World Development, Vol. 11, No. 12, pp. 1075–1081, 1983.
Printed in Great Britain.

0305–750X/83 $3.00 + 0.00
Pergamon Press Ltd.

Why Present Value Calculations Should Not Be Used in Choosing Rural Water Supply Technology

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Summary. – The discounting of future values and their summation into a single Present Value is a standard procedure used by engineers and economists to help them identify the best technology, and the best designs, for capital investments. The author questions the validity of this methodology for investments that will generate recurrent costs whose provision cannot be assured by user charges and must therefore be covered from government budgets. It is wrong to use a methodology that (a) puts such future costs at a discount and (b) which converts capital and recurrent costs into an abstract, undifferentiated concept of 'total resource costs' expressed in a single number, the Present Value (PV). This challenge to the indiscriminate use of PV methodology is illustrated by reference to rural water supply projects; however, the author believes his viewpoint has much wider application.

1. INTRODUCTION

A major application of the discounting technique is the evaluation of competing technologies and equipment. Technology selection and design optimization are two areas of 'engineering economy' that often depend on the calculation of Present Values (PV) to see which technology and design have the lowest present costs. This technique is not likely to be displaced. Yet an increasing number of economists and engineers admit uneasiness with the mandatory use of this calculation for all situations. More often than not, the dissatisfaction arises when high discount rates must be used; these sometimes give results which practical men instinctively mistrust. They 'know' they prefer a different technology from the one to which the PV calculations are giving them 'wrong answers'. Their instinct is to 'get the answer they want' by using a lower discount rate. Would they be justified in doing so?

No one can argue that analysts should be given licence to use any discount rate they wish in order to produce a convenient answer. That is not the way the game should be played. But the uneasiness of analysts in many situations raises questions about the nature of the game. In my view, we have been relying too long on the indiscriminate application of the discounting procedure to a wide variety of situations *in only some of which is the procedure appropriate*. In most rural water supply situations – perhaps in all – PV analysis should not be used.

2. PRESENT-VALUE METHODOLOGY

In any specific field there are always different technologies that can be used to produce a desired output, and these technologies often differ greatly in their capital costs, in their subsequent requirements for operating and maintenance costs, and in their lengths of life. Engineers and economists, and the people who employ them, naturally want to choose that technology which will 'cost the least', consistent with achieving the desired output and agreed standards of service and safety. But when competing technologies have quite different proportions of capital and recurrent costs, and use equipment with very different lives, the task of finding out which technology has 'the lowest cost' can be difficult. To cope with this problem, the technique of converting all values into 'Present-Value' terms has been widely employed. Present-Value analysis is simply the application of compound interest arithmetic to values that occur in the future to derive their PV equivalent. When future values, spread over a number of future years, have each been discounted back to their PV equivalent, they can then be added up to give a single value that tells us how much that whole stream of future values is worth in Present-Value terms. If we did the adding before discounting each value back to the present, we would be adding 'apples and oranges', since $1 that occurs 7 years in the future has a lower PV than $1 that will occur 3 years in the future. Discounting gives all values the same weight and thus gets rid of the 'apples and oranges' problem.

The standard way of identifying the lowest-cost alternatives between two or more technologies is to construct a table in which all cash expenditures (capital and recurrent) are listed according to the years in which they will occur. Each annual figure is then converted into a Present Value by discounting. There are many arguments as to what discount rates should be used, and these arguments can become important since different rates can change the outcome of the calculation. The purpose of the calculation, of course, is to see which technology has the lowest present value. This then becomes the technology of choice.

What role does this standard methodology of engineering economy play in the Rural Water Supply (RWS) field? What role should it play? Is the working out of such calculations the most important contribution economists can make to the design of RWS projects and programmes? The answers to these questions are (a) that PV calculations today play a minor role in choice-of-technology decisions in this sector, (b) that they should not be expected to play more than a minor and occasional role, and (c) that economists have far more important contributions they can make to RWS projects and programmes than testing technologies with Present-Value calculations. To understand these conclusions let us look at some examples of typical RWS design choices.

3. SOME EXAMPLES

Table 1 works out the Present Value of a RWS project for 300 deepwell handpumps estimated to have a capital cost of US $600 per well (cost of well plus handpump, drop-pipe, pumping rods and cylinder). These are assumed to be built in equal numbers over a three-year period. Operating costs are zero but maintenance costs – which are not well known in this still-to-be-built programme – are assumed to vary between $75 and $150 per well (these costs will start during the second year for the first 100 wells built during the preceding year and build up to a constant annual cost of between $22,500 and $45,000). The stream of total costs is then shown at three discount rates: zero, 5 and 10%. The three resulting Present Values are shown, each with a range which reflects the uncertainty over maintenance costs. At the bottom of the table are figures showing the proportion of Present Value accounted for by maintenance costs. The latter are seen to vary from a high of 50–66.7% at zero discount to a low of 40–57% at 10% discount. This modest conclusion is already of some interest; maintenance costs are likely to account for at least half of total present values in many handpump programmes. The proportion will naturally be lower at higher discount rates. But if it appears that resources to cover recurrent costs will be difficult to find, then common sense tells us that these future costs should not be discounted heavily – they deserve to retain a high weight in the calculation; this concern about the future should be allowed to influence the decision on what technology to use. Consultants, donors, or sector officials may not be free to choose a discount rate that reflects their estimate of the amout of weight they want to give future recurrent costs, since there may be standing instructions from a central authority on the rate to be used. If there is a significant difference between the prescribed rate and a rate which sector officials think makes more sense, they should use both rates and present their results as a sensitivity analysis, with supporting arguments.

Table 1 also presents some illustrative figures for the capital and recurrent costs of two additional competing technologies, diesel-pumped boreholes and boreholes pumped with electric submersible pumps. The diesel estimate shows capital and recurrent costs that are *both* higher than those for the handpumps. On a straight cost-effectiveness calculation, therefore, the diesel alternative would be a 'non-starter'. But calculations are rarely that 'straight': I have seen a comparison of this kind done for a region in Tanzania where Swedish consultants estimated that the handpump alternative, which would involve shallower wells, would dry up more frequently than the deeper diesel-pumped boreholes; when they put a high price on the value of 'unavailable handpump water' during these dry periods, and treated this as an extra cost of using handpumps, the choice swung over from handpumps to diesels, which were judged capable of delivering water 95% of the time. Other consultants (Dutch), working in an adjacent region, flatly disagreed with the judgments used to produce this conclusion –

Table 1. *Illustrative capital and recurrent costs of three RWS technologies*

A. Present Value of deepwell handpump scheme (in thousands) (using 5 and 10% discount rates)

Assumptions: Three hundred wells are to be built and fitted with handpumps, the total cost of well plus pumps being $600 per well. The work is to be spread evenly over 3 years and the pumps are estimated to last 10 years. Average maintenance cost is estimated at anywhere between $75 and $150 per well per year; minimum and maximum values of $22,500–$45,000 per year have therefore been used.

Year	Capital	Recurrent	Total $	PV of total costs at 5%	PV of total costs at 10%
1	60	–	60	–	–
2	60	7.5–15	67.5–75	61.4–68.3	56.0–62.3
3	60	15.0–30	75.0–90	64.5–77.4	56.3–62.3
4	–	22.5–45	22.5–45	18.5–36.9	15.3–30.6
5	–	22.5–45	22.5–45	17.6–35.1	14.0–28.0
6	–	22.5–45	22.5–45	16.9–33.8	12.6–25.2
7	–	22.5–45	22.5–45	16.0–32.0	11.5–23.0
8	–	22.5–45	22.5–45	15.3–30.6	10.6–21.2
9	–	22.5–45	22.5–45	14.4–28.8	9.5–19.0
10	–	22.5–45	22.5–45	13.7–27.4	8.8–17.6
	180,000	180–360	360–540	295.3–427.3	249.3–427.3
Recurrent costs as % of total costs:			50–67%		40–57%

B. Cost of diesel and electric alternatives to above handpumps scheme (diesel replaces five handpumps)

Diesel: Sixty diesel sets to pump 60 boreholes, and housed in simple structures. Total capital cost of $330,000. Diesel pumping will also require a storage tank for each set plus a pipe network to neighbourhood standpipes.

Operating cost: Each set will cost over $1.00 per hour for fuel and attendant. With six hours pumping per day, annual operating cost will come to around $2000. Maintenance will cost $30,000–50,000 additional per year for the system as a whole. Thus total O&M costs of $140,000–160,000 are estimated.

Electric: Sixty boreholes costing around $1000 each plus an electric submersible pump costing around $400, for a total at-well investment cost of $84,000. Each well will need a storage tank ($30,000 for 60 wells) plus a reticulation system to serve neighbourhood standpipes. Investment cost is therefore substantially lower than diesel.

Operating cost: Annual operating cost per well is estimated at about $465, or $27,900 for 60 wells. The maintenance cost should be lower than diesel, say $20,000–40,000 for the system. Total recurring cost would therefore run roughly $60,000 per annum.

a conclusion which they felt had been taken on the basis of an excessive respect for calculations whose outcome depended on highly questionable technical judgments. They pointed out that although the boreholes themselves might be capable of yielding water 95% of the time, it would be a minor miracle if diesel pumps could be kept running 95% of the time in rural Tanzania. When a diesel pump fails, there are no alternative improved water sources in a village, since there is only one diesel well per village; but the same village would need five or six handpumped wells: if one or two of them should break down, the remaining wells could still be used. Thus handpumps can spread the high risks of poor maintenance (one risk they could not spread was the risk of aquifers going dry in dry spells: if one well goes dry, it will be highly likely that all the village wells will be dry, and everyone will be forced to go back to the traditional sources they used before the RWS scheme was built).

The electric-pump borehole alternative in Table 1 makes a more interesting and more difficult comparison with the handpumps. The capital costs are estimated to be one-third cheaper than handpumps but the O&M costs substantially higher. The preference is not obvious, so the Present Value of the electric-pump option was calculated. This shows that at all discount rates from zero to 10% the handpumps have a lower Present Value. It is also obvious, even without discounting, that electric pumping would be much lower-cost than diesel pumping. Indeed, all over the world electric pumping is almost invariably preferred to diesel pumping, on both cost and other grounds – provided electricity is available so that electric pumping does not have to include the investment cost of providing the electricity supply.

The examples summarized in Table 1 introduce us to typical numbers involved in technology comparison but do not say much about when it is helpful to use discounting and when it is unhelpful. One balanced and moderate answer to this question is provided in a Swedish consultant's 1977 report on SIDA-assisted RWS schemes in Kenya. The consultant was bothered by the perverse results which the use of high (10–15%) discount rates was producing in the choice of technology in Kenya's RWS sector. High discount rates were doing what they always do, i.e. favouring projects with relatively low capital costs and relatively high running costs over those with a reverse cost structure. But most of the engineers working in the sector had strong reasons for preferring the technologies with the higher capital costs but lower operation and maintenance (O&M) costs. Experience had taught them that 'recurrent resources are more difficult to obtain than capital resources' and 'that pumped schemes are very much more troublesome than gravity schemes and that thermal power is vulnerable to upward oil price shifts'. To avoid getting committed to 'wrong solutions' by formalistic calculations, the consultants gave the following advice to their clients:

> Our studies indicate that the following approach to discounting should be adopted by MWD design teams. When technical options which involve different timing of costs are to be considered, a minimum present value calculation is made using the current Treasury approved discount rate. However, the outcome of this calculation is then evaluated in a similar fashion to evaluation of tender documents. The full implication of accepting the least cost design should be carefully considered. For example, if a gravity offtake is 15% more expensive in present value terms than a pumped solution, then this may be considered a worthwhile premium for the operating advantages of a gravity system. If the difference is 100% then the gravity cost is likely to be too great. Judgments will have to be made in each case on a cross-over point. However, selection does not necessarily have to be made simply on the basis of the minimum net present value calculations. (VIAK EA Ltd., Evaluation of the RWS Programme, February 1977.)

This is too cautious an accommodation of PV methodology and common sense. It is better to 'go all the way' and not use discounting at all. There is one more source to cite before explaining my 'no discounting' conclusion more fully.

4. 'CAPITAL INTENSITY': HOW USEFUL?

The outstanding discussion of appropriate technology in RWS in *Water for the Thousand Millions*[1] addresses itself (near the end) to the role of cost–benefit analysis in the sector. The principal message of this sensitive and comprehensive pamphlet is that while a cost–benefit calculation (the authors really mean a cost-effectiveness calculation) can 'in principle' capture all the considerations that need to be taken into account, a large part of the relevant factors are incapable of quantification. The authors therefore conclude that 'the basic technology choice is largely dictated by the other criteria', i.e. criteria that cannot be captured in a cost–benefit calculation. But such calculations are not put aside completely: 'rational choices between technological alternatives do sometimes depend in an important way on the question of how costs and benefits occurring at different points in time should be compared, i.e. how they should be discounted'. They go on to note, without comment, that high discount rates tend to discourage capital-intensive technology while low discounts tend to favour them. *Capital intensity does not refer to whether the capital costs of one technology are larger than another; it refers to the proportions of capital and recurrent costs in two or more technological alternatives.* Two ways of measuring capital-intensity are shown in Table 2. Method 1 simply adds up all capital and recurrent costs over the estimated life of the project and sees what proportion of these total costs are accounted for by the capital expenditures. The second method involves converting the capital costs into an 'annualized value' and then adding this annual capital value to annual recurring cost to get a total annual cost; the annual capital component of this cost is then expressed as a percentage. Although the two methods will give different proportions, they will both correctly rank the capital intensity of alternative technologies.

But is capital-intensity something we should worry about in RWS schemes? Not much, in my view. At least not nearly as much as we should worry about recurrent-cost intensity of competing technologies. Indeed, paying too much attention to capital-intensity can be downright misleading, since the usual assumption is that LDCs should avoid capital-intensive technologies because they do not have the savings needed to pay for capital. In fact, however, it is often easier for poor countries to acquire the *initial* capital (through aid programmes or liberal financing terms) than to

Table 2. *Measuring capital intensity*

Year	Diesel pumped scheme Capital	Diesel pumped scheme Recurrent	Piped gravity-flow scheme Capital	Piped gravity-flow scheme Recurrent
1	6000	–	12,000	–
2		2500		250
3		2500		250
4		2500		250
5		2500		250
6		2500		250
7		2500		250
8		2500		250
9		2500		250
10		2500		250
		22,500		2250
	Total cost: 28,500		Total cost: 14,250	

Capital intensity:

Method 1: (capital cost as a percentage of capital plus all recurrent costs over the project's life)

Diesel: $\frac{6000}{28500} = 21\%$ Gravity flow: $\frac{12000}{14250} = 84\%$

Method 2: (straight-line depreciation over annual recurrent cost)

$\frac{600}{2500} = 24\%$ $\frac{1200}{250} = 480\%$

Recurrent cost intensity: (annual recurrent cost over annual straightline depreciation)

$\frac{2500}{600} = 4.2$ $\frac{250}{1200} = 0.2$

find the recurrent resources needed to keep a scheme in operation. A simple way of measuring recurrent-cost intensity is to calculate the ratio of recurrent costs to one year's depreciation, using the straight-line method. When this is done for the two technologies of Table 2, the diesel pumps show a recurrent-cost intensity of 4.2, the gravity-flow scheme an intensity of only 0.2. When you divide the second figure by the first you conclude that the gravity-flow scheme has a recurrent-cost intensity less than one-twentieth that of the diesel pumps. An even simpler direct comparison of the recurrent cost streams (250/2500) shows an advantage for gravity-flow that is only half that found when each scheme's recurrent costs are first related to their respective annual capital costs. The second method is intellectually more appealing – but seems less relevant than the first, which focuses all attention on the critical budget problem (depreciation, being an accounting charge that requires no payment, does not show up in public budgets).

The upshot of this discussion is that the gravity-flow scheme would be rejected if the aim were to avoid the more capital-intensive scheme but would be preferred if the aim were to use the scheme with the lowest recurrent costs. Since low recurrent costs is the right criterion, the gravity scheme would be a much better choice.

5. DEFECTS OF DISCOUNTING

The mechanics of discounting are such that the process removes from consideration a higher and higher proportion of values that fall in the future. For example, if one is thinking of installing the diesel pumping scheme represented by the first set of figures in Table 2, discounting with a 5% discount rate will extinguish and (therefore leave out of the PV result) 5% of the investment cost but 25% of the next 10 years' costs (the calculations are not shown). At 15%, almost half the recurrent costs are omitted from the PV figure. In 'collapsing' all costs into a single figure (the Present Value), the distinction between capital and recurrent costs is removed and all costs over the life of the project are treated 'as if' they were capital costs. This does not seem a particularly useful thing to do if a primary basis for choice is the desire to avoid high recurrent costs. If that is a major criterion for choice – as I believe it should be – then the sensible way of comparing different technologies is simply to make a straightforward comparison of annual recurrent costs without extinguishing any of these costs by discounting.

Whether one uses the familiar PV (discounting) technique, or relies on the more heretical but much simpler method of a straight comparison of undiscounted capital and recurrent costs depends on what question you are asking. Choice of technology through the PV technique asks the question: 'Which method involves the least use of resources – undifferentiated resources – over its lifetime?' *That is not what we usually want to know when comparing the costs of competing RWS technologies.* What we usually want to know is: which technology will minimize our future recurrent costs? PV calculations can tell us *nothing* about the relative attractiveness of different technologies with respect to their demands on recurrent budgets. That is the method's fatal flaw.

In projects whose recurrent costs can easily be covered by sales of project outputs (every factory, bank, or store is this kind of a project), ability to meet recurrent costs will be a much less important problem than minimizing life-cycle costs. But in non-revenue-earning projects, which require heavy budgetary subsidies, ability to meet recurrent costs is usually *a far more important consideration* than minimizing life-cycle costs as measured in a single PV figure. What this amounts to saying is that the widely-used present value technique is simply inappropriate for the analysis of a large class of non-revenue-earning projects. Indeed, for such projects the technique can be downright misleading.

If investment decisions in RWS should be governed primarily by undiscounted calculations of financial O&M costs, does this mean that capital costs should play no role in choice of technology? That would be saying too much; but their proper role should be determined qualitatively, not by making use of traditional PV calculations, which remove the distinction between capital and O&M costs.

Some people may believe that there is a systematic inverse relationship between capital and recurrent costs, suggesting that one can save on recurrent costs if one is willing to spend more on capital costs. While this is a familiar phenomenon in many fields, I doubt that any such general law holds for RWS technology. Many examples can be cited where low capital costs are associated with low recurrent costs (e.g. gravity-flow schemes typically have capital and recurrent costs that are *both* low; the India Mark II handpump offers capital and recurrent costs that are both lower than many other handpumps; diesel pumping almost always involves high capital costs plus high recurrent costs). My own view is that the best way to take capital costs into account is to do this qualitatively, by seeing how much coverage one will be able to achieve with a given investment budget. The designers of any scheme, if they are fully aware of the range of technology that should be considered, should narrow the choice down to a very small number of alternatives on the basis of technical considerations and the respective recurrent costs. One then examines the relative capital costs to see if they are significantly different. If there is a trade-off to be made, then one simply has to decide, qualitatively, what weights to assign to capital and to recurrent costs. The argument of this paper is that differences in recurrent costs ought to be given a much higher weight than differences in capital costs. One might argue that PV calculations could be made using, e.g. a 10% discount for capital costs and a 3% (or zero) discount for recurrent costs. My strong preference is not to go this route but to carry out separate, undiscounted comparisons of recurrent and capital costs on the technological 'short list' and then to base decisions on qualitative discussions of whatever trade-offs may exist. But, as noted, there may often be no trade-off at all: the technology with the lowest recurrent costs may also have the lowest (or at least a very low) capital cost. Cost tables constructed to justify choice of technology should give far more emphasis than is normally done to estimates of O&M costs – and who will pay for them.

A conclusion similar to mine about the inappropriateness of PV technique in RWS projects was reached entirely independently by a team of engineers, sociologists, and economists who made a detailed study of RWS in the African country of Lesotho. The team made the following observation on the problem:

> It will often be inappropriate to discount the future cost of maintenance to the present and combine it with construction costs, because they are frequently met from different sources of funds, and with differing degrees of difficulty.

The author also made this pointed observation:

> The formulation of the choice of technology by listing the available range of options . . . is by no means easy. It involves careful study and consideration of almost every aspect of the execution of a rural water supply program. But the con-

> sideration of *all these aspects* is invaluable for the planning of a program, *although very often completely neglected.*[2] (Italics mine.)

Assuring that all feasible technological options receive adequate consideration is the heart of the matter. A good project-preparation form, or a good set of questions, is a far better way of assuring this process than requiring the use of PV calculations which, entirely apart from their fatal neglect of recurrent costs, may give little indication of what technologies have been considered.

6. IN CONCLUSION

I have spent more time on cost–benefit analysis than I meant to. I have done so in the hope that I can persuade other economists, and engineers, to spend less time on it when preparing and appraising RWS schemes. If not less time, they can at least use their time more profitably than in constructing misleading PV choice-of-technology calculations. In RWS, economists should spend most of their time on financial problems, bringing together information on project and programme costs, capital and recurrent, and helping to figure out how these costs will be met. Figuring out the cost-per-beneficiary (= cost per capita) in RWS as compared with other sectors can help justify many RWS schemes, since they usually come out relatively low. But the figures need to be marshalled, and trends in other sectors established from such budgetary material as may be available. Financial viability is frequently a weak point in many RWS projects, and economists should help establish that a project will have the funds, particularly the O&M funds, it will need. The economist or engineer who gets too wrapped up in PV calculations will never come to grips with the questions that ought to govern choice-of-technology decisions in this sector.

NOTES

1. Compiled and edited by Arnold Pacey and published by Pergamon Press, 1977, 58 pp. (Available from the Intermediate Technology Development Group, 9 King St., London WC2E 8HN, U.K. Price £2.50.)

2. Richard Feachem *et al.*, *Water, Health and Development* (London: Tri-Med Books Ltd., 1978), p. 238.