purposes. In general, domestic meters should be taken out of service every five to seven years and completely overhauled.

Reactive maintenance is needed where past routine maintenance has been insufficient, as well as after accidents and where plant is aging. All interventions need to be analyzed and the causes of malfunction or breakage recorded, so as to guide future procurement decisions and help in deciding whether part or all of a network or plant should be upgraded or replaced.

...administrative losses are consistently higher than physical losses

Reducing unaccounted-for water

In association with continuous service and good quality water, a low rate of unaccounted-for water (UfW) is one of the best overall indicators that a water supply utility is successful. Rates of UfW vary from system to system, but evaluation findings confirm that in most water supply entities they are unduly high. In 1989, Singapore's UfW of about 10 percent ranked the lowest in the world. Manila, Philippines, has consistently had UfW rates around 60 percent, and Jordan, around 58 percent.

Reasons for UfW problems include:

- poor engineering, construction, and maintenance;
- poorly managed metering, billing, or collection;
- poor consumer relations;
- illegal connections and theft, endemic in some cities.

In systems where consumption is not metered (that is, where consumers are charged a flat rate, sometimes as part of their property taxes), UfW cannot be measured accurately; best guesses can be attempted from district or night flow metering and routine inspections for leaks.

Programs for reducing UfW often feature in projects supported by the Bank. Such programs often contain highly optimistic projections that are not transparently linked to the financial, technical, and administrative means needed to achieve the targets set. A common feature of these programs is their technical bias; people assume that physical leaks are the main part of the problem, and thus launch intensive leak detection surveys, without taking action to track down and address administrative losses first.

Experience in fact shows that administrative losses are consistently higher than physical losses. Singapore, for example, in 1991 reported administrative losses of 7 percent and physical losses of 4 percent. In the same year, losses in Bogotá, Colombia, were 26 and 14 percent, respectively.

A notable exception is Korea's National UfW Reduction Plan. Recognizing the economic and financial losses caused by high levels of UfW, which exceeded 40 percent in some areas, the government mandated a realistic plan, supported by low-interest government loans, to reduce the countrywide average to 20 percent over 12 years. The plan has specific targets for each utility.

Diagnostic studies

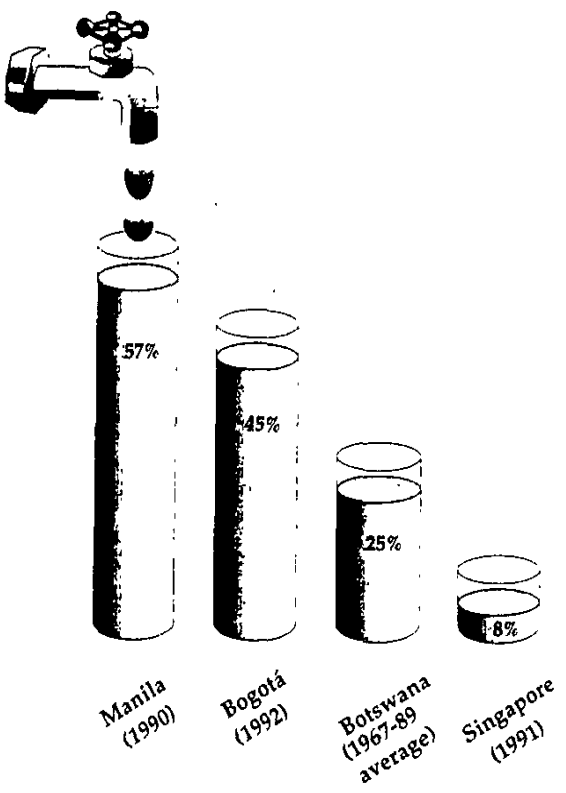
Monitoring of performance may show that UfW has become excessive (that is, more than 10–20 percent, depending on the sophistication of the entity). When this occurs, a diagnostic study is advisable. Such a study, or water audit, seeks to measure UfW and how much is lost at each phase of processing—

production, transmission, service reservoirs, house connections, metering, and billing.

The decision to launch or expand a UfW reduction program should be based on cost/benefit analysis. It makes little sense to pay more for the study than the value of the water to be saved or the additional revenue to be collected.

Comprehensive water audits are expensive, and should not be undertaken unless there is a strong commitment to implement their recommendations. This means, inter alia, that the water entity must agree beforehand to mobilize the necessary manpower, equipment, and materials to implement action programs that may last several years. For example, several cities have used "block mapping" programs to detect illegal connections, but in most of them, the lack of effective legal recourse by the utility has limited the actions taken and their results.

Unaccounted-for water, selected cities and countries
(percent)



Source: OED, "Water Supply and Sanitation Projects: The World Bank's Experience, 1967–89," Report No 10789, 1992

Though water audits may be done in-house, many utilities rely on consultants with wider experience, leaving their O&M staff for normal duties. An excellent example was produced by consultants for Jordan in the late 1980s. (Box 2.)

Measuring losses

To determine and investigate the volume of UfW, the flow of water needs to be measured accurately at the various stages of the operation. Different pressure zones will already have been created for operating purposes. But to detect leaks, it may be necessary to isolate even smaller areas or sectors of the network and install temporary meters to measure flows at night.

One of the first steps in evaluating physical losses is to ensure that production and other bulk meters are working properly. When this has been done, measuring the volume of water produced and transmitted should be quite straightforward.

Accounting for the various uses of water is more difficult. In particular, few municipalities meter the water used for fire fighting, street cleaning, public standpipes, and parks. Meters have no substitute, and should be used to the extent possible.

Techniques for locating and evaluating water losses are well documented. An excellent source is Jeffcoate and Saravanapavan (1987).

Box 2: Diagnosing water losses in Jordan

The city of Amman gets its water pumped from 100 km away, against a static head of 1,500 meters. A comprehensive diagnostic study of the Greater Amman water supply system, using comprehensive hydraulic computer analyses, water loss measurements, data from production and consumption metering, and studies of the condition of meters and water pipes, was completed in 1989. It revealed that 21 percent of the water in the system (or 13 million cubic meters a year) was being lost through leaks, and that in total, 59 percent of the city's water was unaccounted for.

The study's recommendation, of a two-phase program to reduce UfW, is being implemented. The leak-reduction phase is being followed by a rehabilitation phase, with an estimated benefit/cost ratio of 3.8, financed by the water authority, the Bank, bilateral agencies, and the European Investment Bank.

Problems and solutions

Physical losses: Physical losses through leaks may occur in any part of the system: transmission pipes, service reservoirs, pumps, distribution networks, and house connections. It may be that an existing network or part of a network is no longer adequate to serve an area with much-increased population density, or has simply reached the end of its useful life and should be replaced.

Administrative losses: While reducing leaks will increase the volume of water available for sale, correcting administrative losses will not. Legalizing or eliminating illegal connections, replacing faulty (under-registering) or broken meters, and ensuring that consumption is accurately billed will, however, increase revenues.

Meters that have been tampered with, or are faulty or broken, are a major cause of administrative losses. Meters may break from excessive network pressure, freezing temperatures, or malicious damage. They may under-register consumption if water pressure is unusually low, or over-register it because air has infiltrated the system.

Other major causes of administrative losses are incompetence, inadequate training, or corruption of meter readers. These characteristics are even more disadvantageous where poorly paid meter readers also collect water bills. Ways to improve meter reading include better pay and incentives for staff, appropriate training, frequent verifications by supervisors, and changing the routes covered by individual readers. Contracting out meter reading is also becoming more frequent. Modern methods of meter reading by hand-held computers or remote metering generally overcome these problems.

The right frequency for meter readings/billings depends on economy and cash flow. Where labor is expensive, meters for all except large consumers are better read quarterly. In fact, monthly readings/billings are common.

Monitoring performance

One should resist the temptation to map the course of a utility on the basis of known

successes in other countries or even elsewhere in the same country. Monitoring—which shows whether an activity is improving, stagnating, or deteriorating—is a more reliable basis for prediction. The Bank has not produced directives for monitoring operation and maintenance, but Operational Directive 10.70, Project Monitoring and Evaluation, contains some relevant material.

To benefit fully from a monitoring system, managers must have access to its information on a timely basis, and be prepared to act expeditiously on critical issues.

Ways to improve meter reading include better pay and incentives for staff

Business plans

An important planning and control tool of modern businesses, both public and private, is the business plan. A properly prepared business plan is a good preparation for the annual budget exercise. It also forms an excellent basis for an incentive plan and is the principal basis for monitoring performance.

The three-year business plan of a water and sanitation entity would show the overall goals for each quarter, for example in terms of the number of people to be served, including the poor; the intended improvement in the quality of water; the number of uninterrupted service hours; or the improvement in the quality of effluent released into local water bodies. The plan should indicate how targets would be achieved, stating the manpower, tools, equipment, and materials needed.

The plan would contain sub-plans for each major activity or function. One of the sub-plans, for instance, would discuss the nature and number of routine maintenance interventions to be carried out each quarter. Another would, if necessary, show plans for addressing UfW, giving realistic quarterly targets for its gradual reduction.

The annual budget represents one of the time slices of the business plan. It should follow closely the format and system that the water utility's parent organization (government department or municipality) uses to control sector activities.

Accounting systems

Many Bank-supported projects require that the utility install a "commercial accounting system". Commercial accounting systems and reporting methods are preferable to so-called government accounting systems and should be installed whenever appropriate. But if the tool used by both the entity's management and the controlling ministry is a revenue and expenditure budget, it is pointless for an entity to produce accounts that reflect commercial accounting practices and formats.

Commercial accounting systems and reporting methods are usually costly to install. Training is needed, not only within the utility but also within the utility's parent organization in the central or local government.

Cost accounting

Cost accounting systems are rare in water supply and sanitation entities in developing countries. A properly devised cost accounting system allows management to track the cost of vital functions through appropriate cost allocation and analysis. This is especially useful concerning personnel costs, which most water supply and sanitation utilities treat entirely as period costs.

Monitoring and reporting

Monitoring the operating and maintenance activities of a public utility is complex and requires more than just a business plan Water extraction, treatment, quality and conveyance, effluent collection and disposal, plant maintenance, and commercial and financial

operations all need to be monitored, some on a quarterly or monthly basis, some on a weekly or even daily basis.

For each aquifer, the rate of extraction needs to be compared with the rate of replenishment, lest overpumping cause irreparable damage. Also, aquifers near the sea must be monitored for possible salt intrusion—another possible sign of overextraction.

Water levels in impounding reservoirs needs to be tracked, to determine whether they are getting dangerously low.

Total available water needs to be continuously compared with gross water demand (i.e., demand including an allowance for UfW) in order to decide whether expansion programs should be planned or whether, in the shorter term, rationing or pressure reduction programs are needed.

The quality of the water extracted, particularly that drawn from rivers, must be routinely tested in order to adjust treatment as required, and provide feedback to environmental agencies.

Water service reservoirs need to be monitored for possible leaks or overflows due to malfunctioning valves or water-level gauges.

Suggested Reading

Jeffcoate, Philip, and Arumukham Saravanapavan. *The Reduction and Control of Unaccounted-for Water.* Technical Paper No. 72. Washington, D.C.: World Bank, September 1987.

Lindstrom, James D., ed. *Impact of Interventions in Water Supply and Sanitation in Developing Countries.* Washington DC: US Agency for International Development and US Department of Health and Human Services, April 1981.

World Bank. "Project Monitoring and Evaluation". Operational Directive No. 10.70, September 1989.

———. Water Resources Management Policy Paper. Washington D.C.: World Bank, September 1993.

———.World Development Report, 1992: Development and the Environment. Washington D.C.: World Bank, May 1992.

World Bank, Operations Evaluation Department. "Water Supply and Sanitation Projects: The Bank's Experience, 1967-89", Report No. 10789, June 1992.

Yepes, Guillermo. "Infrastructure in LAC: The Costs of Neglect and Options for Improvement", Volume 3 of Water Supply and Sanitation Sector Regional Studies Program Report No. 17. World Bank, Latin America and Caribbean Technical Department, June 1992.

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