



Cost-Effectiveness Analysis for Health Projects

Given the well known difficulties in quantifying benefits in monetary value from health projects, quantitative economic analysis should normally concentrate on comparing costs in relation to health impacts from different project alternatives. The general procedure requires specifying incremental project impact (the difference between a health outcome with and without a particular project) and comparing this with incremental cost (the difference between resources used with and without the project). As with project evaluation in any other sector, both impacts and costs should be converted to a present figure by discounting.¹

¹ The choice of discount rate for health projects is a matter of controversy and should normally differ from that used in productive sector projects where health impacts cannot be expressed as quantifiable monetary benefits. However, ADB practice is to use 10-12 percent in all the projects involving ADB financing (*Guidelines 1997*).

Hence, we can summarize a cost-effectiveness indicator (CEI) as

$$\text{CEI} = \text{PV}(\mathbf{C}_w - \mathbf{C}_{w0}) / \text{PV}(\mathbf{HI}_w - \mathbf{HI}_{w0}) \quad (1)$$

where

- C is annual project costs;
- HI is annual health impact;
- PV is the annual figures over the project life discounted to the present;
- w and w₀ refer to with and without a project, respectively.

CEI can then be used to compare alternatives with the normal decision criteria when choosing between alternatives to select the cheaper (in terms of resource use per unit of health) impact. Application of this general procedure raises several complications. Project economists should, therefore, pay due attention to: project costs, discount rate, and health impacts as well as their indicators which are discussed below.

Project Costs

The costs to be included here are the resource costs over the project's life, which can be measured at both financial and economic prices. Hence, the accounting charge depreciation is excluded, as investment costs are included in the years in which they arise. Interest and loan repayments as financial rather than resource costs are also excluded. Health projects which are not revenue generating will pay no profits or corporation tax; however, they may pay indirect taxes or import duties on the inputs they purchase, such as equipment or drugs. In the calculation of CEI at financial prices, these taxes are part of project costs; but for CEI at economic prices, they must be excluded. Whenever there are significant distortions in an economy, it will be necessary to calculate CEI at both financial and economic prices. This means the principles of economic valuation set out in *Guidelines 1997* should be applied to the valuation of health project costs. National conversion factors – for example, relating to the shadow exchange rate factor (SERF) or its inverse, the standard conversion factor (SCF), or to an unskilled labor conversion factor – that are applied in the economic evaluation of projects from other sectors can be used for the valuation of health costs.

The financial and economic CEI will give different information on projects. The former shows costs from the budgetary viewpoint, while the latter shows the impact on the economy in general. Hence, any scarcity of resources not captured in its financial price (for example, where the exchange rate for local currency is overvalued) should be

incorporated through the use of economic prices (in the exchange rate case, through a SERF or SCF). In addition, the time of patients in waiting or traveling to receive medical attention will not be captured in a financial calculation; but where this is a significant item, it should be costed and included in the economic analysis of the project.

It will be important to include all relevant capital and operating costs in the CEI calculation. Capital costs will include buildings such as hospitals and clinics, laboratories, equipment, vehicles, technical assistance and training. Any residual values (for example, of buildings or equipment) must be entered as negative costs at the end of the project life. Operating or recurrent costs include supplies and drugs, utilities such as power, and the time of the health personnel involved. Often in health projects, services are produced jointly, making it difficult to allocate capital costs to a particular activity. One approach is to allocate capital costs to each activity on the basis of staff time inputs. If this cannot be done accurately (for example, immunization programs for delivery of BCG and DPTT vaccines from the same health clinic), one can establish the costs of the activities when implemented together and then separately for activities that use the same capital resources. One can also estimate the incremental cost of adding one of the alternatives (say a BCG program) to a project to implement the other alternative (say a DPTT program) and vice versa (the cost of adding a DPTT program to a project to implement BCG vaccinations). Different project combinations can be assessed to find the most cost-effective means of achieving a particular level of health benefits.

Discounting

Standard ADB practice, as stated in *Guidelines 1997*, is to apply 12 percent as a test discount rate (with 10 percent used in exceptional cases where there are some additional non-quantifiable benefits). In principle, this is to reflect the opportunity cost of the funds committed to a project. By assumption, funds can be used elsewhere with a national return of 12 percent. The same test rate is applied across countries, which implies that essentially, it is a rationing device to allocate ADB resources between borrowers in an efficient manner. If health benefits can be quantified and valued accurately, then, in principle, health projects can be compared with projects from any other sector. Benefits will be equivalent to an income figure and like any other stream of income, future benefits will be worth less than benefits received today due to the opportunity cost principle. Hence, if health projects are subject to a full cost-benefit analysis, it is clear that they must be treated in the same way as projects from any other sector and discounted at ADB's standard 12 percent rate.

The 12 percent discount rate is used to reflect the opportunity cost of ADB resources and, in principle, acts as a rationing device to efficiently allocate scarce funds between competing projects. This approach is not directly relevant to health projects. With productive sector projects, future benefits and costs are less valuable than present sums because if they were available immediately, they could be productively invested at the discount rate. However, where benefits cannot be quantified in monetary terms as with health projects, this justification for discounting is not valid. Nonetheless, future health impacts may still be less valuable than present impacts because individuals and society in general prefer present to future benefits either because of a dislike for waiting or because incomes are rising over time and hence, future benefits will accrue to a better-off population. This is the rationale for discounting based on social time preference. When the discount rate is defined as reflecting society's preference for better health now rather than in the future, it becomes a subjective parameter; although when specified in this way, there should be, in principle, a unique social discount rate for each DMC.

Most estimates of the social time preference rate of discount set it at below 5 percent. A common figure used in the analysis of health projects is 3 percent (see, for example, *World Bank, World Development Report 1993*). As discussed below, a 3 percent discount rate must be applied in cost-effectiveness calculations where the DALY indicator is used for consistency, since published international DALY estimates are conventionally based on a 3 percent rate. However, if other CEIs are applied, there are basically two choices: either discount at the same rate as for other ADB projects; or use a lower rate such as 3 percent to take account of the theoretical argument that in health, where benefits are not monetized, discounting should be at a time preference rate. All cost-effectiveness illustrations in this *Handbook* use 3 percent. Nonetheless, given the uncertainty involved, the sensitivity of the cost-effectiveness results to different discount rates should be tested if the time profile of project alternatives is very different. Appendix 2 discusses the issue of the discount rate for health projects in more detail.

Health Impacts

The procedure for identifying and valuing health project costs is relatively straightforward and does not differ in principle from that required for projects from other sectors. The assessment of health impacts, required for the denominator of the CEI, is more problematic. In practice, there are a number of alternative measures of project outcome. A realistic aim in health project analysis, therefore, should be to

calculate CEI using one or more of these measures. Which to use will depend on data availability and the nature of the project. Here are several possible indicators in quantifying health impacts, ranging from the relatively simple to the very sophisticated. Project analysts will have to judge if they will be able to apply them in their own cases.

Process Indicators

The simplest approach focuses on a narrow definition of health impact related to the specific goal of a project. Examples are number of patients served (as in, children immunized or pregnant mothers seen) or of medical staff (such as nurses and doctors) trained or of inputs provided (such as bed days or operations). This is termed a process approach to health impact since the process of provision of health services (such as hospital beds or immunizations) is assumed to have a clearly defined and constant relationship with health outcomes. Hence, different hospital projects can be compared on the basis of costs per hospital bed, or different leprosy programs by cost per patient seen. The assumption is that each project alternative is equally effective and differs only in costs. This approach uses relatively simple data and is, therefore, fairly straightforward to implement. Its main limitation is that it allows only narrow comparisons between similar projects and cannot be applied in comparisons between different types of health intervention.

To apply equation (1), the relevant indicator and cost data will have to be estimated for each year of the project and discounted to the present to derive the CEI ratio. *Table 1* illustrates possible process indicators for different types of projects.

To illustrate the use of process indicators, *Table 2* gives a summarized data on three alternative versions of a project to improve the health of mothers. The process indicator is the number of supervised deliveries which is taken as a proxy for improved health during pregnancy. Alternative 1 works through the Family Planning Ministry, alternative 2 through the Ministry of Health, and alternative 3 works at the village level to develop groups of local midwives. In this case, the CEI is cost per supervised pregnancy with alternative 3 providing the least cost at \$27 per supervised pregnancy. It should be noted that the illustration makes the assumption (which may not be correct) that all forms of pregnancy supervision are equally effective.

Table 1
Process Indicators

Project	Process Indicator (number of)
Training	Doctors trained Nurses trained
Inpatient care	Bed days Surgical procedures (e.g., operations) Birth deliveries
General clinics	Outpatient visits
Mother and child health	Pregnancies monitored Children immunized Contraceptive prevalence
Specific diseases	Patients treated
Nutrition	Breast-fed children Supplemented person years

Table 2
Cost-Effectiveness of Alternative Maternal Health Projects

	Alternatives		
	1	2	3
Population (million)	1	1	1
Pregnancies (million)	0.027	0.027	0.027
Deliveries			
Home unsupervised (%)	70	30	30
Home with midwife (%)	10	30	70
In hospital (%)	10	40	0
In clinic (%)	10	0	0
Annual supervised pregnancies (million)	0.0089	0.0189	0.0189
Present value of supervised pregnancies ^a (million)	0.07	0.16	0.16
Present value of project cost ^a (\$ million)	2.59	5.28	4.32
Cost per supervised pregnancy (\$)	33	33	27

^a Discounted over 10 years at 3 percent.

Health Impact Indicators

Years of Life Gained (YLG)

A more complex indicator of health impact relates to deaths averted or years of life gained (YLG). Use of this indicator allows a comparison between different types of projects (for example between different forms of immunization or between preventive or curative treatment). The comparison now in the CEI is on the basis of costs per year of life saved. Calculation of years of life saved requires an estimation of the difference between expected duration of life with and without the project for all those affected by a project. This requires data on diseases that the project will combat. Such data include: average age at onset of the disease, average age at death as a result of the illness, incidence of the disease in the population, fatality rates from the disease, survival rates for those not affected, and life expectancy without the disease at the age of premature death. These data can be combined in equation (2) below to give life years gained. YLGs are given per 1,000 of the population affected but any unit can be used.

$$\text{YLG} = \text{IN} * \text{CF} * \text{SR} * \text{PV}(\text{ad..ar}) \quad (2)$$

where

- YLG is years of life gained;
- IN is the incidence of a disease (new cases per 1,000 of the population);
- CF is the case fatality rate (percent);
- SR is the probability of survival without the disease between years a_0 and a_d , where a_0 and a_d are average age at onset of the disease and average age at death with the disease respectively;
- a_d and a_r are average age at death with the disease and average age of death without the disease respectively; and
- PV($a_d..a_r$) is present value of years survived between a_d and a_r discounted to the present.

To use equation (2) in comparisons between health projects, apply data on the disease involved and make an assumption about how effective different projects will be in reducing its incidence. Different levels of effectiveness will imply different figures for IN and possibly, different ages for average premature death a_d for those

for whom the treatment is not fully effective. CEI, in this case, compares discounted costs with discounted YLG, so that for project j ,

$$CEI_j = PV(C_w - C_{wo}) / PV(YLG) \quad (3)$$

where as before,

C_w and C_{wo} are costs with and without the project;

YLG is net years of life gained as a result of the project; and

PV is discounted present value.

Use of equation (2) requires national life expectancy tables to identify the expected age at death of someone of age ad who does not contract the disease concerned. However, use of such tables rests on two simplifying assumptions that should be made explicit. First, if a death is saved by a health intervention, the individual affected is assumed to have the same survival probability as the average individual in the population. Second, survival rates and life expectancy in the future are calculated at currently observed rates of mortality. Mortality patterns may change significantly as incomes rise and medical science advances; hence, using contemporary figures for calculations over the lifetime of individuals may be misleading. Appendix 3 discusses the procedure for compiling life tables.

YLG has an advantage over process indicators, like patients seen or bed days, since it is based on health outcomes rather than on an assumed constant link between certain measurable variables and health outcomes. Unfortunately, it does require epidemiological data that may not always be forthcoming. But it can be a highly important indicator in dealing with diseases with high mortality effects, particularly childhood diseases. If the main objective of health interventions is mortality reduction, then YLG will be the appropriate indicator. In projects which have large morbidity effects however, judging projects on cost-effectiveness grounds using YLG as the measure of health outcome can be misleading. Hence, YLG may give a misleading picture of the impact of projects that combat chronic diseases with a large morbidity but low mortality impact. To address this problem, several alternative indicators have been devised.

Healthy Years of Life Gained (HYLG)

This is the simplest of the alternative indicators that combine mortality and morbidity effects. HYLG is the sum of the years of life saved as a result of a project plus the years of life that will no longer be affected by morbidity, with weights applied to the latter to make them comparable with healthy years saved. HYLG extends the

formula for YLG by calculating the years affected by disability before premature death (YD) plus the years of chronic disability for those affected by a disease who do not die prematurely (YCD), and finally, plus years lost to temporary illness (YT). Calculating these additional health outcomes requires further information on the degree to which those affected by a disease suffer disability between the onset of the disease and premature death, on the proportion of those affected who survive but are permanently disabled, and on the severity of their chronic condition. With these data, YD, YCD, and YT can be calculated from the following formulas:

$$YD = IN * CF * SR * w_1 * PV(ao..ad) \quad (4)$$

where YD is years of life affected by disability before premature death;
 IN and CF are as defined in equation (2);
 ao and ad are average age at onset of the disease and average age of death with the disease respectively;
 SR is the probability of survival without the disease between years ao and ad;
 w_1 is the disability weight attached to a year of morbidity from the onset of the disease to premature death; and
 PV(ao..ad) is the value of the years survived between ao and ad discounted to the present.

$$YCD = IN * PD * w_2 * PV(ao..ar) \quad (5)$$

where YCD is years of chronic disability;
 IN is as defined in equation (2);
 PD is the percentage of those affected by the disease who do not die but are permanently disabled;
 w_2 is the disability weight attached to a year of morbidity from the onset of the disease to death at the normal expected age; and
 PV is the value of the expected years survived between ao and ar discounted to the present.

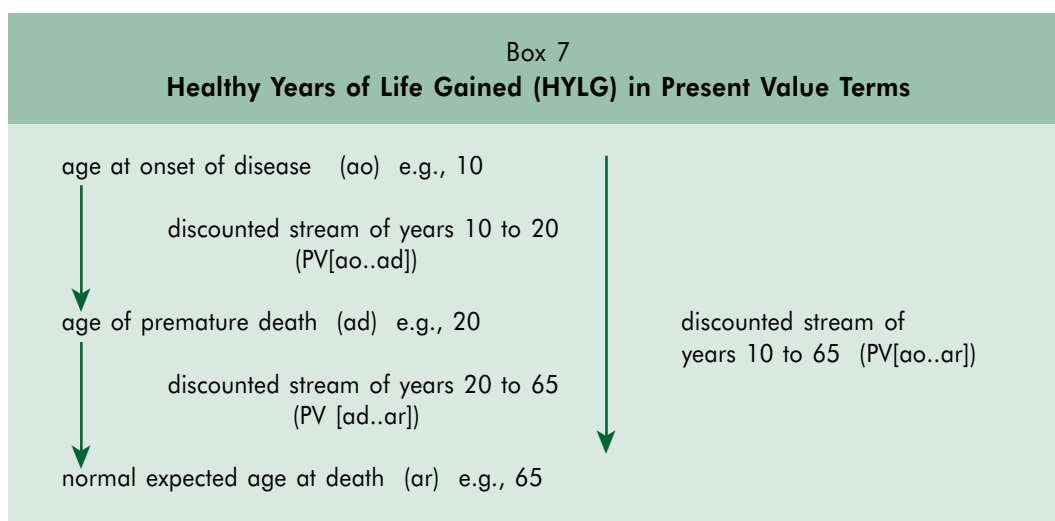
Survival probabilities do not appear explicitly in (5), but they are implicit in the estimate of ar.

$$YT = PV(IN * [1-CF-PD] * t * w_3) \quad (6)$$

where

- YT is years of temporary disability;
- IN, CF, and PD are as defined in equations (2) and (5);
- (1-CF-PD) is the proportion of those affected by a disease who suffers only temporary disability in year a_0 ;
- t is the proportion of a year affected by disability
- w_3 is the disability weight attached to a year of temporary disability; and
- PV is the value of $(IN * [1-CF-PD] * t * w_3)$ discounted to the present.

Box 7 illustrates the general procedure for identifying healthy years of life gained.



The HYLG indicator can therefore be derived as the sum of YLG, YD, YCD and YT so that

$$HYLG = YLG + YD + YCD + YT. \quad (7)$$

Use of this indicator for cost-effectiveness comparisons will require an assessment of how different projects affect the incidence of a disease (and for those for whom the treatment is not effective, the fatality rate), the disability rate in the period up to premature death, and the age at premature death. Hence, for project j,

CEI now becomes

$$CEI_j = PV(C_w - C_{wo}) / PV(HYLG) \quad (8)$$

where $PV(HYLG)$ is discounted net healthy years of life gained and other terms are as above.

The main departure in composite indicators like HYLG as compared with the simpler indicator YLG is the use of disability weights w_1 , w_2 , and w_3 . These convert a year of morbidity saved by a project into the equivalent of a year saved. Hence, a year saved through the avoidance of premature death has a weight of 1.0. A year of morbidity and disability that is saved will have a weight of less than 1.0; but the greater the level of disability that the disease would have created, the higher will be the weight. Disability weights of this type should be constant over the life of the project. Weights may be derived from judgment on the proportion of a year in which an individual is not in full health due to the disease concerned. However, this does not take account of the varying degrees of the severity of the disability. Two individuals may be in less than full health for 200 days of the year, but one may be in great pain during this time while the other may be only immobile. To allow for this, an alternative approach is to base these weights on expert opinion on the severity of particular illnesses. For example, the weight on disability suffered during the period from the onset of leprosy to premature death might be 0.5, while the weight on disability suffered from tuberculosis might be 0.25. But because of the contentious nature of this type of weighting, use of HYLG as an indicator is more controversial than the more straightforward YLG. Nonetheless, where morbidity effects are important, HYLG could be applied either as the sole CEI or in conjunction with the YLG. It is probable that if this approach were to be adopted, ADB staff would have to develop their own weighting system to be used consistently across projects. Appendix 4 gives an illustration of YLG and HYLG calculations.

Table 3 gives the basic data which, in addition to life tables, are needed to estimate YLG and HYLG impacts. Where data specific to a particular country or location within the country are not available, it may be necessary to apply data available for a broadly similar country or location.

Disability Adjusted Life Years (DALY)

HYLG is only one of several composite indicators that combine morbidity and mortality impacts (there is also Quality Adjusted Life Years or QALY but will not be covered in this *Handbook* because there is limited empirical research on QALY in

Table 3
YLG and HYLG: Data Requirements for Diseases

- Incidence of cases (per 1,000 of population at risk)
- Fatality rate per case (%)
- Permanent disability rate per case^a (%)
- Temporary disability rate per case^b (%)
- Proportion of year for which temporary disability applies (%)
- Average age at onset of disease
- Average age of premature death with disease
- Life expectancy at various ages^c
- Weights on temporary and permanent disability^d

^a Proportion of cases who do not die prematurely but are permanently disabled.

^b Proportion of cases who neither die prematurely, nor are permanently disabled.

^c From life tables.

^d Necessary for HYLG calculation. Can be derived from medical data (for example, number of days per year patient cannot work), from expert opinion on severity of disease, or from surveys of patients' opinions.

developing countries). It is simpler than the other well-known indicator, the DALY. The difference between the two is that the DALY adds another level of complexity and uses not only disability weights but also weights for years of life saved at different ages. Appendix 5 gives the age and disability weights used in the *World Development Report 1993* and applied in our illustration. If we view society's preference for saving life as based on the productivity of those affected (or alternatively, on their responsibility to the young and the old), then clearly, saving the lives of those of working age will create a higher social gain than saving the lives of the elderly and the very young. For example, the original DALY age weighting gives a weight of more than one to ages between 9 and 54, and weights of below one for those in the age groups 1-8 and 55 upwards. The maximum weight is at age 25. This reasoning has controversial implications and it should be clear that it is implicit whenever DALYs are applied.

DALYs can be defined by amending equations (2), (4), (5), and (6) and including age weights. As with healthy years of life estimates, whenever there are both mortality and morbidity impacts, the total DALY effect will be the sum of: years of life gained; years affected by disability before premature death; years of chronic disability for those who do not die prematurely; and years of temporary disability. The expressions for YLG, YD, YCD, and YT are as before, except that now, each year saved has a weight that differs from unity. Now, using d to denote

that YLG, YD, YCD, and YT refer to DALY calculations, equations (2), (4), (5), and (6) become as follows:

$$\mathbf{YLG_d = IN * CF * SR * PV(wa[ad..ar])} \quad (9)$$

where YLG_d is years of life gained in DALYs;
 IN is the incidence of disease (new cases per 1,000 of the population);
 CF is the case fatality rate (percent);
 SR is the probability of survival without the disease between years
 ao and ad, where ao and ad are average age at onset of the disease
 and average age of death with the disease respectively;
 ad and ar are average age at death with the disease and average age at
 death without the disease respectively;
 PV(wa[ad..ar]) is the value of the weighted expected years survived between
 ad and ar discounted to the present; and
 wa is the age weight that differs for each year of life.

$$\mathbf{YD_d = IN * CF * SR * w_1 * PV(wa[ao..ad])} \quad (10)$$

where YD_d is years of life affected by disability before premature death in DALYs;
 IN and CF are as above;
 ao and ad are average age at onset of the disease and average age of death
 with the disease respectively;
 SR is the probability of survival without the disease between years
 ao and ad;
 w₁ is the disability weight attached to a year of morbidity from the
 onset of the disease to premature death;
 PV(wa[ao..ad]) is the value of the weighted expected years survived between
 ao and ad discounted to the present; and
 wa is the age weight that differs for each year of life.

$$\mathbf{YCD_d = IN * PD * w_2 * PV(wa[ao..ar])} \quad (11)$$

where YCD_d is years of chronic disability in DALYs;
 IN is as above;
 PD is the percentage of those affected by the disease who do not
 die but are permanently disabled;

w_2 is the disability weight attached to a year of morbidity from the onset of the disease to death at the normal expected age;
 PV is the value of the weighted expected years survived between a_o and a_r discounted to the present; and
 w_a is the age weight that differs for each year of life.

$$YT_d = PV_{a_o}(IN * [1-CF-PD] * t * w_3 * w_a) \quad (12)$$

where YT_d is years of temporary disability in DALYs;
 IN, CF, and PD are as defined in equations (9) and (11);
 [1-CF-PD] is the proportion of those affected by a disease who suffer only temporary disability in year a_o ;
 t is the proportion of a year affected by disability;
 w_3 is the disability weight attached to a year of temporary disability;
 w_a is as above; and
 PV is the value of $(IN * [1-CF-PD] * t * w_3 * w_a)$ discounted to the present.

The DALY indicator can therefore be derived as the sum of YLG_d , YD_d , YCD_d , and YT_d so that

$$DALY = YLG_d + YD_d + YCD_d + YT_d. \quad (13)$$

Hence, for project j, CEI now becomes

$$CEI_j = PV(C_w - C_{w_o}) / PV(DALY) \quad (14)$$

where $PV(DALY)$ is discounted years of life gained in DALYs and other terms are as above.

Once YLG, HYLG or DALY figures have been calculated per 1,000 of population, total impact will depend on the population reached by the projects. Appendix 4 illustrates the approach using YLG and HYLG indicators for two projects: one to combat meningitis and the other to combat schistosomiasis. To illustrate, assume that the projects have different costs but same total populations. In each case, however, assume that the aim will be to reach 20 percent of the target population in each of the first five years of the project; and for an additional 5 years, reach only the population growth in the project area of influence. To allow for under-achievement, assume these targets at 95 percent. Annual HYLG and YLG estimates per 1,000 of population are

converted into annual total health impacts by multiplying by the population reached in each year of project life. These annual total life figures are then discounted to the present, so that there is a process of double discounting as the annual HYLG and YLG are also discounted. Hence, altering the discount rate involves not just a revaluation of the benefit and cost flows but also a change in the HYLG and YLG figures used to calculate benefit streams.

In this comparison, at a 3 percent discount rate, the base case results are set out below.

	Meningitis	Schistosomiasis	
	\$/YLG	\$/HYLG	\$/YLG
CEI	23.3	22.2	305.5

In this case, since meningitis has no chronic disability effects, its \$/YLG is directly comparable with the \$/HYLG for schistosomiasis. The latter is approximately 4 percent below the meningitis cost. Hence, if the weighting scheme used to compare mortality and morbidity effects is acceptable, the schistosomiasis project is the more cost-effective of the two. However, if we are only interested in lives saved and are unconcerned with reducing morbidity, then the meningitis project is far more cost-effective than the schistosomiasis project since costs per YLG are more than 10 times higher for the latter due to its weak impact on mortality rates. Hence, it is clear that objectives must be made explicit if this type of cost-effectiveness comparison is to give meaningful results.

Appendix 5 shows how the DALY approach can be applied to the same illustrations. The disability weights are the same for all calculations so that the only difference lies in the application of age weights in the calculation of DALYs. But because of the differential impact of the two projects on different age groups, use of the DALY indicator reverses the original ranking since the meningitis project is now slightly more cost-effective, with a cost per DALY just below that of the schistosomiasis project. See also Appendix 6 which reworks the calculation of cost per DALY using data from the Pakistan Women's Health Project.

Although it is increasingly used for the analysis of health projects, the DALY is the most complex of the indicators discussed here. The calculation of the DALY for specific conditions and individual projects is a major research task. However, a shortcut procedure is already available since a large international database of global DALY estimates had been produced by the World Health Organization (WHO) in 1996 (*The Global Burden of Disease*, edited by C. Murray and A. Lopez). Appendix 7 explains how, with some adjustments, these global data can be used to generate the approximate DALY for individual DMCs. The appendix also gives the results of an exercise to derive this approximate country-specific DALY for use on new projects.