The practice of economic assessment of small-scale drinking-water interventions

John Cameron and Paul Jagals

This chapter provides a practical and stepwise guide to doing a social cost–benefit analysis. It draws on more detailed work on the economic assessment of small-scale drinking-water interventions. We set out the practical methods for doing such an economic assessment in the following five steps:

- assessing the effect that small-scale drinking-water interventions have on people’s livelihoods;
- costing feasible interventions, and assessing their discounted cost–efficiency;
- identifying and measuring the benefits in physical terms, and assessing cost-effectiveness;

• putting values on the benefits and undertaking a social cost–benefit analysis;
• conducting a sensitivity test on a scenario to take account of possible inaccuracies in variables.

These five steps are described below, providing a practical set of tools that can be applied to any small-scale drinking-water intervention in any economy.

To give a sense of application to this process, each step is based on information from a case-study. The case-study chosen is a drinking-water system intervention in the village of Folovhodwe in the north-east of the Limpopo province of South Africa, close to the Zimbabwe and Mozambique borders. The case-study is not offered as typical or representative, rather it offers a range of characteristics that are more challenging than usual for a small-scale drinking-water intervention.

Although the design of the method is robust and the economic assessment could be conducted sitting at a desk, agencies planning or evaluating a small-scale drinking-water intervention should collect primary data beforehand to understand the local context within the target population. The primary data for the case-study were collected using a variety of techniques:

• questionnaire-based surveys;
• direct expert field observation (an important source);
• semi-structured focus groups (which proved a cost-effective technique for collecting the kind of broad parameters required);
• group conversations at standpipe tap points where people were collecting water or washing clothes.

The parameters used here are derived from our own collection of primary and secondary data in the field. We show how such parameters can be used for economic assessment.

ASSESSING THE EFFECT OF DRINKING-WATER INTERVENTIONS ON PEOPLE’S LIVELIHOODS

The first step in any economic assessment of the impact of a drinking-water intervention is to describe the context into which the intervention is introduced. This involves describing the demography of the target group of local people who will be primarily affected by the intervention. This provides a vital factor for scaling economic estimates of variables based on household or individual observations up to aggregate estimates, for example total days of illness.
prevented. Disaggregation by sex and age is essential for improving the accuracy of such estimates.

We obtained and augmented demographic profiles and maps of the households and the water system. A house-to-house household census was conducted, plus some sample surveys and key informant interviews to gather livelihood data on economic activities and their rates of reward. The data revealed complex patterns of intra-household migration. The Global Positioning System was used to map the water points.

All our survey work was conducted with the full knowledge of local civil society leaders and local government, and no ethical problems were met.

Livelihoods

Data collection on livelihoods in the case-study area was undertaken (in line with the approach recommended in Chapter 6). The aim was to establish the kinds of activities people would undertake with additional time, energy and any other resources released by a small-scale drinking-water intervention. Triangulation of various observations and house-to-house interviews suggested a very low level of monetized economic activity and little produced wealth – the occasional general store and vehicle maintenance or repair workshop were the only signs of commercial activity or investment in technology within the village.

Significant local agricultural activity was observed. For instance, tomatoes are marketed nationally from this area, using natural wealth in land close to the main river. But household surveys suggested very little involvement of the intervention target households in this activity on a continual basis. Similarly, the presence of natural wealth with tourism potential – in the form of a nearby game park – appeared to have little influence on local livelihood activities.

Direct observation and conversations about new housing construction as an indicator of the distribution of produced wealth suggested a heavy influence of remittances from urban areas – often older women were observed living with only their grandchildren or alone in newly constructed sizable houses, some with private water connections. Thus there are both productive and vulnerable people in the population, but they are spatially separated for much of the year. It is difficult, therefore, to talk accurately about the distribution of economic activities and overall labour productivity for many households. Protection against poverty appeared to rest significantly on intra-family remittances and regular State payments of monetary allowances, both for child support and old age pensions.

In terms of human wealth development, there are two primary and one secondary school in the case-study area, and direct observation suggested a high
uptake of formal education at both levels. Therefore, the impact on school performance (not necessarily enrolment) is a factor to be considered in the economic assessment.

It was difficult to find evidence of strong social wealth in the area. Support from kin and neighbours, the authority of benign, local chiefs, and the presence of well-attended churches seemingly operated to smooth day-to-day life, reduce vulnerabilities and settle disagreements. But there was a lack of clear collective, deliberative institutions, such as collective meeting places (other than the water taps), or posters or other evidence of advertising events or public meetings.

Some reflection of this limited local social wealth was reflected in the institutional management arrangements for the water scheme. The drinking-water intervention had not been designed or implemented through self-generated local institutions but is a responsibility devolved to the local municipality, though the municipality is not visibly active in running the scheme. Part of the result of this distribution of authority is a widespread sense of powerlessness among local people with respect to undertaking even minor repairs to the system, especially the taps. This causes a general vulnerability of the system to breakdown, and is dealt with in one of the sensitivity tests.

Taken together, these livelihood observations in the case-study area would—at this point—suggest that it would be very unlikely that an economic assessment, based on the local conditions alone, would show a significant net economic benefit or favourable rate of return from a drinking-water intervention. The causal linkages between improved access to safe drinking-water and additional high-value, local economic activities in a rural settlement area with large scale emigration are likely to be weak. If significant economic benefits in terms of high value added do indeed exist in the small-system context, then the economic assessment would need to be extended to a full social cost–benefit analysis, taking account of links to the economy of the whole country (in this case, South Africa) over the long term.

COSTING FEASIBLE INTERVENTIONS AND ASSESSING COST–EFFICIENCY

The framework for the basic costing of a small-scale drinking water system is set out in Chapter 8. It is applied here to assess cost–efficiency.

The first step is to decide on a realistic physical life for the water system; for the case-study intervention, this was set at 20 years (from 1998 to 2017). The significance of a hypothetical moment of closure (in this case in 2017) is that it forces the proponents of all interventions, not just drinking-water interventions,
to reflect upon possible environmental impacts that the system might have, such as depleting an aquifer, rather than letting the time-discounting factor erode into insignificance concerns for the more distant future. Environmental impact was not judged to be a significant factor in this scheme because water was drawn from a recharging aquifer at a sustainable rate.

All costs to all affected organizations (public and private), including households, were entered into an EXCEL spreadsheet for the years in which the expenditure actually takes place and the resources are used. The costs were entered for the year when the money was actually spent. A pattern of total costs (including capital, operation and maintenance, and other costs) for the system in the case-study might then look as shown in Table 2.1.

Table 2.1 Synthesized time profile as well as discounted costs for the case-study drinking-water intervention (all costs expressed in terms of prices prevailing in early 2008)

| Year | Total costs (thousand rand) | Comments | Discounted value at 3% per annum $Y(0) = Y(t)/(1.03)^t$
<table>
<thead>
<tr>
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<th></th>
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<tbody>
<tr>
<td>1998</td>
<td>1 500</td>
<td>Start of construction</td>
<td>1 500</td>
</tr>
<tr>
<td>1999</td>
<td>1 500</td>
<td></td>
<td>1 456</td>
</tr>
<tr>
<td>2000</td>
<td>1 500</td>
<td></td>
<td>1 414</td>
</tr>
<tr>
<td>2001</td>
<td>1 500</td>
<td></td>
<td>1 373</td>
</tr>
<tr>
<td>2002</td>
<td>1 500</td>
<td></td>
<td>1 333</td>
</tr>
<tr>
<td>2003</td>
<td>1 500</td>
<td></td>
<td>1 294</td>
</tr>
<tr>
<td>2004</td>
<td>175</td>
<td>Taps turned on for normal operation</td>
<td>147</td>
</tr>
<tr>
<td>2005</td>
<td>175</td>
<td></td>
<td>142</td>
</tr>
<tr>
<td>2006</td>
<td>500</td>
<td>Repairs of teething problems</td>
<td>395</td>
</tr>
<tr>
<td>2007</td>
<td>175</td>
<td></td>
<td>134</td>
</tr>
<tr>
<td>2008</td>
<td>175</td>
<td></td>
<td>130</td>
</tr>
<tr>
<td>2009</td>
<td>175</td>
<td></td>
<td>126</td>
</tr>
<tr>
<td>2010</td>
<td>175</td>
<td></td>
<td>123</td>
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<tr>
<td>2011</td>
<td>175</td>
<td></td>
<td>119</td>
</tr>
<tr>
<td>2012</td>
<td>500</td>
<td>Replacement of pump</td>
<td>331</td>
</tr>
<tr>
<td>2013</td>
<td>175</td>
<td></td>
<td>112</td>
</tr>
<tr>
<td>2014</td>
<td>175</td>
<td></td>
<td>109</td>
</tr>
<tr>
<td>2015</td>
<td>175</td>
<td></td>
<td>106</td>
</tr>
<tr>
<td>2016</td>
<td>175</td>
<td></td>
<td>103</td>
</tr>
<tr>
<td>2017</td>
<td>500</td>
<td>Costs to closure less any residual value of remaining assets</td>
<td>285</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td></td>
<td>10 732</td>
</tr>
</tbody>
</table>
The time profile of expenditures for the case-study system was synthesized from the technical specifications of the system, based on standard parameters used by engineers. The pattern shown in Table 2.1 suggests six years dominated by development through construction, and then two years of normal running followed by some minor upgrading as well as maintenance and repairs, while reflecting continual normal running costs, with a hypothetical major maintenance or repair cost in year 2012 for replacement of the pump. The assessment of the intervention ends in 2017 with an endpoint estimate of the costs of restoring non-recharging or slow re-charging aquifers minus the residual value of the remaining assets. These costs were considered both necessary and sufficient to ensure that the system could deliver the planned amount of drinking-water.

In the case-study area, about 7900 households receive water from a system that pumps untreated, but potable, groundwater to a concrete reservoir from where it is gravity-fed to neighbourhood (communal) taps. Capital costs include installing the pump, building the reservoir, assembling and burying piping, and constructing neighbourhood access points (communal taps in this case).

In practice, running the system on a day to day basis is the duty of a villager who is paid 300 rand a month. These costs seem necessary to sustain the system’s day to day operational capacity, but are notably insufficient to build the social capital necessary to ensure speedy repairs, local ownership and fair distribution of the water. Running costs to genuinely sustain the system should be considerably higher than this.

It was difficult to get maintenance costs for the case-study. The system seems to be repaired (rather slowly in terms of the taps) rather than receiving preventive maintenance. The pump equipment appears to have functioned well from 2004 to 2007 but, in terms of likely future breakdowns requiring major repairs, the pump is a clear candidate for concern. Therefore provision is made in the costing spreadsheet for the pump being replaced in year 2012. Other than this, maintenance costs have been included at the level considered necessary to sustain the system – higher than actual expenditure in the case-study system because actual expenditure involves some loss of service to significant numbers of people, which fails to meet the political objective of a sustained, high quality supply to all in the target group.

Finally, the system involved no additional expenditure on water transportation or processing by households. Observation showed that households were still using the numbers and types of containers (and occasional wheelbarrows) that they used with the unimproved drinking-water sources.

It is worth noting here that if households paid a tariff or fees for water provision, this would not affect the costing method. In terms of an economic assessment aimed at understanding the social value of an intervention, the
concern is with the monetary value of the real resources being used, not who pays the bills.

**Discounted cost-efficiency**

Discounting is the way economists put a value on time. The discounted value of a cost in the case-study is determined by reducing its value by a discount rate (in the case-study, 3%) for each year between the time when the cost is to be valued (the base year, 1998) and the time that the cost is actually incurred.

To create a level playing field for comparison requires all costs be expressed in terms of one point in time (usually the first year of the intervention, \( t_0 \)). In the case-study, the heavy expenditure to replace the pump in year 2012 will, at differing interest rates, have present values in 1998 as shown in Table 2.2. All the interest rates are real, in the sense that they ignore price inflation over the life of the system.

**Table 2.2**  Discounted values in 1998 of 500 000 rand spent or received in 2012 at differing interest rates

<table>
<thead>
<tr>
<th>Discount or interest rate (%)</th>
<th>0</th>
<th>3</th>
<th>5</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present value in 1998</td>
<td>500 000</td>
<td>331 125</td>
<td>252 500</td>
<td>143 600</td>
<td>70 188</td>
</tr>
</tbody>
</table>

The rate of 3% will be used here because it is a rate often used by WHO and other public agencies. It also roughly corresponds to the historic very long term rate of return to low-risk investments. The dramatic power of discounting as a way of putting a value on time is clearly revealed. What prevents discounting from becoming a de facto technical rule of always postponing to tomorrow rather than doing today is the politically set goal of delivering a given level of service to a given group of people as soon as possible – the politics trump the economics in setting a given target in cost–efficiency analysis.

Synthesized costs for the case-study show that the total present value, discounted at 3% per annum give a total cost of 10.7 million rand (Table 2.1). This is the estimated simple cost–efficiency of the system taking account of the time profile of the expenditures as shown in Table 2.1. Any other scheme proposed to provide the target population with safe drinking-water on a sustainable basis should be able to match this total cost in 1998 present value (all expressed in early 2008 prices to remove the element of price inflation).

**ASSESSING COST–EFFECTIVENESS**

In this section we focus on physical indicators of benefits as measures of cost-effectiveness. Freeing time as a result of the intervention is a general
effectiveness indicator, allowing an even wider range of interventions aimed at improving livelihoods and well-being to be compared (see the discussion in Chapters 11 and 12).

In an economic assessment focused on time saving, health benefits come from time freed by fewer episodes of ill-health; that time can now be used for additional livelihood activities. Time may also be made available by preventing premature deaths (discussed separately below). In the simplest case, the number of days that a person is ill in a year is treated as days totally unavailable for any meaningful livelihood activities. But a simple dichotomy of being either totally in or totally out of economic activity ignores the possibility that some activities can continue to be undertaken during an episode of less acute illnesses.

**Benefits of reducing morbidity and mortality**

The reduction, in the study area, in days affected by illness related to drinking-water was estimated by using days with diarrhoea as a proxy. The estimate was based on studies of the prevalence of the disease 6 months before and 12 months after the intervention. The total number of episodes of diarrhoea prevented was estimated to be 2450 for the 3500 people previously using water from the river. In other words, fieldwork suggested a reduction from 1.1 to 0.3 in diarrhoeal episodes per person per year in the approximately 3500 strong population that had used microbially-contaminated water from the nearby river before the intervention.

The total time savings from diarrhoea reduction can be calculated assuming an estimated average time unavailable for livelihood activities of three days per episode (livelihood activities for our purpose here include any adult activity – both productive and reproductive for the household in economic terms – plus schooling for children). Thus total time available for livelihood activities resulting from the reduction in diarrhoea episodes as a result of the drinking-water intervention for the 3500 people in the area previously using river water can then be calculated as about 7500 (3 × 2450) days per year (or 20 person-years per year). Those in the study area who had access to a previous smaller scheme are assumed to have no health benefits.

Closely related to time saved in illness, livelihood benefits for those who previously used the river also appear as additional time made available for other activities than caring for a sick person. In the case-study, the time dedicated to caring for sick people was directly linked to the time that the people were ill and was estimated at half a day for every day of illness (that is 3750 days a year or about 10 person–years for the part of the case-study population who previously used the river).
Diarrhoea is also a significant mortality threat for very young children. We considered infants and children under 5 years of age to be at risk if they lived in households that used river water. In the case-study area, about 50 at-risk (i.e. in households relying on the river for their domestic water needs) babies were born in the year before the intervention came into operation, with a further 230 young children being in the highly vulnerable age of 1–5 years. Given the wide access to local primary health care facilities in South Africa, it might be expected that young children to a large extent would be shielded from death resulting from drinking unsafe water. It is also well-known that providing access to safe water is an effective way to prevent early child deaths. Therefore it is assumed for the case-study area that five early deaths are prevented on average per year by the drinking-water intervention.

These five deaths per annum will be added on a cumulative basis to the annual person–years made available in each year over the whole life of the system. No account will be taken that these gains will continue after 20 years, and no account will be taken of the savings in funeral expenses.

**Time saved in collecting and processing water**

In many circumstances, the largest element in time available for other activities will result from less time spent collecting and (possibly) treating water. Of course, providing better quality water does not necessarily mean decreasing the time and effort involved in collecting water – the better quality water may be further away, depending on the positioning of the taps. But, in general, interventions seek both to improve quality and decrease collection time by providing water from a potable source and creating access points (taps) closer to people’s homes (improved access). There might also be time savings in collecting water from the taps, instead of the more remote river, for washing clothes and personal hygiene.

In the case-study, the time saved in collecting water for all activities was very varied, given the large area covered by the water supply system and the wide differences in distances from previous surface water sources. But an average saving of 1.5 hours a day in collecting water per household previously using water from the river seems reasonable. There was no evidence that home-treatment of water was a common practice before the intervention, so no savings (time or produced inputs) were identified. Therefore, total time saved for the previously river-using households in a year was estimated at 330,000 person–hours (1.5 × 600 × 365). If on average a person spends 10 hours a day on broadly defined, socially valuable livelihood activities (including care for children and the elderly, pre-school learning, formal schooling and community
decision-making) that would otherwise have been disrupted by illness, then this is equivalent to 33,000 days or 90 person–years per annum, assuming that the system has operated normally, according to its design specifications.

**Savings on health-care expenditure**

The estimate of the cost of health sector treatment per episode of diarrhoea is based on the cost of private sector consultation and treatment. In an economic assessment, this can be justified as representing the social cost of treatment by assuming that private sector charges represent market-tested pricing. Consulting a private sector doctor in the broader areas surrounding the case-study area can incur a fee of up to 250 rand. Including medicine, a total cost of up to 1000 rand per treated episode is indicated. Given that the private sector is quite competitive, we treat this as the economic cost to society of health care (in economics terms, the opportunity cost of the resources).

For the population previously using the river, this suggests maximum savings from reducing the number of episodes of diarrhoea by 0.8 episodes per person per year for 3500 people of 2.8 million rand per year if all episodes were treated privately. But in many cases, symptoms would be recognised but medical advice would not be sought or sought only from a nurse in the local primary health care facilities (free to the household but a social cost in public sector resources). Therefore a much lower figure for actual health sector treatment would be reasonable. Assuming this to be the equivalent of about one in seven episodes being treated privately, then the total monetary equivalent of the social cost to households and to the public sector in providing subsidies for public sector health treatment would be 400,000 rand a year.

**The complete cost–effectiveness analysis**

Now a cost-effectiveness analysis can be undertaken of the impact of the drinking-water intervention in the case-study area. First, discounting will be used for all indicators of effectiveness. For example, preventing an illness now will be considered more socially valuable than preventing the same illness in the future. There is an element of inter-generational bias in favour of the current generation in this approach. But at a discount rate of 3%, this bias should be acceptable, because it is hoped that future generations will have an advantage in terms of access to better medical technology.
We have three different dimensions of effectiveness, measured in three different units:

- reduction in total numbers of episodes of diarrhoea, discounted over the whole life of the intervention;
- greater time available for broadly defined livelihood activities for sick people, those caring for sick people, and time released from collecting and treating water, discounted over the whole life of the intervention;
- monetary or budgetary savings in treatment costs by households and the public sector, discounted over the whole life of the intervention.

A conventional cost–effectiveness approach to the third indicator is to subtract the monetary present value saved in health care from the present value of building, operating and maintaining the system—in other words to treat these savings as a negative cost. This will reduce the total cost of the intervention. The total cost will then be more of a “social” cost, in the sense that the costs taken into account go beyond the direct costs to the agency of building and operating the drinking-water intervention.

Having disposed of this monetized dimension in the costs numerator, the remaining two dimensions are both candidates for the effectiveness denominator. The first is simpler from a health perspective and can be used to compare interventions reducing episodes of diarrhoea. The second includes wider livelihoods data in terms of putting all savings in terms of time saved.

For the case-study, calculations suggested the following values for cost–effectiveness indicators:

- The net present cost is obtained by deducting the present value of financial savings on medical treatment from the present value of capital investment and operation and maintenance costs. At a discount rate of 3% per year, the net present value after this deduction falls significantly to 3.7 million rand (instead of 10.4 million rand, derived earlier in this chapter using a simple cost–efficiency calculation).
- Total discounted reduction in numbers of episodes of diarrhoea was estimated at 25,700. Dividing this figure into the total discounted social costs of 3.67 million rand gives a cost–effectiveness measure of about 150 rand per episode prevented in addition to the costs of health treatment.
- Total discounted gains in terms of time for livelihood activities (released by less illness, less caring for sick people, less time collecting water, and reduced infant mortality) were estimated at 1400 person–years. Dividing
this into 3.67 million rand gives a cost–effectiveness figure of around 2500 rand per person–year of livelihood activity gained.

By themselves, the absolute values of these cost–effectiveness indicators have no meaning. Putting them in a South African context, the sum of money involved in preventing one episode of diarrhoea does not appear cost-effective. The amount of 150 rand is equivalent to almost the weekly wage of a low-paid, full-time employee.

The livelihood time cost–effectiveness indicator looks more cost–effective. A low-paid full-time worker might expect to receive an income of over 12 000 rand a year. So 2500 rand may be an acceptable ‘social price’ for gaining a whole year of activity. These results are consistent with global economic assessments of small-scale drinking-water schemes, which conclude that a large proportion of the benefits come from time saved in collecting water.

As a final point on using cost–effectiveness analysis to set priorities, there is a need for caution in using cost–effectiveness statistics to make comparisons. Before comparing and making decisions informed by that comparison, it is crucial to ensure that like is being compared with like in terms of the specification of the cost–effectiveness indicator. For instance, there is a need to ask the following questions:

- Have monetary savings been deducted as negative costs in all cases?
- Is the effectiveness indicator identical in specification for all cases?
- Have the same discounting procedures been followed for all variables at an identical discount rate?

Social cost–benefit analysis (an extension of cost–effectiveness analysis) can remove problems of ensuring comparability, not just between drinking-water interventions or across the whole health sector. At its most ambitious, it seeks to compare all interventions coming from every sector that claim to offer improvements in human well-being anywhere in the world. The next section of this chapter is devoted to social cost–benefit analysis.

**UNDEARTAKING A SOCIAL COST–BENEFIT ANALYSIS**

This section demonstrates how to put values on benefits, and use the values to undertake a full social cost–benefit analysis. The cost–effectiveness analysis in the previous section arrived at two estimates of cost–effectiveness: cost per diarrhoea episode prevented; and cost per additional year of human life made
available for livelihood activities (including higher quality learning in and out of formal schooling). Social cost–benefit analysis goes beyond this and allows comparisons to be made between all interventions that aim at improving well-being for any group of people on any scale. Clearly, this is important for any agency that wishes to make claims for funding from general development funds beyond that part of the national budget earmarked for the health sector.

Social cost–benefit analysis demands that all costs and benefits be given a monetary equivalent value in terms of prices at a given base year (in our case, 2008 prices). The analyst must choose these values—even where there is no buying and selling in observable markets. Thus the analyst must choose a price that reflects the scarcity of the good or service, for example water in a depleting aquifer. If there is no market but there exists a public sector charge for a good or service, the analyst should reflect on how that charge was decided and how far the charge represents what a competitive market price might be.

**Estimating costs and benefits for a full social cost–benefit analysis**

Fortunately, social cost–benefit analysis for most small-scale drinking-water interventions is not particularly complex, and robust conclusions can be drawn from the relatively simple framework presented here. For the case-study, costing was provided by an experienced water engineer plus direct observations from the field. Given this, the cost pattern described above is acceptable for the purposes of social cost–benefit analysis.

In terms of the benefits side, we can now treat the savings in health care costs as a monetary benefit, rather than as a saved cost as we did above. We used the price that people pay for private health treatment as a current market-tested monetary value. This is therefore a “shadow” price (in other words, not the real cost paid by most case-study households, but a price representing an open market valuation assuming competition in the private health sector). People, especially in rural areas, predominantly use subsidized public sector clinics or hospitals when they seek treatment, but what they pay does not reflect the full value to South African society of the resources used in diagnosis and treatment.

Using a shadow price has an economic theoretical rationale in social cost–benefit analysis of approximating a market price where forces of demand and supply are freely operating and equated. It also has the advantage of being practical, given that it was impossible to work out a full social costing for the use of local public-sector health facilities to treat diarrhoea without intrusive
data collection at local health centres. Even with such data, there would be problems of underestimating full costs, given the way the primary health centres are embedded in a wider, complex public-sector accounting system. This device, of using a chain of equivalent activities (for example different channels for receiving medical treatment) until an open market transaction with a price is identified, is a common practice in social cost–benefit analysis.

A present value of the savings on health treatments was calculated above as about 4 million rand per year. After the intervention, this sum is assumed to be available to support changes in livelihood activities and provide produced assets. These assets can be used to complement additional human time freed by the drinking-water intervention. Thus the freed time could be used more productively in livelihood terms, including possibly purchasing more or better hygiene-related items.

While we now have monetary values for treating an episode of diarrhoea, we have no monetary value for the benefits expressed in terms of gains in person–years of livelihood choices (as a result of time released for livelihood activities through less sickness, less caring for sick people, and time spent collecting water). The starting point is to find answers to the following questions:

- What activities will now be chosen to use the released time?
- Is there a market price for those additional activities?

Given that, in the case-study area, a very low proportion of adults’ time is directly sold locally, and much of the time saved concerns people under 18 years of age (who make up over 40% of the population), it might be assumed that there is little monetary value that can be attached to additional time available. So perhaps a monetary equivalent close to zero would be appropriate.

But context is important in developing this aspect of social cost–benefit analysis. First, it is useful in this context to take account analytically of sex and age. In the case-study, assuming that episodes of diarrhoea are evenly distributed by sex and age, then around 25% of time sick will involve adult men, 35% adult women and 40% young people under 18 years of age. For time savings in caring for sick people and collecting water for all its uses, it is

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1 Mullins et al. (2007) make an impressive attempt to calculate the actual total cost of treating an episode of diarrhoea in the public sector in a number of locations in South Africa. Generally, the results show very large differences in cost between treatment in a clinic and a hospital. Our average figure of 1000 rand for a complete treatment lies within the possible range, depending on the proportion of people treated in clinics as outpatients compared with those treated in hospital as inpatients.
assumed that about 75% will be adult women’s time, 5% adult men’s and 20% that of young people.

In a typical year, adult women will gain a large proportion of the time saved (about 60%) followed by young people under 18 years of age (25%). Therefore, placing a value on time for these two groups is crucial. In the case-study context, given the high level of open unemployment among local males and their limited contribution to work in the home, men over 18 years of age and resident in the case-study area will be given a zero value for their time. The men working as migrants outside the case-study area are vital to the local economy in terms of remittances, but are less likely to suffer from local drinking-water induced illness, care for sick people, or be involved significantly in water collection. Therefore, they do not receive any significant time saving benefits from the drinking-water intervention. Their livelihood activities are therefore assumed to be unaffected by the intervention.

In the case-study area, adult women report that they use time saved to improve the quality of life in the home environment by spending more time in improving hygiene and for better child care. This time has indirect economic value in terms of facilitating the work of other people (including the physiological and psychological impact on rural-urban migrant workers when visiting home) and the schooling of young people.

We will calculate the gains induced by increased studying time when looking at economic gains by young people. The indirect monetary-equivalent gains for supporting other adults in their activities to generate incomes outside the household (in the local economy or as temporary migrants) can be looked at from a wages-for-housework perspective. That is, the additional time freed by the water intervention will enable other household members to be more productive in the wider economy, and this can be expressed in monetary terms. On this basis, it is reasonable to attribute a shadow price of 50 rand a person–day to the additional time made available by the drinking-water intervention (the local wage of a woman working as an employed cleaner). Thus in a typical year, 72 years of adult women’s time freed up by the drinking-water intervention will be worth a monetary equivalent of 1.3 million rand (72 × 50 × 365).

It is difficult to estimate with any precision the qualitative educational gains from the increased total time for studying by people under 18 years of age, resulting from less illness and less time spent caring for people or collecting water, as a result of the drinking-water intervention. However, an order of magnitude for the case-study can be estimated by assuming that:

- there are 200 young people in each one-year cohort who benefit from the drinking-water intervention;
• as a result of the increased study time, energy and adult support attributable to the drinking-water intervention, 10% of each cohort (20 young people) leave formal education having successfully completed one more year than they would have done before the intervention;

• an additional year in formal education is worth, on average, an additional 1000 rand a year over a 30-year working life to each person achieving the extra grade.

Under these assumptions, each young person who achieves an extra year of formal education can expect an increased income valued at a present value in 1998 at 2008 prices of 20 000 rand on a 3% discount rate. Thus 20 young people a year will be credited with a present value equivalent of 400 000 rand to the benefits in every operational year of the intervention following their leaving school.

To put an economic value on infant deaths saved by the intervention will mean that they will be a net cost to their family in terms of consumption costs for much, if not all, of the operational life of the intervention.

Demographically, an additional 65 people (five deaths prevented in each of the 13 years, 2004 – 2017, in which the system is in operation) will be alive at the end of the intervention but who would not have been alive without it. Calculating a value for the net contribution of these 65 people to South African society is a challenge, as the eldest will be only 13 years of age in 2017. Thus significant additional incomes will start around 2020, and from that year more incomes will be added until the oldest start to retire in about 2060, after which total income starts to fall until the last person retires in around 2075. The highest annual total income could be around 1.3 million rand (65 people earning an average of 20 000 rand). Setting this up in spreadsheet format and discounting at 3% per year gives a present value in 1998 of about 15 million rand.

Putting all these benefits into a spreadsheet gives the pattern shown in Table 2.3. Thus the total present value for 20 years of intervention for all types of benefits shown in Table 2.3 in monetary equivalent form is 34 million rand.

**Bringing costs and benefits together for analysis**

We are now in a position to bring costs and benefits together in a social cost–benefit calculation. Going back to the original cost estimates, the rounded total present value of the costs was 11 million rand. This indicates a net present value (present value of benefits minus present value of costs) of 23 million rand. But net present value in absolute terms is sensitive to scale of operation: generally, a much larger initial investment might be expected to produce a much larger net present value thus confusing comparisons of larger and smaller projects. One
way to remove the question of scale is to convert the net present value into a ratio of the present value of benefits (PVB) to the present value of costs (PVC), giving $PVB/PVC = \frac{34}{11} = 3.1$.

### Table 2.3 Summary of total discounted benefits

<table>
<thead>
<tr>
<th>Year</th>
<th>Discounted benefits (million rand) at 3% per year</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>15</td>
<td>Discounted flow of income from earnings of saved lives (2020 to 2070)</td>
</tr>
<tr>
<td>2004–2016</td>
<td>19</td>
<td>2100 rand each year (400 rand from medical cost savings, 1300 rand from added time for adult women for livelihood choices, 400 rand from income effect of improved school performances). Each year is credited with the same sum of 2100 rand in benefits. The discounting calculation can be simplified as benefits $\times$ (sum of all the discounting factors from year 7 to year 19 inclusive). This can be rewritten, as for the case-study, as present value $= 2100000 \left((\frac{1}{1.03})^7 + (\frac{1}{1.03})^8 + (\frac{1}{1.03})^9 + (\frac{1}{1.03})^{10} + (\frac{1}{1.03})^{11} + (\frac{1}{1.03})^{12} + (\frac{1}{1.03})^{13} + \cdots + (\frac{1}{1.03})^{19}\right) = 2300000 \times 9.2 = 21160000$</td>
</tr>
<tr>
<td>TOTAL</td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

This is a very impressive ratio by any standards and certainly suggests the investment was justified. Generally, a ratio greater than 1.5 is judged to be very satisfactory in assessing public sector investments.

Another way of taking account of scale is to calculate the discount rate that would reduce the net present value to zero. In economics language this is the internal rate of return. Calculating the internal rate of return starts from discarding the assumption of a 3% discount rate and instead calculating the maximum rate of interest that people could afford to pay if a lump sum was borrowed to pay all the costs at the beginning and the whole loan paid back at the end of 20 years. This can be calculated by trial and error using any spreadsheet software. Varying the discount rate and looking at the relative sizes of total costs and benefits (see Table 2.4) will result in the totals of costs and benefits approaching each other; that is, the net present value is getting close to zero and the discount rate is approaching the internal rate of return. At the time
of the case-study, the internal rate of return is about 16% per annum – a very creditable rate of return by commercial standards.

Table 2.4 Comparing costs and benefits at varying discount rate

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>Discounted total costs (in million Rand)</th>
<th>Discounted total benefits (in million Rand)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>15%</td>
<td>7.2</td>
<td>7.7</td>
<td>Need to raise interest rate (internal rate of return) to reduce value of later benefits relative to earlier costs</td>
</tr>
<tr>
<td>16%</td>
<td>7.0</td>
<td>6.9</td>
<td>The interest rate (internal rate of return) that almost equates costs and benefits, i.e. the rate the intervention could afford to pay and therefore the higher the better</td>
</tr>
<tr>
<td>17%</td>
<td>6.9</td>
<td>6.2</td>
<td>Costs are now higher than benefits so the rate of interest (internal rate of return) needs to fall to increase the value of later benefits relative to earlier costs – that is the intervention can afford to pay a higher rate of interest on a loan</td>
</tr>
</tbody>
</table>

It must be emphasised that this return comes over a period of 20 years. When informing decision-makers, it must always be emphasised that the social cost–benefit analysis estimates are based on estimates of future values of variables, often far into the future, that involve considerable uncertainty.

This may even apply to impact evaluations based on data collected after the end of the intervention if, for instance, they involve estimates of future incomes for people still in school.

This concern with uncertainty about the future (added to doubts about the accuracy in current observations) explains why all the data cited in this chapter are expressed in rounded numbers with two or three significant figures.

Therefore this section must end with a warning. Beware the temptation of offering or demanding spurious accuracy from a social cost–benefit analysis. Citing numbers which give the illusion of much greater accuracy than justified by the procedure for deriving the numbers is very unprofessional and verges on being unethical if it is intended to inhibit discussion of the assumptions being made by the analyst or the likely sampling and measurement errors in the data. Such concerns lead us to the necessity of sensitivity tests, as discussed in the following section.
SENSITIVITY TESTING TO DETERMINE THE ROBUSTNESS OF THE SOCIAL COST–BENEFIT ANALYSIS RESULTS

One of the few truths in economics is that estimates of any mean are accurate only to plus or minus 5% (often attributable to sampling error). Once other forms of inaccuracy are factored in, then the margin of error is likely to be plus or minus 10% or more. Any decision-maker faced with figures rounded to three significant figures and words and phrases such as “about”, “estimated”, “assumed”, “close to”, “probably” or “approximately”, will be alerted to the fact that they are being offered an imprecise, point estimate of the current situation on the ground. This indicates the need for sensitivity tests.

A sensitivity test constructs a scenario that adjusts some of the values of variables in a social cost–benefit analysis on the grounds that they are comparatively:

- vulnerable to sampling or wider measurement error (in which case both high and low values may be tested to assess impact on cost–benefit ratio or internal rate of return), for example choice of respondents;
- influential on the results of the social cost–benefit analysis because of the sheer scale of their effects (large numbers occurring relatively early in the intervention life), for example delays in construction;
- open to future uncertainty (in the judgement of local key informants or judging by experiences of similar interventions elsewhere), for example breakdown of key equipment;
- of particular concern to decision-makers; that is, some variables have a higher weighting in the political decision than the monetary equivalent value they have been given in the “most likely” social cost–benefit analysis scenario, for example increasing social cohesion;
- of particular concern to people in greater poverty and suffering greater discrimination; that is, some variables have a higher weighting for such people than the monetary equivalent value they have been given in the “most likely” social cost–benefit analysis scenario, for example livelihood damage caused by having to provide “voluntary” labour to construct a new drinking-water system.

Deciding which variables to include in a sensitivity test

The major variables for the social cost–benefit analysis in the case-study are shown in the first column of Table 2.5, with subsequent columns indicating the priority for sensitivity testing. The number of Xs in a cell indicates the sensitivity of the
<table>
<thead>
<tr>
<th>Parameter variable</th>
<th>Criteria for selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inaccuracy in measurement</td>
<td>XXX (histories of poor maintenance locally and globally)</td>
</tr>
<tr>
<td>Scale of influence</td>
<td>X (if system maintained and population using system remains manageable)</td>
</tr>
<tr>
<td>Vulnerability to future uncertainty</td>
<td>XXX (rising aspirations to have in-house connections)</td>
</tr>
<tr>
<td>Interest to decision makers</td>
<td>X (if system maintained and population using system remains manageable)</td>
</tr>
<tr>
<td>Interest to poor people</td>
<td>XX (availability and quality of health services)</td>
</tr>
<tr>
<td>Total costs in each year From 1998 to 2017</td>
<td></td>
</tr>
<tr>
<td>Livelihood time benefits from fewer diarrhoea episodes</td>
<td></td>
</tr>
<tr>
<td>Livelihood time benefits from caring for fewer sick people</td>
<td></td>
</tr>
<tr>
<td>Proportion of people seeking formal health treatment for diarrhoea episodes</td>
<td></td>
</tr>
<tr>
<td>Health treatment cost per episode of diarrhoea</td>
<td></td>
</tr>
<tr>
<td>Livelihood time benefits from improved access to water</td>
<td></td>
</tr>
<tr>
<td>Numbers of infant deaths prevented</td>
<td>XX (through monetary equivalent value attributed)</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Putting a value on each infant death prevented</td>
<td>XXX (distant in time but very high value)</td>
</tr>
<tr>
<td>Savings from reduced societal resources needed for health treatment</td>
<td></td>
</tr>
<tr>
<td>Proportion of young people improving school performance</td>
<td>XXX (there is a question of attribution to drinking-water improvement?)</td>
</tr>
<tr>
<td>Lifetime income gains from better school performance</td>
<td></td>
</tr>
<tr>
<td>Valuation of livelihood time ains differentiating between adult women and adult men</td>
<td></td>
</tr>
</tbody>
</table>

X = sensitivity of row variable to the factor in the column; XX = very sensitive; XXX = extremely sensitive.
column criteria to changes in the value of the row variable. In economic language, this means the relative degree of elasticity of percentage response of the column variable to a percentage change in the row variable.

Table 2.5 suggests that there are reasons for carrying out sensitivity tests on all of the variables listed. Rather than treat each variable separately, it is often more convenient and more accessible for decision-makers to group the modifications to variables into scenarios with a plausible story to bring out any interrelationships between the variables.

One scenario is presented here that is not dependent on the specific context of the case-study area. It can be applied in almost any situation. Given the positive results of the “most likely” social cost–benefit analysis scenario described above, it seems appropriate to prioritize changes in those benefits most vulnerable to measurement inaccuracy.

The aim of the sensitivity tests is to see whether changes in the variables where accuracy is most in doubt can reverse this positive conclusion. If the social cost–benefit analysis “most likely” result had been negative, it would be logical to see whether modifying the variables in a positive direction within a plausible range would produce a positive result.

In the test scenario, the values of the benefits variables with three XXXs in the appropriate column of Table 2.5 are radically modified to the values shown in Table 2.6.

Putting these modified values into the spreadsheet does not affect the present value of the costs, but it reduces the present value of the benefits to 14 million rand. Therefore, the benefit/cost ratio falls to 1.3 which, while still greater than one, may be less compelling in terms of arguing for a drinking-water project to have priority, as compared with other possible uses of the resources.

Table 2.6  Variables modified to test sensitivity of outcome of social cost–benefit analysis

<table>
<thead>
<tr>
<th>Parameter variable</th>
<th>Adjustment made</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health treatment cost per episode of diarrhoea</td>
<td>Reduced to 500 rand from 1000 rand</td>
</tr>
<tr>
<td>Value of infant deaths prevented</td>
<td>Reduced to zero</td>
</tr>
<tr>
<td>Proportion of young people improving school performance as a result of drinking-water intervention</td>
<td>Reduced to 5% of each cohort</td>
</tr>
<tr>
<td>Lifetime income gains from better school performance</td>
<td>Reduced to zero</td>
</tr>
</tbody>
</table>
At a conceptual level, this scenario does raise important issues of inter-generational relationships. Any estimates of the state of the world at a time 15 to 45 years in the future must be subject to doubts about the accuracy of the variables involved. The “most likely” scenario puts a considerable value in economic terms on young people’s long-term futures and on saving infants’ lives. There will always be controversy over putting a value on a human life, and this sensitivity test scenario brings that issue into stark focus.

It encourages decision-makers to take responsibility for long term change and to think about the world of work that will be accessible to the next generation of people.

A LAST WORD

The scenarios offered here are intended to show how social cost–benefit analysis can help the would-be analyst explore issues surrounding a particular small-scale drinking-water intervention in order to offer additional evidence to decision makers. Taken together, the two scenarios show that an economics assessment using social cost–benefit analysis is a tool to assist, rather than dictate, decision-making. Any economic assessment should provoke thought and inform debate, not close the decision-making process.

REFERENCES
