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Water and Sanitation

Infrastructure and Urban Development
Department
The World Bank
October 1992
WPS 1005

An Approach to the Economic Analysis of Water Supply Projects

Laszlo Lovei

A simplified method aimed at improving the quality of economic analysis on water supply projects.

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This paper — a product of the Infrastructure, Energy, and Environment Division, Europe and Central Asia Country Department III — is part of a larger effort in the Bank to improve operational practice and raise the quality of projects in the water and sanitation sector. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Mari Dhokai, room S12-005, extension 33970 (October 1992, 37 pages).

Development economists are increasingly concerned about the correct approach to economic analysis of projects. By looking for a compromise between theory (which identifies ideals) and practice (which deals within the bounds of time and resource constraints), Lovei focuses on potential guidelines for economic appraisals of water supply projects.

He summarizes theory and the current World Bank guidelines on the economic analysis of water supply projects; reviews the method of economic analysis applied in 21 recently approved Bank projects; and describes a simplified method that was tested in practice and found to improve substantially the quality of economic analysis in the sector.

This new method relies on standardized and rigorous use of information that is routinely available during the preparation of water supply projects.

An Approach to the Economic Analysis of Water Supply Projects

by

Laszlo Lovei

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1. Summary

Development economists in the World Bank and elsewhere are increasingly concerned about the correct approach to economic analyses of projects.[1] By looking for a compromise between theory (which identifies ideals) and practice (which deals within the bounds of time and resource constraints), this paper focuses on potential guidelines for project economic appraisal in the water supply sector. No "final solution" is proposed here, but the discussion should stimulate further efforts to develop a responsive approach.

The first section of the paper summarizes the theory and the current World Bank guidelines on the economic analysis of water supply projects. The next section reviews the method of economic analysis applied in 21 recently approved Bank projects, and the final section describes a simplified method that was tested in practice and found to improve substantially the quality of economic analysis in the sector. This method relies on standardized and rigorous use of information that is routinely available during the preparation of water supply projects.

2. Theory and Guidelines

Water is a good that has both consumption value and, in certain circumstances, value from external benefits for those who do not consume it. In theory, the benefits of private goods are fully divisible and excludable, and the benefits of public goods are indivisible and nonexcludable.[2] Industrial water is a private good, but residential water can supply external health benefits and is therefore neither a purely private nor public good. On the spectrum of private to public goods, residential water lies between the two extremes, probably closer to pure private goods.

The economic analysis (or cost-benefit analysis; these terms are used interchangeably in this paper) of water supply projects consists of the (1) estimation of project costs; (2) estimation of project benefits; and (3) comparison of costs and benefits (over time, with uncertainty). While project costs are estimated in the same way for water supply as for other sectors, estimating the benefits, particularly for a residential water supply component, is not so straightforward. For example, estimating benefits by using a measure of consumer willingness to pay captures only private gains and does not account for the public health improvements in the community at large. Public benefits are generally considered difficult to quantify and intangible.[3] Moreover, willingness to pay provides a good estimate of project benefits only when consumers fully understand the relationship between water and their own health.

In economic analysis, both costs and benefits are defined as the difference between results with the project and without it. The analyst develops these two scenarios in sufficient detail to estimate the difference for the period of project implementation and operation.

[1] See, for example, Little and Mirrlees (1990), Anderson (1989).

[2] For a useful definition of these terms, see Cornes and Sandler (1986).

[3] For a brief review of the literature on the quantification of health benefits, see Churchill (1987) pp. 10-12. In fact, although it requires voluminous data, it is possible to assess the monetary scale of health effects, as demonstrated in Harrington, Krupnick, and Spofford (1989). That paper analyzes the effects of an outbreak of waterborne disease and estimates nine categories of economic losses: doctor visits, hospital visits, emergency room visits, tests, medication, time and travel losses associated with medical treatment, work loss, work productivity loss, and leisure time loss.

World Bank guidelines on economic analysis do not separately discuss water supply projects.[4] The guidelines present a general description of cost-benefit analysis but not a blueprint for the sector practitioner. Various central concepts are briefly addressed, such as "with" and "without" scenarios, willingness to pay, external benefits, non-quantification of benefits. Yet there is no guidance on how to estimate consumer willingness to pay. However, detailed entries cover other problems, such as the selection of a numeraire, valuation of traded and nontraded goods, conversion factors, shadow wage, and interest rates.

Operational Manual Statement (OMS) 3.72 on the preparation of "Energy, Water Supply and Sanitation, and Telecommunications" (EWT) projects contains six paragraphs on the subject of "economic justification." Three steps are mentioned: (1) estimation of demand; (2) selection of the least cost supply option; (3) comparison of costs and benefits. However, the last step is considered quite difficult[5] in practice; therefore, the calculation of the financial internal rate of return (FIRR; adjusted for transfer payments) is proposed since it "usually represents at least a minimum estimate of the economic rate of return." There is no guidance on the procedures to be followed if the financial rate of return is below the opportunity cost of capital.[6]

3. Current Practice at the World Bank

To assess the existing Bank practice, Staff Appraisal Reports (SAR) of 21 recently approved water supply projects were reviewed.[7] Four different approaches to economic analysis can be identified. One SAR demonstrated that the project was the least-cost solution to meet assumed demand but did not go further. Let's call this a type A analysis. Fourteen SARs calculated the financial internal rate of return of the project and briefly mentioned other, non-quantified benefits. That is type B analysis. Three SARs calculated the FIRR and also provided an estimate for the consumer surplus--type C analysis. Only three SARs attempted to carry out an independent economic analysis without relying on the projected financial revenue stream--type D analysis.

Generally, type A analysis is justified when the majority of project benefits are considered non-quantifiable and the benefits of different supply options are thought to be the same. In practice, there are two problems with this approach. First, while the relative importance of expected health benefits may change from one water supply project to another, non-health-related benefits are seldom negligible and should be accounted for. Second, in cases where benefits are intangible but quantifiable, cost effectiveness analysis is more appropriate to determine the correct level of supply to achieve health improvements. Such analysis should consider whether the incremental health benefit due to the last unit of water supplied might be achievable at lower cost.

Type A, or least-cost analysis, has to be performed during the preparation of any water supply project, for example, to select the best water source.[8] It should come before the calculation of project costs. However, if the analyst only wants to ensure the economic viability of the project and is not interested in the net present value or the economic rate of return, then, assuming certain conditions are met, the estimation of benefits can be considered unnecessary. If the average incremental cost (AIC) of water[9] is equal to or less than the water tariff, and the demand at that tariff is estimated with reasonable certainty, it can be said without further analysis that the economic rate of return of the project is not less than the opportunity cost of capital. However, not all water projects in developing countries meet these conditions. In the case of the SAR that simply conducted a least-cost analysis,[10] the existing tariff was only 70 percent of the AIC and even the projected tariff (six years later) was less than the AIC.

[4] See World Bank Operational Manual Statement 2.21.

[5] Operational Manual Statement 3.72, para. 34 states, "In most cases it will not be possible to quantify the economic benefits by consumers in excess of amounts they actually pay, and therefore the estimation of the social value of the project is precluded."

[6] "A low return may simply indicate that tariffs are too low, rather than that the project is not justified." OMS 3.72, para. 34.

[7] For a list of the SARs reviewed, see Annex 1.

[8] See OMS 3.72, para. 32.

[9] AIC is defined as C/Q, where C and Q are the discounted present value of incremental costs and incremental water quantity supplied, respectively. The discount rate is equal to the opportunity cost of capital, and incremental means the difference between the "with" and "without" project scenarios.

[10] As a matter of fact, the SAR presented an economic rate of return calculation based on the comparison between the least cost and the second least-cost solution to the problem of providing the water source for the piped supply system. There was no comparison with the "without" project scenario.

Type B analysis has two potential problems. The first and more important problem is the reliability of the estimated incremental revenue stream. Water demand is a function of the price of water. Therefore the standard procedure of estimating water sales independently and multiplying that with the projected tariff is highly questionable (unless the price elasticity of water demand is very low over the whole range of relevant supply levels). The larger projected tariff increases are, the less reliable are the revenue estimates. None of the type B analyses examined the relationship between water tariff and water consumption. If no tariff increase was expected, this might be acceptable. But in 5 out of the 14 cases tariff increases ranging from 40 to 300 percent (in real terms) were calculated into the estimates of incremental revenues.

The second problem is the usefulness of the estimated FIRR. If the tariff is expected to stay at the present level and the estimated FIRR is higher than the opportunity cost of capital, the project is justified.[11] Among the nine type B analyses that did not project a tariff increase, only three estimated the FIRR to be higher than the opportunity cost of capital (assuming a 10 percent rate for the sake of simplicity). For additional justification, the other six type B analyses referred to non-quantified benefits.[12] However, it is not possible to assess whether, if quantified, those benefits would have made the projects economically viable. In these cases, without additional information, the FIRR calculations did not give enough support to decision making and only indicated how high the non-quantified benefits need to be.

The three type C analyses tried to come up with the additional information by estimating the value of consumer surplus. To do that, the water demand function had to be estimated in the relevant range. The same procedure was followed in all three cases: the coordinates of two points on the ordinary (uncompensated) demand function[13] were determined and then connected by a linear or loglinear curve. After the demand curve and quantities consumed under the "with" and "without" scenarios had been estimated, the calculation of the area that represented consumer surplus was relatively straightforward.

Accuracy of the whole procedure depends on the selection of the two points on the demand curve. That is exactly where two of the analyses went wrong. Coordinates of the first point were based on the price and quantity of water purchased by households from distributing vendors. Projected piped water consumption and water tariff determined the coordinates of the second point. But these two points are not on the same demand curve. Connected households use piped water for drinking, cooking, bathing, washing, and sometimes even for gardening. Water sold by distributing vendors is used only for drinking and cooking (sometimes for bathing). This is reflected in the small quantities purchased, 5-20 liters per capita per day (l/c/d). Bathing, washing, and other water demand is usually met from secondary sources like shallow wells, rivers, and ponds that provide lower quality water at lower cost. When there is no information on water purchased from vendors, other than the price and quantity, consistency requires that the other point on the demand curve be based on piped water consumption for drinking/cooking only.

The third type C analysis tried to place both points on the same demand curve by restricting the calculation of consumer surplus to the first 15 l/c/d of piped water.[14] However, that may actually have underestimated the benefits of piped water supply. When piped water costs less than other nonpiped sources, consumers will enjoy a surplus on their water for other use also. Despite this discrepancy, such a conservative approach might be useful when the FIRR (based on existing tariff) is close to the opportunity cost of capital.

If a second point on the demand curve represents the full quantity of piped water consumption, the first

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[11] See OMS 3.72, para. 34.

[12] One SAR, without presenting a demand analysis, used the assumed tariff as a proxy for benefits of proposed small rural water supply schemes. The tariff was simply set to achieve the required level of cost recovery (part of the capital cost and all operation and maintenance costs). "Additional" benefits were mentioned without quantification: time savings because water would be carried over shorter distances, fuel cost savings because less boiling would be required, and health benefits. Since these benefits are usually the reason why consumers might be willing to pay for water, quantifying them would lead to double counting.

[13] For the definition of ordinary and compensated demand functions and a review of the relationship between ordinary demand functions, consumer surplus, and compensating variation, see Johansson (1987) Chapter 4.

[14] While the method of estimating part of the consumer surplus appears correct, estimates of water sales revenue and the economic rate of return (ERR, in this case 11 percent) are questionable. The revenue stream was based on a tariff increase of more than 500 percent (in real terms) during the first six years of the project, apparently with no effect on water consumption.

point must be based on observations of water use from all available sources. Otherwise, as in two of the type C analyses, consumer surplus can be grossly overestimated. Both analyses aimed to determine only the average value of consumer surplus based on cubic meters of water consumed. To do that, each calculated the area of the triangle under the demand curve between the quantity sold by vendors and the quantity provided by the piped water system and therefore implicitly assumed that the "without project" consumption was not more than the amount of water purchased from vendors. As a result, the two analyses arrived at similar conclusions: the average value of consumer surplus is about equal to the water tariff; therefore, total benefits should approximate two times the sales revenue.[15]

One of the three type D analyses provided an estimate of the average cost of existing nonpiped water (including the value of time spent fetching water) and assumed that project benefits were equal to that cost, based on cubic meters of water consumed. This procedure is correct as long as the incremental piped water delivered by the project only replaces water from other sources without resulting in an increase in overall consumption.[16] However, since piped water consumption (per consumer) was projected to be higher than existing water use, and since consumers generally assign a decreasing value to additional water, the end result (13 percent ERR) probably overestimated the true economic rate of return.

While the second type D analysis initially followed a similar procedure, it recognized that additional supplies had a diminishing value. Although the relationship between water price and quantity was not described explicitly, it was assumed that the average value of additional water consumed was halfway between the price of piped water and the current cost of nonpiped water. This assumption implies a demand curve that is linear between the points representing existing and projected water costs and prices. Several water supply schemes were analyzed that way in the SAR. The calculated ERRs were between 5-27 percent. There was not any cut-off level applied, and all schemes were accepted, based on additional, nonspecified, "unquantifiable" health benefits.

The third type D analysis divided the consumers into two groups, existing consumers (already served by the water system) and new consumers. Water demand curves were estimated separately for each group. At first two points on each demand curve were identified. One point was based on drinking/cooking water demand, priced at the rate charged by water vendors, while the other point was based on projected per capita piped water use, priced at the expected average tariff under the project. Again, unless vendors were the only water source used by the nonconnected consumers, these two points are not on the same demand curve. This might explain why the two points identified that way produced a (constant) price elasticity of water demand higher than unity (in absolute value). To stay consistent with expectations, a variable elasticity approach was selected and the demand curve was assumed to consist of two straight lines running through the two identified points, with elasticities of (-0.2) and (-0.8).

After estimating the demand curves, the average willingness to pay per gallon of incremental water was estimated for each group of consumers. Existing consumers' average willingness to pay was estimated at the midpoint on the demand curve between the with- and without-project consumption levels. One part of the water delivered to new consumers was assumed to replace drinking/cooking water purchased from vendors and was valued at the vendor price to account for cost savings. The other part was assumed to represent incremental consumption and was valued according to the demand curve. As a result, new consumers' average willingness to pay, as a proxy for project benefits, was estimated 70 percent higher than the projected tariff. If these consumers had been using other water sources in addition to vendors, then the applied method overestimated project benefits. However, since the project's ERR was estimated at 15 percent, and less than 20 percent of incremental water would go to new consumers, this project seems to be viable.

Altogether, only three type B and one type D analyses appear methodologically correct out of the 21 reviewed (see Table 1). That does not mean that the other 17 projects are not economically viable. Some of them could be justified on the basis of information in the SARs, but many of them cannot be assessed without further information and analysis. However, rather than assessing the viability of these projects, this review aims to

[15] One of the two analyses did not stop here. "Additional" benefits were quantified, such as sickness cost avoided, fire prevention and land value increase. Beginning with an FIRR of 15 percent based on existing tariff (which means that the project, as a result of a type B analysis, appears justified), the analysis ended with an ERR of 34 percent. However, it was admitted that "some (sic) overlap may exist between the fire and health benefits and consumer surplus."

[16] To be exact, two additional assumptions are needed. It must be assumed that there are no transfer payments among the costs of existing water supply and that there is no producer surplus.

demonstrate that currently used approaches to the economic analysis of water supply projects need substantial improvement.

Similar conclusions appear in a number of annual reviews prepared by the sector policy and research staff of the World Bank. According to the 1990 water sector review, "the economic analysis of projects does not follow a consistent approach and the reported rates of return seem, in several cases, to be subject to substantial upward bias due either to the approach used or the data employed in its calculation."[17] The same review observed that, "water demand continues to be projected as a completely inelastic consumption trend with an assumed growth in per connection consumption, unrelated to prices assumed in financial forecasts and in revenue projections used in the economic justification." Obviously, specific guidelines on the economic analysis of water supply projects are needed to rectify these problems. The guidelines should be based on a methodology that is flexible and structured according to the complexity of the projects to be analyzed--namely, it should be kept simple and the critical assumptions of any particular case application should be clear and well understood. Furthermore, the methodology should be user friendly and usable also to borrowers.

[17] World Bank (1990) pp. 14-15.

4. A Proposal for Improvement

"Time for a change" --that is the subtitle of a World Bank discussion paper on rural water supply and sànitation issued in 1987.[18] Although primarily policy oriented, the paper addresses many of the problems described here. Regarding health effects, it argues that "the existence of substantial, health-related externalities is in doubt, given the evidence."[19] On this basis, the paper recommends that analysts should concentrate on the assessment of economic benefits of water supply projects, especially on time savings. However, not relying on external health benefits to justify a project does not mean that all health benefits are unaccountable. Health benefits known to users are reflected in their willingness to pay for good quality water, and willingness to pay can be derived from the demand function. This leaves only two kinds of benefits that cannot be captured: (1) those unknown to users and (2) benefits to others through reduced disease transmission. Experience suggests that health benefits will not materialize unless consumers understand the relationship between water and health and use water properly.[20] Also, the people most affected by disease transmission are those living in the same household and probably their benefits are reflected in consumers' willingness to pay.

[18] Churchill (1987).
[19] ibid. p. 32.
[20] ibid. pp. 10-11.

Table1 Review of Twenty-One SARs

	Type of Economic Analysis			
	A (least Cost)	B FIRR	C (FIRR+CS)	D (true econ. analysis)
Problems in the Analysis				
AIC > tariff	1			
Tariff has no effect on demand		5	1	
FIRR < 10%		6		
Misspecified "without project"			2	1
Constant marginal utility of water				1
Subtotal	1	11	3	2
Correct Analysis	0	3	0	1
Total	1	14	3	3

Another World Bank paper on rural water supply recommends that "for project preparation, more precise tools are needed to determine the willingness to pay for different service levels and to assess the consequences of this information on technology choices and financial decisions."[21] The paper identifies direct and indirect methods of determining what water supply service people want and are willing to pay for. The direct method is to interview potential customers and ask how much they are willing to pay for different types and levels of service. Detailed guidelines for applying this approach, called the "contingent valuation method," have been published by USAID.[22] The indirect method is to collect data on observed behavior (quantities of water used from different sources, time spent collecting water, money spent on purchasing water) and, on the basis of consumer demand theory, infer how much consumers would be willing to pay for improved water supply.

The type C and type D analyses obviously tried to follow the indirect method but, at least in some aspects, applied the theory of consumer demand inconsistently. Yet, for the indirect method, all elements for practical improvements are readily available. Improved economic analysis would result in better design and selection of projects and would potentially increase the reliability of revenue projections.

All the economic analyses reviewed here made the assumption that the number of consumers connected to the system or relying on public taps is a given. However, whether to connect to the system and how much to consume are two interdependent decisions. Whittington, Briscoe, and Mu (1987) present a theoretical framework that makes it possible to model both simultaneously. This paper does not deal with water source selection despite its importance for the economic and financial viability of water supply projects. The methods described here assume that the number of customers is known. The estimated demand function depends on the number of consumers who select water from the piped system. Therefore, estimated project benefits indicate potential benefits only. While the proposed project may appear viable, if the consumers decide to stay with their existing sources of water (because of high connection charges or water tariff, or simply as a matter of taste), that potential will not materialize. Although estimating the number of customers should be integral to any economic analysis, the proposed methodology does not cover it.

Shortcut method. This method assumes that the purpose of economic analysis is strictly to decide whether a particular project is economically viable--namely, whether the present value of net benefits is likely to be positive. While this approach provides a *lower bound* for the expected economic benefits, it does not provide the practitioner with an estimate of total benefits. This helps keep the analysis simple. If an order of priority has to be assigned to a set of possible projects, the shortcut method cannot be applied. But, since Bank appraisals usually work with a yes or no investment criterion (which assumes that the opportunity cost of capital is known), it seems worthwhile to consider the simplified approach first.

If the existing tariff is adequate to meet financing requirements and a real tariff increase is not expected, a FIRR calculation based on existing tariff and projected demand can be carried out. The demand estimate should not be a simple extrapolation of past trends but should take into account the changing composition of customers (either due to service area extension or real income increase over time). If the needed information is available or accessible, an analysis of income and water demand should be carried out to understand better how a shift towards higher or lower income customers will affect water consumption. Even if there is not enough data to compare income and water consumption, the income elasticity of water demand should be taken into account when customers' real income is expected to rise substantially. An educated guess in the range of 0.4 to 0.8 (water is a necessity) may be acceptable. Generally ERR $\geq$ FIRR, therefore the project is justified if the FIRR is not less than the opportunity cost of capital.[23] Looking at the 21 reviewed SARs, four projects (three type B and one type C) would probably pass this test.[24]

If a real tariff increase is expected, projection of water demand requires estimation of the price effect. Since econometric investigations are data intensive and time consuming, an educated guess is again probably the

[21] Briscoe and de Ferranti (1988) p. 25.

[22] Whittington, Briscoe, and Mu (1987); Whittington (1988).

[23] It is assumed that (1) economic costs of the project are not higher than financial costs; (2) the project has no negative externalities. When these conditions are not met (e.g., the planned extraction of surface or groundwater for the piped system will decrease the availability of water for certain consumers who will not be connected to the system and rely on the same water sources as the project), the cost stream has to be corrected before the internal rate of return calculations are carried out.

[24] This test is exactly the same as described in OMS 3.72 (although OMS 3.72 does not list the necessary conditions for the validity of the test).

most efficient way to determine the price elasticity of water demand. Based on econometric studies, the short- and medium-run price elasticity of water demand is usually in the -0.2 to -0.8 range.[25] Price elasticity changes as one moves along the demand curve. Arc elasticity over the assumed range of price change is more relevant for economic analysis than point elasticity. If known, the effects of previous tariff increases can be analyzed to select a particular value for the price elasticity.[26] After the price effect is taken into account, the same test as above can be carried out to see whether the project is justified.

These demand projections assume that the observed quantity of piped water consumption with the corresponding price provides a point on the demand curve. If supply is intermittent or consumption is not metered and a flat monthly fee is charged, that assumption will be unfounded. Also, if the number of existing customers is small compared to the planned expansion, extrapolation of observed piped water consumption patterns is highly uncertain.

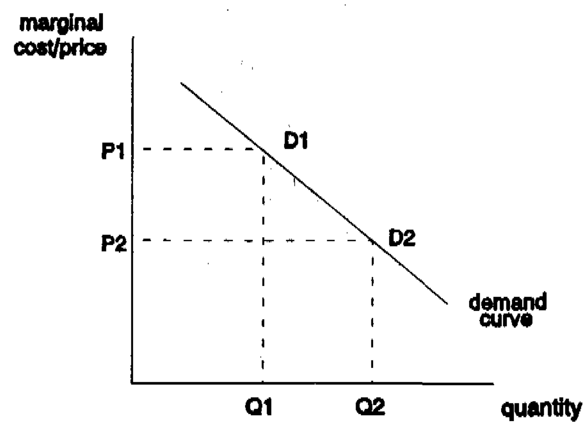
When the FIRR is below the opportunity cost of capital, the "shortcut" method cannot be applied. Adding consumer surplus to the revenues might raise the calculated internal rate of return; however, *the consumer surplus of new customers cannot be estimated without taking into account their existing, nonpiped water consumption.*27 The indirect method described below can be applied in all these cases as well as when a completely new system is to be constructed.

Indirect method. Residential consumers use water for drinking, cooking, bathing, washing, and so forth. The water quality required depends on the purpose or use. Brackish water might be acceptable for washing but not for drinking. When piped water is not available, people usually rely on a variety of water sources: vendors, wells, rivers, ponds, springs, rainwater. Both the quality and the price of water from these sources are different, and each water source serves different needs. When piped water becomes available, it is a potential substitute for water from all other sources.[28]

The incremental quantity of piped water supplied by a project can be divided into two parts: one part *replaces* the previous sources and quantity of water use, the other part is a net *increase* in water consumption. In this context, benefit of the first part is equal to the savings of economic costs of consumers who do not need to use the former water sources any longer (the area represented by OQ1D1P1 in Graph 1). Benefit of the second part is equal to the area below the demand curve between the with-project and without-project water use of each consumer (the area Q1Q2D2D1 in Graph 1).

Before benefits can be estimated, a survey of existing water consumption patterns must be undertaken to determine the quantity of water used from each source

Graph 1: Benefit of Piped Water



Q1 Water use without project
Q2 Water use with the project
P1 Marginal cost/price of water without the project
P2 Marginal cost/price of water with the project

[25] For example, Al-Qunaibet and Johnston (1985).

[26] If these effects are not documented, one could, as a last resort, rely on Martin and Thomas (1986), who found that the long-run price elasticity for residential water was about -0.5 over a wide range of price changes and across several countries. With respect to industrial water demand, Renzetti (1988) found that the price elasticity was in the -0.1 to -0.6 range, with the demand of water intensive industries being generally more elastic.

[27] The without project consumption of these customers would be zero unless nonpiped water use is also taken into account.

[28] Whether this actually happens depends on the quality and price of piped water compared to water from other sources.

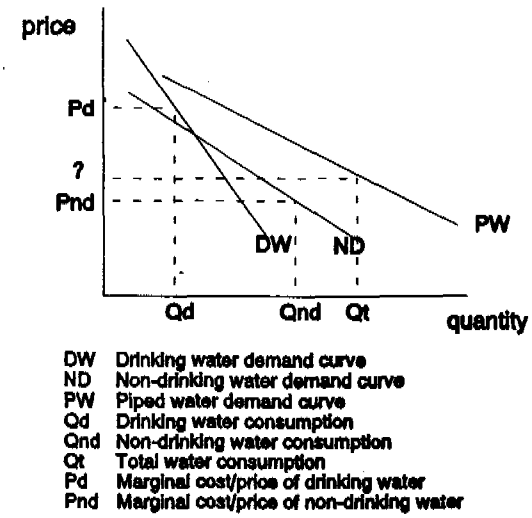
and the amounts spent on water sold by vendors,[29] on the construction and repair of wells, handpumps, water storage tanks, and on the operation of diesel or electric pumps, and time spent collecting and carrying water and operating handpumps. While the value of consumers' time is not directly available from the water use survey, recent research suggests that it is close to the market wage rate for unskilled labor.[30]

Unless there are indications to the contrary, it can be assumed that actual payments represent economic costs--that is, the production and operation of wells, storage tanks, and pumps is a competitive industry with a flat cost curve. It is also assumed that no element of monopolistic rent distorts the price of water sold by vendors, and that vendors who lose their jobs due to the piped water project can find alternative occupations without incurring any costs.[31]

Usually it can be assumed that all nonpiped water use will be replaced by piped water in households that choose to connect to the piped system.[32] This assumption should not apply to households that will be served by public taps; the amount of water use replaced will depend on the price of water and the location of the taps compared to the cost and convenience of presently used water sources. After the amount and cost of replaced water are estimated, the calculation of cost savings resulting from the first part of water supplied by the project is relatively straightforward (area $OQ_1D_1P_1 = Q_1 \times P_1$, see Graph 1).[33]

The demand curve for piped water is needed to estimate benefits due to the second part. If there were only one water source, the quantity and marginal cost of water used from the source would determine a point on the piped water demand curve. Frequently there is more than one water source used, and water from different sources serves different needs. Theoretically, there is a separate water demand curve for each need (DW and ND in Graph 2). Observations obtained from the water use survey describe the consumption of water from these sources. The marginal cost of water from various sources is different; therefore, the points on the demand curves obtained from the water use survey belong to different prices. The piped water demand curve (PW) is the aggregate of these curves since piped water can serve all these needs. However, the points obtained from the survey cannot be aggregated because their coordinates on the vertical axis (that is, prices P_d and

Graph 2: Aggregation of Water Demand Curves



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[29] When vendors are active in the project area, information obtained from the water use survey about the cost and quantity of water purchased from vendors will be substantially more reliable than information describing consumption of water from other sources. However, water vending is not a necessary condition for using the proposed method.

[30] Whittington, Mu, and Roche (1989).

[31] If a project is expected to replace a substantial amount of water purchased from vendors, a water-vending survey to validate these assumptions is warranted. The survey should provide information about the cost and price of water at each phase of the vending system: at the water source, at the retail outlets (hydrants or kiosks), and, after distribution, at the point of delivery to the households.

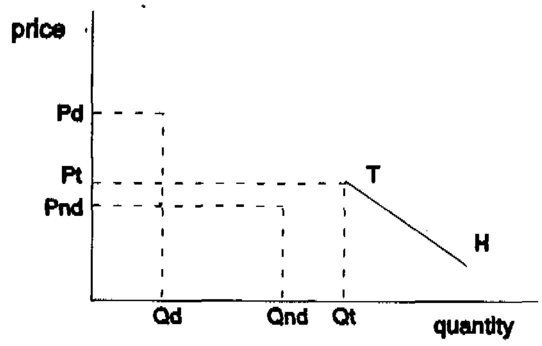
[32] The problem of determining how many households want to connect to the system is not analyzed in this paper.

[33] Sunk costs cannot be saved, therefore only those costs should be taken into account which would not be incurred if the project was implemented. While the cost of an already existing well or water pump cannot be avoided (that is, it is sunk except for salvage value, if any), future replacement costs or the cost of new wells should still be considered.

P_{nd}) are different.[34] In other words, we do not know exactly what price belongs on the aggregated demand curve to the total consumed quantity of water (Q_t).

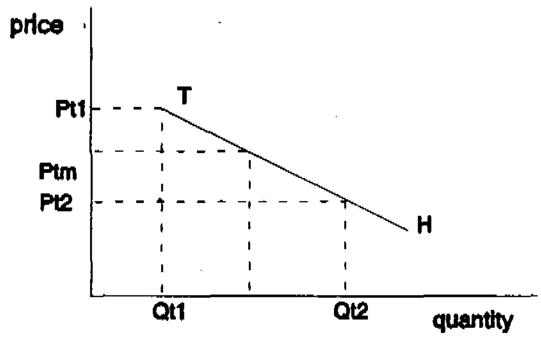
The method proposed here assumes that this price (P_t, see Graph 3) is equal to the weighted average of the prices/costs of water from the various sources (the weights are the consumed quantities). It is further assumed that the segment of the piped water demand curve that belongs to prices lower than this weighted average price is linear.[35] But one more point is needed--on the low end of the water demand curve (point H in Graph 3)--and its coordinates can be based on previous observations of piped water consumption under similar income levels, low prices, and unconstrained supply.[36]

Graph 3. Estimation of a segment of the piped water demand curve



Qd, Qnd, Qt, Pd and Pnd are the same as above
Pt = (Pd x Qd + Pnd x Qnd)/Qt
H High quantity - low price point on the priped water demand curve

Graph 4. Calculation of the benefit of the net increase in water use



Qt1 Total water use without the project
Qt2 Total water use with the project
Pt1 Marginal cost/price of water w/out project
Pt2 Marginal cost/price of water with the project

After the segment [T,H] of the piped water demand curve is determined, the benefit of the second part of incremental water supplied (namely, the benefit due to the net increase in water use) can easily be estimated. Since the

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[34] The aggregation problem is related only to the observations in the survey, not to the water demand curves themselves. If we knew the curves already, their aggregation would not present any difficulties.

[35] Selection of the form of the demand curve will influence the estimation of consumer benefits (it affects the benefits obtained from the net increase in water consumption--that is, area $Q_1Q_2D_2D_1$ in Graph 1). However, the difference was found to be marginal in most practical examples. The proposed method works with linear curves because they're simpler to estimate. Gomez (1987) provides a good description of experience with a similar method used in the Inter-American Development Bank with linear and logarithmic functional forms in the estimation of water demand curves.

[36] If estimated with reasonable certainty, the point determined by the tariff projection and the corresponding water sales under the project can substitute for this high quantity--low price point. However, if that estimate is uncertain, it is better to follow the procedure proposed above. The results are not sensitive to the selection of the high quantity--low price point and the proposed procedure at least ensures that the benefit calculation is not implicitly based on an upward sloping demand curve.

demand curve is assumed to be linear between the presently consumed quantity of water (Q_{t1}, see Graph 4 below) and the new, increased consumption quantity (Q_{t2}), the average economic value of one unit of incremental water is equal to the price (P_{tm}) on the demand curve that belongs to the midpoint between these two quantities--that is, $P_{tm} = (P_{t1} + P_{t2})/2$. The benefit (B) due to the net increase in water consumption is equal to the average economic value calculated accordingly, multiplied by the total net increase in water use, or $B = P_{tm} \times (Q_{t2} - Q_{t1})$.

Since the proposed method works with the aggregated demand curve, it implicitly assumes that the consumers' "without project" condition (or, without the net increase in water use) is equivalent to the situation when only piped water is consumed at the weighted average price (point T on the demand curve in Graph 3). The benefit of the incremental water calculated accordingly will equal the true benefit if the incremental consumption ratio for any two kinds of water use is the same as their existing consumption ratio.[37] However, the (relative) incremental consumption of water for basic needs is usually higher.[38] That makes the benefit of incremental piped water somewhat underestimated (for a numerical example, see Annex 2).

Two simple Lotus-based computer programs, ECOWAT1 and ECOWAT2 were developed to carry out these calculations for small and medium-sized water supply projects (Annexes 3 and 4 present the input and output tables of the programs). ECOWAT1, the simpler version, needs data input only for the project implementation period plus the first year after project completion. It was designed for small projects (less than US$0.5 million total investment cost). ECOWAT2, the multiperiod version, needs input for the project completion period plus every fifth year for 25 years after the project is completed. It was designed for medium-sized projects and allows the user to incorporate dynamic effects on both the demand and supply sides.[39]

Although relying on aggregated demand curves can lead to a downward bias in estimating benefits, they are used in ECOWAT1 and 2 based on the following considerations. The data needed to estimate two (drinking and nondrinking) or more water demand curves would require a more detailed survey. Such a survey would assess not only the quantity, source, and cost of existing water use but also the purpose of water consumption. The number of survey questions would be substantially higher, increasing the cost of economic analysis. Experience with the computer programs indicates that the advantage of using multiple water demand functions would be modest, since benefits due to incremental water consumption are usually not very large (the incremental water consumption in the numerical example in Annex 2 is quite substantial, 45 percent).[40] Also, ECOWAT could be run twice (separately for drinking and nondrinking water), if the data were available. In such a case, the fixed cost of piped water could be arbitrarily divided between drinking and nondrinking water. The net present values (NPVs) of the two runs should be combined to arrive at the true NPV of the project.[41]

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[37] More precisely, assuming there is only two kinds of water use, this condition is met if $(Q_{d2} - Q_{d1})/(Q_{nd2} - Q_{nd1}) = Q_d/Q_{nd}$, where Q_{d2} and Q_{d1} (Q_{nd2} and Q_{nd1}) are the quantity of drinking (and nondrinking) water used with and without the project, respectively.

[38] The assumption that one kind of water (piped) with the same price will satisfy all needs frequently leads to that result. Basic needs require higher quality and costlier water, and relative incremental consumption is usually positively correlated with the marginal cost of the existing supply, such that the higher the marginal cost of water currently serving a particular need, the higher the incremental consumption (for that need) will be after piped water becomes available.

[39] Large projects, however, should not be analyzed with these standardized programs. While the principles of a method analyzing a large project should basically be the same, more detailed analysis is warranted. It is advisable to divide consumers into three to five income groups. Also, unless the availability of alternative (nonpiped) water sources is the same for the whole area, the future service area should be divided into regions with similar "without project" conditions. Specific guidelines for the appraisal of large urban water supply projects were developed in the Inter-American Development Bank in 1977, see Powers (1977). These guidelines were later incorporated into a computer model, see Powers and Valencia (1980).

[40] This also explains why the selection of different functional forms for the water demand curve has only a marginal impact on the estimated benefit stream.

[41] However, the aggregation problem cannot be completely avoided; it is there from the beginning, when the water consumption of several households are added together to estimate their combined water demand. Different households usually face different water costs when they rely on nonpiped water sources, which again raises the problem of estimating the price on an aggregated demand curve.

The computer programs were tested in Indonesia in 1988 and soon became widely used by both expatriate and local consultants preparing water supply projects. Government departments built the programs into their project appraisal guidelines. Recently one department, in the context of a project appraisal workshop, has begun to train its staff in the use of the programs. Currently the programs are used to test the economic viability of proposed projects and also to identify areas where the economic benefits of piped water service expansion are expected to be the highest.

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Annex 1: Staff Appraisal Reports Reviewed

1. Uruguay: Water Supply Rehabilitation Project (6790-UR), March 1, 1988.
2. Nigeria: Lagos Water Supply (6375-UNI), April 25, 1988.
3. Colombia: Water Supply and Sanitation Project (7120-CO), May 26, 1988.
4. Zaire: Third Water Supply Project (7204-ZR), June 2, 1988.
5. Brazil: Water Project for Municipalities (7083-BR), June 10, 1988.
6. Yemen: Al Mukalla Water Supply Project (6995-YDR), June 22, 1988.
7. Pakistan: Second Karachi Water Supply and Sanitation (7355-PAK), December 30, 1988.
8. Guinea: Second Water Supply Project (7304-GUI), January 9, 1989.
9. Haiti: Port-Au-Prince Water Supply Project (7613-HA), April 4, 1989.
10. Yugoslavia: Istria and Slovenia Water Supply and Sanitation Project (7479-YU), May 1, 1989.
11. Brazil: Water Sector Project in the State of Sao Paulo (7650-BR), May 17, 1989.
12. Ghana: Water Sector Rehabilitation Project (7598-GH), May 18, 1989.
13. Mexico: Water, Women and Development Project (7726-ME), May 24, 1989.
14. Kenya: Third Nairobi Water Supply Project (7500-KE), July 6, 1989.
15. Philippines: Anggat Water Supply Optimization Project (7801-PH), August 23, 1989.
16. India: Hyderabad Water Supply and Sanitation Project (7501-IN), January 4, 1990.
17. Korea: Juam Regional Water Supply Project (8083-KO), February 16, 1990.
18. St. Lucia: Water Supply Project (8244-SLU), March 8, 1990.
19. Uganda: Second Water Supply Project (8254-UG), March 22, 1990.
20. Yemen: Tarim Water Supply Project (8362-YDR), May 29, 1990.
21. Philippines: First Water Supply Sewerage and Sanitation Sector Project (8143-PH), May 31, 1990.

Annex 2: Numerical Example

Estimate of the benefit of incremental water:

Without Project

1. drinking water demand	q_d	=	-0.25 * price + 3
2. nondrinking water demand	q_n	=	-price + 6
3. drinking water price/cost		=	6
4. nondrinking water price/cost		=	3
5. drinking water consumption		=	1.5
6. nondrinking water consumption		=	3
7. weighted average price/cost		=	(6 *1.5 + 3 * 3)/4.5 = 4

With Project

1. piped water demand	q_p	=	$q_d + q_n$
2. piped water price		=	2
3. piped water consumption		=	2.5 + 4 = 6.5

Estimated Benefit of Incremental Water

1. incremental water quantity	=	6.5 - 4.5 = 2
2. average value of incr. water	=	(4 + 2)/2 = 3
3. estimated benefit	=	2 * 3 = 6

True Benefit of Incremental Water

1. incr. drinking water quantity	=	2.5 - 1.5 = 1
2. average value of incr. dr. water	=	(6 + 2)/2 = 4
3. benefit of incr. dr. water	=	1 * 4 = 4
4. incr. nondrinking w. quantity	=	4 - 3 = 1
5. average value of incr. n-d water	=	(3 + 2)/2 = 2.5
6. benefit of incr. n-d water	=	1 * 2.5 = 2.5

Error

1. estimated benefit	=	6
2. true benefit	=	6.5
3. difference	=	-0.5 (-7.7 percent)

Annex 3: Introduction to ECOWAT1

The following section shows a printed version of ECOWAT1, a program designed to carry out economic analysis of small water supply projects in Indonesia. ECOWAT1 is a Lotus 123 working file, which contains subroutines--so-called macros--making the calculations convenient and helping you to print the results in a standard format.

Determining the economic viability of a project requires affirmative answers to two questions. Is the present value of net benefits (NPV) of the project positive?, and Is the present value of net benefits at least as high as the NPV of any mutually exclusive project alternative? Looking at a new piped water supply system or at the extension of an already existing system, the supplied quantity of water as a result of the implemented project can be divided into two parts: one part replaces the previous source and quantity of water use (wells, springs, rivers) and the other part is a net increase in water consumption. Benefit from the replacement part is equal to the cost savings (actual payments plus own labor) of consumers who no longer need to use other sources of water supply. Benefit from the incremental water use is equal to the consumers' willingness to pay, which can be determined by estimating the area under the consumers' water demand curve. When both parts of the benefits are quantified, the net benefits of the project can be calculated by adding them together and subtracting the cost of new water supply. This answers the first question. An affirmative answer to the second question should result from careful project design, which requires two important components: to select a least-cost solution for raw water intake, storage and treatment, and to extend the distribution system towards those consumers who, without the project, would have the highest-cost water supply (including the costs of their own labor in carrying the water) from alternative sources.

With few exceptions, ECOWAT1 only requires data that describe the water supply/demand situation in one particular year: the first year after project completion. Data input is divided into two parts: the first part refers to the 'WITH' project, the second to the 'WITHOUT' project alternatives. Calculations are based on constant prices and a 10% (real) social rate of interest. ECOWAT1 is most useful if applied at an early stage of project design. Sensitivity analysis of different design alternatives will help to choose a design that maximizes the expected net economic benefits.

The following pages show what appears on the computer screen when working with ECOWAT1. They are not a substitute for the program itself but demonstrate the nature of information required to carry out the analysis. A survey of water use in the project implementation area is the most important requirement before using the program.

As a result of its simplicity, ECOWAT1 can be used to analyze only small projects (less than two billion rupiah investment cost). Medium-sized or large water supply projects require a more detailed description of water use in the years after implementation.

To run the program.

- Load LOTUS 123
- Type " / "
- Select FILE, RETRIEVE, ECOWAT1.WK1.

Comments are welcome. Please contact Laszlo Lovei at (202) 473-2772.

ECONOMIC ANALYSIS OF SMALL WATER SUPPLY PROJECTS -- INDONESIA

All data refer to the first year --year(1)--after project completion, except where indicated otherwise. Input data in the highlighted/coloured areas. To reach a paragraph directly, press F5 and type PARAx , when x is the number you want. To see the results, press F5 and type RESULT. Arrow keys move the cell pointer.

A. 'WITH' project situation:

1. Population served and piped water delivered by the project:

	house connection	yard	public standpipe	non-residential	total (press F9)
no. of persons	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0

2. Investment cost (connection excluded) on constant prices:

	year(-4)	year(-3)	year(-2)	year(-1)	year(0)	total value (in year(1))
million rupiah	0	0	0	0	0	0.00

3. Connection cost (including household storage tank):

MRp	year(-4)	year(-3)	year(-2)	year(-1)	year(0)	year(1)	total (pr.v)
house	0	0	0	0	0	0	0.00
yard	0	0	0	0	0	0	0.00
standpipe	0	0	0	0	0	0	0.00
non-res.	0	0	0	0	0	0	0.00

4. Operation and maintenance cost of supply system (including company overhead cost) on a cubic meter delivered basis:

rupiah/ cub.met.	0

5. Do water vendors or the consumers themselves carry the water from standpipes to the place of consumption ? (if answer is consumers, change indicator to "1", if vendors, leave as "0")

vendor indic.	0

Are there -- or are there going to be -- public standpipe/ hydrant operators ? (if the answer is no, change the indicator to "1",otherwise leave as "0")

concess. indic. 0

Estimated delivery rate of vendors (if no information, use 2 cum/day/vendor):

cum/day/ vendor 0

Opportunity cost of vendor labour (may be different from their net income as a result of monopoly or restricted entry -- if no information, use Rp 2500/day/vendor):

Rp/day/ vendor 0

Average delivery rate of standpipes :

cum/day/ standpipe 0

Opportunity cost of standpipe/hydrant operator services (may be different from their net income as a result of a monopoly -- if no information, use Rp 2500/day/concessionaire):

Rp/day/ conc. 0

Average time required to get 1 cubic meter water from standpipe (hauling excluded):

hour 0

Average distance from standpipes to those households which rely on water from standpipes:

meter 0

Value of private time (if no information, Rp150/hour in Java/Bali, Rp200/hour in the Outer islands is proposed):

Rp/hour 0

6. Did local people boil the drinking/cooking water before project implementation ? (if the answer is yes, change the indicator to "1", no "1" , if no write "0")

boiling indic. 0

Do you assume project will make a difference in boiling habits over time ? (if answer is yes, change indicator to "1", if no write "0")

boiling indic. 0

What percentage of population served by piped water will drink the water without boiling as a result of the project after implementation is completed /year(0)/?

	year(5)	year(10)
%	0	0

Average quantity boiled daily before project implementation (if no information use 2 liter/capita/day):

liter/capita/day 0

Price of kerosene sold by street vendors:

Rp/liter 0

THIS IS THE END OF DATA INPUT FOR THE 'WITH' PROJECT CASE. PLEASE PRESS CALC (F9) AND REVIEW THE RESULTS BELOW. THE ONLY PROPER WAY TO MODIFY RESULTS IS TO MODIFY THE INPUT DATA. IF FINISHED, PROCEED TO THE 'WITHOUT' CASE (PARA8).

7. Economic cost of piped water:

Rp/cum	house connection	yard	public standpipe	non-resid.
capital	0	0	0	0
connect.	0	0	0	0
O&M	0	0	0	0
hauling	0	0	0	0
boiling	0	0	0	0
total	0	0	0	0

B. 'WITHOUT' project situation:

8. Water use of the consumers (project beneficiaries defined in para.1.) to be replaced by the project :

	electric shallow well	handpump	bucket	other source	vendors	non-residential	total (pressF9)
no. of	0	0	0	0	0	n/a	0

persons							
cubic meter/year	0	0	0	0	0	0	0

(Allocate no. of persons according to drinking water source.
Be sure the total number of persons is the same as in para 1.
To check, press F9, then 'HOME', if the total is 'ERR'.)

9. One–time investment cost of these (private) water sources to supply demand given above:

	electric shallow well	handpump	bucket	other other source	non–resid.
million Rp	0	0	0	0	0

Percentage of these facilities already installed (before project implementation begins):

%	0	0	0	0	0

10. Operation and maintenance cost of residential electric pump shallow wells and non–residential water sources (wells or other private supply) on a cubic meter consumed basis:

	electric pump shallow wells	non–residential
Rp/cum	0	0

Time required to get one cubic meter residential water (hauling excluded) from:

	handpump shallow wells	bucket	other sources of resid. water
hour	0	0	0

Maintenance cost on a cubic meter consumed basis:

	handpump shallow wells	bucket	other sources of resid. water
Rp/cum	0	0	0

11. What share of water use within each type of source (excluding vendors) comes from sources located outside own yard/household?

handpump bucket other sources of

	shallow wells		resid. water
%	0	0	0

Average distance of these water sources (outside yard/household) but used by the consumers themselves) from place of consumption:

	handpump shallow wells	bucket	other sources of resid. water
meter	0	0	0

Average price of water sold by vendors (carriers):

Rp/cum 0

Do you consider this price an acceptable indicator of the cost of water (considering hauling cost and the cost at the source of the water)? If answer is yes, change indicator to "1" and go to paragraph 12, if no write "0" and continue here.

indic. 0

Average quantity supplied by those water sources which the vendors use to purchase the water they distribute:

cum/day/source 0

Cost of that water at the source (different from price -- exclude remuneration/net income of concessionaires/owners):

Rp/cum 0

Average delivery rate of vendors:

cum/day/vendor 0

THIS IS THE END OF DATA INPUT FOR THE 'WITHOUT' PROJECT CASE. PLEASE PRESS CALC (F9) AND REVIEW THE RESULTS BELOW. THE ONLY PROPER WAY TO MODIFY RESULTS IS TO MODIFY THE INPUT DATA. IF FINISHED, PROCEED TO SECTION C (PARA13).

12. Economic cost of water to be replaced:

Rp/cum	electric	handpump shallow well	bucket	other source	vendors	non-resid.
capital	0	0	0	0		0
O&M	0	0	0	0	0	0
hauling	0	0	0	0		0

boiling	0	0	0	0	0	0
total	0	0	0	0	0	0

C. Benefit from incremental water consumption:

13. Net incremental water use as a result of the project:

	residential	non-residential
cum/year	0	0

The following calculation assumes a linear relationship between water demand and price and is based on a so-called (high-quantity ; low-price) reference point of the residential water demand function, estimated as

(100 cum/year/capita ; 300 rupiah/cum)

If you wish to change the coordinates of this point, do it now:

(100 ; 300) (AND PRESS CALC /F9/)

Average economic value of incremental water:

	residential	non-residential	
Rp/cum	0	0	(includes consumer surplus)

D. Results:

14. Net benefit of the project (in one year):

mill.Rp 0

Net benefit/investment ratio (over the lifetime /25years/ of the project -- may be used for ranking):

% 0

Economic internal rate of return (should not be used to rank projects):

% ERR

(If the value above is 'ERR' or a large negative number press ALT and type E simultaneously.)

E. IF YOU WISH TO PRINT THE RESULTS OF YOUR WORK, PLEASE SUPPLY THE FOLLOWING INFORMATION:

Project location:

Province:
Kabupaten:
Kecamatan:
Desa:

Number of variant tested (e.g. 1st, 2nd,etc):

Sensitivity of results was analyzed with respect to:

name of variable:
value of variable in this variant:

PRESS ALT AND TYPE P SIMULTANEOUSLY TO BEGIN PRINTING (IF YOU HAVE A PRINTER ON LINE AND CONNECTED TO THE COMPUTER).

THE END

Annex 3: Mathematical Formulas of ECOWAT1

1. In paragraph 7:

- Capital cost of piped water = INV*0.1/OUTP
  where INV is the present value (in year 1) of investments
  OUTP is the piped water delivered by project in year 1

- Connection cost of piped water = CONN*0.1/OUTP
  where CONN is the present value of connection costs

-Hauling cost of water from public standpipes =
  a) if vendors carry the water:
  = VENT/VEND + CONT/COND
  b) if consumers carry the water:
  = (DISP/40 + STPD)*TIME
  where VENT is the opportunity cost of vendor services
  VEND delivery rate of vendors
  CONT is the opp. cost of standpipe operator services
  COND delivery rate of standpipes
  DISP distance of standpipes from place of consumption
  STPD time to get 1 cu. m. from standpipe
  TIME value of time

- Boiling cost of water =
  a) if project has no impact on boiling: 0
  b) if project makes a difference:
  = 5*KERP/200*BQUA*365*PERS/OUTP*
  *(0.812 - 3.48/1000*NB05 - 2.16/1000*NB10)
  where KERP is the kerosene price
  BQUA is the quantity boiled daily/capita
  PERS is the number of persons relying on piped water
  NB05 is the percentage of people giving up boiling in year 5
  NB10 is the percentage of people giving up boiling in year 10

2. In paragraph 12:

- Capital cost of water to be replaced = 0.11 * INVN*
  *(1-INST/100)/WREP
  where INVN is the total investment cost of non-piped sources
  INST is the % already installed
  WREP is the water to be replaced (quantity)

- O&M cost of water from handpump, bucket systems and other sources =
  MAIN + HOUR*TIME
  where MAIN is the maintenance cost/cu.m.
  HOUR is the time required to get 1 cu.m. water

- Hauling cost of water from handpumps, bucket systems and other sources =

SHWU/100*DISR/40*TIME

where SHWU is the share of water use coming from outside the yard

DISR is the distance from place of consumption

- Capital & O&M & hauling cost of water from vendors =

a) if vendor price is accepted = VPR

b) if vendor price is not accepted =

COST + CONT/SOUD + VENT/VENDR

where COST is the cost of water at the source

SOUD is the delivery rate of the water source

VENDR is the delivery rate of vendors carrying water to be replaced

VPR is the vendor price

- Boiling cost of water to be replaced =

a) if project has an impact on boiling

= 5*KERP/200*BQUA*365*PERSR/WREP

b) otherwise 0

where PERSR is the number of persons relying on the water source.

3. In paragraph 13:

- incremental non-residential water use = OUTN-WRN

whereOUTN is the water delivered to non-residential customers by the project.

WRN is the water use of non-residential customers replaced by the project

- incremental residential water use = (OUTP-OUTN)-(WREP-WRN)

-average economic value of incremental residential water =

(MGW+MGWO)/2

where MGW is the marginal value of water, with project

MWGO is the marginal value of water, without project

and MGWO = $\text{sum}_i(\text{MGWO}_i * \text{WREP}_i)$

whereMGWO_i is the marginal value of water from ith source, defined as O&M + handling + boiling cost or vendor price (in the case of vendors) + boiling cost

and MGW = (MGWO * (REFQ-WCWO-WCWI) + REFP * WCWI)/(REFQ-WCWO)

where(REFQ, REFP) are the coordinates of the (high quantity; low price) reference point on the demand curve;

WCWO is the water consumption per capita, without project

WCWI is the incremental water consumption per capita, with project

- average economic value of incremental non-residential water =

a) if the net incremental water use is positive = (CNRP+CNRR)/2

whereCNRP is the economic cost of non-residential piped water defined in para. 7.

CNRR is the total cost of non-residential water, without project, includes sunk capital cost

b)if the net incremental water use is zero or negative: = CNRR

4. In paragraph 14:

-net benefit of the project = INCR * VALR + INCN * VALN + sum_i(CWWO$_i$ * WRQ$_i$) - sum_j(CPW$_j$ * OUTP$_j$)

where INCR is the net incremental water use of residential customers

VALR is the value of incremental residential water defined in para. 13.

INCN is the net incremental water use of non-residential customers

VALN is the value of incremental non-residential water defined in para. 13.

CWWO$_i$ is the economic cost of the ith source of water defined in para. 12.

WRQ$_i$ is the quantity of the ith source of water to be replaced

CPW$_j$ is the economic cost of the 7th type of piped water defined in para. 7.

OUTP$_j$ is the quantity of the jth type of piped water delivered

-net benefit/investment ratio = 100 * 10 * NB/ (INV + CONN - 1.1 * (1-INST/100) * INVN)

-economic internal rate of return is calculated on the basis of a time series of data describing the impact of the project from year (-4) to year (25). The first five numbers describe the annual net investment costs, the sixth number (year 1) is equal to the recalculated annual benefits (to avoid double counting, capital costs are eliminated) minus the scheduled connection costs, the next 24 numbers are all equal to the recalculated annual net benefits.

Annex 4: Introduction to ECOWAT2

The following section shows a printed version of ECOWAT2, a program designed to carry out economic analysis of water supply projects in Indonesia. If the project is small (less than two billion rupiah investment cost), a simplified version of ECOWAT2--called ECOWAT1--should be used, since it requires substantially less input from the user. ECOWAT2 is a Lotus 123 working file, which contains subroutines--so-called macros--that calculate conveniently and prints the results in a standard format.

Determining the economic viability of a project requires affirmative answers to two questions. Is the present value of net benefits (NPV) of the project positive?, and Is the present value of net benefits at least as high as the NPV of any mutually exclusive project alternative? Looking at a new piped water supply system or at the extension of an already existing system, the supplied quantity of water as a result of the implemented project can be divided into two parts: one part replaces the previous source and quantity of water use (wells, springs, rivers) and the other part is a net increase in the water consumption. Benefit from the replacement part is equal to the cost savings (actual payments plus own labor) of consumers who no longer need to use other sources of water supply. Benefit from the incremental water use is equal to the consumers' willingness to pay, which can be determined by estimating the area under the consumers' water demand curve. When both parts of the benefits are quantified, the net benefits of the project can be calcualted by adding them together and subtracting the cost of new water supply. This answers the first question. An affirmative answer to the second question should result from careful project design, which has two important components: to select a least-cost solution for raw water intake, storage, and treatment; and to extend the distribution system towards those consumers who, without the project, would have the highest-cost water supply (including the costs of their own labor in carrying the water) from alternative sources.

ECOWAT2 requires data that describe the water supply/demand situation every five years for the 25 years after project completion. Data input is divided into two parts: the first part refers to the "WITH" project, the second to the "WITHOUT" project alternatives. Calculations are based on constant prices, linear interpolation, and a 10% (real) social rate of interest. ECOWAT2 is most useful if applied at an early stage of project design. Sensitivity analysis of different design alternatives will help to choose a design that maximizes the expected net economic benefits.

The following pages show what appears on the computer screen when working with ECOWAT2. They are not a substitute for the program itself but demonstrate the nature of information required to carry out the analysis. A survey of water use in the project implementation area is the most important requirement before using the program.

To run the program.

- Load LOTUS 123
- Type "/"
- Select FILE, RETRIEVE, ECOWAT2.WK1.

Comments are welcome. Please contact Laszlo Lovei at (202) 473-2772.

Year(0) refers to the year of project completion -- everything, with the possible exception of connections, is installed. Input data in the highlighted/coloured areas. To reach a paragraph directly, press F5 and type PARAx , when x is the number you want. To see the results, press F5 and type RESULT. Arrow keys move the cell pointer.

A. 'WITH' project situation:

1. Population served and piped water delivered by the project:

Year(1)	house connection	yard	public standpipe	non-resid.	total (press F9)
no. of persons	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0

Year(6)	house connection	yard	public standpipe	non-resid.	total (press F9)
no. of persons	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0

Year(11)	house connection	yard	public standpipe	non-resid.	total (press F9)
no. of persons	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0

Year(16)	house connection	yard	public standpipe	non-resid.	total (press F9)
no. of persons	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0

Year(21)	house connection	yard	public standpipe	non-resid.	total (press F9)
no. of persons	0	0	0	n/a	0

cubic meter/year	0	0	0	0		0

Year(26)	house connection	yard	public standpipe	non-resid.		total (press F9)
no. of persons	0	0	0	n/a		0
cubic meter/year	0	0	0	0		0

2. Investment cost (connection excluded) on constant prices:

	year(-5)	year(-4)	year(-3)	year(-2)	year(-1)	year(0)	total value in year(0)
million rupiah	0	0	0	0	0	0	0

3. Connection cost (including household storage tank):

MRp	year(-4)	year(-3)	year(-2)	year(-1)	year(0)	total value in year(0)
house	0	0	0	0	0	0
yard	0	0	0	0	0	0
standpipe	0	0	0	0	0	0
non-res.	0	0	0	0	0	0

MRp	year(1)	year(6)	year(11)	year(16)	year(21)	year(26)	total value in year(0)
house	0	0	0	0	0	0	0
yard	0	0	0	0	0	0	0
standpipe	0	0	0	0	0	0	0
non-res.	0	0	0	0	0	0	0

4. Operation and maintenance cost of supply system (including company overhead cost) on a cubic meter delivered basis:

rupiah/cub.met. 0

5. Do water vendors or the consumers themselves carry the water from standpipes to the place of consumption ? (if answer is consumers, change indicator to "1", if vendors, leave as "0")

vendor indic.	0

Are there -- or are there going to be -- public standpipe/ hydrant operators ? (if the answer is no, change the indicator to "1",otherwise leave as "0")

concess. indic.	0

Estimated delivery rate of vendors (if no information, use 2 cum/day/vendor):

cum/day/ vendor	0

Opportunity cost of vendor labour (may be different from their net income as a result of monopoly or restricted entry -- if no information, use Rp 2500/day/vendor):

Rp/day/ vendor	0

Average delivery rate of standpipes :

cum/day/ standpipe	0

Opportunity cost of standpipe/hydrant operator services (may be different from their net income as a result of a monopoly -- if no information, use Rp 2500/day/concessionaire):

Rp/day/ conc.	0

Average time required to get 1 cubic meter water from standpipe (hauling excluded):

hour	0

Average distance from standpipes to those households which rely on water from standpipes:

meter	0

Value of private time (if no information, Rp150/hour in Java/Bali, Rp200/hour in the Outer islands is proposed):

Rp/hour	0

6. Did local people boil the drinking/cooking water before project implementation ? (if the answer is yes, change the indicator to "1", no "1" , if no write "0")

boiling indic.	0

	Do you assume project will make a difference in boiling habits over time ? (if answer is yes, change indicator to "1", if no write "0")
boiling indic.	0

What percentage of population served by piped water will drink the water without boiling as a result of the project after implementation is completed /year(0)/?

	year(1)	year(6)	year(11)	) year(16)	) year(21)	) year(26)
%	0	0	0	0	0	0

Average quantity boiled daily before project implementation (if no information use 2 liter/capita/day):

liter/ capita/ day	0

Price of kerosene sold by street vendors:

Rp/liter	0

THIS IS THE END OF DATA INPUT FOR THE 'WITH' PROJECT CASE. PLEASE PRESS CALC (F9) AND REVIEW THE RESULTS BELOW. THE ONLY PROPER WAY TO MODIFY RESULTS IS TO MODIFY THE INPUT DATA. IF FINISHED, PROCEED TO THE 'WITHOUT' CASE (PARA8).

7. Variable cost of piped water in year(1):

Rp/cum	house connection	yard	public standpipe	non-resid.
O&M	0	0	0	0
hauling	0	0	0	0
boiling	0	0	0	0
total	0	0	0	0

Capital cost of piped water (connection cost excluded):

Rp/cum	0

Connection cost of piped water (average over time):

	house connection	yard	public standpipe	non-resid.
Rp/cum	0	0	0	0

B. 'WITHOUT' project situation:

8. Water use of the consumers (project beneficiaries defined in para.1.) to be replaced by the project:

(allocate no. of persons according to drinking water source)

year(1)	electric shallow well	handpump	bucket	other sources	vendors	non-residential	total (pressF9)
no. of persons	0	0	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0	0	0

year(6)	electric shallow well	handpump	bucket	other sources	vendors	non-residential	total (pressF9)
no. of persons	0	0	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0	0	0

year(11)	electric shallow well	handpump	bucket	other sources	vendors	non-residential	total (pressF9)
no. of persons	0	0	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0	0	0

year(16)	electric shallow well	handpump	bucket	other sources	vendors	non-residential	total (pressF9)
no. of persons	0	0	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0	0	0

year(21)	electric shallow well	handpump	bucket	other sources	vendors	non-residential	total (pressF9)
no. of persons	0	0	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0	0	0

year(26)	electric	handpump	bucket	other	vendors	non-resi-	total

	shallow well			sources		dential	(pressF9)
no. of persons	0	0	0	0	0	n/a	0
cubic meter/year	0	0	0	0	0	0	0

(Be sure the total number of persons is the same as in para 1.
To check, press F9, then 'HOME', if the total is 'ERR'.)

9. One-time investment cost of these (private) water sources divided by the daily average rate of utilization:

Rp/cum/day	electric shallow well	handpump	bucket	other sources	vendors	non-residential
average utilization	0	0	0	0	n/a	0

Percentage of these facilities already installed (before project implementation begins) to serve demand in year(1):

%	0	0	0	0	n/a	0

10. Operation and maintenance cost of residential electric pump shallow wells and non-residential water sources (deep wells or other private supply) on a cubic meter consumed basis:

	electric pump shallow wells	non-residential
Rp/cum	0	0

Time required to get one cubic meter residential water (hauling excluded) from:

	handpump shallow wells	bucket	other sources of resid. water
hour	0	0	0

Maintenance cost on a cubic meter consumed basis:

	handpump shallow wells	bucket	other sources of resid. water
Rp/cum	0	0	0

11. What share of water use within each type of source (excluding vendors) comes from sources located outside own yard/household?

handpump bucket other sources of

	shallow wells		resid. water
%	0	0	0

Average distance of these water sources (outside yard/household but used by the consumers themselves) from place of consumption:

	handpump shallow wells	bucket	other sources of resid. water
meter	0	0	0

Average price of water sold by vendors (carriers):

Rp/cum 0

Do you consider this price an acceptable indicator of the cost of water (considering hauling cost and the cost at the source of the water)? If answer is yes, change indicator to "1" and go to paragraph 12, if no write "0" and continue here.

indic. 0

Average quantity supplied by those water sources which are used by vendors to purchase the water they distribute:

cum/day/source 0

Cost of that water at the source (different from price -- exclude remuneration/net income of concessionaires/owners):

Rp/cum 0

Average delivery rate of vendors:

cum/day/vendor 0

THIS IS THE END OF DATA INPUT FOR THE 'WITHOUT' PROJECT CASE. PLEASE PRESS CALC (F9) AND REVIEW THE RESULTS BELOW. THE ONLY PROPER WAY TO MODIFY RESULTS IS TO MODIFY THE INPUT DATA. IF FINISHED, PROCEED TO SECTION C (PARA13).

12. Variable cost of water to be replaced in year(1):

Rp/cum	electric	handpump shallow well	bucket	other sources	vendors	non-residential
O&M	0	0	0	0	0	0
hauling	0	0	0	0		0
boiling	0	0	0	0	0	0

total	0	0	0	0	0	0

C. Benefit from incremental water consumption:

13. Net incremental water use as a result of the project in year(1):

	residential	non-residential
cum/year	0	0

The following calculation assumes a linear relationship between residential water demand and price and is based on a so-called (high-quantity ; low-price) reference point of the residential water demand function, estimated in year(0) as

(100 cum/year/capita ; 300 rupiah/cum)

If you wish to change the coordinates of this point, do it now:

(100 ; 300) (AND PRESS CALC /F9/)

Water demand depends on income, too. Even for the same price, households buy more water, if their income is higher. What is your estimate of the per capita real income, if year(0)=100 ?

	year(1)	year(6)	year(11)	year(16)	year(21)	year(26)	
%	100	100	100	100	100	100	(PRESS F9 AGAIN)

Average economic value of incremental water:

	residential (year(1))	non-residential (same in every year)	
Rp/cum	0	0	(includes consumer surplus)

D. Results:

14. Net present value of the project:

mill.Rp 0

Net benefit/investment ratio (may be used for ranking):

% 0

Economic internal rate of return (should not be used to rank projects):

% ERR

(If the value above is 'ERR' press ALT and type E simultaneously.)

E. IF YOU WISH TO PRINT THE RESULTS OF YOUR WORK, PLEASE SUPPLY THE FOLLOWING INFORMATION:

Project location:

Province:
Kabupaten:
Kecamatan:
Desa:

Number of variant tested (e.g. 1st, 2nd,etc):

Sensitivity of results was analyzed with respect to:

name of variable:
value of variable in this variant:

PRESS ALT AND TYPE P SIMULTANEOUSLY TO BEGIN PRINTING (IF YOU HAVE A PRINTER ON LINE AND CONNECTED TO THE COMPUTER).

THE END

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