Handbook of Cost-Benefit Analysis
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Foreword

The *Handbook of Cost-Benefit Analysis* (hereafter the *Handbook*) provides guidance in the use of cost-benefit analysis for evaluation and decision-making. It is aimed at enhancing capacities and fostering good practices in the use of cost-benefit analysis. The *Handbook* also covers two alternative methodologies – financial evaluation and cost-effectiveness analysis – for the evaluation of projects and programmes.

The target audience of this *Handbook* is Australian Government agencies[1]. It is intended for use by those officers involved in appraising and evaluating projects and programmes that carry major resources implications. However, it should be noted that other evaluation methodologies, which are not covered in the *Handbook*, are available and may be used by agencies. In any case, agencies should outline and justify the evaluation methodology chosen. Agencies are responsible for conducting and presenting (normally through written reports) their own evaluations.

The *Handbook* is intended to be a resource document and guide for officers undertaking a cost-benefit analysis of a project or programme. It aims to explain concepts clearly and, in this way, does not assume any prior knowledge of economics. However, readers with a background or particular interest in economic principles are likely to relate to the material more readily than others.

Officers seeking less comprehensive guidance on cost-benefit analysis should refer to the Department of Finance and Administration's *Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies – January 2006* (Financial Management Reference No. 5).

This *Handbook* replaces the Department of Finance and Administration's *Handbook of Cost-Benefit Analysis* (1991). In issuing this revision, the Department of Finance and Administration would like to acknowledge the authors of the original publication as well as Professor Peter Abelson for the updated material included as part of this *Handbook*.

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January 2006

[1] For the purposes of the Handbook, the term 'agencies' covers *Financial Management and Accountability Act 1997* agencies and *Commonwealth Authorities and Companies Act 1997* bodies.

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Executive Summary

This summary outlines the main topics and issues covered in the *Handbook of Cost-Benefit Analysis*.

What is cost-benefit analysis?

Cost-benefit analysis is a method for organising information to aid decisions about the allocation of resources. Its power as an analytical tool rests in two main features:

- costs and benefits are expressed as far as possible in money terms and hence are directly comparable with one another; and
- costs and benefits are valued in terms of the claims they make on and the gains they provide to the community as a whole, so the perspective is a 'global' one rather than that of any particular individual or interest group.

Why use it?

Cost-benefit analyses can provide guidance on the efficient allocation of resources in areas, of which there are many in the public sector, where no markets exist to provide this information 'automatically'.

Cost-benefit analysis is useful in contexts where there are grounds for mistrusting the signals provided by market prices: for example, where inputs are underpriced relative to costs, or where outputs are overpriced.

Cost-benefit analysis is also helpful where, without any commercial transactions taking place, projects impose costs or benefits on third parties. Finally, the method is useful when a project is so large in scale that it is important to be fully aware of its wider economic effects.

How is it used?

Undertaking a cost-benefit analysis provides the decision maker with quantitative comparisons of options, together with supporting information for any costs and benefits that could not be quantified. Cost-benefit analyses serve to aid decision-making. However, a cost-benefit analysis does not replace the need for sound judgment based on a wide range of considerations, and in accordance with the various obligations officials face, such as those prescribed under the *Financial Management and Accountability Act 1997* and the *Commonwealth Authorities and Companies Act 1997*.

Cost-benefit analysis is employed in various ways. It may assist government to:

- decide whether a proposed project or programme should be undertaken;
- decide whether an existing project or programme should be continued;
- choose between alternative projects or programmes;

- choose the appropriate scale and timing for a project; and
- determine regulations affecting the private sector.

All of these applications are ex ante (or 'before') uses of the method. The method can also be used when a project or programme has matured as part of an evaluation of programme impact or outcomes. In this context the method may:

- provide information on whether the outcomes achieved justify the resources used, relative to alternative uses; or
- clarify the focus on different components of a project or programme, in order to see how the project or programme can be improved, and which areas should be cut back or expanded.

Where is it used?

Traditionally, cost-benefit analysis was used to evaluate 'projects' or individual activities rather than 'programmes' or larger groupings of such activities or indeed of policies. Moreover, it was used mainly in evaluations of a particular project type - economic infrastructure investments such as dams, roads and power stations. However, cost-benefit analysis in now applied much more widely. It is often applied to programmes as well as to projects, to activities outside the economic infrastructure sector, and to public policies. The labour market, education, the environment and scientific research are examples of areas where the method has been usefully applied.

However, it should be noted that cost-benefit analysis is only one method of evaluation. The main constraints in using the approach are the feasibility and appropriateness of assigning money values to the costs and benefits generated by the activity. Where determining the money equivalent value of outcome is not feasible, cost-effectiveness analysis is frequently a viable alternative approach.

Key concepts

The cost-benefit analyst's 'toolkit' includes the following basic concepts:

- opportunity cost: resources are priced at their value against their best alternative use, which may be above or below the actual cost of production;
- willingness to pay: outputs are valued at what consumers are willing to pay for them; and
- the cost-benefit rule: subject to budget and other constraints and equity considerations, a project or policy is acceptable where net social benefit (total benefit less total cost), valued according to the opportunity cost and willingness to pay principles, is positive rather than negative.

Valuing costs and benefits

Cost-benefit analysis is often used in situations where the signals that market prices normally provide are either absent or fail to reflect the opportunity cost of the resources involved. The *Handbook* describes valuation procedures in a number of contexts, including:

- valuing intermediate goods such as savings in travel time resulting from transport projects;
- valuing 'externalities' or unmarketed spillover effects such as those that arise from pollution or from vaccination against contagious disease;
- valuing goods affected by taxes and subsidies;
- valuing goods subject to import or export restrictions; and
- valuing labour inputs in the presence of unemployment.

Computing present values

The time dimension is also important in valuing costs and benefits. Costs and benefits should be valued at the specific time that they occur. Because a dollar's consumption in the future is usually valued less than a dollar's consumption today, future costs and benefits are discounted to a 'present value'. This means that the cost-benefit rule needs to be consistent with the net present value rule:

- subject to budget and other constraints, a project should be undertaken if its net present value is positive; or
- subject to budget and other constraints, those projects should be undertaken with the highest positive net present values.

Other decision criteria such as the internal rate of return rule, the benefit-cost ratio and the payback period can be used but, unlike the net present value rule, they are not reliable in all circumstances.

The discount rate used should generally reflect the opportunity cost of capital – that is the return on capital foregone in alternative use of the resources. Depending on the circumstances, this may reflect the return foregone on marginal public or private sector projects or a project-specific discount rate that reflects the rate of return that private lenders would require for financing this specific type of project. Differentiated discount rates are appropriate where organisations are fully commercialised.

Allowing for risk

Projects are also exposed to many sources of uncertainty. Sensitivity analysis is the most helpful general procedure to identify the risk or uncertainty associated with project outcomes. This involves testing the effects on net present value of plausible better-case and worse-case assumptions. Sensitivity analysis should also be applied to the level of the discount rate, to accommodate uncertainty concerning the opportunity cost of capital over the project period.

In cases where the values of more than two or three variables are considered highly uncertain, a full risk analysis, which takes into account the variety of causes of risk, should be undertaken.

Distributional issues

Distributional implications may be obscured by the aggregating character of the cost-benefit process. So that decision-makers are fully aware of the groups likely to gain or lose as a result of project or programme choices, and the nature and size of the gains and losses, this information should be carefully presented, most usefully in the form of a distributional incidence table.

Because the cost-benefit method tends to assume that the value of a dollar is the same for a poorer person as for a wealthier person, where services are provided at below cost, a potential bias exists against lower income gainers and losers. While in principle the bias can be overcome by assigning differential weights to the income changes which accrue to different social groups, the judgements entailed in the approach are almost always most appropriately made by government at the political level.

Limitations

The effective use of cost-benefit analysis requires awareness of the method's limitations as well as its strengths. Some limitations are:

- design weakness - cost-benefit analysis compares a project scenario with an alternative scenario based on estimates of what would have happened in the absence of the project. Any margin for error in the specification of the alternative scenario is carried over into the project analysis;
- treatment of 'intangibles' - not all costs and benefits are amenable to dollar quantification and those that are not (the intangibles) may be overlooked;
- equity concerns - the potential bias against those with a lesser ability to pay that may result from measuring benefits in dollars can be allowed for with the use of judgement, but this is necessarily external to the basic framework; and
- obscurity - when the user's interest is focused on the 'bottom line' of the analysis, the analysis itself may be rather obscure. However, the analysis will only be as good as its assumptions and these should always be set out as clearly as possible.

Financial evaluation

Closely related to, but distinct from cost-benefit analysis, a financial evaluation or appraisal asks 'what is the net benefit to the individual organisation?' rather than 'what is the net benefit to the community as a whole?' Only cash flows in and out of the organisation are considered: cash flows involving other players are excluded, as generally are costs and benefits that are unpriced.

Cost-effectiveness analysis

Cost-effectiveness analysis differs from cost-benefit analysis in that benefits are expressed, not in money units, but in physical units. In cost-benefit analysis, costs are expressed in money terms.

In relaxing the approach towards benefits measurement, cost-effectiveness analysis is particularly useful in areas (such as health, accident safety and education) where it may be easier to specify benefits than it is to value them.

Assuming that adequate quantitative measures of programme effectiveness can be found, the method is very useful in comparing alternative options or existing projects and programmes. Its limitation is that, because costs and benefits are not directly comparable, it does not provide a criterion for acceptance or rejection of a project or programme.

Introduction

Introduction

This handbook covers three analytical approaches to the evaluation of policies, projects and programmes: cost-benefit analysis, cost-effectiveness analysis and financial evaluation. The three approaches differ in certain respects, while also sharing features in common. We begin by briefly introducing the three methods.

Cost-benefit analysis

Cost-benefit analysis is a procedure for comparing alternative courses of action by reference to the net social benefits that they produce for the community as a whole.

The term 'net social benefit' refers to the difference between social benefits and social costs. Benefits and costs are 'social' in that they are measured to whom they accrue; they are not limited to specific market transactions. Thus, they tend to be identified on a more comprehensive basis than private sector evaluations. However, in the case of many public sector projects, there are no market prices. Here cost-benefit analysis proceeds by estimating hypothetical dollar amounts that reflect real economic values.

The net social benefit criterion requires comparability of costs and benefits, as one must be subtracted from the other. This is achieved through valuing both costs and benefits in money terms. Inevitably, some costs and benefits resist the assignment of dollar values. These costs and benefits, known as 'intangibles', are separately presented to the decision-maker for assessment in conjunction with the quantified estimate of the net social benefit of the activity.

A third defining feature of cost-benefit analysis is that costs and benefits occurring at different points in time are explicitly compared. This is necessary because costs are usually concentrated at the beginning of the project, while benefits occur over an extended time period. The technique of converting benefits and costs that occur over time into present values is known as discounting. This involves 'factoring down' costs and benefits according to the extent to which they occur in the future.

Cost-benefit analysis has been widely used in the following contexts:

- accepting or rejecting a single project;
- choosing the appropriate scale and/or timing for a project;
- choosing one of a number of mutually exclusive projects;
- choosing a number of discrete alternative projects from a larger number of discrete alternative projects;
- evaluating government policies, notably though not only related to government regulations; and
- evaluating projects or policies *ex post* (after they are completed or made) rather than *ex ante* (beforehand).

Traditionally, cost-benefit analysis has been applied most extensively to projects that are sufficiently large and important to justify the resources needed for analysis and where the benefits are amenable to quantification and assignment of money values. In Australia, as elsewhere, the main area of application traditionally was large infrastructure projects: for example power generation, irrigation, airports and road projects. It was also applied to a more limited extent to the ex-post evaluation of programmes (such as disease eradication and education).

In recent years cost-benefit analysis has been applied increasingly to smaller projects. As people have become more familiar with cost-benefit analysis and data has become more readily accessible, the cost of doing a cost-benefit analysis has fallen. The method has also been used increasingly for evaluating public policies. Under national competition policies, government agencies that wish to retain regulations must provide a public benefit justification based on cost-benefit analysis. An example of policy evaluation is the cost-benefit study of proposed regulations for health warnings about tobacco consumption to accompany any tobacco materials (Applied Economics, 2003; see www.treasury.gov.au).

Financial evaluation

A financial evaluation differs from a cost-benefit analysis in that it is conducted from the viewpoint of the individual firm or agency rather than from the perspective of society. It provides an answer to the question 'Is this a good investment for the organisation?' rather than to the question, 'Is this a good investment for the community as a whole?'

In contrast, a financial evaluation shares with a cost-benefit analysis the use of a money measure of both inputs and results. In theory, there are no 'intangibles', although 'goodwill' is sometimes an important exception. Nor, strictly, are there any 'costs' or any 'benefits'. Instead, the comparison is between the cash receipts and the cash expenditures of an activity, which in turn yields a net cash flow. Thus a financial evaluation is a *cash flow analysis*.

Cost-effectiveness analysis

Whereas the aim of cost-benefit analysis is to identify the option which will *maximise* social welfare, cost-effectiveness analysis contrasts alternatives in terms of their *relative* contribution towards a specific objective. That is, a non-monetary criterion of effectiveness is predetermined and alternatives are compared in terms of either their cost per unit of effectiveness or units effectiveness per dollar.

Cost-effectiveness analysis contrasts with cost-benefit analysis in three respects. First, it does not provide a complete measure of the benefit of the project or policy to the economy. This limits its use in comparing a wide range of government activities. Second, for the alternatives under consideration to be assessed according to a particular criterion of effectiveness, the alternatives must be similar in nature.

Finally, the discounting procedure is usually applied only to the cost side of the analysis, if at all. Where costs are incurred close to the start of the activity, they may simply be summed, rather than discounted, without significant inaccuracy. Because the output side is expressed in a physical rather than a money unit, it is less readily amenable to discounting.

Relaxation of the cost-benefit requirement that outputs be expressed in money terms makes cost-effectiveness analysis readily applicable to most social and community service programmes. Internationally, agencies have used cost-effectiveness analysis to evaluate health, education and labour market programmes and practice in Australia is consistent with this pattern – see, for example, the Productivity Commission's review of the Job Network programme (Productivity Commission, 2002).

Programme evaluation and cost-benefit analysis

Although cost-benefit analysis originated with the evaluation of 'projects' or individual activities rather than with larger groupings of such activities or 'programmes', it can be applied to programmes as well as projects, and to activities outside the economic infrastructure sector (for example, the labour market, education, the environment and scientific research). For example, the Australian Government Department of Health and Ageing has commissioned studies of the benefits and costs of public health programmes to reduce tobacco consumption, coronary heart disease and HIV/AIDS, and to evaluate immunisation programmes (Applied Economics, 2003; see www.health.gov.au).

Because cost-benefit analysis seeks to place costs and benefits on a directly comparable basis, it is well-suited to resource allocation decisions – to situations where choices must be made ex-ante between alternative uses of funds. However, the method can also play a role in effectiveness evaluations (also described as 'impact' or 'outcomes' evaluations) which examine whether a programme which has had some time to mature is achieving its objectives and whether the objectives themselves are still relevant and of high priority. In essence, the programme outcome that is measured in cost-benefit analysis is the estimated value that consumers place on the goods or services that they purchase or receive even when the goods or services are not sold in a conventional market. While this way of measuring effectiveness will not be appropriate in all contexts, the approach is a powerful one in those situations in which it can sensibly be applied.

When used to evaluate ongoing (or completed) programmes, cost-benefit analysis retains the resource allocation focus: it should provide information in response to the question 'would the resources allocated to the programme have been better used in other activities?' Conversely, an ex-ante application of cost-benefit analysis should also provide an effectiveness focus. It does this by providing information to answer the question 'do the expected programme outcomes justify the commitment of the proposed level of resources?'

Structure of the Handbook

The *Handbook* is divided into twelve chapters, nine of which relate to cost-benefit analysis.

Chapter 1 presents cost-benefit analysis as a step-by-step *process* starting from the identification of a resource allocation problem through to the writing-up of a cost-benefit analysis report.

Chapter 2 briefly outlines the key concepts of welfare economics which are essential to understanding and applying the cost-benefit approach.

Chapter 3 examines how to value costs and benefits, with particular regard to circumstances where it may be appropriate to adjust market prices in order to value costs and benefits in cases where market prices do not exist.

Chapter 4 outlines the technique of converting benefits and costs that occur over time into their present values, the net present value rule and issues in using it, and the treatment of inflation.

Chapter 5 looks at concepts of the discount rate, together with recommended values and approaches, while **Chapter 6** examines the more general aspects of the problem of risk (or uncertainty) in project evaluation.

Chapter 7 discusses the treatment of the distribution of costs and benefits across the community. Methods of correcting for the tendency of cost-benefit analysis to overlook issues of social equity are discussed.

Chapter 8 discusses a cost-benefit analysis case study – the Gordon-below-Franklin Hydroelectricity Development Proposal.

Chapter 9 outlines the major criticisms of cost-benefit analysis as a decision framework and offers some responses to those criticisms.

Chapter 10 looks at issues in applying financial evaluation while **Chapter 11** outlines the method of cost-effectiveness analysis. **Chapter 12** offers some concluding remarks.

Six Appendices provide supporting material for the main text.

1

Cost-Benefit Analysis as a Process

1 Cost-Benefit Analysis as a Process

This chapter looks at cost-benefit analysis as a process and provides an overview of the main steps in undertaking it. Details relating to each step are provided in subsequent chapters. The sequence of steps presented here should not be regarded as rigid; analysts may often find it necessary to return to previous steps as the nature of the problem they are investigating becomes more evident.

(a) What is the problem?

The first step entails an investigation and assessment of the problem, its context and its background. This is an opportunity to 'place' the project or programme in its broader context, before narrowing the focus to the project or programme itself. This step includes a definition of the objectives to be achieved by the project or programme and identification of who the beneficiaries are.

(b) What are the constraints?

Constraints on meeting the objectives should be identified to ensure that all alternatives examined in the analysis are feasible. Constraints may be:

- financial (for example, budget limits, price ceilings and price floors);
- distributional (for example, requirements relating to the distribution of project benefits among individuals or groups);
- managerial (for example, limits on the quantity and/or quality of staff available to implement the activity);
- environmental (for example, environmental protection standards which must be met); and
- of other types.

The nature of constraints relevant to a particular project or programme may not always be known with certainty. For example, it may be known that a road upgrading project would be affected by a proposed nearby rail upgrading programme, but not known whether or not the latter will take place. *Potential* constraints, therefore, should also be clearly set out.

(c) What are the alternatives?

While every alternative that is identified implies a requirement for a considerable amount of subsequent analysis (if it is fully incorporated into the cost-benefit analysis), the number of alternatives generated should be sufficient to provide the decision-maker with real scope for exercising choice. Alternatives should also be clearly distinguished from one another.

Finally, a 'do nothing' alternative should always be identified. This is necessary because costs and benefits are always incremental to what would have happened if the project had not gone ahead. Thus the 'do nothing' option is also the 'base case' or the 'without project' situation.

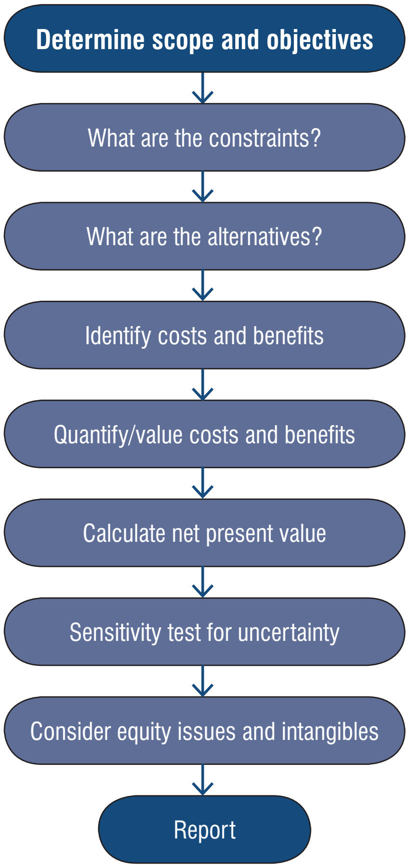


Figure 1.1 *Key steps in the cost-benefit process*

(d) What are the benefits?

A list of the benefits that are expected to flow from the proposed project should be drawn up. To identify benefits (and costs), a thorough understanding of the chain of causation of the project or programme is needed. The list of benefits might include such items as:

- the value of output as reflected in revenues generated by a particular project;
- the scrap value of the project's capital equipment;
- avoided costs - costs which would have been incurred in the 'do nothing' or 'without project' situation;
- productivity savings - reductions in existing levels of expenditure which can be shown to result from the project or programme;

- health, environmental and other social benefits all of which are either not marketed or are characterised by prices which reflect less than the full value of the benefits; and
- a reduction in unemployment.

(e) What are the costs?

Similarly, for each alternative a list of costs should be drawn up. Examples of costs are:

- capital expenditures;
- operating and maintenance costs for the entire expected economic life of the project;
- labour costs;
- costs of other inputs (materials, manufactured goods, transport and storage, etc);
- research, design and development costs;
- opportunity costs associated with using land and/or facilities already in the public domain; and
- harmful effects on other parties (for example, environmental costs such as air pollution and noise nuisance).

(f) How can costs and benefits be quantified?

Cost-benefit analysis compares costs and benefits using a common measure, preferably dollars. So values must be assigned to as many of the costs and benefits as possible.

Market prices, where they exist, provide a great deal of information concerning the magnitude of costs and benefits. In most markets, consumers at the margin are willing to pay no more or no less than the actual price in the market. Accordingly, that price can generally be taken as a measure of the value placed by society on the good or service. Similarly, prices of inputs usually reflect the value which alternative users of these inputs place upon them. However, actual prices sometimes have to be adjusted to convert private costs and benefits into social ones, that is, costs and benefits which reflect gains and losses to the economy as a whole, rather than to individual persons or groups. The following paragraphs discuss examples of adjustments that may be required.

(i) Value of final outputs

While private firms will net out excise and other taxes on final outputs in calculating their revenues, the social benefits arising from the consumption of outputs are determined by what consumers are willing to pay for them (provided that the project does not displace any pre-existing output). Estimates of social benefits will normally therefore include any taxes on outputs.

(ii) *Value of physical inputs*

Taxes on material inputs increase the price that private firms have to pay for them, while subsidies reduce it. From a social point of view, if the physical inputs for a project come from new supplies and are not diverted from other users, costs should reflect the costs of the resources needed to produce the inputs. On the other hand, if the material inputs are obtained at the expense of other users, the appropriate valuation of costs is market prices, which represent the marginal value of the inputs in alternative uses.

(iii) *Interest on borrowed capital*

All expenditures, including capital expenditures, should be recorded in full at the time that cash payment is made. The *discounting procedure* (Table 1.1) captures the opportunity cost over time that is associated with the resources tied up in the purchase – an opportunity cost which, in a practical sense, may be approximated by the interest payments that would be required on borrowed capital. To include interest payments on borrowed capital, in addition to using the discounting procedure, would be to *double-count* project costs.

(iv) *Depreciation allowances*

Depreciation charges are an accounting device to 'expense' capital costs over a period and should not be included as costs. Instead, the cost of the physical capital actually purchased should be included as an entirety when the purchase is made, with account being taken of the year in which the purchases are made via the discounting process.

(v) *Land*

The value of land should be determined by its opportunity cost, that is, what it could produce in its best alternative use. If there is a reasonably free market for land, the market price of land or the present value of its future rent stream will adequately measure its opportunity cost. If a public project uses government-owned land that has no clear market price or rent, a shadow price for land has to be estimated (where possible, using comparable private sector land).

(g) What other quantification problems are there?

Reliable evidence is needed to quantify costs and benefits. In practice quantification often depends on detailed technical studies – for example, the electricity output expected from a new power plant. In these circumstances, careful attention is needed to the pricing assumptions which underlie the studies: demand may increase if prices are lower than has been assumed, but decrease if they are higher than has been assumed.

Costs and benefits must be estimated for the entire period of the project. Hence forecasting is a key part of the process of valuing costs and benefits. Econometric techniques are widely used for forecasting purposes. Whatever technique is used, the temptation often exists to overestimate the rate of growth of benefits and to underestimate the rate of growth of costs.

Costs and benefits that cannot be quantified are called 'intangibles' and should be presented to the decision-maker together with appropriate descriptive information, so that they can be weighed up alongside the quantifiable variables in the decision-making process. It may be possible to quantify some costs and benefits in physical units but not to express them in money terms – for example, complex pollution effects. Analysts must usually make an explicit decision on how far to pursue money valuation. It is clear that some costs and benefits are not amenable to such valuation; in other cases, this decision will involve taking into account the cost of the project and the costs of the necessary processes of data collection and analysis.

(h) Preparing a computer-based spreadsheet

For all except the simplest cost-benefit studies, the data input and output for a cost-benefit study should be prepared using a computer-based spreadsheet programme. The use of spreadsheets enable the analyst to store large amounts of input data, to do calculations rapidly, and to do sensitivity tests easily. Above all, spreadsheets can show the results in a comprehensive and user-friendly way. The major costs and benefits should always be presented along with the key results on one page.

Table 1.1 shows a spreadsheet for a hypothetical and simplified land development project that takes eight years. There are 700 lots developed at a rate of 100 a year for seven years. The developed lots sell for $150,000 each. Resources are required for land acquisition and development. Using a 7 per cent real discount rate, the estimated net present value is $14.4 million and the estimated internal rate of return is 15.0 per cent. These results indicate that the proposed land development project provides a net social benefit.

Table 1.1 *Hypothetical cost-benefit spreadsheet for proposed land development ($million - 2004 prices)*

	Year							
	1	2	3	4	5	6	7	8
Benefits								
No. of lots		100	100	100	100	100	100	100
Revenue = total benefit		15	15	15	15	15	15	15
Costs								
Land acquisition	10							
Land development	8							
Road, drainage	16							
Water, sewerage	13							
Other costs	5	1	1	1	1	1	1	1
Marketing, sales		1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total costs	**52**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**
Net benefit	**-52**	**12.5**	**12.5**	**12.5**	**12.5**	**12.5**	**12.5**	**12.5**
NPV @ 7%	**14.4**		**IRR**	**15.0%**				

(i) How should net benefits be assessed?

To facilitate comparison between alternatives, it may be desirable to draw up a graphic profile of net benefits (that is total costs less total benefits occurring in each time period). Figure 1.2 shows two net cost-benefit profiles; costs are more weighted towards the early years of the project in one alternative than the other.

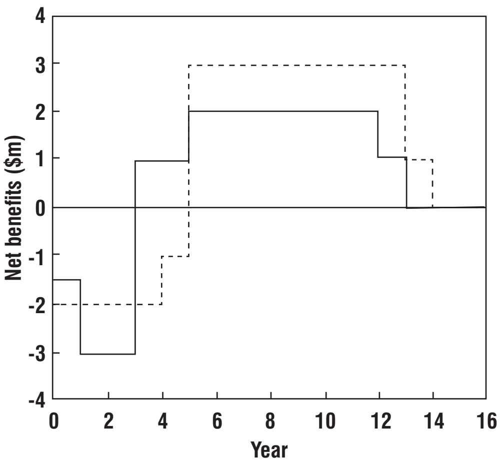


Figure 1.2 *Two net benefit profiles*

Normally, costs and benefits will be valued in constant prices with the base being that of the current year. This is described as an analysis in real rather than in nominal terms. Costs and benefits can be estimated with some explicit forecast rate of inflation, but this is generally not necessary.

Total costs in each year of the project's life are subtracted from total benefits in that year to yield net benefits in each year. The stream of net benefits should then be discounted to take account of the fact that the further into the future that a dollar's worth of net benefit occurs, the less should be its weight in determining the project's 'bottom line'.

The stream of discounted net benefits is then summed to yield the *net present value* of the project or programme. The formula for the net present value is:

$$NPV = \sum_{t=0}^{t} \frac{(B_t - C_t)}{(1 + r)^t}$$

where B denotes the dollar benefits received in any future year, C refers to the costs incurred in any future year, r is the rate of discount, and t refers to the year.

Subject to budget and other constraints, consideration of intangibles and distributional issues, *a project is acceptable if the net present value is equal to or greater than zero*. Similarly, where budget and other constraints make it necessary to *rank* alternative projects, the package of projects with the *highest* net present value should be chosen.

Other decision criteria such as the internal rate of return rule, the benefit-cost ratio and the payback period can also be used but, unlike the net present value rule, they are not reliable in all circumstances (for example, when project alternatives differ in scale).

(j) How should uncertainty be dealt with?

Estimated net present values are based on estimates of future costs and benefits that are not, and cannot, be known with certainty. To gain an appreciation of the effects of uncertainty or risks to which the project is exposed, the analyst should employ sensitivity analysis. The first step in such an analysis is to estimate the net present value using plausible 'pessimistic' and 'optimistic' assumptions about key variables that determine costs and benefits. If the 'pessimistic' scenario gives a net present value below zero, it is necessary to identify the variables to which the project's outcome is most sensitive. This is done by adopting plausible pessimistic values for each variable in turn, holding all other variables to their most likely or mean value (see Chapter 6 for a further discussion of the choice between most likely and mean values).

If it turns out that there are only one or two critical variables, the analyst needs only to assess the likelihood of these variables falling above or below the critical value, in order to present the decision-maker with an adequate assessment of the riskiness of the project. If there are several such variables, and particularly if there are more than four or five, it will not be possible to assess the uncertainty of the project in this manner. A full risk analysis is then required in which probability distributions are assigned to the values of all key variables and, through repeated computer iterations, a probability distribution of the net present value of the project can be generated.

(k) How should social equity be allowed for?

The procedure of cost-benefit analysis involves aggregating costs and benefits across individuals, without explicit regard to the equity or otherwise of the distribution of those costs and benefits between individuals.

However, decision-makers would normally wish to take account of the identity of gainers and losers resulting from a project (and the magnitude of the gains and losses) in making a decision to proceed or not. In most cases, this need is best met by including a distributional incidence matrix, which sets out the identity of groups or communities which gain or lose from the project or programme, and the expected size of those gains and losses.

In exceptional circumstances, where it can be justified by clear reference to established government policy, analysts may be justified in attaching differential weights to costs and benefits which accrue to particular groups. Any such weights and the basis for them should be stated explicitly. However, a full unweighted analysis should always be presented.

(l) How should the report be structured?

The final step in the cost-benefit process is the writing-up of the analysis, which includes the recommendation(s) to the decision-maker(s). The report should enable the decision-maker(s) to find satisfactory answers to the question 'what did you do and why did you do it?' The report should include:

- a brief written summary and a spreadsheet summary of the results of the analysis;
- an introduction describing the reasons for undertaking a cost-benefit analysis;
- the objectives of the project or programme;
- a description of the alternatives considered;
- the constraints considered in conducting the analysis and the alternatives selected;
- the time profiles of costs, benefits and net benefits, together with information on the sensitivity of those profiles to alternative assumptions;
- information on intangible costs and benefits;
- a list of assumptions made in performing the analysis, and information on how benefits and costs were estimated;
- a description of distributional effects;
- a conclusion discussing the results of the analysis; and
- an outline of how the outcome of the proposal could later be evaluated.

The report should be short and concise. The background work should be available in supplementary reports which may be referenced in the main report and which are available on request.

(m) To what level or depth should the analysis be conducted?

The steps outlined are recommended for every cost-benefit analysis. However, obtaining and analysing information has a cost. There are therefore important choices to make regarding the level or depth to which the analysis is conducted.

In the first place, the benefits of obtaining and analysing additional information should always exceed the costs of so doing. Often better information reduces the uncertainty surrounding estimates. In general, the larger the project, the greater the resources at stake, and so the more that can usually be justified in terms of expenditure on information and analysis. The viability itself of smaller projects can be threatened by investing too much in analysis: this should set obvious limits on the level and depth of analysis in these cases.

It should also be noted that detail and complexity are not the same thing as rigour – ultimately the more important value. An elaborate and detailed analysis of a problem that has been wrongly conceptualised may be worthless. On the other hand, a 'back of the envelope' analysis of a problem that has been thought through correctly will, at the very least, be a helpful first step.

2

The Conceptual Basis of Cost-Benefit Analysis

2 The Conceptual Basis of Cost-Benefit Analysis

The objective of a cost-benefit analysis is to assist the decision-maker to take a decision which is consistent with efficiency in allocation of resources in areas where, for one reason or another, private markets cannot or do not achieve this outcome. This chapter briefly discusses what is meant by the notion of 'efficiency in the allocation of resources' and places the concept in the context of other objectives of public policy decisions.

2.1 Allocative efficiency

The concept of *allocative efficiency* refers to the *overall* efficient allocation of resources. It deals both with whether the most highly valued set of outputs is created and with whether the least cost inputs are used to created these outputs. Formally, the concept of allocative efficiency can be defined as an economic state in which it is impossible to make any one person better off without in the process making someone else worse off – the notion of the Pareto Optimum. Note also that allocative efficiency so defined includes the notion of productive efficiency (producing an output at least cost). However, productive efficiency may also be considered an important goal in its own right (see Section 2.5).

In cost-benefit analysis, the most highly valued set of outputs is measured by the maximum amount that people would be *willing to pay* for the products that they enjoy. Further to this, the production conditions necessary to achieve allocative efficiency require:

- each commodity be produced at the least possible cost for the quantity actually produced; and
- each selling price to be set equal to the marginal cost of producing the commodity, where marginal cost is the cost of production of the last unit produced.

Allocative efficiency is *maximised* when the benefit that an individual derives from the last unit of consumption of a product is just equal to its cost of production. Should production deviate from this level, the value placed on the last unit produced would no longer equal the cost of producing it, and welfare could be increased by altering the level of output.

The market price of a good plays a key role in equating the benefits from consumption with the costs of production. Thus a producer in competitive markets who prices his or her output at the marginal cost of production will be operating consistently with the concept of allocative efficiency, since the marginal consumer may be expected to be willing to pay no more or no less than the actual price in the market.

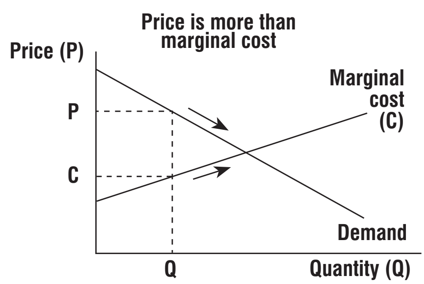


Figure 2.1(a) *Inefficiency and efficiency in pricing*

This idea can be illustrated geometrically. In Figure 2.1(a) the marginal benefit corresponding to the indicated price significantly exceeds the marginal cost; this implies that *more* should be produced at a lower price. In Figure 2.1(b) the marginal cost of the last unit is greater than its value to the consumer: this suggests that *less* should be produced but at a higher price. In Figure 2.1(c), however, where price is *equated* to marginal cost, there is both a stable state and an optimum one in the sense that the combined welfare of consumers and producers is at a maximum.

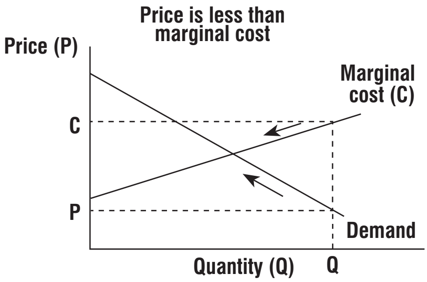


Figure 2.1(b) *Inefficiency and efficiency in pricing*

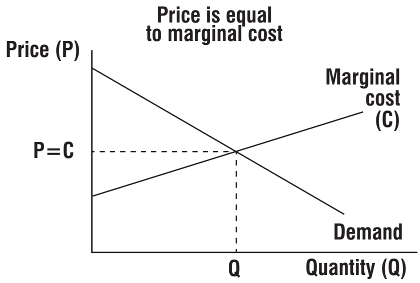


Figure 2.1(c) *Inefficiency and efficiency in pricing*

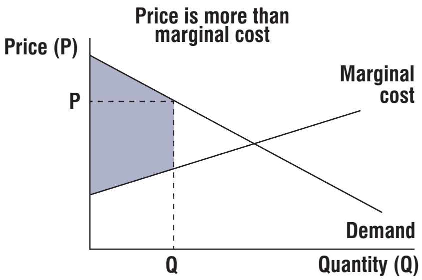


Figure 2.2(a) *Net benefits with inefficient and efficient pricing*

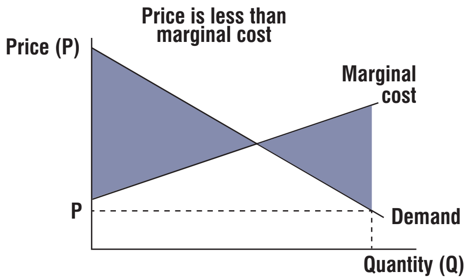


Figure 2.2(b) *Net benefits with inefficient and efficient pricing*

We can also use the diagrams to show that the level of output ensuring allocative efficiency (Figure 2.1(c)) is the one that *maximizes* net benefits. Figure 2.2 contrasts the same three alternative levels of output emphasising the area which represents net benefits. Benefits are represented in the diagrams by the total area under the demand curve (which is a straight line in the figure rather than curved) and bounded by the quantity demanded (or produced). Variable costs are represented by the area under the cost curve and bounded by the quantity demanded (or produced). Net benefits (shaded) are represented by the difference between the two areas. It can readily be seen from the diagrams that net benefits are largest when price is set equal to marginal cost (P=MC).

It is important to clarify that the area of maximum net benefits (Figure 2.2(c)) represents the sum of *consumer surplus* and *producer surplus* benefits. Consumer surplus is the amount in excess of market price which some consumers are willing to pay, but which at the prevailing market price they are able to retain. Similarly, the notion of producer surplus refers to the price in excess of the variable supply cost of some suppliers.

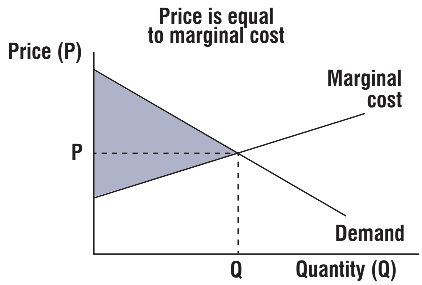


Figure 2.2(c) *Net benefits with inefficient and efficient pricing*

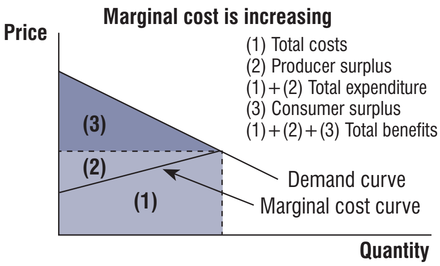


Figure 2.3(a) *Consumer surplus, producer surplus and total benefits*

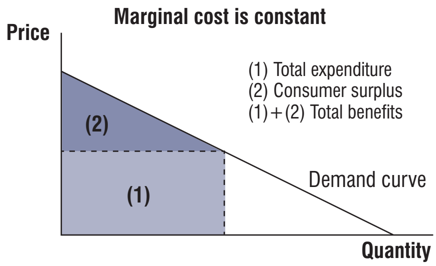


Figure 2.3(b) *Consumer surplus, producer surplus and total benefits*

Figure 2.3 illustrates consumer surplus and producer surplus benefits. The two frames differ from those in Figure 2.2 in showing *total benefits* rather than *net benefits* (or benefits less costs). Beyond this, Figure 2.3(b) differs from the earlier cases in that the marginal cost curve is flat rather than upward-sloping. In this situation with a constant marginal cost, there is no producer surplus.

2.2 Opportunity cost

The notion of opportunity cost underpins cost-benefit analysis. Opportunity cost is the cost of what has to be given up to gain some good or service.

In competitive markets, pricing at marginal cost implies that costs and benefits are equated with their *opportunity costs*. In the case of benefits, the price that the marginal consumer is willing to pay represents what he or she is willing to forgo through not purchasing something else. In the case of costs or inputs, the price implies the amount that alternative producers would be willing to pay for the particular input. When markets are not competitive, the cost-benefit analysis must estimate the appropriate opportunity cost using the principles discussed in Chapter 3.

It is worth emphasising that this concept of cost contrasts, and often conflicts, with the accounting approach to costs. Whereas the accountant may seek to apportion the historical costs of a facility over the activities of a project, the cost-benefit analyst asks 'what is the value of the facility in its best alternative use?' If the answer to the question is zero, the costs should be considered 'sunk', and may be disregarded, irrespective of the financial cost of the facility in times past. For example, the financial costs of the buildings that comprise a remotely located airport are 'sunk costs' if there is no ongoing demand to use the airport and the buildings have no alternative use. Alternatively, if the answer to the question is an amount much larger than the depreciated historical value of the facility, then it is the larger amount that properly represents the opportunity cost. Cost-benefit analysis is oriented towards present and future values, and not at all towards past costs.

2.3 The willingness to pay criterion

The opportunity cost concept is made operational in cost-benefit analysis principally through the willingness to pay criterion.

Benefits are valued according to the willingness of individuals to pay for them, with willingness to pay consisting of two elements: actual expenditure and consumer surplus (Section 2.1). Note that this statement assumes that a market exists for the good in question. If there is no market – for example, for environmental protection – instead of 'actual expenditure' an estimate is substituted of what the marginal consumer would pay for the good if a market existed. See also Section 3.3, 'Valuing externalities'.

Costs are valued similarly according to the willingness of others to pay for the resources involved and therefore reflect the best alternative foregone, where this exists. For example, suppose that a power station uses coal sourced from a tied mine which is priced notionally at $X per tonne. Suppose also that the coal could instead be exported to Japan or South Korea (without affecting prevailing market prices) at $(X + 20) per tonne, the real cost of supplying coal to the power station is $(X + 20) per tonne. In general, the real cost of a resource is the highest price that someone will pay for it.

Where there is no clear foregone alternative, inputs should be valued on the basis of the actual cost of supply. Thus if the power station's coal were of too poor a quality for export or any other market, the coal should be valued at the cost of the resources used to extract it from the ground and transport it to the power station, plus the cost of any environmental side-effects. It might be noted that this simply changes the 'level' at which the principle of the willingness to pay of alternative users applies. For example, the cost of mining the coal would reflect the willingness of other users to pay for the capital equipment and the labour required for the process.

2.4 The cost-benefit rule

The core cost-benefit rule, based on the concept of allocative efficiency, is to accept projects for which the net social benefits are positive (subject to budget and other constraints). That is:

$$NSB = (B - C) > 0$$

where NSB is net social benefits, B is social benefits and C is social costs.

We have seen that application of this rule will generate an efficient allocation of resources where prices are set equal to marginal cost. That is, the P=MC rule governs the choice of the level of output that is associated with the investment under evaluation. We now look briefly at two other important premises.

The first is that prices are also set at marginal cost in all other markets in the economy. It can be shown that when this does not apply a Pareto Optimum is not attainable in the market under consideration and that a 'second best' Pareto Optimum can only be attained by departing from a policy of allocative efficiency (and, in particular, from marginal cost pricing).

Since the 'real world' economy is full of cases of inefficient pricing, this might be considered a fatal blow to the conceptual basis of cost-benefit analysis. However, cost-benefit analysis usually proceeds on the basis that only a small segment of the economy is under examination and that 'everything does not depend on everything else in any significant degree' (Dasgupta and Pearce, 1972). This is a 'partial equilibrium' approach. The corollary is that, where prices are distorted in a market that is complementary with, or a close substitute for, the market under examination, it may be necessary to take into account the effects in those markets (a 'general equilibrium' approach). In both cases, the aim is to measure the sum of changes in consumer and producer surpluses along with any third party effects.

A classic example of a distortion in a competitive market is the public transport project which competes with private road transport. When roads are congested, the private road user often does not pay the full marginal cost of road use; the road user imposes traffic congestion costs on other road users that he or she does not pay for individually. However, in such cases, it is usually possible to measure the extent of inefficiency in the related market and to make the appropriate adjustments to the estimated costs and benefits of the project. These adjustments are made through the shadow pricing procedure, as discussed in Chapter 3.

Another important premise of cost-benefit analysis is that the distribution of income in society is equitable. To an extent, cost-benefit analysis can accommodate the fact that projects create gainers and losers. The rule that social benefits must exceed social costs allows for those who gain from a project to 'share the benefits' with those who lose from it on the basis that both parties are better off than they would be without the project. This is known as the Kaldor hypothetical compensation principle or, alternatively, the Potential Pareto Improvement criterion. This principle states that a project is acceptable if gainers could compensate losers and still leave both parties better off than they would have been in the absence of the project.

However, two problems arise. First, compensation may not be paid to losers in actuality. Second, valuation according to a money metric and the willingness to pay criterion is necessarily influenced by the ability of individuals to pay (depending on their wealth and income) and ability to pay is unequally distributed. Thus in cases where the income distributional consequences of a project are important, it may be inappropriate for the decision-maker to accept or reject the project on the basis solely of the cost-benefit rule.

2.5 Efficiency in context

It may help to distinguish the concept of allocative efficiency from other concepts which also play an important role in public sector decision-making: productive efficiency, profitability and social equity.

(a) Productive efficiency

Productive efficiency concerns the relationship between inputs and outputs. It may be viewed as producing output at least cost or as maximising output produced per unit of input.

Productive efficiency may be distinguished from allocative efficiency in two important ways. First, productive efficiency is not concerned with the valuations that consumers place on output. For comparing options, it is therefore a less powerful concept than overall allocative efficiency. Second, in some cases the 'unit of input' is given and it is not necessarily the least cost unit. Given a competitive market, we can assume that inputs are indeed the least cost inputs. However, the concept of productive efficiency may be interpreted as relating only to the ratio between outputs (however specified) and inputs (however specified), which is a form of cost-effectiveness analysis.

While cost-benefit analysis aims to apply the full principles of allocative efficiency in situations where market structures do not guarantee allocatively efficient outcomes, cost-effectiveness analysis (Chapter 10) is oriented towards the issue of productive efficiency.

(b) Profitability

In a world of perfect competition, an organisation that produces at the 'efficient' level of output would be financially viable. However, many public projects face little or no competition and are characterised by increasing returns to scale (that is, decreasing unit costs). In these circumstances, the requirements of allocative efficiency (prices that reflect marginal cost) may conflict with those of financial profitability. When price is set to equal marginal cost (the cost of the last unit of output produced) revenue may fail to cover the large fixed costs of the investment. It follows that some departure from marginal cost pricing and allocative efficiency may be unavoidable if financial self-sufficiency is to be achieved. Pricing issues in cost-benefit analysis are discussed in Chapter 3 (Section 3.10).

(c) Social equity

The concept of allocative efficiency can be made operational for any particular distribution of income in society. However, the concept provides no basis on which to assess whether that distribution of income is an equitable one or not. Moreover, as noted in Section 2.4, the cost-benefit *method* necessarily introduces a bias in favour of the existing distribution of income. We discuss ways of introducing equity considerations into cost-benefit analysis in Chapter 7.

2.6 The main points in summary

- Cost-benefit analyses are undertaken to identify options that are consistent with efficiency in resource allocation. Allocative efficiency means that in an environment of scarce resources, the level of output of any good or service cannot be increased without reducing the output of some more highly valued good or service.

- Resources are allocated efficiently when the benefit an individual derives from the last unit of consumption is just equal to the cost of production of that unit. Thus a producer in competitive markets who prices his or her output at the marginal cost of production will be operating consistently with the concept of allocative efficiency.

- Pricing at marginal cost implies that costs and benefits are valued at their opportunity costs, that is, the return they would earn in their best alternative use. The opportunity cost principle can be clearly distinguished from the accounting approach to costs: the former is concerned only with present and future costs, whereas the latter takes into account past costs.

- The opportunity cost concept is made operational in cost-benefit analysis through the willingness to pay criterion. Outputs are valued according to the willingness of consumers to pay for them – an amount that includes the consumer surplus, or the difference between the price actually paid and the amount the consumer would have been willing to pay for them. Inputs are valued on the basis of the maximum amount that other users would be willing to pay for them. If there is no 'other user', inputs are valued on the basis of the relevant constituent costs.

- The fundamental principle of cost-benefit analysis, based on the concept of allocative efficiency, is to accept projects when the net social benefits are positive (subject to budget and other constraints). The rule produces outcomes that are consistent with allocative efficiency.

- Overall allocative efficiency requires productive efficiency. However, in some cases analysts will have principal concern for productive efficiency (which is equivalent to cost-effectiveness analysis) rather than the broader objective of allocative efficiency.

- Financial profitability and social equity may also be important goals in public sector decision-making.

3

Valuing Costs and Benefits

3 Valuing Costs and Benefits

Cost-benefit analysis is employed most frequently when the signals normally provided by market prices are either absent or inadequately reflect the opportunity cost of the resources involved. This usually occurs in one or more of the following circumstances:

- production of non-marketed goods, including 'pure public' (that is, collective consumption) goods such as defence or road safety;
- 'external' effects where one producer or consumer imposes non-market and hence unpriced costs or benefits on other producers or consumers, for example pollution costs;
- situations where a project's output, or its use of an input, is large enough to alter the market price expected in the future;
- situations where production or consumption, or both, are affected by taxes and subsidies;
- situations where there are quantity restrictions and/or price controls affecting a project's output or input; and
- problems of 'indivisible' investments and of monopoly power where market prices may diverge from the marginal cost of production.

As discussed in Chapter 2, the principles on which costs and benefits are valued are those of willingness to pay and opportunity cost. In simple cases, benefits are valued on the basis of the amount that consumers are willing to pay for them, measured by the price actually paid. Costs are valued on the basis of what other users would be willing to pay for the resources employed (except when there is no clear 'alternative user', and they are valued on the basis of the relevant constituent costs). However, in all of the situations listed, the analyst faces a problem of valuation: that is, the value of a benefit must either be imputed (where there is no market) or found by appropriately adjusting the observed market price. The resulting values are known as shadow prices and the technique of deriving values in these circumstances is known as *shadow pricing*.

It is necessary to recognise that measurement problems are often costly and difficult to resolve. As an alternative first step, it may be wise to estimate approximate 'threshold values' rather than precise shadow prices. This is a form of reverse sensitivity analysis (sensitivity analysis is discussed in Section 6.5). The project may be 'fail safe' at most plausible values of inputs (costs) or outputs (benefits); alternatively, it may have negative net benefits at most likely values of inputs and outputs. In either case, the 'return' on undertaking a detailed shadow pricing exercise is likely to be small.

It is still important, however, to have a clear understanding of the conceptual issues involved in valuing costs and benefits where market price information is either non-existent or potentially misleading. This chapter therefore looks at these issues in some detail. Before discussing shadow pricing, we examine the prior issue of properly *identifying* the costs and benefits to be valued.

3.1 Identifying costs and benefits

One of the first tasks for the analyst is to distinguish the allocative effects of a project, that is, the effects due to changes in the use of resources and in outputs, from the distributional effects. Generally speaking, it is only changes in resource use that involve opportunity costs. Distributional effects may be regarded as 'transfers' – that is, some individuals are made better off while others are made worse off. Distributional effects do not add to or subtract from estimated net social benefit. However, they may affect social welfare if the judgement is made that one group derives more value from the resources than another group.

To clarify this distinction, suppose that a labour market programme provides retraining for long-term unemployed workers. The principal allocative benefits are the increase in output of persons who, in the absence of the programme, would have remained unemployed, as well as their enhanced sense of well-being. The principal allocative costs are the costs of the training and the unpaid work output and/or leisure that the workers themselves forego in entering the programme. On the other hand, the income support that they receive while retraining and the unemployment benefits that they subsequently give up when employed represent transfer effects.

Table 3.1 *Incidence of costs and benefits of an unemployment retraining programme*

	Unemployed workers who are retrained	Rest of the community
Allocative costs	Some foregone work output Foregone leisure	Training costs
Allocative benefits	After-tax wages after training due to rise in output Enhanced well-being and self-esteem	Possibly increased profits to employers Increase in tax take from wages due to rise in output
Distributional transfers	Income support while training Loss of unemployment benefits	Income support to trainees Savings in unemployment benefits

In making the distinction between allocative and distributional effects, it is often helpful to draw up a matrix setting out the incidence of costs and benefits between groups. For the above example, we can do this with just two main groups – the unemployed workers who receive training and the rest of the community. The matrix is shown in Table 3.1. The net social benefit of the training programme is the sum of the allocative benefits less the allocative costs. The last row shows the distributional transfers.

The transfers do not affect the net social benefit. However, this assumes that a dollar has the same 'value' to the taxpayers who fund the income support component of the programme as it does to the programme's participants. If the money is worth more to the recipients than it is to the taxpayers – or vice versa – that difference in value may be included in the analysis as a non-offsetting gain or loss. This takes us into the area of *distributional* considerations, and specifically weighting the dollars received by different social groups, which are discussed in Chapter 7.

3.2 Valuing non-marketed outputs

(a) Pure public goods

Some projects and programmes produce outputs termed 'pure public goods'. Public goods are non-rival or non-excludable goods, and sometimes both. A non-rival public good exists when consumption of the good by one individual does not reduce the amount available for consumption by another individual (for example some information services). A non-excludable good exists when someone cannot be excluded from consuming a good. National defence, from which all citizens are likely to benefit, and street lighting, where all road users benefit, are two examples. Markets tend to produce too few of such goods. They overprice non-rival goods for which the marginal cost of consumption is zero and they have no incentive to provide non-excludable goods for which in effect they cannot charge for (at least to some consumers).

In the absence of markets, a key issue for public goods is their value. As discussed in Appendix II, there are a number of ways to estimate what people are willing to pay for public goods. These methods fall into two main categories – revealed and stated preference methods.

Revealed preference methods draw indirectly on markets or on household behaviour, such as expenditure or travel behaviour, to infer individual preferences from behaviour. Revealed preference methods include proxy prices or markets, and analyses of property prices, travel behaviour, and defence expenditure. For example, the analyst might infer what people are willing to pay for public training courses by reference to fees for private training courses. Property prices are often used to infer the values that households attach to local environmental goods or access to transport. Travel behaviour, and in particular the choice between more or less expensive methods of travel (for example the use of toll roads), provides information in the value of travel time savings that underlie most transport investments. Defensive expenditures, for example on noise insulation of properties, are an indicator of what households are willing to pay to mitigate or avert a nuisance, in this case noise.

Stated preference methods use questionnaires of various kinds to ask people what they would be willing to pay for some public good. For example, households could be asked what they would be willing to pay for a new military equipment programme – on the understanding that they and everyone else would be bound by the responses of a majority. A problem with this approach is that respondents may not take the question seriously, because in contrast to an actual market they may believe that they will not suffer a cost if they get their valuation 'wrong'. Moreover, respondents may have an incentive to 'free ride'. They may exaggerate their true preferences in the desire to encourage provision of a public good in the expectation that it will be provided from consolidated revenue at no cost to the respondent. However, some research suggests that such 'strategic' incentives may be overstated and that, where they exist, they can be overcome by appropriate survey design and other measures (Resource Assessment Commission, 1991, Mueller, 2003).

If valuation problems persist, the opportunity cost concept can still be used to establish the *cost* of an activity, thereby identifying a threshold value that beneficiaries must place on the outcome if the programme is to be worthwhile. Analysts may then leave it to the political process to resolve whether or not the expected benefits equal or exceed the threshold value.

Additionally, once a political decision is made to undertake expenditures on pure public goods, cost-effectiveness analysis can be used to ensure that the services are supplied in the most efficient way possible (see Chapter 11).

(b) Intermediate goods

Some public goods are intermediate goods: these goods are inputs in the production of final goods. Examples include roads that assist freight and business transport and the provision of water for agriculture. Often the final goods are valued in the market. In these cases the valuation of benefits is less of a problem.

A direct valuation method is to estimate what the publicly supplied intermediate goods add to the value of the final product. This approach has been applied in areas such as water resources, education, health and transport. For example, the value of the additional farm output made possible by irrigation is used to estimate the value of the water distributed in such projects. Another example is the increase in a worker's earnings due to reduced illness, disability and premature mortality, which are some of the benefits from public expenditures on health services.

In using this method care needs to be taken in defining the boundaries of the project. For example, if a rural road is valued on the basis of the additional farm output it generates, the inputs to the project include not only the road inputs, but also any additional farm inputs (land, labour, machinery, etc). In this sense, the product under consideration is a joint road and agricultural activity rather than simply one or the other in isolation.

(c) A cost savings approach

A related approach to valuing publicly supplied goods and services is to value the savings in costs made possible by such outputs. For example, a hydro-electric power scheme may reduce the fuel bills consumers would incur if it were necessary to obtain power from alternative sources. Similarly, information technology (IT) systems are frequently introduced to reduce recurrent costs, especially labour costs. The cost savings are then a measure of the benefit (if the service would have been provided by some other means in the no project case).

The estimation of benefits of a project on the basis of the cost savings is often used where the outputs are essentially intermediate goods, but where the final output is difficult to quantify. IT systems, providing a support or management information role, often fall into this category. Note however that the use of cost savings as a measure of benefit implies that the output was worth producing in the first place. It is important to keep an eye on the ultimate product to ensure that this is the case.

Other types of savings may be included also. In particular, *time* has an opportunity cost, reflecting the value of output, income or leisure forgone when it is spent in a particular activity. Savings in travel time (quantified in imputed dollar values) typically comprise 80 per cent or more of the expected benefits of road and other transport projects. Time savings are also relevant in other contexts, for example, in determining the optimal automated call systems.

Additionally, and often controversially, expected savings in *human lives* can be valued in a cost-benefit analysis. Medical technologies which are expected to reduce mortality and/or morbidity and road construction or road safety projects which are expected to reduce road accidents and the probability of death fall into this category.

There are three basic approaches to the valuing of human life in cost-benefit analysis:

- the *human capital* approach which equates the value of life with the productivity of the individual, as measured by the discounted stream of higher future earnings;
- the *required compensation* approach which imputes a value of life from the wage premium that workers may require in compensation for jobs which involve a higher than normal probability of death; and
- a stated preference approach based on questioning individuals about how much they are *willing to pay* to achieve a reduced risk of death.

These approaches, and some of the values which they have generated, are discussed in Appendix II.

3.3 Valuing externalities

(a) Definition

An externality may be defined as any production or consumption process which ‘spills over’ such that other parties receive a benefit for which they do not have to pay or incur a cost for which they are not automatically compensated. Externalities are ‘positive’ (benefits) or ‘negative’ (costs): an example of the former is the benefit to the members of a community from universal vaccination against contagious disease; an example of the latter is the adverse impact on a community of the water pollution due to the discharge from a chemical plant.

(b) Equating price and marginal social cost

Where externalities are generated in the production of a good (for example, chemical or noise pollution), benefits from production are maximised when the price of the good is set equal to marginal *social* cost (MSC). Marginal social cost is defined as marginal private cost (MPC) of production plus marginal external cost (MEC) minus marginal external benefit (MEB) (that is, MSC = MPC + MEC - MEB).

This implies that the market can be guided towards optimal production if an appropriate excise is levied where there are negative externalities, and an appropriate subsidy is optimal in the instance of positive externalities. Thus, where a negative externality is present, the efficient allocation of resources to the production of the good is less than it otherwise would be under a purely market determined outcome; and where a positive externality is present, the optimal allocation of resources is more than it otherwise would be.

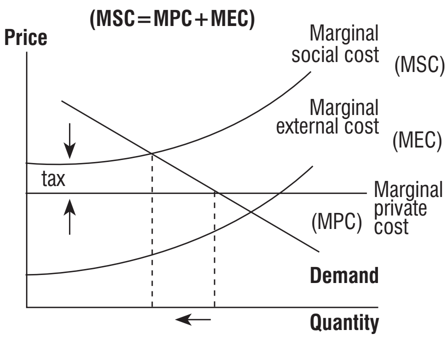


Figure 3.1(a) *Efficiency in the presence of a production externality*

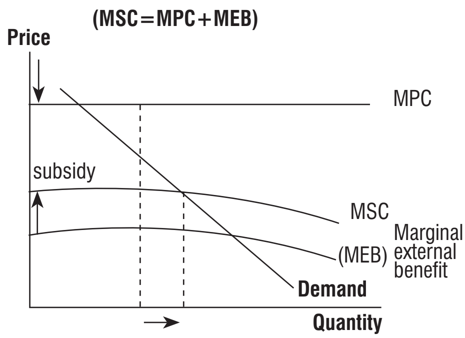


Figure 3.1(b) *Efficiency in the presence of a production externality*

Figures 3.1 shows the two cases. In Figure 3.1(a), the negative externality case, the marginal private cost is constant at every level of output. Marginal external cost, however, increases with output, and marginal social cost is the summation of the two curves. Were an appropriate tax to be imposed, prices would be increased and demand and supply would contract to the point where the value of the last unit demanded was equal to its marginal social cost – an efficient outcome. However, in the absence of any scheme to recover the external costs imposed by the activity, social costs will exceed social benefits – an inefficient outcome.

In Figure 3.1(b), the positive externality case, the situation is reversed and production will be inefficiently low, unless there is a scheme (such as a subsidy) to reflect the external benefits which are associated with each unit of the activity.

It should be noted that these diagrams do not apply if the externality is generated as a byproduct of 'consumption' rather than 'production'. For example, a public bus service generates private benefits for passengers and public 'external' benefits for non-passengers (primarily car drivers) if the effect of the service is to decongest roads. This situation is characterised in Figure 3.2.

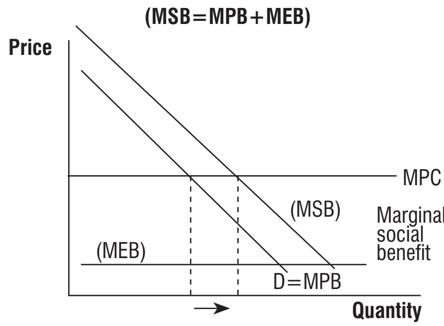


Figure 3.2 *Efficiency with a positive consumption externality*

(c) Willingness to pay or willingness to accept?

In valuing spillover costs, those affected could be asked to nominate *either* the minimum compensation they would require in order to be restored to an externality-free level of welfare, *or* the maximum amount that they would be prepared to pay to have the externality terminated. We can characterise the approaches respectively as a *willingness to accept* approach and a *willingness to pay approach*.

Negative externalities will generally be assigned a greater value if the willingness to accept approach is adopted. This is because the money value which respondents nominate is not constrained by their current income. However, the choice of approach depends ultimately on a judgement about where property rights lie. For example, do industrial facilities have a 'right' to pollute waterways, or to pollute them up to a certain level (if so, consumers may be *willing to pay* a given amount to forgo the pollution)? Or do residents and farmers have an absolute right to enjoy totally pollution-free waterways (if so, consumers may be *willing to accept* a given amount in compensation for a given level of pollution)?

Both the willingness to accept and the willingness to pay approaches imply that 'trades' can take place between those who generate externalities and those who are affected by them. While this is generally not the case, governments are often called on to resolve disputes of this nature and to find a balance between gainers and losers. This means that a view must be reached about the nature of the underlying property rights. In the absence of clear direction on the matter, analysts should adopt the approach that is most appropriate in the particular context.

(d) Quantifying externalities

Since externalities comprise *non-marketed* costs and benefits, measuring externalities can often raise significant difficulties. The main techniques for valuing these costs or benefits are similar to those used for valuing public goods (see Appendix II). The methods include:

- the *related market* technique: this involves finding an actual market which is closely related to the external effect. An example is the use of the residential property market to value aircraft noise nuisance;
- the *contingent valuation* approach: this stated preference approach involves asking what people would be willing to pay (to receive a benefit or remove a cost) or accept (to forgo a benefit or in compensation for a cost) if a market existed for the external effect;
- the *dose-response* approach: this approach focuses on the physical relationship between an externality (the 'dose') and some response (the 'effect'). For example, the approach has been used to assess the effects of acid rain on buildings in North America.

Alternatively the analyst can adopt the *threshold value* approach. This involves estimating the costs of eliminating a negative externality, for example, the costs of 'cleaning up' pollution-affected beaches. The analyst or decision maker would then assess whether the expected benefits from eliminating the externality, in this case beach pollution, exceed the (threshold) cost of doing so.

3.4 Valuing costs and benefits when prices change

Many projects are sufficiently large that either the increase in output lowers product prices, or their purchases of factors of production raise input prices, or both. The problem of valuing a large increment to output frequently arises with major transport projects such as new roads, tunnels or airports that lower the cost of transport services. The problem may also arise in valuing large office accommodation projects which significantly increase the supply of office space. It is also possible that large (private) export projects, for example coal or bauxite projects, may be of sufficient size to affect world prices for those commodities.

Whether even a large project affects input or output prices depends on *the price elasticity of demand* for the product. The price elasticity of demand is the percentage change in quantity demanded brought about by a change in price (also measured as a percentage). If this is infinite (that is, the demand curve showing the relationship between price and quantity is horizontal) the project will have no impact on the price of the product or service. The value of the additional output generated by a project will be given by the (unchanged) market price multiplied by the additional quantity produced. If instead the price elasticity of demand is finite (for example, minus one – that is, a one per cent change in price produces a one per cent change in quantity demanded and the demand curve is downward sloping) the benefits of the additional output fall into two parts:

- the change in *net* benefits to existing consumption, measured by the quantity consumed multiplied by the difference between the old price and the new lower price; and
- the net benefits to the new consumption attracted into the market by the fall in price, that are approximated by an *average* of the old and the new price, less the new price, multiplied by the additional quantity consumed.

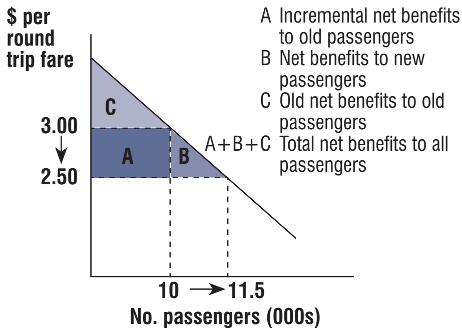


Figure 3.3 *Net benefits and the price elasticity of demand*

To illustrate, suppose that a bus licence on a particular route is transferred to a new operator, who is more efficient than the previous operator. As a result unit costs and fares decline from $3 per trip to $2.50 per trip. Area A in Figure 3.3 shows the incremental net benefit per trip to existing users:

0.5 x 10,000 = $5,000

In addition, the reduction in fare encourages some users to make more than one trip per day and also attracts new customers. Assuming a linear demand curve, the net benefits to new consumption (Area B) are given by:

(0.5 x 1500) x 0.5 = $375

Thus the increase in net benefits resulting from the new service is $5,375.

Note that both Areas A and B represent *consumer surplus* benefits – that is, the value consumers place on the service in excess of price paid. Similarly, the net benefits of the *old* service (Area C) are also consumer surplus benefits. Generally, the larger the project and the smaller the estimate of the price elasticity of demand, the more important consumer surplus benefits become in the estimate of total willingness to pay. Similarly, the smaller the project and the greater the price elasticity of demand, the less likely that consumer surplus benefits will occur.

Because the output of many public projects is large relative to the market in which it serves, consumer surplus is often an important component of total benefits. In such cases, ideally the study would estimate a demand function which indicated the likely changes in price and consumption. In the absence of resources for such a study, studies typically draw on elasticities estimated in studies of comparable situations. However, whatever the estimated changes in prices and outputs, it is common to assume that the demand curve linking the old and new prices is linear. It follows that the consumer surplus of new consumers can be estimated as the product of the change in consumption and half the change in prices. This is generally preferred to assuming that there will be no change in price in response to the additional output of a large project.

3.5 Allowing for taxes and subsidies

Taxes and subsidies create a wedge between prices paid by purchasers and prices received by producers. Since there are two sets of prices – the prices gross of taxes or subsidies, and prices net of taxes or subsidies – which should be used in cost-benefit calculations?

In general, the answer depends on the relative importance of what can be termed *incremental effects* and *displacement effects*. When a government project makes more *output* available, at least *some* (if not all) of the extra output will usually be incremental output. This is appropriately valued at the market price. This is the price inclusive of tax because this is the price that the marginal consumer is actually willing to pay (see Figure 3.4(a)). However, some output may displace other output being sold. This output should be valued at the value of the resources saved that are now diverted to other uses. Given competitive markets, this is the equivalent of the price at which the output sells less the tax on the output. The appropriate precise shadow price then becomes a *weighted average* of these two values (with and without tax), with the weights reflecting the proportion of output that increases consumption of the good and the proportion of output that displaces existing consumption.

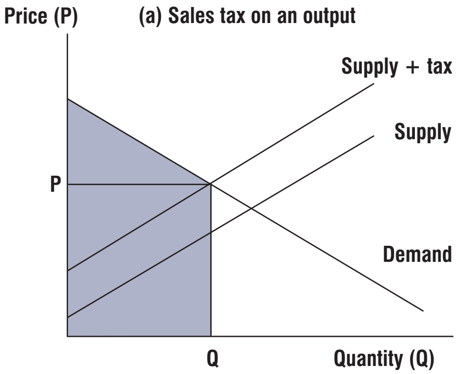


Figure 3.4(a) *Benefits in the presence of taxes and subsidies on outputs*

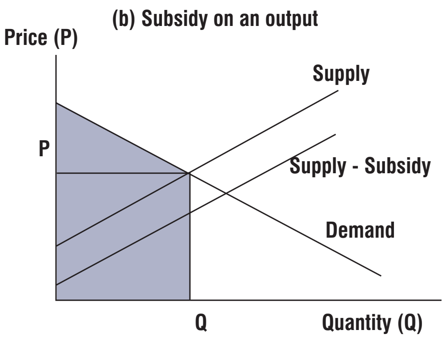


Figure 3.4(b) *Benefits in the presence of taxes and subsidies on outputs*

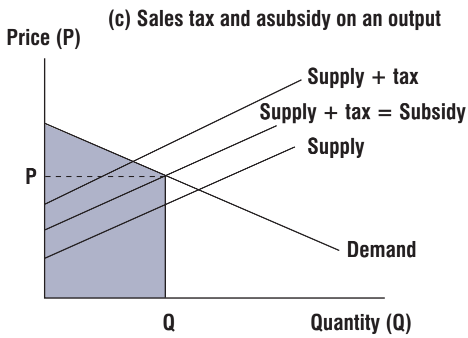


Figure 3.4(c) *Benefits in the presence of taxes and subsidies on outputs*

Similar reasoning applies to valuing *inputs* for government projects:

- if the project's inputs are *diverted (displaced)* from other users, the opportunity cost is the price those other users would have been willing to pay to obtain the inputs: that is, the price gross of taxes and net of subsidies if any;

- if the input demand is met by *increased* production, the best alternative use is the value of the real resources expended, that is, the price net of taxes and gross of subsidies.

We summarise the approach to be taken in respect of both inputs (costs) and outputs (benefits) in the table below.

Table 3.2 *Allowing for taxes and subsidies on inputs and outputs*

Supply/demand	Produce output	Consume Input
Incremental	Market price	Market price less taxes plus subsidies
Displaced	Market price plus subsidies less taxes	Market price

To illustrate the argument, Figure 3.5 shows a case where a project sources an input partly by displacing existing users and partly by additional production. We suppose that a project involves the purchase of 200 computers, 50 of which are diverted from other users and 150 of which are produced for the project. The relevant valuation or shadow price then becomes approximately 50/200 multiplied by the demand price ($10,000) plus 150/200 multiplied by the supply price which is the demand price less a hypothetical sales tax of 20 per cent, or $8000:

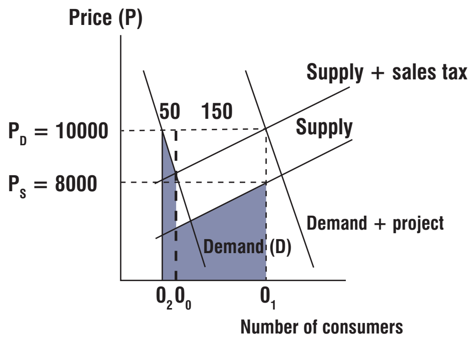


Figure 3.5 *Cost of taxed input*

$$\frac{50}{200} \times 10000 + \frac{150}{200} \times 8000 = \$8500$$

It is worth emphasising that there are many cases where the project's demand for an input is small relative to the total production and where the price elasticity of demand is large (that is, the slope of the demand curve is flat). In such cases the appropriate shadow price will be close to the market price and this sort of analysis is unnecessary. However, there are some cases in which the project's demand for an input is large relative to the previous level of production and where the price elasticity of supply is low, as in Figure 3.5. In these cases the divergence between the two prices may be substantial and justify additional effort involved in quantifying costs. Similar principles apply in respect of project outputs.

Note also that the 'weighted average' computer price in the example is only approximate. It can be seen in Figure 3.5 that the shaded area, which represents the opportunity cost of the resources used, is slightly *smaller* than the area implied by the two 'price times quantity' magnitudes. A more accurate weighted average price requires use *of average* supply and demand prices. These can also be calculated using the diagram. In many instances the weights will be unknown. However, they can be derived using information about supply and demand elasticities as explained in Harberger (1969) or Boardman et al (2001).

3.6 The cost of government revenue

In the preceding analysis the taxes paid on the incremental production of an input used by the project are 'assumed away'. This reflects a premise that they are a costless transfer from the producer to the taxpayer and are therefore not a resource cost. Put another way, this implies that the extra tax payments which government receives by undertaking the project are returned to taxpayers on a cash or 'lump sum transfer' basis. However, it may be more realistic to assume that the Government instead *reduces* taxes, thereby lessening the extent of distortions in the economy.

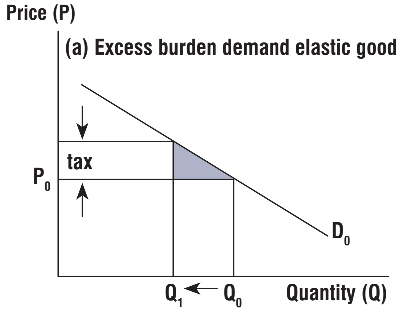


Figure 3.6(a) *Excess burden and marginal excess burden of taxation*

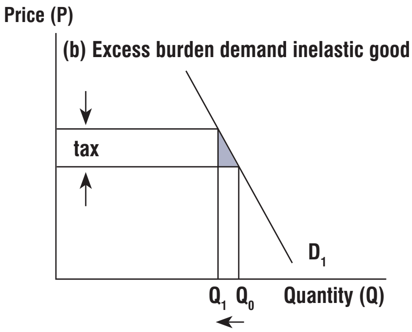


Figure 3.6(b) *Excess burden and marginal excess burden of taxation*

A sales tax on a good, by creating a wedge between the cost of production and the market price, denies the good to those who value it at *more* than its opportunity cost but *less* than its market price. This notion of the value forgone as a consequence of taxation is known as the *excess burden* of a tax. As Figure 3.6 shows, the size of the excess burden depends on the relevant price elasticity.

The *marginal excess burden* of a tax is the additional value forgone when a tax rate is increased to fund certain government spending (Figure 3.6(c)). It represents the change in deadweight loss as a result of the change in tax. Similarly, a reduction in taxation will involve a *marginal reduction in excess burden* – that is, a welfare gain. Campbell (1997) estimates the marginal excess tax burden for general taxation in Australia to be around 25 per cent of revenue raised.

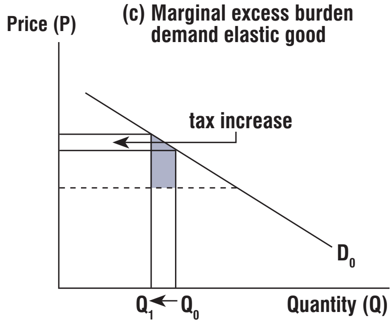


Figure 3.6(c) *Excess burden and marginal excess burden of taxation*

The excess burden of taxation means the supply cost of public investment or services is greater than the actual amount of funds used. Consequently, it is appropriate to make an upward adjustment to financial costs in cost benefit analysis to ensure the calculated *net present value* is unbiased. This is, however, only where there is a significant net cost to the budget. It excludes cases where costs are fully recovered (such as where there is a user charge) or the resources are already committed (which is effectively so for cost-effectiveness analysis and lease-purchase analysis). It would also be appropriate to make an upward adjustment to any project revenue streams that reduce the net financial cost. Supposing the marginal excess tax burden was assumed to be 25 per cent, financial costs and revenues would, therefore, be multiplied by a factor of 1.25.

It has not been common practice in the past to make explicit allowance for the excess tax burden in cost benefit studies. Implicit allowances may have been made by means such as applying high discount rates or rejecting proposals where the calculated *net present value* is only marginally positive (and so would probably turn negative if costs were scaled up to account for the excess tax burden). Consequently, it would be important to highlight where an adjustment has been made for the excess tax burden and to show the impact on *net present value* calculations. This makes it easier for the results of cost benefit studies to be assessed and may improve comparability between studies. It would be appropriate, therefore, for any adjustment for the excess tax burden to be presented in the form of a sensitivity test.

Continuing the hypothetical example, a sales tax also means that the Government receives revenue from project inputs, such as purchased computers. It follows that if the Government were to use the additional revenue from increased production of computers to reduce other tax rates in the economy, the economic cost of those additional computers would be *less* than previously calculated. We can say further that if all taxes were set optimally (if they are set on the basis of the relevant elasticities of supply and demand so that welfare costs are minimised), there would be no need for the weighted average formula and the shadow price would similarly equate to the marginal cost of the good.

However, many considerations determine tax regimes and it is not reasonable to assume that taxes are set optimally. Nor can we assume that incremental revenue (from taxes that are set less than optimally) is always returned to taxpayers so as to maximise welfare gains. Thus it would be unwise to suggest that the cost of taxed inputs should be routinely adjusted downwards when undertaking cost-benefit analysis. Further, the appropriate magnitude of any such adjustments is by no means clear.

3.7 Restrictions on international trade

Suppose that a project involves the purchase of 100 four-wheel drive vehicles. The vehicles are manufactured locally for sale at a unit price of $30,000. However the identical vehicle model could, in the absence of trade protection arrangements, be purchased on the world market at a freight-inclusive unit price of $20,000. What is the shadow price of each vehicle? As with taxes and subsidies, the answer depends on how the project's inputs are sourced. It also depends on the nature of the protection arrangements for imports.

Suppose further that the 100 vehicles could be sourced from domestic production, which is protected by tariffs, from increased imports. The outcome is likely to depend, among other things, on whether there is spare capacity in the local industry. If the vehicles are sourced locally, providing there are several possible suppliers, the local market price will reflect approximately the marginal cost of the resources used in production and so should be used as the shadow price. However, if vehicles are imported, the imported price exceeds the real cost to Australia by the amount of the tariff, which is a transfer payment. Consequently, the import price of $20,000 (that is, the price excluding the tariff) should be used as the shadow price.

However, if domestic production were protected by quotas on imports rather than by tariffs, the world price of the vehicles would no longer be relevant. Since under a quota system, additional imports are impossible, the additional demand would have to be met from local production and the 'weighted average' approach outlined in the previous section should be applied. Project inputs sourced from other users (often the larger part under such an arrangement) would be valued at the market price and inputs sourced from additional production would be valued at their actual marginal cost. Because protected domestic producers are the source of the incremental supply, the shadow price can be expected to be higher than in the tariff protection case, where the world market supplies most of the new demand.

3.8 Valuing labour inputs

Because of the complex issues relating to unemployment and rigidities in labour markets from a resource allocation point of view, the costing of labour inputs deserves special discussion.

Note first that, if markets can be considered to be perfectly competitive (implying zero involuntary unemployment), labour can be regarded as similar to any other project input that is subject to tax, as discussed above. It follows that when labour is sourced from the existing employed labour force, it should be priced at the going wage rate gross of tax: this can be taken to reflect the willingness to pay of alternative employers and hence the value which they place on labour at the margin. Where an increment above the gross wage in alternative employment is required to attract workers, this also should be included in the shadow price of labour. On the other hand, to the extent that a project increases the supply of labour (for example through increased labour force participation), the shadow price of labour is the net of tax wage. In the absence of any alternative employment, the net of tax wage reflects the cost of attracting labour – to forgo the alternative of leisure and/or unpaid work: thus it reflects the opportunity cost of the worker's forgone alternative.

The existence of involuntary unemployment complicates this picture. If there is a significant gap between the level of unemployment benefits and the prevailing net of tax wage, it can be inferred that some workers would be willing to accept a take-home wage that is below the net of tax wage rather than remain unemployed. Provided people place a positive value on leisure or their involvement in unpaid work, it is inappropriate to assume that there is a zero opportunity cost in employing labour which would otherwise be unemployed. At a minimum, the shadow price of labour is likely to equal the value of unemployment benefits plus some amount in compensation for forgone leisure. The choice of a precise figure can be somewhat arbitrary and any analyst attempting to assign such a shadow price should make his or her assumptions very explicit.

Having settled on a shadow price, care is also required in determining the number of workers to whom the price should be applied. To say that a project will create 100 jobs is not to say that a project will reduce unemployment by 100 people. As a general rule, it is recommended that analysts assume that labour, as with other resources, is fully employed. Moreover, unless the project is specifically targeted towards the goal of reducing unemployment, it can be expected that many of the jobs will be filled by individuals who are currently employed but who are attracted either by the pay or by other attributes of the new positions. The research necessary to justify the use of shadow pricing of labour should include, therefore, the mix of unemployed and continuously employed persons in the additional employees.

3.9 Valuing benefits from 'lumpy' increases in capacity

Many public sector investments involve large indivisible physical units and lumpy expenditures. In these circumstances 'marginal cost' will mean different things depending on whether or not the existing capacity is fully utilised.

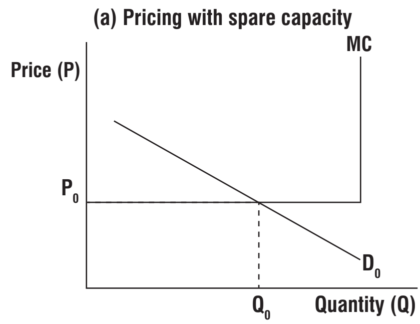


Figure 3.7(a) *Efficient pricing of an indivisible facility as demand grows*

When spare capacity exists, marginal cost is the incremental operating cost associated with meeting an additional unit of demand. This cost represents the allocatively efficient price. Any higher price would be inefficient because some consumers would be deterred from buying the good or service even though they are willing to pay more than the real resource cost of meeting their demand (Figure 3.7(a)). As demand increases, however, to (and beyond) the point where capacity is fully utilised, the efficient price is that price which clears the market by equating demand and supply (Figure 3.7(b)). In principle, the benefits to consumers from the expansion in capacity are equal to the capital costs of the incremental increase in capacity. At this point the new facility is opened and the price is reduced sharply (Figure 3.7(c)) to reflect the 'new' marginal cost, which in effect is the unit operating cost of the new facility. The process may then begin again.

It is perhaps not surprising that this model is seldom translated into reality. Prices which fail to cover the cost of capital expenditure may persist for some years, causing financial losses for the organisation owning or managing the project. The rate of growth of prices may be regarded as excessive; there may be strong resistance to the high prices required to ration demand to capacity just before an expansion is undertaken and to the consequentially large profits; also the sudden plunges in price may be viewed as disruptive.

Yet 'any other pricing pattern will involve welfare losses' (Rees, 1984). Because of this, the appropriate pricing policy where projects involve discrete steps in capacity should be considered explicitly in a cost-benefit analysis and the implications for the magnitude of costs and benefits carefully assessed. We now briefly discuss three important pricing scenarios where discrete steps in capacity are involved.

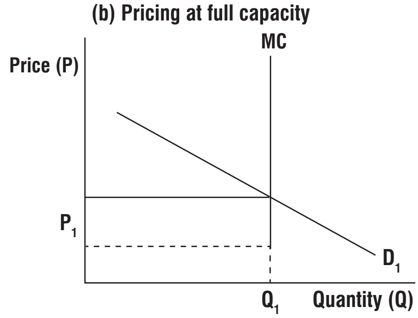


Figure 3.7(b) *Efficient pricing of an indivisible facility as demand grows*

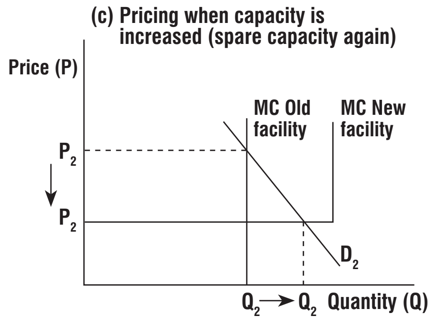


Figure 3.7(c) *Efficient pricing of an indivisible facility as demand grows*

(a) Average cost pricing

To ensure that the enterprise breaks even financially, including securing the appropriate rate of return on capital, it may be impossible for the facility to be priced at marginal cost (that is, the direct operating cost) when capacity is less than fully utilised. The cost recovery price will result in a lower quantity demanded and lower consumer surplus, with the result that benefits will be less than they otherwise would be.

This problem also exists in any context where there are decreasing average costs, and thus where marginal cost is less than average cost. However, from the perspective of the 'shadow price of government revenue' (Section 3.6), prices that are set equal to or higher than average cost will not necessarily be inefficient in these circumstances. This is because the efficiency cost of raising additional revenue through taxation to fund an operating deficit may be greater than the efficiency cost of charging users more than the actual marginal cost of their use. 'If anything, imposing a simple revenue-equal-costs constraint may result in inefficiently low, not high, prices' (Forsyth, 1989).

(b) Capacity is rationed by congestion

As demand increases over time, the prevailing pricing policy may prevent increases in price which are sufficient to clear the market. The result will be that the market is cleared by non-price means, that is, by congestion or rationing. The idea of congestion is readily understood in relation to facilities such as airports, ports or freeways; it may seem somewhat forced in respect of other facilities such as power plants. However, the effects of shortages when electricity generating capacity is fully utilised are similar to those for aircraft or road traffic congestion in that they also impose costs on users.

Congestion is a less efficient solution to the capacity rationing problem than pricing for two reasons. First, in the presence of congestion, users impose delay costs on other users. Thus some users value their use at less than its marginal cost, which now includes the negative externality of congestion, while some users value it at more than marginal cost. Consequently, there is scope for 'gains from trade'; everyone can be made better off by appropriate exchanges of money for some quantities of the good (that is, access to the facility). Secondly, a non-price rationing scheme is likely to absorb more resources than would rationing by price; the effects of congestion at major Australian airports (on, for example, airport and airways operating costs) is an illustration of this.

In summary, if rationing capacity (when fully utilised) by price is not envisaged, the marginal costs of the congestion in each relevant period should be estimated and included in the cost-benefit analysis.

(c) Peak-load pricing

Up to this point we have assumed implicitly that demand for use of the facility is uniform through time. However, for many outputs there is a systematic pattern of demand fluctuation within a given period. The existence of such a pattern tends to increase the feasibility of marginal cost pricing. The capital costs of the facility can be assigned to peak-period demand while only operating costs are assigned to off-peak demand. The effect of this approach to pricing (also described as 'time-of-day' pricing) is that, as Figure 3.8 show, there is much less pricing instability as demand expands than in the uniform demand case discussed above.

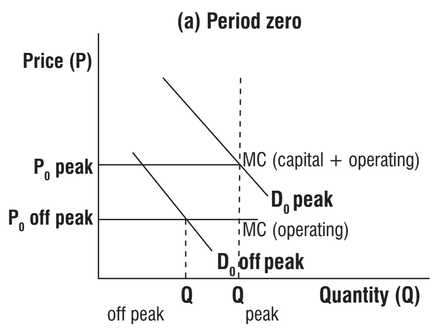


Figure 3.8(a) *Peak-load pricing as demand grows*

In theory, the peak-load price should still be increased over time as demand grows, until demand is sufficient to cover the capital costs of a new facility, at which point the expansion takes place and prices fall so that they just cover those capital charges. Off-peak prices continue to be set at the level of incremental operating costs. However, the extent of variation in the level of prices through time is likely to be much less than in the non-peak-load pricing case. Moreover, the greater the number of pricing periods, the less the need for any pricing instability at all. Conversely, the efficiency losses from any failure to increase peak-load prices, once set, in order to ration demand, are also much less than in the uniform demand case.

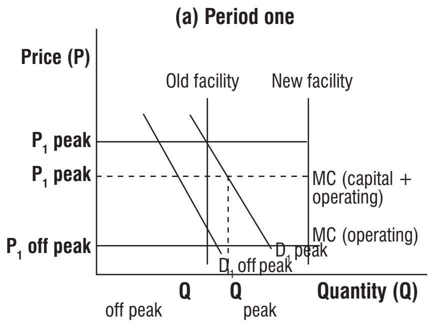


Figure 3.8(b) *Peak-load pricing as demand grows*

Where a peak-load pricing regime is actually likely to be introduced, analysts should take this into account explicitly in estimating costs and benefits. In particular, it is important in this scenario to allow for variation in operating costs and in benefits as demand responds to the pricing pattern: that is, demand may be higher during off-peak periods and lower during peak periods than would otherwise have been expected. In an extreme case, there may be a problem of a 'shifting peak' in which the peak-load pattern is reversed.

3.10 Multipliers and secondary benefits

(a) Employment multipliers

The existence of unemployment sometimes leads analysts to augment the benefits from government projects due to indirect effects of the project on employment and output. The reason given is that if labour which would otherwise be unemployed is used on a public project, the expenditures of the newly employed workers may raise employment and incomes in other sectors of the economy where labour and other factors of production would otherwise be involuntarily idle, and so on in a chain reaction.

The problem with this approach is that any such multiplier effect could also be achieved by alternative uses of the project resources. Instead of undertaking the project, the government could reduce taxation or increase expenditure, either of which could be expected to have an expansionary (though not necessarily similar) effect on income and employment. It should be remembered that cost-benefit analysis is always concerned with incremental costs and benefits, that is, with effects which would not have occurred in the absence of the project.

(b) Secondary benefits

In the situation where resources are assumed to be fully employed, it is necessary to take care not to 'double count' allocative benefits.

Road projects provide standard examples of the double-counting problem. Suppose, for example, that there are two roads between towns A and B. The roads are similar in length and condition and traffic is evenly divided between them. A project is proposed to improve and widen one of the roads. The cost-benefit analyst identifies the main benefit of the project as the reduction in travel time for those using the improved route. The savings will accrue to more than just the existing travellers on that road, because vehicles are expected to be diverted from the unimproved road to the improved one. Someone remarks that property values on the improved route are likely to increase and that local business along the road will be more profitable than previously: it is suggested that these effects be included in the analysis as secondary benefits. However, the analyst declines to do so on the basis that these effects are the direct result of benefits that have already been counted. That is, the sole cause of the rise in property values is the improved access between towns A and B, which in turn has been captured by the estimate of time saving benefits. Similarly, business profits have increased solely because of increased traffic on the road and a larger residential population, the greater part of which, at least, has also been captured in measuring time saving benefits.

To further clarify this point, it may be helpful to distinguish the impact of the road improvement project itself from the impact of this project in stimulating other projects. A road project may act as a catalyst in stimulating other investments in businesses, property and production along the improved road. However it is legitimate to include the benefits of the latter activities only if their own incremental costs are also included.

Moreover, these so-called secondary benefits tend to be closely related to transfer effects discussed in Section 3.1. In this example, gains to property owners and businesses on the improved route are likely to be substantially or even wholly offset by losses to property owners and businesses on the unimproved route, which is now less desirable. It follows that a distributional incidence matrix is helpful in disclosing double-counting problems just as it is in disclosing transfer effects (Table 3.3). Note that, in the table, the allocative effects are italicised; the transfers are shown in normal font.

Table 3.3 *Incidence matrix of a road upgrading project*

Participant group	Costs	Benefits
A. Improved road Road users Residents Businesses	-	*Time savings* Property values increased Income increased
B. Unimproved road Road users Residents Businesses	Property values reduced	*Time savings (small)*
C. General taxpayers	*Construction and maintenance costs*	

3.11 A general equilibrium framework

Notwithstanding scepticism about secondary and multiplier effects, some projects are of a size sufficient to materially affect prices and outputs in sectors of the economy outside the immediately affected sector. To capture these effects requires the use of general equilibrium models of the economy. These models comprise sets of equations which express the relationships among the key variables in the economy. The aim is to estimate the effects of changes in one variable on all other interrelated variables. The general equilibrium approach can be contrasted with the 'partial equilibrium' assumptions that are commonly adopted in cost-benefit analysis.

It is important to stress that, in principle, there should be no valuation differences between a partial and a general equilibrium approach to economic evaluation. Both should be concerned with the maximisation of net social benefit (the sum of producer and consumer surpluses and net positive externality effects). The difference would lie in the breadth of the analysis.

However, in practice there are often differences. General equilibrium models (such as the Monash model) are set up primarily to simulate the production sectors of the economy subject to various demand equations. These models focus on the effects of exogenous changes, including policy changes, on the market economy and on gross domestic product. They are not designed to estimate non-market effects, consumer surpluses and externalities.

Thus when a project or policy is expected to have wide-ranging effects, the policy maker has a choice to make. They can commission a cost-benefit analysis that will focus on the welfare effects but may not capture all the market economy effects or a general equilibrium model that captures more economy effects but is less focused on the welfare consequences. Of course, they may commission both kinds of study. Before the Australian Government introduced the GST in 2000, it commissioned the consulting firm Econtech to produce a general equilibrium study of the impacts on gross domestic product and the National Centre for Social and Economic Modelling at the University of Canberra to provide a study of the distributional effects. Proponents of major new rail infrastructure from say Melbourne or Canberra to Sydney may provide both cost-benefit studies and general equilibrium studies of the impacts.

3.12 The main points in summary

- Before they can be valued, benefits and costs must first be identified, and separated clearly from transfer or distributional effects which do not entail any opportunity costs. Use of a simple incidence matrix can assist in this process.
- Cost-benefit analysis has an important role to play in estimating the value of public (collective consumption) goods, whether these are final consumption goods or intermediate goods. Valuation methods include a variety of revealed and stated preference methods.
- Similar valuation methods can be used to value externalities. Externalities are therefore benefits and costs which accrue to some individual or group external to the market transaction.
- Where projects are large relative to the relevant market, the estimate of benefits should, in principle, include the change in consumer surplus that results from the project. The change in consumer surplus depends on the degree of responsiveness of demand to movements in price (that is, the price elasticity of demand).
- The valuation of a cost or benefit subject to tax or subsidy depends on whether the cost or benefit is incremental to the project or displaces existing output. Incremental *output* is valued at its market price including taxes and excluding subsidies because this is the price that consumers are willing to pay. However, output that displaces other output should be valued at the latter's economic cost (that is, market price less taxes plus subsidies). Similarly, an incremental project input is valued at its economic cost while the project input that is diverted from another producer is valued at its market price. When incremental and displacement effects are present, a *weighted average* will represent the proper valuation.
- Inputs to a project which are subject to trade protection arrangements may be treated as follows: in the presence of a tariff, the inputs should be valued at the net of tariff price unless there is spare capacity in the industry, in which case it should be valued at the market (gross of tariff) price; in the presence of an import quota, inputs should be valued at either the market price or the marginal cost of any incremental supply (which could be expected to be higher than the market price).
- Where there is full employment, labour should be valued as another input that is subject to tax. Where labour is diverted from another employer, it should be valued at the gross of tax wage. However, where a project increases the supply of labour (increased labour force participation), the appropriate shadow price is the net of tax wage.

- Because of the financial instability inherent in economically efficient pricing of 'indivisible' projects such as airport capacity and electricity plants, and for other reasons, departures from marginal cost pricing are common. Analysts need to take account of the reduction in net benefits that may result from either average cost pricing or from capacity rationing through congestion. In contrast, peak-load pricing may, in some circumstances, offer both economic efficiency and, (for the organisation), financial stability.
- 'Employment multipliers' seldom measure actual benefits or opportunity costs and should generally not be included in cost-benefit analyses. Likewise, 'secondary benefits' are often another way of presenting primary benefits that have already been included in the analysis or that represent transfers. While secondary effects of a project may be important for distributional analysis or for planning purposes, their inclusion in a cost-benefit analysis involves inappropriate double counting.
- In valuing the costs and benefits of a project or programme, the 'common sense' starting point is that markets provide a great deal of information at minimal cost. Analysts need to undertake their own 'cost-benefit analysis' of whether the resources required to develop a set of shadow prices can be justified.

4

Present Values and Decision Rules

4 Present Values and Decision Rules

A characteristic of most projects and programmes is that the costs and benefits they give rise to are spread out over time. However, people are not indifferent with respect to the timing of costs and benefits – usually they prefer to receive benefits as early as possible and to pay for costs as late as possible. It is, therefore, important that the *valuation* of costs and benefits takes account of the *time* at which they occur. In this chapter, we show how this is achieved by discounting future costs and benefits to present values and show how the estimated net present value (NPV) is the basis for decision making in cost-benefit analysis. We also show how other decision rules relate to the NPV rule.

4.1 Discounting to a present value

The standard approach to valuing costs and benefits that occur at different times is based on the fact that a dollar now is worth more than a dollar next year. Suppose an individual wishes to spend the dollar in question. If it is received next year, they will have the inconvenience of waiting. Alternatively, if the recipient intends to save, they could earn interest on the dollar saved: in which case in a year's time its value will be *more* than one dollar.

The standard approach to discounting reduces a time stream of costs or benefits to an equivalent amount of today's dollars. That single amount is known as *the present value* of the future stream of costs and benefits. The present value is calculated using the method of compound interest; and the rate that converts future values into present value is known as the *discount rate*. The discount rate is in effect an 'exchange rate' between value today and value in the future.

If we denote the dollar value of benefits received in any future year by B_t, where t refers to the year, and the project lasts for T years, the present value of the stream of benefits is the sum of all annual benefits, with each annual benefit discounted by the appropriate discount rate (r) to convert it into present value terms:

$$\textit{Present value of benefits} = B_0 + \frac{B_1}{1+r_1} + \frac{B_2}{(1+r_1)(1+r_2)} + \frac{B_3}{(1+r_1)(1+r_2)(1+r_3)} + \frac{B_T}{(1+r_1)\ldots(1+r_T)}$$

Using more condensed notation and assuming for convenience that r is constant over all future periods, we get the standard equation for the present value of the benefits of a project:

$$\textit{Present value} = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t}$$

To see how the formula can be applied, suppose that we have two investments, A and B. Investment A yields $1000 one year from now. If r, the discount rate, is 5 per cent, its present value would be 1000/1.05 = $952. In contrast, investment B yields $500 one year from now and $540 two years from now. Its present value is (500/1.05) + (540/1.103) = $966. B has a higher present value than A and thus is the preferred investment. But what if the appropriate discount rate were to be 10 per cent rather than 5 per cent, in effect lowering the present value of money received in the future? Recomputing the present values yields:

$$\frac{1000}{1.10} = \$909 \text{ for } A \text{ and } \frac{500}{1.10} + \frac{540}{1.21} = \$901 \text{ for } B$$

Now A yields a higher present value.

It follows that, if the two projects were strict alternatives, it would be essential to decide on the correct discount rate to use *before* making a selection. While in the example the difference in present value, at either discount rate, is small, this is often not so in the case of long-lived investments. The longer the life of the project, the greater the difference in present value for a change in the discount rate used, due simply to the compounding effect of the discounting process. To illustrate, for benefits received in one year's time, the present value of each dollar is 1/1.05 = 0.952 when the discount rate is 5 per cent, and 1/1.1 = 0.909 when the discount rate is 10 per cent, a relatively small difference. However, for benefits received in ten years' time, the present values become 1/1.629 = 0.614 for 5 per cent and 1/2.594 = .386 for 10 per cent, a very much larger difference. (See also the 'Gordon-below-Franklin hydro-electric proposal' in Chapter 8). The expression 1/(1+r) is known as the *discount factor*.

4.2 Choosing the base date for discounting

Costs and benefits may be discounted to any year and to the beginning or end of any year. The choice of discount point affects the magnitude of the reported results. The earlier the point, the lower the magnitude of the results. However, for any given stream of effects, the chosen date has no effect on the sign of the estimated net present value.

Usually costs and benefits are discounted to the base (first) year. They may be discounted either to the beginning of the year – which assumes a payments in advance system – or to the end of the year – which allows for a payments in arrears system. The difference between these approaches is shown below for a notional project which has a first year investment cost of $10 million and which yields benefits of $2 million a year for 10 subsequent years.

(1) Beginning of year discounting

$$\overset{1}{-10} + \overset{2}{\frac{2}{1.05}} + \overset{3}{\frac{2}{(1.05)^2}} + \overset{\cdots\cdots\cdots}{} + \overset{11}{\frac{2}{(1.05)^{10}}}$$

(2) End of year discounting

$$\overset{1}{\frac{-10}{1.05}} + \overset{2}{\frac{2}{(1.05)^2}} + \overset{3}{\frac{2}{(1.05)^3}} + \overset{\cdots\cdots\cdots}{} + \overset{11}{\frac{2}{(1.05)^{11}}}$$

Of the two alternatives, it can be argued that the beginning of the year approach is generally closer to the actual pattern of expenditure. Note that the Excel financial function for net present value (=NPV (discount rate, range)), where the range is say cells S1:S20, assumes that the first cash flow occurs at the end of the first period. To allow for cash flow occurring at the start of the first period, the formula can be adjusted to =NPV(discount rate, S2:S20) +S1.

There is of course no arithmetical constraint on the choice of the point in time within the project period to which costs and benefits are discounted. In an ex ante evaluation it usually makes good sense to use the first year of the project as the relevant date to which to discount. In an ex post evaluation, the final year of the project, or perhaps the year in which the evaluation is being conducted, will usually be the appropriate year to which to discount.

When discounting to the end of a project period, absolute values are multiplied by discount factors rather than divided by discount factors. (When discounting to the end of the project period from a vantage point that is earlier in time, we speak of a 'future value' rather than a present value.) To illustrate the contrast, Table 4.1 shows the process of discounting to the middle of a project period, that is, to year three of a five year project.

4.3 Within-year discounting

To this point we have adopted a *discounting period* of a year. However, the length of the discounting period used in an analysis is a matter of choice and can be a month, a quarter, or indeed any period duration.

Table 4.1 *Net benefits discounted to the middle of a project period*

Year	Net Benefits	Discount Factors	Discounted Net Benefits
1	-5	$(1.05)^2$	- 5.51
2	2	1.05	2.10
3	2	1.00	2.00
4	2	1/1.05	1.90
5	2	$1/(1.05)^2$	1.81

To illustrate, suppose that an agency is interested in receiving funding for a programme at the beginning of each quarter rather than on a fortnightly basis. This arrangement would involve costs to the Australian Government in terms of forgone interest on its cash balances or alternatively interest payments on additional borrowings. These costs can be identified by comparing the present values (say over a total period of a year) of the two payment streams.

These present values are calculated by adjusting the discount rate to match the discounting period. If the annual discount rate is 8 per cent, conversion to the equivalent quarterly basis is carried out as follows:

$$1.08 = (1 + r_q)^4$$
$$(1.08)^{1/4} = 1 + r_q$$
$$r_q = 1.0194 – 1 = 1.94 \text{ per cent}$$

and the equivalent fortnightly discount rate is:

$$1.08 = (1 + r_{ft})^{26}$$
$$(1.08)^{1/26} = 1 + r_{ft}$$
$$r_q = 1.0030 – 1 = 0.30 \text{ per cent}$$

where subscripts *q* and *ft* stand for quarter and fortnight respectively.

4.4 Calculating an equivalent annual cost

It is often useful to express present values in terms of an annualised or 'equivalent annual' cost. This technique can be used when comparing options with different lifetimes. It may also be used to express the capital value of an asset or project over its economic life as a level annual amount; this can serve either as a basis for charging (the basis being, in effect, an estimate of the long run marginal cost) or alternatively it can offer a threshold value which average annual discounted benefits would need to exceed for the project to be considered viable. The approach is valuable also in estimating the 'life cycle' or 'whole of life' costs of capital goods before acquisition decisions are made.

The technique entails treating the equivalent cost as an annuity, that is, as an asset that pays a fixed sum each year for a specified number of years. The formula for an annuity is:

$$PV = C\left[\frac{1}{r} - \frac{1}{r(1+r)^t}\right]$$

where PV is the present value (say, of the costs of a project), C is the annual cashflow (that is, the equivalent annual cost), r is the discount rate and t is the number of periods.

Thus, suppose that we wish to calculate the equivalent annual cost at a discount rate of 8 per cent of a project which has an economic life of 10 years and the costs of which have a present value of $100 million. The answer calculated from the formula is:

$$100 = C\left[\frac{1}{0.08} - \frac{1}{0.08(1.08)^{10}}\right]$$

$$100 = C\,(12.50 - 5.79)$$

$$C = \frac{100}{6.71} = \$14.9m$$

4.5 The net present value decision rule

Having discussed the nature of discounting, we now look more closely at the decision rule for accepting or rejecting projects.

The *net present value* (NPV) of a project is calculated as shown in Section 4.1 except that now each year's costs are subtracted in the numerator to give the present value of the net benefits (or net present value) of the project. That is:

$$NPV = \sum_{t=0}^{t} \frac{(B_t - C_t)}{(1+r)^t}$$

Subject to budget constraints and other considerations, and assuming that there are no alternative projects under consideration, a project may be accepted if the sum of its discounted benefits exceeds the sum of its discounted costs; that is, where its net present value exceeds zero.

Where mutually exclusive projects are under consideration (that is, where projects offer alternative solutions to a single problem), the project which *maximises* net present value should be selected.

By way of example, Table 4.2 illustrates two methods for calculating the net present value of a hypothetical road project, using an Excel spreadsheet. In the first method, discounted net benefits are calculated using *discount factors,* which are shown in the table. The discounted net benefits in the final column are then summed to yield a net present value. In the second method, the Excel NPV function is applied to the *undiscounted* net benefits column, yielding the identical result. To emphasise the contrast in methods, by showing the cell formulas for Table 4.2 are shown in Table 4.3.

Table 4.2 *Two methods of calculating the net present value of a road project*

	Costs		Benefits				
	(-)	(-)	(+)	(+)			
		Operating					
Year	Capital	Maintenance	Time Savings	Cost Savings	Net Benefits	Discount Factors (r=.08)	Discounted Net Benefits
1	16.0				-16.0	0.926	-14.8
2			2.0	0.4	2.4	0.857	2.1
3		0.5	2.1	6.4	2.0	0.794	1.6
4		0.5	2.2	0.4	2.1	0.735	1.6
5		0.5	2.0	0.5	2.3	0.681	1.6
6		0.5	2.4	0.5	2.4	0.630	1.5
7		0.5	2.6	0.5	2.6	0.583	1.5
8		0.5	2.7	0.5	2.7	0.540	1.5
9		0.5	2.7	0.5	2.7	0.500	1.4
10		0.5	2.7	0.5	2.7	0.463	1.3
11		0.5	2.7	0.5	2.7	0.429	1.2
12		0.5	2.7	6.5	2.7	0.397	1.1
14		0.5	2.7	0.5	2.7	0.340	0.9
15		0.5	2.7	0.5	2.7	0.315	0.9
16		0.5	2.7	0.5	2.7	0.292	0.8
Method 1: Total = net present value							4.9
Method 2: @NPV command							4.9

Table 4.3 *Cell formulas for Table 4.2*

	A	B	C	D	E	F	G	H
1								
2		Costs		Benefits				
3		(-)	(-)	(+)	(+)	(=)		
4				Operating			Discount	Discounted
5			Main-	Time	Cost	Net	Factors	Net
6	Year	Capital	tenance	Savings	Saving	Benefits	8.0%	Benefits
7						-		
8	1	16				=(D8+E8)-(B8+C8)	=1/(1+$G$6)^A8	=F8*G8
9	=A8+1			2	0.4	=(D9+E9)-(B9+C9)	=1/(1+$G$6)^A9	=F9*G9
10	=A9+1		0.5	=D9*1.05	=E9*1.05	=(D10+E10)-(B10+C10)	=1/(1+$G$6)^A10	=F10*G10
11	=A10+1		0.5	=D10*1.05	=E10*1.05	=(D11+E11)-(B11+C11)	=1/(1+$G$6)^A11	=F11*G11
12	=A11+1		0.5	=D11*1.05	=E11*1.05	=(D12+E12)-(B12+C12)	=1/(1+$G$6)^A12	=F12*G12
13	=A12+1		0.5	=D12*1.05	=E12*1.05	=(D13+E13)-(B13+C13)	=1/(1+$G$6)^A13	=F13*G13
14	=A13+1		0.5	=D13*1.05	=E13*1.05	=(D14+E14)-(B14+C14)	=1/(1+$G$6)^A14	=F14*G14
15	=A14+1		0.5	=D14*1.05	=E14*1.05	=(D15+E15)-(B15+C15)	=1/(1+$G$6)^A15	=F15*G15
16	=A15+1		0.5	=D15	=E15	=(D16+E16)-(B16+C16)	=1/(1+$G$6)^A16	=F16*G16
17	=A16+1		0.5	=D16	=E16	=(D17+E17)-(B17+C17)	=1/(1+$G$6)^A17	=F17*G17
18	=A17+1		0.5	=D17	=E17	=(D18+E18)-(B18+C18)	=1/(1+$G$6)^A18	=F18*G18
19	=A18+1		0.5	=D18	=E18	=(D19+E19)-(B19+C19)	=1/(1+$G$6)^A19	=F19*G19
20	=A19+1		0.5	=D19	=E19	=(D20+E20)-(B20+C20)	=1/(1+$G$6)^A20	=F20*G20
21	=A20+1		0.5	=D20	=E20	=(D21+E21)-(B21+C21)	=1/(1+$G$6)^A21	=F21*G21
22	=A21+1		0.5	=D21	=E21	=(D22+E22)-(B22+C22)	=1/(1+$G$6)^A22	=F22*G22
23	=A22+1		0.5	=D22	=E22	=(D23+E23)-(B23+C23)	=I/(1+$G$6)^A23	=F23*G23
24								
25	Method 1 : Total = net present value						=SUM(H8:H23)	
26	Method 2: = NPV function			=NPV(0.08,F8:F23)				

4.6 Issues in using the net present value rule

While the net present value rule is a straightforward one, it is helpful to address a number of issues which arise in its use. These are: the impact of budget constraints; complementarity among projects; the interaction of budget constraints and project timing choice; and comparison of projects with different lengths of life.

(a) Accommodating budget constraints

Where budget constraints limit the number of projects which can be undertaken, the appropriate decision rule is to choose that subset of available projects which maximises *total* net present value.

To illustrate, suppose that a department has a capital outlay budget of $8 million:

Project A costs $2 million and has a NPV of $140,000
Project B costs $6 million and has a NPV of $500,000
Project C costs $4 million and has a NPV of $320,000
Project D costs $4 million and has a NPV of $450,000

With a combined net present value of $770,000, projects C and D should be undertaken.

Suppose that, with the budget constraint still at $8 million, project A is estimated to have a net present value of minus $140,000 while project C has a net present value of minus $320,000. The best strategy now is to undertake only project B, which would yield a net present value of $500,000. The unused $2 million should be returned to the Budget. On the assumption that returning $2 million to the Budget avoids borrowing, the NPV implied under the latter 'project' is zero and thus is superior to any two projects in combination that meet the budget constraint. This serves to illustrate the point that choices which entail a *reduction* in total net present value should, other constraints aside, be rejected, even when there is enough money in the budget to undertake them.

(b) Complementarity among projects

The larger the number of projects under consideration, the more complex the optimal choice can become, where a budget constraint applies. This is especially so where there is *complementarity* between investments; that is, where the net benefit stream of one project depends on the acceptance and implementation of another project (for example, an irrigation project may depend upon the construction of a hydroelectric plant). If necessary, mathematical optimising techniques can be used to look at all combinations of projects and to select that set or package which satisfies the specified constraints on choice and has the greatest net present value.

(c) Budget constraints and project timing

It is also important to take account of the way in which budget constraints interact with choices about the optimal *timing* of projects.

Suppose that there are two projects, A and B. The NPV of project A ($10 million) is less than that of project B ($12 million). However, the benefits of project A occur sooner than those of project B. Either project would exhaust the annual capital budget. Provided that next year's capital budget can be forecast with confidence, it is necessary to look at the combined NPV of the alternative sequencing of projects before making a decision. The options are:

Table 4.4 *Project sequencing options*

Year	Project (NPV)	Project (NPV)
1	B ($12m)	A($10m)
2	A (9m)	B($ll.5m)
Total	$21m	$21.5m

In this example, the expected NPV *today* of project B declines less when the project is delayed by one year than does the NPV of project A, which has an earlier benefit profile.

A further assumption in this case is that no other project is available for consideration in year 2 (but not in year 1) with an expected NPV *today* of greater than $9.5 million. If there were such a project, project B should be undertaken in year 1 (not project A) along with this new project, in year 2. This combination would maximize the total net benefit from the available projects. Also, if a comparable budget in year 2 may not be available, the higher returning project should be undertaken in year 1.

(d) Accommodating projects with different lengths of life

When comparing projects with different lengths of life, the usual assumption is that the demise of a shorter project cannot be expected to give rise to subsequent project opportunities with above normal rates of return – that is, opportunities with net present values exceeding zero. It follows that the estimated net present value is the appropriate criterion for comparing projects with different lengths of life, with the net benefit profiles of the projects being discounted at the social opportunity cost of capital (see Chapter 5).

In some situations, it may be necessary to compare a large capital investment with a series of short projects. If the short project is likely to be repeated through time, it would not be meaningful to compare its net present value with the net present value of a longer-lived project.

For example, it may be necessary to compare alternative power sources, one with an expected life of 30 years and another with an expected life of 15 years. On a stand-alone basis, the former might have the higher NPV. However, the best approach here is to place the projects on an equivalent 30-year basis. This may indicate that it is better to have two projects with an expected life of 15 years each rather than one project that lasts 30 years.

4.7 Other decision rules

In addition to the net present value rule, a number of other decision rules are widely used for appraising projects and programmes. These include:

- the internal rate of return;
- the benefit-cost ratio; and
- the payback period.

Appendix III describes these rules and their main advantages and disadvantages. A brief summary is provided here.

The internal rate of return (IRR) is the rate of discount that produces a net present value of zero (that is, it is the rate that equalises the discounted costs and the discounted benefits). Suppose that the estimated IRR is 8 per cent and that the discount rate used in the NPV calculation is 7 per cent, the project must then have a positive NPV. In general, when the estimated IRR exceeds the selected discount rate, NPV is positive and projects are efficient. When the estimated IRR is less than the selected discount rate, NPV is negative and projects are inefficient. However, as shown in Appendix III, the IRR presents little information that is not available in estimated NPV and it can provide misleading information when projects have to be ranked.

The benefit-cost ratio (BCR) is most appropriately estimated as the ratio of discounted recurrent net benefits to discounted capital costs, but is often estimated more simply as the ratio of discounted benefits to discounted costs. When properly estimated, the BCR can assist with the selection of projects when agencies have capital constraints (more projects than can be funded at the selected discount rate), but it does not displace the objective of maximising net present value. However, in more general cases, the BCR is biased towards small projects and must be used cautiously.

The payback period is simply the time taken, usually in years, to pay back the capital expenditure of a project. There is generally no discounting, which is a major weakness.

In general, we recommend that project analysts should calculate and show the net present value. Other decision rules should be used with caution.

4.8 Allowing for inflation

Future costs and benefits can be valued in real (constant) or nominal (current) prices. In the real terms approach, all variables are expressed in terms of the price level of a single given year. While any year may be used, the present year will usually carry most meaning as a base. Note that if an entire analysis is conducted in the prices of the year in which the analysis takes place, it is being carried out in *real* terms.

The method assumes that future inflation will affect all costs and benefits even-handedly. If there are good reasons for thinking that particular cost or benefit streams will not follow general price movements, those changes in relative prices should be built into the analysis. If office rents, for example, in the context of a property evaluation, are expected to exceed the rate of inflation by two per cent a year for the next three years, the analysis should include this parameter. Assumptions regarding expected relative price changes should be made explicit.

In the nominal price approach, the impact of expected inflation is explicitly reflected in the cash flow projections. As in the real price case, different inflation rates can, if necessary, be applied to different cost and benefit streams. Because of the demanding nature of the data requirements under this approach (inflation rates need to be estimated for the entire project period), the approach is not generally used.

As noted, when using constant values, it is usual to accept the prices of the first year of the project. However, when the cost-benefit analysis is undertaken as part of an *ex post* evaluation, the convention is to use the prices of the final year of the project.

Table 4.5 illustrates conversion from nominal to constant prices for a hypothetical ex post evaluation of a seven year project. The method is to take the index for the base year, divide it by the index for the year to be converted, and multiply by the relevant nominal amount of costs or benefits. For example, to express net benefits in year two in this table in year seven prices, the operation is:

$$\frac{115.1}{79.6} \text{ x } 41.7 = \$60.3m$$

The Australian Bureau of Statistics publishes numerous implicit price deflators (IPDs) which may be used to convert nominal net benefits to real net benefits (see Australian National Accounts – National Income and Expenditure, annual, ABS Catalogue No. 5204.0). However, unless a specific IPD seems applicable, a general deflator such as the Gross Non-Farm Product IPD may appropriately be used.

Table 4.5 *Net benefits converted from nominal to real prices*

Year	GDP deflator for this example	Net Benefits (current prices)	Net Benefits (Year 7 prices)
1	71.5	25.4	40.9
2	79.6	41.7	60.3
3	88.4	37.1	48.3
4	94.4	46.3	56.5
5	100.0	50.2	57.8
6	107.1	52.0	55.9
7	115.1	80.0	80.0

It is important that real prices and nominal prices are not confused in the analysis. In particular, when the analysis is presented in nominal prices, the discount rate should be adjusted for inflation. This captures the point that investors require compensation for anticipated inflation as part of the price of making funds available. With annual compounding, the formula for converting a real discount (r) into a nominal one (n) is:

$n = (1 + r)\,(1 + \textit{inflation rate}) - 1$

Thus with a real discount rate of say 6 per cent, and an expected annual rate of price inflation of 3 per cent, the correct nominal discount rate is 9.2 per cent. Note that the 'intuitive' alternative of *summing* the real discount rate and the inflation rate (to give 9 per cent), slightly underestimates the correct value.

Conversely, to convert nominal discount rates into real discount rates, the equation is:

$r = (1 + n) / (1 + \textit{inflation rate}) - 1$

Thus, if the nominal discount rate is 9 per cent and the expected inflation rate is 3 per cent, the corresponding real discount rate is 5.8 per cent. Note here that an intuitive 'subtraction' approach *overestimates* the correct value. While inflationary expectations are difficult to measure, the inflation parameter is commonly based on recent inflation experience, for example the experience over the previous year. On the presumption that the consumer price index (CPI) is central to the capital market's assessment of the current rate of inflation, it is recommended that the CPI be used for this purpose (Consumer Price Index, ABS Catalogue No. 6401.0).

4.9 The main points in summary

- Costs and benefits occurring at different points in time have different values. *The present value* of that stream of costs or benefits is the value in today's dollars. It is calculated using the method of compound interest, with the rate by which the present value is computed known as the discount rate. Thus, the discount rate is the exchange rate between a given value today and the same value in the future.
- Subject to budget constraints, other considerations and where alternative projects are not under consideration, a project should be accepted if the sum of its discounted benefits exceeds the sum of its discounted costs; that is, where its net present value exceeds zero.
- Where alternative projects are under consideration, as is the most common case, the project which maximises net present value should be selected.
- Where budget constraints limit the number of projects which can be undertaken, the appropriate decision rule involves choosing that subset of the available projects which maximises total net present value, in accordance with other considerations.
- Provided that future budget constraints can be forecast, it is possible to work out the optimal timing of projects: in some circumstances the combined net present value will be greater if projects with 'lower' net present values are undertaken first.
- Other decision rules such as the benefit-cost ratio and internal rate of return may be included with caution in the analysis alongside the net present value criterion. However, these rules can be misleading and should not be used in place of the net present value rule.
- As a general rule, it is appropriate to compare projects with different lengths of life. However, when it is expected that projects of short lives will lead to further projects that yield above normal returns, it is necessary to adjust the alternative investment strategies so that they span approximately the same period of time.
- Project evaluations should normally be undertaken in real values; that is, the price level of a given year. This assumes that future inflation will affect all costs and benefits equally. Where this assumption is inappropriate, cash flows should be adjusted for inflation separately and assumptions regarding relative price changes made explicit.
- It is important to ensure that real and nominal prices are not confused in the analysis. Where a decision is taken to present the analysis in nominal prices, the discount rate should be adjusted upwards to take account of the expected inflation rate.

5

Setting Discount Rates

5 Setting Discount Rates

In this chapter, we discuss principles and approaches used to choose a discount rate in cost-benefit analysis. Note that, following the discussion in Chapter 4, we are generally choosing a real rate of discount. This means that any chosen discount rate must exclude the inflationary component of market rates. The choice of discount rates is also complicated by the number of alternative concepts of interest rates from which to choose. These include various costs of capital rates and two main time preference rates. We review these concepts in this chapter and then draw out some recommended practices.

5.1 Concepts of the discount rate: cost of capital rates

In considering the appropriate discount rate, a natural starting point is the Australian Government's borrowing rate. This represents the direct or observed *cost of funds* to the Government. This approach implies basing the discount rate on the Government's cost of borrowing (normally represented by the long-term bond rate).

However, the Government's borrowing rate does not reflect the true opportunity cost of the use of capital funds, known as the social opportunity cost of capital. The *social opportunity cost of capital* (SOC) represents the return on the capital funds that could be achieved by another project or programme. If government funds are regarded as fixed, the alternative project is the marginal project in the public sector. However, in an optimal situation, government borrowing would not be fixed but would be flexible to accommodate worthwhile marginal private projects. In this case, the appropriate point of comparison is the marginal rate of return in the private sector, that is the return on the displaced private investment. Efficient allocation of resources requires that, at the margin, the rate of return in the private and public sectors be equal, after allowing for all social costs and benefits attributable to projects.

As will be seen, the SOC is generally higher than the government's borrowing rate. A major reason for this is that government can borrow at low rates because lenders know that their money is secured by government's power of taxation. However, as we saw in Section 3.6, taxation imposes an excess burden on the economy. This means that the real cost of borrowing is higher than the nominal cost. This is another reason for focusing on the true opportunity cost of capital – the SOC.

A method closely related to the SOC is to use an estimated *project-specific cost of capital* (PSCC) as the discount rate. This method is based on the Capital Asset Pricing Model (CAPM) developed to explain the relationship between the return expected by shareholders in any particular private sector firm and the *market risk* characteristics of the shares. Market risk can be defined as the risk to which all business enterprises are exposed through business cycle and other general business conditions. In the CAPM framework, equity holders seek a risk premium in compensation for the price volatility of their investment. Estimates of the size of the average market risk premium are typically based on the risk premium for equity investments and, for Australia, are generally in the order of 6 per cent[2].

[2] The equity risk premium is based on recent research by the London Business School (Dimson E., Marsh P. and Staunton M. 2003, 'Global evidence on the equity risk premium', *Journal of Applied Corporate Finance*, vol. 15, no. 4) which estimates a geometric mean for Australia of 6.3%.

While all businesses are exposed to market risk – the risk is said to be undiversifiable – some firms and some industry sectors are more or less risky than others. Market risk is measured through the so-called 'beta factor'. While the market as a whole has a 'beta factor' of one, low risk firms and sectors have betas of substantially less than one and high risk firms have betas of substantially more than one. Typically, resource companies will have high betas while food retailing firms will have low ones. An appropriate beta needs to be determined for the project. Under the CAPM, this beta value is then multiplied by the average market risk premium and then added to a generic 'risk-free' rate, which is typically proxied by the Treasury long-term (ten year) bond rate. It should be noted that long-term bonds are considered risk-free only in the technical sense that the nominal return at the end of the term is assured; other risks, particularly inflation uncertainty, are not avoided.

5.2 Concepts of the discount rate: time preference rates

Both the SOC and the PSCC reflect the rate of return available on alternative projects. The PSCC tends to be related mostly to privately financed projects. As such, it also reflects the rate of return that lenders require for these projects. In a perfect capital market with no taxation, the rate of return achieved on capital and the rate of return that lenders require for giving up present consumption and for taking on risk would be equal. However, because of taxation the SOC generally exceeds the marginal return that lenders require. The matter is complicated because tax applies to nominal income (returns) rather than to real income.

Suppose that a project makes a nominal 8 per cent rate of return and that inflation is 2 per cent. The real rate of return is (1.08 / 1.02) - 1 = 5.8 per cent. Suppose also that the lender is taxed 30 per cent on the 8 per cent. Then the lender's return is (1+(.08 * 0.7) / 1.02) - 1 = 3.5 per cent. The lender's required rate of return is known as his or her private time preference rate (PTPR). It is the rate at which lenders are willing to give up a marginal dollar's worth of consumption this year for extra consumption next year. If the PTPR is 3.5 per cent, the lender is willing to give up $100 of consumption this year for $103.50 consumption next year.

Before discussing the relationship between the SOC and the PTPR further, brief mention may be made of the *social time preference rate* (STPR). This concept represents society's preference for present as against future consumption. The STPR is similar to the PTPR but it aims to take a social view of the additional future consumption required to exactly compensate for postponement of a unit of present consumption. Conceptually, the STPR may vary from the individual's preference for present rather than future consumption. For example, if individuals systematically take decisions which fail to take account of the needs of future generations, the STPR will be lower than the private time preference rate.

5.3 Choosing between cost of capital and time preference discount rates

In practice, therefore, there is a hierarchy of possible discount rates ranging from the PSCC, which is usually the highest rate, through the SOC, the PTPR, and the STPR, which is usually the lowest rate. Not surprisingly, this has led to a great deal of debate about the appropriate choice of discount rate (see for example Pearce 1983).

There are, it may be observed, two main choices. One is whether to use a cost of capital or producer measure of the discount rate (the PSCC or the SOC) on the one hand, or a time preference or consumer rate of discount (PTPR or STPR) on the other hand. The second choice is which of the producer or consumer rates of discount to choose.

Because the stream of costs and benefits to be discounted (the net benefits stream) is essentially a stream of consumption goods foregone and of consumption goods gained respectively, it can be argued that one of the consumer rates of discount is the appropriate discount rate concept. However, use of a consumer rate of discount raises the difficulty that projects with low rates of return may be selected, which displace projects in the public or private sector that would have earned a return greater than the consumer rate of discount.

This difficulty can be resolved by using a shadow price for capital which reflects its real opportunity cost. The shadow price is computed by estimating the stream of returns that would be achieved by the capital in another project and by discounting these returns back to a present value using a consumer rate of discount (Feldstein, 1973). The estimated present value for this capital becomes the shadow price of capital employed. This is a technically attractive procedure because it employs the time preference rate for consumption but also allows fully for the opportunity cost of capital. However, this is a somewhat complex procedure. Moreover, as various writers have shown (Pearce 1983, Abelson 2003), the effect of this procedure is that projects or programmes are generally efficient only if they obtain a return on capital at least equal to the SOC.

The general conclusion (and a common international practice) is that a producer rate of discount is the appropriate rate of discount to employ. This ensures that resources are used efficiently. Consumer rates of discount should be used only in exceptional cases, where for some reason resources have no opportunity cost and a programme involves only a comparison of consumption streams.

5.4 Benchmark discount rates

For most evaluations of public projects, programmes or policies, this *Handbook* recommends the use of a cost of capital or producer rate of discount. The use of a producer rate of discount ensures that the true opportunity cost of capital is reflected in the project evaluation and that resources are used efficiently.

For projects that are typically financed by the public sector and for which there is no readily available private operation, a benchmark rate is required that reflects the SOC. However, while it is generally accepted that the SOC reflects the cost borne by society resulting from the transfer of resources from the private to the public sector, there is no standardised measurement technique for determining the SOC. In any case, the SOC will be greater than the long-term bond rate and consumer rates of discount based on time preference.

However, in some cases, a rate based on the PSCC may be appropriate. These cases arise when the risk of a project is borne by specific investors who require a higher real rate of return for participating in the project. Typically these are joint public-private ventures or wholly private ventures. In these cases, the benchmark rate should reflect the rate that investors are willing to accept for providing the capital. This may encompass some risk from the investor's point of view. As discussed earlier, the PSCC is calculated using the CAPM and an appropriate beta needs to be determined for the project. Also, it is important that the benchmark rate for public sector investment not be so low as to bias capital expenditure toward the public sector and away from the private sector.

Two other sets of circumstances should be recognised. One is the case where consumer rates of discount may be used. Typically the real consumer rate of discount, or the real private time preference rate, is considered to be about 3 per cent. This may be used where two sets of consumption streams are being compared where there are no resources with opportunity costs being employed. This may occur in the evaluation of some environmental goods. However, it is rare that goods do not have some resource components with opportunity costs.

Second, where the decision question is strictly 'what is the cost of the various options to the Commonwealth budget?' rather than 'what is the intrinsic value or the value to the economy of the various options?', the current long-term bond rate may be an appropriate discount rate. Suppose the Government has a choice of receiving a lump sum of revenue immediately or receiving a certain stream of revenues over time. The Treasury bond rate would be the appropriate discount rate to apply to the revenue stream if extra revenue was purely used to retire public debt.

However, with public debt in Australia currently at a low level, it may be unrealistic to assume financial decisions will largely affect debt. Rather, pressures on the budget balance will affect current public spending and investment as well as the tax burden on the community. Consequently, the discount rate should reflect the SOC.

5.5 The main points in summary

- There are two main concepts of the discount rate. These are cost of capital or producer rates of discount, and time preference or consumer rates of discount.
- Cost of capital rates of discount include the government's borrowing rate, the low risk opportunity cost of capital (known as the social opportunity cost of capital) and the project specific cost of capital that reflects the return on capital that the private sector would require for this particular project.

5 Setting Discount Rates

- Time preference rates of discount reflect consumers' preference for current consumption as against future consumption. Because tax creates a wedge between the rate of return that producers receive and the return to lenders, the producer cost of capital generally exceeds time preference rates.
- Most common international practice is that a producer rate of discount is the appropriate rate of discount to employ. This ensures that resources are used efficiently. Consumer rates of discount should be used only in exceptional cases, where for some reason resources have no opportunity cost and a programme involves only a comparison of consumption streams.
- However, in many cases a project specific discount rate is appropriate. These cases arise when the risk of a project is borne by specific lenders who require a higher real rate of return for participating in the project or where a project could be undertaken by the private sector.
- The *Handbook* does not prescribe a benchmark real SOC discount rate. The appropriate discount rate may vary from one year to the next, and is under continuous review.
- Nor is it possible to be prescriptive about project-specific discount rates because they will vary not only from one year to the next but also from project to project.
- In instances where a Commonwealth financial, rather than broader economic, perspective is appropriate, the Treasury long-term bond rate generally provides an appropriate discount rate value.

6

Allowing for Risk and Uncertainty

6 Allowing for Risk and Uncertainty

Up to this point we have generally assumed single-value estimates of future costs and benefits. This is consistent with an assumption that future costs and benefits are known with a high degree of *certainty*. Yet clearly the values of many future costs and benefits are *uncertain*. It is important, therefore, to provide decision-makers with adequate information relating to the margin for error surrounding single-point estimates of project net present values. This chapter describes how this can be achieved and discusses other problems relating to the treatment of risk and uncertainty in project evaluation.

6.1 Definitions

A distinction is sometimes made between the terms risk and uncertainty. Risk is measurable; it refers to situations with known probabilities. Uncertainty in contrast is vague; it refers to situations with unknown probabilities. In practice the distinction is a fine one. A probability may be *assigned* to a particular event but that probability is seldom *known* with complete certainty; conversely, few events are so uncertain that probabilities cannot be assigned if it is thought worthwhile to do so. Except where the distinction is made explicit in this *Handbook*, the two terms are used interchangeably.

6.2 Risk-neutrality and risk aversion

It has traditionally been argued that public sector decision-makers should evaluate projects and programmes on a 'risk-neutral' basis. This implies that decision-makers should be indifferent to the dispersion or variability of the expected returns as a result of that risk and accept those activities with the highest expected returns regardless of the risk.

To illustrate, suppose that a project has an 80 per cent probability of producing a net present value of $2 million and a 20 per cent probability of producing a net present value of $500,000. The expected net present value (ENPV) would be calculated as:

ENPV = 0.8*$2m + 0.2*$0.5m= $1.7m

In effect we are saying that if the project were repeated many times, 80 per cent of the resulting net present values would be around $2 million and 20 per cent of the outcomes would be close to $500,000. In this sense, the *expected net present value* of $1.7 million is an average outcome.

This project could then be compared with another which has a 50 per cent probability of resulting in a NPV of $1.8 million and a 50 per cent chance of producing a NPV of $1.6 million. The ENPV would be calculated as:

ENPV = 0.5 *$1.8m + 0.5* $1.6 = $1.7m

The risk-neutral decision-maker would be indifferent between these two projects, despite the difference in variability, and would opt to undertake both, provided that the projects were not mutually exclusive and there were no budget and other constraints.

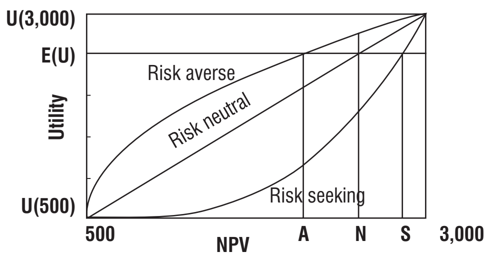
Now suppose that only one project can be undertaken and that the first project is redesigned so that it has an 80 per cent chance of producing a net present value of $3 million and a 20 per cent chance of yielding a net present value of $500,000. Thus:

ENPV = 0.8 * $3M + 0.2 * $0.5M = $2.5M

A risk-neutral decision-maker will accept the redesigned project. However, another decision-maker might choose the project with the lower expected net present value ($1.7 million) and the lower variability. This decision-maker would be acting in a *risk-averse* manner and we could say that the 'cost' of the uncertainty, or the extent of risk aversion, was some amount up to the difference between the two expected net present values: that is, $800,000.

Note that to know exactly the cost of the uncertainty we would need to know the risk-averse decision-maker's *certainty equivalent*. This is the sum of money at which the decision-maker is indifferent between the two alternatives: that is, acceptance of this certain sum of money and acceptance of the uncertain project outcome are valued equally. The certainty equivalent is never less than the minimum payoff – in this instance $500,000. If it were less, the second decision-maker would reject *both* alternatives – but it may be more than this amount.

In summary, a risk-neutral decision-maker values projects and programmes at their expected values. In this case, there is no difference between the expected value and the certainty equivalent. In contrast, a risk-averse decision-maker values projects and programmes at *less* than their expected value. Finally, *risk-seekers* value uncertain outcomes at *more* than the expected value. Figure 6.1 provides illustration.



A = Certainty equivalent for risk averse
N = Certainty equivalent for risk neutral = E[NPV]
E[NPV] = 0.2*500 + 0.8*3000 = 2500
S = Certainty equivalent for risk seeking
E[U] = 0.2U(500) + 0.8U(3,000)

Figure 6.1 *Attitudes to risk*

6.3 Determinants of attitudes towards risk

Under certain conditions, certainty equivalent and expected value will be the same, rendering a risk-neutral approach appropriate (Sugden and Williams, 1985).

One condition is that only small changes in wealth are at risk. For most people, it seems likely that a gamble involving a gain of twenty cents if a coin falls 'heads' and a loss of twenty cents if it falls 'tails' has a certainty equivalent very close to zero. However, a similar gamble with a stake of $2000 rather than twenty cents would have a certainty equivalent less than zero. This means that they would only enter the gamble under duress – they would rather pay a sum of money in order to avoid this 50-50 gamble.

An important qualification is that individuals may not be risk-neutral concerning small changes in wealth if they already face a large burden of risk – for example, if repayments on borrowings are at a level where control of the assets which provide the security for the borrowings are under threat; but in other circumstances the condition holds.

Another condition is that risks should be independent. An example of a *non-independent* risk is a project involving use of additional fertilisers to grow a particular crop. The amount and value of incremental output will depend not only on the fertiliser inputs but also on the weather conditions. Additionally, the difference between good weather and bad weather may mean significant variations in income for the farmer, irrespective of whether an investment is made in fertilisers. In essence, the project is likely to produce high returns when the farmer is relatively rich because of good weather conditions – and poor returns when the farmer is relatively poor. Put another way, the value to the farmer of the returns which follow good weather conditions is reduced by the fact that he or she is already relatively well off. This situation provides an additional reason for the farmer to be risk-averse and to attach a certainty equivalent value to the project returns that is lower than its expected value.

A third potential determinant of attitudes towards risk is the *number* of projects to which the individual is exposed. By the law of large numbers, the variability in the return from a portfolio of risky individual projects will be less than that of any individual project selected at random. This is the concept of *risk-pooling*. If risky projects are pooled, the risk the individual faces in respect of any particular project is likely to be quite small. With risk-pooling, the riskiness of a project is lessened by portfolio diversification. This is distinct from *risk-spreading* where a project's costs and benefits are spread amongst a large number of owners and beneficiaries.

6.4 Risks facing public sector projects

Many public sector projects are small and hence conducive to a risk-neutral approach.

Project costs that are borne ultimately by taxpayers in general are typically small for each individual person. This is an example of *risk-spreading or sharing,* which is far from being exclusive to the public sector. The risks associated with the projects of private firms are shared among the firm's shareholders. However, the opportunity for risk-sharing provided by the tax system generally exceeds that provided by even the largest companies.

In contrast, when project effects are concentrated on particular individuals or groups, they may involve large changes in welfare. In this case, a risk-neutral approach may not be appropriate. For example, a new dam that is expected to reduce the risk of floods for a community may give rise to benefits which exceed the more readily quantifiable aggregates, such as the expected value of the additional agricultural output and avoided damage to property. This is because the flood risks involved are large rather than small risks for the people involved, and the benefits of removing those risks are accordingly greater. (This example is set out in more detail in Box 6.1.) Careful research is invariably necessary to identify and then quantify concentrated risks.

Box 6.1 Dealing with concentrated risks

Suppose that a new dam is proposed which will reduce the risk of floods for an area which has a population of 10,000 people. The present value of the cost of constructing the dam is $110 million. In the absence of the dam, there is a 10 per cent probability that the area will be flooded some time during the life of the project, with an estimated cost to property of $1 billion. The expected value of the potential loss is $100 million (or $10,000 per person) calculated in this way:

Probability		Possible loss		
0.1	x	$1000m	=	$100m
0.9	x	0	=	0
Expected value			=	$100m

On risk-neutral principles the project has a net present value of $110 million less $100 million, or minus $10 million. However, for the local people, who are risk-averse, the risks attaching to the "no-dam" option are unacceptably large. Suppose the people have taken out insurance which, taking a present value over the life of the project, totals $15,000 per person, or $150 million in total. This shows that the community's certainty equivalent is $150 million, which in turn implies a net present value of $40 million – an entirely different result.

Secondly, risks facing public sector projects may not be independent. The benefits of many public projects, including large infrastructure projects such as roads, airports and power stations are not independent of cyclical national income. Also, the outcome of public projects may be linked to other 'external' factors such as climatic conditions. In either case, a risk-averse response may be more appropriate than a risk – neutral one.

Thirdly, separate risky projects may not be 'pooled'. This issue is frequently one of perspective. From the average taxpayer's perspective, he or she is the ultimate 'owner' of a large number of projects: we can say that his or her portfolio is well diversified, with the particular risks of each individual project tending to cancel one another out, and that a risk-neutral approach is likely to be appropriate. However, from the perspective of the decision-maker or project manager, the situation is usually different. He or she has a small number of projects within the field of view and the outcome of each project is a matter of more or less pressing concern. Scope is also needed for differences in personal attitude and approach: that is, some people are more risk-averse than others.

Additionally, it is usually desirable that the managers responsible for a project act *as if they personally* faced some risk in the event the project was not successful – even if, in an ultimate sense, the risks are borne by taxpayers who can afford to be largely risk-neutral. It has been argued that the commitment and effort of managers is related to the risks which they personally are required to bear (Laffont, 1987). It can also be argued that divergence of interest between 'managers' and 'owners' is a particular problem in the public sector, where mechanisms for ensuring the accountability of managers for financial performance are somewhat weaker than in the private sector. From this perspective, the risk borne by the Australian Government and the taxpayer is greater than it would otherwise be.

In the next section, we outline some techniques that can be used to accommodate risk aversion and to minimise risk in project design. The main techniques are sensitivity analysis, full risk analysis (Monte Carlo simulation technique) and the addition of a loading to the discount rate.

6.5 Techniques for handling uncertainty

(a) Sensitivity analysis

The values included in a cost-benefit analysis are the average estimates. In principle they should represent estimated mean values. Sensitivity analysis is a simple procedure for providing the decision-maker with information about the effect of errors in those estimates on the viability of the project.

The first step in a sensitivity analysis is to substitute plausible pessimistic estimates for each important variable simultaneously and to estimate a revised net present value. If the estimated value is still positive, we can say that even with pessimistic assumptions the project is likely to yield net social benefits. No further sensitivity analysis is needed. If, however, the estimated net present value falls below zero, we have confirmed that the project is indeed risky, at least to a certain extent.

The second step is to assess how risky the project is and which variables significantly affect the net present value. One way to do this is to vary each variable one at a time, holding all other variables to their best estimate value. However, in some cases variables are correlated. The best approximation would be to move these variables together. This process, while more complex, will help to determine the variables that are critical to the robustness of the net present value estimate. The value of the variable at which the net present value changes from positive to negative is known as the 'switching value'.

If there are only one or two critical variables, the analyst can:

- indicate that if this variable were less than (or more than) the switching value, the project is very likely to be justified or not justified, as the case may be; and
- evaluate the likelihood of a switching value outcome for the determining variable in order to give a clear idea of the riskiness of the project.

The decision-maker is thereby provided with the information with which to make an informed judgement.

If there are more than two determining variables, it is more difficult to convey in words any meaningful judgement about the real riskiness of the project. If there are, say, more than five such variables, there may be many combinations of the variables that would justify a project, and also many combinations that would not do so. See Box 6.2 for an example of sensitivity analysis.

Box 6.2 Sensitivity testing of a road project

Box Table 6.2 summarises a number of sensitivity tests for the hypothetical road project in Chapter 4 (Table 4.2 and 4.3).

The variables which are considered uncertain are the capital costs of the project and the rate of growth in traffic (and consequently also the rate of growth in time savings and operating cost savings). It is believed that maintenance costs will only be larger if road use – and with it, benefits – are also larger. Thus maintenance costs are excluded from the sensitivity analysis.

The first step is to enter the worst case values for all of the uncertain variables. This results in a net present value of minus $3.3 million. The second step is to vary each parameter independently, in order to assess its influence on the project Net Present Value (NPV).

However, note that the time saving and operating cost saving variables are adjusted *jointly* because separate adjustment would be unrealistic. This analysis shows that the NPV would be marginally negative if maximum capital costs eventuate but would still be positive at minimum traffic growth estimates. The third step is to establish the switching value for capital costs – both with and without worst case benefit estimates. It turns out that if capital costs exceed $21.3 million, the NPV will be less than zero. The NPV will also be zero if capital costs exceed $18.4m and time and operating cost savings grow at only 2 per cent a year.

We have thus achieved a focus on the key information that the decision-maker needs: in practical terms, the probability that capital costs will exceed $21.3 million and the joint probability that capital costs will exceed $18.4m when time and operating cost savings grow at only two per cent a year. However, further information will assist the decision: we also need to know who bears the risk of loss if capital costs blow out, and who will gain if benefits meet or exceed their best estimate values. If either costs or benefits are concentrated on a small or defined group (see Sections 6.3 and 6.4 and Box 6.1), rather than being widely dispersed, risk-averse assumptions will be appropriate. In respect of the cost blow-out scenario, the decision-maker may reject the project, even if the probability of the blow-out is considered to be low. Conversely, with regard to the benefits, he or she may prefer this project over others with larger net present values but where the projects produce only small increases in welfare at the individual level.

Box Table 6.2 *Road project sensitivity tests*

Variable	Value	NPV$m	Switching Value
1. Capital Costs	$22m	-0.7	$21. 3m
2. Time and op cost savings	g=2%yr (Yrs 2-6)	2.3	$18.4m
3. All variables	See above	-3.3	
4. All variables	Best estimates (Table 4.3)	4.9	

(b) Full risk analysis

When there are many uncertain variables, a full risk analysis may be undertaken. In this analysis, probabilities are assigned to the values of all key variables and estimates made of the covariance of the variables. Then, through repeated computer iterations based on a random sampling of the values of the variables, a probability distribution of the net present value of the project is generated (see Appendix IV).

It is worth emphasising that this is the only type of analysis that provides a comprehensive picture of the potential variability of a project. To be completely informed, the decision-maker would require a full risk analysis for every project. Nevertheless, in most cases, a sensitivity analysis provides sufficient information about the riskiness of a project or programme.

(c) Raising the discount rate

Another method for allowing for risk is by 'loading' or raising the discount rate, or in other words allowing a discount rate premium. Although this method is used widely in the private sector, it is not generally advised for the public sector. Exceptions arise for projects that are funded from specific private sources that are specifically exposed to the project's risk (see Chapter 5).

The strategy of loading the discount rate is often used to counter apparently systematic over-optimism in net benefit forecasts (see Section 6.7). However, the approach is valid only where the concern is that benefits, and especially late-occurring benefits, may be too high. The method fails if it is late-occurring costs that are the source of the uncertainty. Construction projects and projects with adverse long-run environmental effects may provide examples here. The correct approach would then be to reduce the discount rate rather than add a premium to it, so that the cost estimates can be maximised rather than minimised.

This difficulty illustrates that it is impossible to use a risk loading to guard simultaneously against both overestimation of benefits and underestimation of costs. In general, as Sugden and Williams (1985) put it, 'Where there are reasons for supposing the certainty equivalents of the costs or returns of projects to be different from their expected values, it is sounder to make explicit judgements about how great the difference is than to conceal these judgements behind the smoke-screen of a risk premium'. Sensitivity analysis is the most helpful vehicle for making these judgements.

Strictly speaking, a risk loading is appropriate where there is a constant (exponentially increasing) probability of a project failing (that is, of all costs and benefits terminating). However, such circumstances are rare. Generally, a project is more likely to fail during its set-up period or at the end of its life – for example, as capital equipment becomes obsolete. Accordingly, loading the discount rate is not recommended as a general practice for publicly funded projects.

6.6 Sensitivity analysis and discount rates

It is important to extend sensitivity analysis to the discount rate that is applied to the project net benefit stream. Suppose that a central discount rate of 7 per cent were adopted, sensitivity testing at 5 per cent and 9 per cent can accommodate uncertainty about the level of the opportunity cost of capital during the project period ahead.

In addition, use of more than one test discount rate may assist in focusing on key uncertainties in cases where there are significant differences in the time profile of net benefits of project alternatives.

Consider two projects, A and B. A is characterised by early-occurring costs and late-occurring benefits, while B is the opposite – it has late-occurring costs and early-occurring benefits (Figure 6.2). At a low discount rate (4 per cent), Project A, with its late benefits, is the preferred choice, while at a high discount rate (12 per cent), Project B, with its early benefits, is the superior option. At a central discount rate (8 per cent), Project A is the preferred choice, but only marginally: its net present value is $1.5 million compared with $1.4 million for Project B. However, if the analyst had reason to doubt the magnitude of the net benefits of Project A, or considered that the net benefits of Project B may have been marginally underestimated, he or she might re-examine the analysis and perhaps reach a different recommendation.

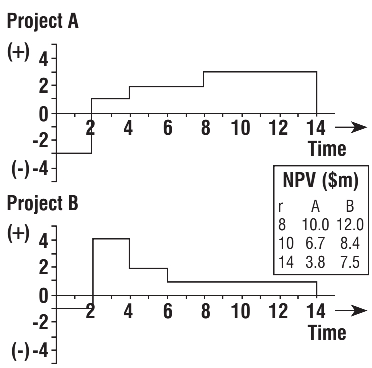


Figure 6.2 *Project choice with contrasting net benefit time profiles*

Given the closeness of the two net present values at the central discount rate, such a re-examination should take place even if the net present value at different discount rates has not been calculated. However, a demonstration that the recommendation is highly sensitive to the choice of discount rate – which this testing provides – is a helpful source of additional motivation.

6.7 Optimism bias

'Optimism bias' or 'appraisal optimism' is a further reason for a risk-averse approach to project evaluation and one that justifies separate attention.

Optimism bias occurs when favourable estimates of net benefits are presented as the most likely or mean estimates. It is an endemic problem in cost-benefit analysis and may reflect overestimation of future benefits or underestimation of future costs. Overestimation of benefits is often linked to an unrealistically high estimate of the *annual rate of growth* of benefits. Conversely, underestimation of costs often involves excluding some relevant costs. Three remedies for the problem can be considered.

The first remedy is sensitivity analysis. Varying each parameter to their pessimistic values one by one and collectively can uncover a great deal of the over-optimism that may underpin an analysis. This process must be done honestly and should, if anything, err on the pessimistic side.

A second alternative is to load the discount rate. However, because this technique assigns a reduced value to both benefits *and* costs, loading the discount rate will obscure any underestimation of costs. Further, the knowledge that the appraisal process builds in a correction factor for optimism bias may, itself, cause distortion of the information submitted.

The third option is to provide a clear statement of the assumptions in the analysis, particularly forecasting assumptions, and the reasons for those assumptions. For example, if analysis of an office construction project depends on office rents increasing at more than the rate of inflation, the assumption could be justified by pointing to an established trend or by giving evidence of the underlying demand for office space in the area. In many cases, independent and expert assessments should be obtained in order to develop and justify cost and demand estimates. Such explicit justification not only aids the analyst; it also 'opens up' the analysis to the decision-maker who is then in a much better position to avoid being misled.

6.8 The main points in summary

- Traditionally public sector projects have been evaluated on a risk-neutral basis: this entails accepting projects with the highest expected net present value irrespective of the potential variability of that net present value due to uncertainty about estimated costs and benefits. In contrast, in the risk-averse approach, the value of a project is its certainty equivalent, which is lower than the expected net present value.
- A risk-neutral approach is generally appropriate when only small changes in individuals' wealth are at risk (risk-sharing) or when a project is one of a large number of projects (risk-pooling). These are common conditions for public projects.
- Each project should be examined separately in terms of its risk characteristics. The tax system provides an institutional framework for sharing project risks so that risks are small for most individuals. However, particular projects may entail large risks for certain individuals or groups. Additionally, potential conflicts of interest between 'managers' and 'owners', combined with weaknesses in the financial accountability of managers, provide a reason for some risk-aversion from those responsible for funding public sector projects.
- Three techniques are used to allow for risk aversion: sensitivity analysis, full risk analysis, and loading the discount rate. Sensitivity analysis is the generally recommended approach. In complex cases, full risk analysis may be warranted. Altering the discount rate is a cruder method because it applies to all benefits and costs regardless of the degree of risk attached to them and is generally not recommended as a method for assessing risks of public projects.
- These techniques, in particular sensitivity analysis, are also useful in uncovering optimism bias in projects: that is, the tendency to base net present values on optimistic estimates of costs and benefits rather than the most justifiable and reliable estimates.
- Sensitivity testing of projects at a range of discount rates will disclose the dependence of project choice on the level of the discount rate, in cases where the time profile of net benefits differs significantly between options. It can therefore help in focusing attention on any uncertainties in those time profiles.

7

Analysing Distributional Effects

7 Analysing Distributional Effects

Unless distributional effects of projects are addressed in some way, a conventional cost-benefit analysis may ignore such effects. This chapter examines three limitations associated with distributional effects and ways to deal with them.

7.1 Distributional limitations in cost-benefit analysis

First, conventional cost-benefit analysis compares expected costs and benefits without attaching specific importance to the groups in society that incur the costs or receive the benefits. In a democratic society, decision-makers need to know the identity of the groups that may be expected to gain or lose as a result of their decisions, and the nature and size of those gains and losses.

Second, a premise of the cost-benefit rule, under the Kaldor compensation criterion (see Chapter 2) is that a project can be approved if those who gain from a project can fully compensate those who lose and still be better off than if the project were not implemented. However, in the great majority of cases there is no automatic mechanism whereby compensation can be assessed and subsequently paid. In the absence of actual compensation there will remain losers as well as winners.

Third, both costs and benefits that accrue to lower-income groups may be underestimated in the cost-benefit procedure. While economists usually seek to avoid interpersonal comparisons of welfare, cost-benefit analysis aggregates, across individuals, costs and benefits that are measured in money terms. This approach could be taken to imply that the marginal utility of income is equal for all persons, that is, that an extra dollar of income has the same value for a rich person as a poor person. It is unlikely that many people would accept this assumption.

Put another way, the benefits and costs from a project reflect the existing distribution of income. The distribution of income affects the demand of consumers (their willingness to pay is influenced by their ability to pay) and the supply of inputs by resource owners. Other initial distributions of income would entail other patterns of production and consumption, and different efficient allocations of resources in the economy. The adequacy of the cost-benefit procedure can be questioned, therefore, on broad equity grounds.

In response to these latter arguments it is sometimes suggested that cost-benefit analysis should be kept entirely separate from issues relating to income distribution. In a classic text, Musgrave (1969) proposed that all public expenditures should be selected solely on efficiency grounds, with undesired distributional effects being subsequently corrected by means of taxes and direct transfer payments. Aside from the uncertain administrative and political feasibility of this alternative approach, the redistribution of income through taxes and transfer payments is not a costless procedure in efficiency terms: that is, such taxes and transfers require administrative resources and are also likely to have adverse effects on incentives to work. Thus projects which have *favourable* distributional effects save costs which would otherwise be incurred in direct income redistribution. On the other hand, projects that have *unfavourable* distributional effects imply that costs would have to be incurred in tax and transfer programmes designed to remedy the adverse redistribution of income.

7.2 The display approach

The first two limitations outlined can usually be addressed satisfactorily if the identities of the groups that gain and lose, and the size of the gains and losses, are carefully documented in the cost-benefit analysis.

A distributional incidence matrix, that shows gains and losses on one axis and the identities of affected groups on the other axis, can greatly assist the decision-maker. It should be included in all reports unless the distributional effects are sufficiently straightforward to make this unnecessary: for example, where there is only one group in each of the two (gaining and losing) categories. Even in this case, however, the cost-benefit analysis should include a discrete section on the project's distributional effects.

A side-benefit of this approach is that a distributional incidence chart can clarify the relationship between efficiency effects and transfer effects and the distinction between them. For example, an improved arterial road may cause an increase in residential property values in the suburbs with which it connects, due to the enhanced access for people living in those suburbs. However, property values in less well located suburbs, which experience a loss of residents to the other suburbs, may fall. Because people would not have moved location if they did not expect to become better off, it is unlikely that the net efficiency benefits captured by the various effects on property values are zero. But the change in values in the advantaged suburbs also represents a transfer effect. The discipline of displaying gains and losses by relevant groups provides a useful check of project effects. See Section 3.11 for a similar example.

A potential difficulty with the display approach to distributional incidence is that the matrix can be complicated if a large number of groups are involved. Some loss of detail and accuracy is unavoidable in the interest of keeping the display easily accessible for the decision-maker, for example, through aggregation of certain groups. The apparent need for a highly complex display may also serve to encourage those developing the project to check that all of the research and consultation (for example, social impact and environmental impact studies) which is appropriate in the circumstances has been completed, before proceeding further.

7.3 The distributional weights approach

The third limitation in handling the distributional effects of a project is that of a 'built-in' bias in cost-benefit analysis against low-income gainers and losers. This can be addressed through assigning differential weights to the costs and benefits that accrue to specific groups.

To illustrate how this method works, suppose that two alternative projects, A and B, produce certain changes in income for different income groups as set out in Table 7.1.

Table 7.1 *Distribution of benefits by household income*

Annual income (households)	Number of (households)	Benefits per Project A	Household Project B	Total Project A	Benefits Project B
Less than $25,000	100	+ 100	+ 300	10000	30000
$25,001 - $50,000	400	+ 200	+ 250	80000	100000
$50,001 - $100,000	300	+ 300	+ 150	90000	45000
More than $100,000	50	+ 400	+ 100	20000	5000
Total	**850**			**200000**	**180000**

The Table shows that the total annual benefits are $200,000, for Project A compared with $180,000 for Project B. For simplicity, we set aside the issues of discounting and the cost of the two projects. However, Project B provides substantially greater benefits to households with an annual income below $25,000 ($300 per household compared with $100 per household in Project A), as well as larger benefits to households in the $25,001 – $50000 income range. Because the target beneficiaries of the project are these two lower income groups, a weighting structure is applied to the benefits that favours these groups and which disadvantages the two higher income groups. In order of increasing income, the weights are 1.0, 0.9, 0.6 and 0.4. The weighted benefits are calculated as shown in Table 7.2. Estimation of weights is discussed in Section 7.4.

Table 7.2 *Weighted benefits by household income group*

Annual income (households)	Distributional weight	Weighted Project A	Benefits Project B
Less than $25,000	1.0	10000	30000
$25,001 - $50,000	0.9	72000	90000
$50,001 -$100,000	0.6	54000	27000
More than $100,000	0.4	8000	2000
Total		**144000**	**149000**

The total benefits of Project B ($149,000) now exceed those of Project A ($144,000), suggesting that the decision-maker should select Project B.

7.4 Estimating distributional weights

The two main techniques used to estimate distributional weights are:

- inferring weights from existing or past policies and decisions; and
- postulating weights.

In the first approach, weights may be *inferred* from existing programmes that have a redistributional character. An illustration might be the personal income tax scale. A high-income person faces a marginal tax rate on the last dollar of income earned of $0.47 (ignoring the Medicare levy) whereas a low-income person above the threshold faces a marginal tax rate of only $0.17. So it could be inferred that the wealthier person's sacrifice of $0.47 is just as painful as the poorer person's sacrifice of $0.17. Alternatively, a $0.47 sacrifice by the poorer person is more than twice as painful as the $0.47 sacrifice by the richer person. Taking the logic one step further, all benefits to low-income people could be given a weight of t_r/t_p times the weight given benefits to rich people, where t_r and t_p are the marginal effective tax rates paid by rich and poor people respectively.

However, there are various difficulties with such an approach. First, the income tax scale does not merely reflect judgements about the desirable distribution of income (that is, the concern to share the burden of the operations of government equally). If it did, there might be a much steeper schedule of tax rates in order to equalise incomes. Governments are also concerned with efficiency or incentive effects, that is, the effect on work effort and the economy as a whole if, say, taxation rates approached 100 per cent (or more) at the high-income end of the spectrum and zero at the low end. Thus it would be necessary to separate out the incentive-oriented policy thrust from the redistribution-oriented thrust in the tax scale at any time in order to estimate what the relevant rates might be in the absence of concern about efficiency effects. It is not at all clear how this can be achieved.

Alternatively, analysts could adopt distributional weights that have been postulated by the decision-maker. Note, however, that 'for a decision-maker to postulate a set of distributional weights is for him to express an intention to act in accordance with these weights' (Sugden and Williams, 1985). Thus *postulated distributional weights* imply a clear policy objective to redistribute income to a particular target group from other groups.

This method is only acceptable if it is used in the appropriate contexts. However, under no circumstances should an analyst apply weights based on his or her own ethical preferences, rather than on the established decision-making intention of government.

7.5 Letting the decision-makers decide

The distributional weights issue can be resolved relatively easily by recognising that distributional judgements can be made properly and adequately at the political level. As a general practice, it is recommended that analysts refrain from attaching distributional weights to cost and benefit streams in the interest of avoiding subjective bias. The exception is where an unambiguous government policy objective can be identified to assist the specific group at which the project or programme is aimed; and where the priority of assistance to this group relative to other groups is also clearly established. These are stringent and restrictive conditions. Moreover, even in these instances, it is important to include in the report the estimate of the *unweighted* net present value, so that the absolute cost of the distributional judgement can be measured. It is also highly desirable to develop an estimate of the efficiency cost of the alternative means of achieving a similar income redistribution, for example, through a direct transfer payment. In this way a realistic perspective can be maintained on what is an appropriate efficiency 'price' to pay for the redistributional benefits of the project or programme.

7.6 The main points in summary

- Decision-makers generally need information about the distributional effects of projects and polices.
- Displaying gains and losses by the relevant groups, in chart or tabular form as an adjunct to the cost-benefit analysis itself, provides the information that decision-makers need concerning the distributional impact of projects and programmes. Reports should include such displays in all but the most straightforward cases.
- It can be argued that cost-benefit analysis, in assuming implicitly that the value of a dollar is the same for a poor person as for a wealthy person, entails a structural bias against low-income individuals and groups. To overcome this bias, differential weights can be assigned to the income changes that accrue to different social groups. However, it is only in those instances where distributional weights can be reliably extrapolated from stated Government policy objectives that this approach is recommended.
- As a general rule, we recommend that distributional weights not be assigned and that recommendations of cost-benefit analyses flag the need for distributional judgements to be made at the political level. Even in these instances, the estimate of the unweighted net present value should be included in the analysis, so that the absolute cost of the distributional transfer can be fully taken into account by decision-makers.

8

Case Study

8 Case Study

This chapter discusses a cost-benefit study that has been undertaken in Australia. In outlining this study, the intention is only to illustrate and reinforce points made in the preceding chapters. Thus we do not offer an exhaustive review of the study.

8.1 The Gordon-below-Franklin hydro-electric development proposal

In 1979 the Tasmanian Department of Environment asked the Centre for Resource and Environmental Studies (CRES) at the Australian National University to assess a *Report on the Gordon River Power Development Stage Two* prepared by the Hydro-Electric Commission (HEC). The CRES assessment was subsequently published (Saddler et al, 1980).

The HEC proposal comprised an integrated development that would harness the water resources of the Gordon and Franklin rivers to provide additional electricity generating capacity for the state of Tasmania. The HEC report argued that the proposal was the most cost-effective way to meet future electricity demand in Tasmania. HEC considered a number of alternative options, including a coal-fired thermal power station using coal from New South Wales; however, it found that none were cost-effective. The preferred proposal entailed the flooding of the Lower Gordon-Franklin area, an area recognised as one of outstanding natural beauty and significant archaeological interest. The proposal generated widespread community opposition on environmental grounds. In May 1983 the Commonwealth Parliament enacted the *World Heritage Properties Act 1983* which, following an unsuccessful High Court challenge, prevented construction of the dam from proceeding.

The basic approach of the CRES study was to compare the willingness of consumers to pay for electricity from the hydro-electric development with both the capital and operating costs of the scheme and the opportunity cost of the Lower-Gordon-Franklin area as a wilderness area. The base (or 'without project') case involved the construction of a coal-fired thermal station of comparable capacity to meet future demand. The contrast may be summarised as follows:

With project: $NSB_n = B_H - C_H - C_{WD}$
Without project: $NSB_c = B_c - C_c$

where B, C and NSB are benefits, costs and net social benefits respectively; and subscripts H, C and D represent hydro-electricity and coal options, and wilderness destruction respectively.

The CRES study commenced by comparing the costs of meeting the forecast future demand for electricity via hydro-electricity and coal methods. The study found that, ignoring the costs of wilderness destruction, the hydro option yielded estimated present value benefits of $189 million or $11.5 million at discount rates of 5 per cent and 10 per cent respectively. The study team found that it could not quantify precisely the costs of wilderness destruction (or conversely the benefits of conservation), due to a lack of adequate identification of those costs and corresponding data.

The study team therefore asked whether it was plausible that the *benefits of wilderness preservation* might exceed the estimated cost savings associated with hydro power? The study found that *not* to proceed with the hydro option was economically sound given benefits from preservation in the first year were between $500,000 and $1 million.

We discuss below three specific aspects of the CRES study: the role of pricing in estimating the net benefits of the two options; discount rates; and the approach taken to valuing environmental effects.

(a) Pricing and electricity benefit estimation

The HEC estimated that the present value of the savings of the hydro option compared with the coal-sourced electricity option was $345.5 million (at 1980 prices and using a discount rate of 5 per cent). This estimate was based on the difference in the unit cost of electricity between the two fuel sources multiplied by forecast demand, which was the same for both fuel sources. The CRES study accepted the HEC's cost estimates but considered that the approach to demand estimation was incorrect. It found that the cost differential, at the same discount rate, was only $189.1 million, or just over half of the HEC's estimate.

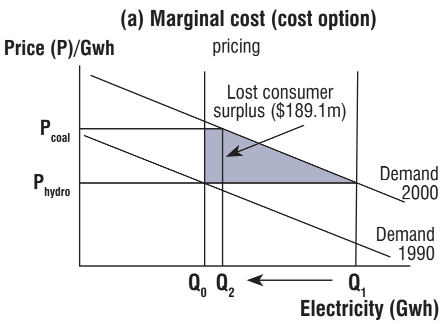


Figure 8.1(a) *The Gordon-below-Franklin proposal: the effect of different pricing assumptions on cost estimates*

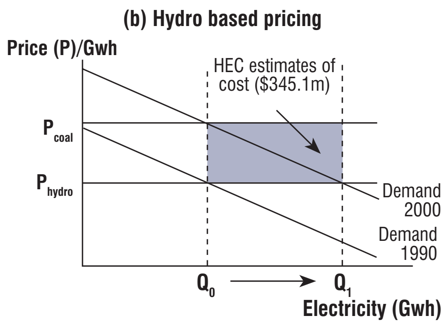


Figure 8.1(b) *The Gordon-below-Franklin proposal: the effect of different pricing assumptions on cost estimates*

The CRES study argued that electricity should be sold to consumers at a price equal to marginal cost - in this case the cost per unit from the *incremental* supply installations. Thus, if the thermal option were to be adopted, electricity prices should reflect the higher real unit costs of power from this source, rather than set at a level which covered average unit cost for the system as a whole. And a higher price would necessarily lead to a reduction in demand for electricity.

Drawing on international evidence, the study used a price elasticity of demand for electricity of -0.8 (that is, a one per cent increase in price induces a long-term reduction in quantity demanded of 0.8 of one per cent). Figure 8.1(a) shows the loss in consumer surplus benefits resulting from adoption of the coal option with electricity (measured in gigawatt hours) priced at the cost of the coal option and consumption at Q_0. Figure 8.1(b) shows the larger economic loss from the coal option with electricity priced at the cost of the hydro option and consumption at Q_1.

Although HEC did not take into account the responsiveness of demand to price, the HEC estimate of the economic cost of the coal option was correct given a policy intention to adhere to an inefficient pricing system based on the cost of the hydro option. In this regard, the CRES study suggested that a transition from hydro-based prices to coal-based prices could be achieved by *delaying* construction of the thermal station until such time as the price of electricity had been increased to a level at which it cleared the market at the *existing* level of capacity. That is, there would be incremental real price increases as demand increased (Figure 8.2) over a number of years.

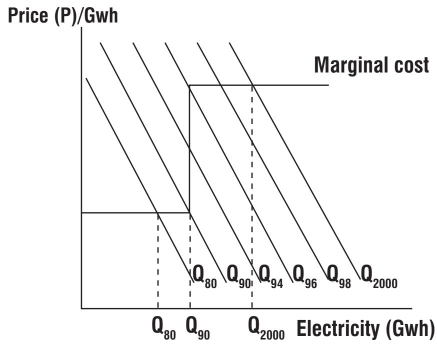


Figure 8.2 *The Gordon-below Franklin proposal: investment timing decisions using rationing by price*

(b) Discount rates

The two options for generating electricity differed significantly in their cost profiles. The capital cost of the hydro option was almost twice that of the thermal option. However, the running costs of the thermal option were around ten times those of the hydro option, largely due to the cost of coal as fuel.

The difference in cost profile made the value selected for the discount rate particularly critical. The higher the discount rate, the lower the present value of the thermal option's fuel costs. Conversely, the lower the discount rate, the higher the present value of those costs.

(c) Environmental effects

In order to value the wilderness preservation benefits associated with the coal based option, the study developed a model as follows:

$$PV_{Wilderness} = z \times \sum_{t=0}^{k} \left[\frac{(1 + w + c)}{1+r} \right]^{t}$$

where w = the rate of growth in willingness to pay;

c = the rate of growth of consumption at given prices;

r = the discount rate; and

z = the value of preservation benefits in year one.

The basic idea of this model is that the value of preserving the Franklin region in its natural state will grow over time. This would result in a much higher capitalised present value of preservation than if the current preservation per annum were to stay constant over time. This is equivalent to using a lower discount rate for the wilderness benefit stream.

As to the specifics, it was assumed that 'w' would be determined primarily by the growth in household incomes and the rate of technological progress. It was assumed that the growth in incomes would be associated with changing consumer preferences in favour of environmental 'goods', while the latter was an indicator of the extent to which the real cost of coal-fired technology could be expected to fall over the life of the hydro project. In the base case, estimates of 3 per cent for income growth (a little below Australian performance in the 1970s) and 1 per cent for technological change gave a value for w of 4 per cent per annum.

The estimate of 'c' was based on recent rates of growth in numbers of recreational visitors to national parks in Australia and overseas. Many studies showed rates of increase of well over 10 per cent per annum, and a figure of 10 per cent was used for the base case. Thus the base case value for 'w+c' was 14 per cent.

In addition, the model allowed for slower growth in visitor numbers after 30 years due to capacity constraints and assumed that changes in preferences for wilderness would cease after 50 years.

The model showed that a stream of benefits starting from $1 worth of wilderness benefits in year one (the value of 'z') would be equal to a present value of $259.76 (at a discount rate of 5 per cent). This number was then divided into the cost differential between the two options to yield a *threshold value* for preservation benefits in year one.

r = 5 per cent

$$\frac{\$189.1m}{\$259.76} = \$727{,}980$$

r = 10 per cent

$$\frac{\$11.5m}{\$76.05} = \$151{,}216$$

The question was then posed implicitly to the decision-maker whether preservation of the wilderness area was worth $727,980 in the first year at a discount rate of 5 per cent (and substantially less at a discount rate of 10 per cent).

As in other cases where future benefits are expected to grow at such a high annual rate, the assumptions in the model can be questioned. Also sensitivity testing was limited: the minimum value of 'w+c' was 10.5 per cent. However, the general model and approach were innovative and sound.

9

Criticisms and Limitations of Cost-Benefit Analysis

9 Criticisms and Limitations of Cost-Benefit Analysis

Cost-benefit analysis has seldom suffered from a shortage of critics. We review the main criticisms of the approach in this chapter.

9.1 False accuracy

It is sometimes argued that the use of the money yardstick for measuring costs and benefits lends a false accuracy to the result of a cost-benefit analysis. Analyses may be criticised for conveying a false sense of accuracy by *including* quantified values for non-monetary effects such as the value of forecast savings in human lives. Such values are often controversial and may diminish the authority of the analysis as a whole. On the other hand, analyses may be criticised for *excluding* intangible effects. Downs and Larkey (1988) state that 'The exclusion of intangibles is important because for many public projects there is a strong suspicion that the intangible effects are more important than the tangible effects.'

Both criticisms have been valid in some cases. However, neither criticism need apply. Analysts should be clear about what can and cannot be quantified reliably and valued, within the resources available to the study. The remaining intangible effects should then be listed and described as fully as possible. There are always matters for judgement. On the one hand, it is necessary to avoid imparting a false accuracy to the estimates. However, it is also essential that analysts accept their responsibility to quantify as much as they reasonably can. As Mishan (1970) put it, after noting that the Roskill Commission on the Third London Airport had adopted an approach that the so-called intangibles were in principle quantifiable, 'the research team has not yielded to the temptation to hand back part of its brief to the political process, which had offered it to the economists in the first place'.

9.2 Self-serving analyses

Cost-benefit analyses have been criticised as too readily serving a vested interest. In particular, assumptions may be biased to make a project 'look good'. This is again a comment on particular analyses, rather than on the method itself. Moreover, one of the objectives of the *Handbook* is to assist those involved in the decision process to uncover biased assumptions whether these involve unrealistic forecasting assumptions, double-counting of benefits, the exclusion of costs, or other problems. As a general rule, those involved in the decision process should be wary of analyses which are not *verbally and numerically explicit* about the assumptions on which they are based, and the reasons for those assumptions.

9.3 Problems with quantification

It is sometimes argued that non-market goods cannot be valued in the same way as goods that are bought and sold in markets. For example, it may be suggested that 'quality of life' attributes and human life itself simply 'cannot be valued'. The problem with this position is that government decisions routinely and necessarily imply *finite and quantified* values in areas where projects and programmes require resources in order to save lives or to improve the physical or mental well-being of individuals in some way. For example, a decision – even by omission – not to provide separated lanes on all roads in Australia implies that human life is valued at less than the average cost of the measure per life thereby saved. However, it would be naive for analysts to fail to recognise the difference between implicit valuation and explicit valuation in areas where people's sensitivities are understandably involved. It is advisable, therefore, always to make clear the margin for error in estimates of 'difficult to quantify' values, and to make clear the assumptions on which the estimates are based.

9.4 Complexity

Cost-benefit analysis is also criticised as being both too complex and too onerous in its information requirements.

In some instances the methodology is indeed complex, but this may only reflect the complexity of the public choice problem involved. Unnecessary complexity should and can be avoided.

With regard to information requirements, it is always important to try to estimate the potential payoff from acquiring more information. It makes little sense to exhaust the entire analytical and research budget in analysing one alternative when there are ten alternative projects to consider. In these circumstances, simplified pre-screening of all alternatives is likely to be a wise course. At the same time, cost-benefit studies can often be replicated time and time again: thus investing in a cost-benefit 'model', and in acquiring data to calibrate that model, can be very worthwhile. For example, many road investment models have proved highly replicable.

9.5 Equity overlooked

Cost-benefit analysis is also criticised for ignoring social equity. There are two main aspects to this criticism. First, it is argued that cost-benefit analysis reflects the basic orientation of economics towards improving welfare irrespective of the identity of the beneficiaries. The criticism is correct in theory but need not be so in practice: that is, the incidence of costs and benefits can and should be clearly set out to assist the decision-maker (as described in Chapter 6).

Second, it is argued that cost-benefit analysis contains a conservative bias because its valuation principle, willingness to pay, depends upon *ability* to pay (ie wealth and income), which is unequally distributed. Again, the criticism is valid in theory but need not be so in practice. Weights may be assigned to benefits which accrue to specific groups, if there is a clear and explicit policy justification for doing so. Also merely *displaying* the incidence of (unweighted) costs and benefits will often provide useful indicators of the equity implications, in income distributional terms, of projects and programmes. It is then up to the political process to trade off equity and efficiency considerations.

Finally, by seeking to quantify consumer choice, cost-benefit analysis is often considerably more equitable in practice than other less rigorous decision-making frameworks in which the actual preferences of individuals occupy a less central, and hence less important, place.

9.6 Limitations of the method

Cost-benefit analyses are likely to be the better if analysts accept that the method, like any analytical approach, has limitations.

The treatment of intangibles (quantification) and the problem of equity have been discussed above. These issues represent *limitations* of the method in the sense that neither is addressed 'automatically' in the cost-benefit process. If the decision-maker is to be in a position properly to take account of intangible considerations and equity concerns, the analyst must, in a sense, go beyond the ordinary requirements of a cost-benefit analysis.

Similarly, when the decision-maker's interest is naturally focused on the 'bottom line', it is easy for the analysis itself to be rather obscure. No analysis is better than the assumptions on which it is based and, in the interest of 'quality control', assumptions should always be made explicit. So the limitation, in a sense, is that the analyst can, if he or she chooses and if readers are not alert, take advantage of the user's interest in the outcome of the analysis to conceal doubtful or flawed assumptions.

Finally, it should be noted that, in cost-benefit analysis, a project scenario is compared with an alternative scenario based on estimates of what would have happened in the absence of the project (the base case). Although the base case represents a continuation of the present situation, some changes are likely and have to be forecast. Therefore, the evaluation is based on a comparison of two forecast uncertain scenarios. This is a limitation of cost-benefit analysis. However, it is also a limitation of any other method of social evaluation.

10

Alternative Methodologies: Financial Evaluation

10 Alternative Methodologies: Financial Evaluation

This chapter examines the differences between financial evaluation and cost-benefit analysis; the circumstances in which a financial evaluation should be undertaken; discount rates in financial evaluation; and some specific applications.

10.1 The concept of financial evaluation

A financial evaluation or appraisal is a cash flow analysis, generally a discounted cash flow analysis. A financial analysis examines the cash income and expenditure of a project or programme as it impacts on a particular agency, usually the agency that is mainly responsible for carrying out the project or programme. The agency may be a private firm, a government department, a publicly owned corporation, or even the whole of government. Thus a financial evaluation assesses the impact of a project or programme on the agency's own financial performance. Usually the analysis is done in constant prices.

Table 10.1 *Cost-benefit analysis and financial evaluation compared*

Issue	Included in a cost-benefit analysis	Included in a financial evaluation
Externalities	Yes	No
Non-marketed inputs and outputs	Yes	Marketable opportunity costs (eg land) included.
Shadow pricing	Yes	No
Distributional analysis	Yes	No
Interest and depreciation expenses	No	Depreciation not included. Interest not included, unless analysis includes borrowing.

A financial evaluation is quite different from a cost-benefit analysis. The latter considers non-cash costs and benefits and costs and benefits to the community as a whole. The differences between cost-benefit analysis and financial evaluation (which should not be confused with *accounting analysis or financial ratio analysis*) are summarised by reference to some of the key issues discussed in earlier chapters in the table below.

It is important to note that a financial evaluation still makes use of the concept of opportunity cost: but it is the opportunity cost faced by the organisation (for example, the Australian Government or a specific Department) rather than by the community as a whole. Externalities, shadow prices and distributional analysis have no place in financial evaluation. Similarly, non-marketed costs and benefits are excluded from the analysis *unless* they reflect a relevant opportunity cost that affects the profitability of the operations of the organisation itself. Thus, a roads department would *exclude* from a financial evaluation of a road project estimates of time savings to road users, but would *include* the potential sale value of the publicly owned land on which it planned to build the road. Similarly, an agency planning the collocation of its staff in a single building might be justified in quantifying the time savings during working hours from easier communication between staff if this saved on labour costs. However, the agency would not quantify the time savings (or losses) from employees' changed commuting trips unless these affected the functioning of the agency as a corporate entity.

Note also that financial evaluation is *similar* to cost-benefit analysis in not including depreciation expenses and generally not including interest costs. Capital expenditures should be recorded in full when items are purchased. The discounting procedure then captures the opportunity cost over time of the capital and resources tied up in the project. For a fully equity-funded project, including the use of funds from consolidated revenue, discounting a net income stream that included expenditures and interest costs would represent a double-counting of project costs.

However, where a project is funded partly by specific borrowing, these loans on the one hand and the interest and loan repayments on the other may be included in a financial analysis that aims to simulate all the cash flows of the project. In this case, the analysis may need to allow for inflation.

Depreciation expenses, similarly, involve a *spreading* of capital costs across periods. Depreciation is a necessary feature of accounting statements but has no place in financial evaluation (or in cost-benefit analysis) where costs are recorded in full at the time that the cash payment is made. Again, inclusion of depreciation expenses represents a double-counting of costs.

10.2 Uses of financial evaluation

The main reason to undertake a financial evaluation of a revenue-generating project is to answer the question 'is it a good investment for the organisation?' This contrasts with the question posed through a cost-benefit analysis, 'is it a good investment for the economy or for society?'

Cost-benefit analysis is generally more important than a financial analysis for determining public policy or the viability of projects. It is quite possible for public projects to be in the public interest and not financially viable. Even toll roads may be justified by cost-benefit studies, which show the general transport benefits over the road network, but not be financially viable. Also for large revenue-earning projects (such as power stations, or major bridges and tunnels subject to tolls), or for revenue-earning projects, whether public or private, that involve significant externalities (eg pulp mills, mine and timber projects in certain situations), a cost-benefit analysis is often required.

Nevertheless, financial evaluations are often important especially when financial viability is a necessary condition of a project proceeding. If a *private* project is not financially viable, it is unlikely to proceed. Thus it may be a waste of resources to undertake a cost-benefit analysis. *A public* project that is not financially viable may also not proceed if the sponsoring agency is constrained not to make a financial loss. Where agencies have a corporate structure, a financial analysis is required to determine the impact of the project on the agency's net worth. And, in some cases governments require an analysis of the impacts of a project or policy, say a regulation, on the public finances.

Alternatively, a public project that is required to make a financial return on capital, if it operates in less than perfectly competitive conditions, may be able to structure its prices and output so that it makes a profit even though it is not economically efficient (because prices exceed marginal costs). However, it is important that the price-output level selected in the financial evaluation is taken fully into account in any cost-benefit analysis. If prices are set above marginal cost and consumption is less than it would be at when price is set equal to marginal cost (Chapter 2), aggregate *benefits* in the cost-benefit analysis are likely to be lower than they otherwise would be. This may be overlooked if a financial analysis is not made.

10.3 Discount rates in financial evaluation

The principles applying to the choice of discount rate in financial evaluation are similar to those appropriate in the cost-benefit analysis context as outlined in Chapter 5. Thus, real interest rates should be used when constant prices are used.

When organisations undertaking financial evaluations are required to operate on a commercial basis, a differentiated discount rate that is specific to the main activity should normally be used. However, the one organisation might employ different discount rates for different activities. The Capital Asset Pricing Model (CAPM) framework provides a basis for setting differentiated discount rates (and target rates of return). When a real rate of discount is required, care needs to be taken to ensure that inflation is dealt with properly in estimating a discount rate using the CAPM method.

(a) Altering the timing pattern of payments

In some cases, a project under consideration involves only an adjustment to the timing of a pattern of payments that is known with certainty and the key question is 'what is the approximate cost to the Australian Government in terms of additional public debt interest outlays?' Where the project is under one year's duration, the appropriate discount rate is usually the weighted average yield of Treasury Notes allotted in the most recent tender. When 'projects' involving altered payment timings exceed two years, the appropriate risk-free rate will usually be the ten year Treasury bond rate.

It should be noted that both Treasury Notes and the bond rate are stated in nominal terms. Where the analysis is conducted in real terms, the discount rate must also be a real value. A method for converting nominal discount rates into real ones is described in Section 4.8. On the other hand, tax paying agencies should normally use nominal cash flows and nominal discount rates. Since tax is levied on nominal rather than real income, this is necessary to ensure accurate results.

(b) 'Lease versus buy' decisions

The decision to buy or lease equipment can also be viewed as a comparison of alternative timing patterns for similar payments. The choice is typically between borrowing a larger amount up front in order to purchase the item or making periodic payments – either as an ordinary cost expense or through a series of smaller borrowings. In these cases also, it is important to use a discount rate that approximates the Commonwealth's actual cost of funds (ie the Treasury bond rate or a short-term borrowing rate). If a higher discount rate is used, the result will usually be biased in favour of the leasing alternative. With a higher discount rate, the cost of the later-occurring lease payments will be inappropriately reduced relative to the cost of the early-occurring 'buy' payments.

10.4 Financial evaluation of property proposals

The process of decision-making for long-term Commonwealth office accommodation projects involves extensive use of financial evaluation. It therefore provides a useful illustration of the basic methodology. It also helps to point up some contrasts between financial evaluation and cost-benefit analysis.

Options

The Australian Government's decisions on access to office accommodation space involve, in most instances, a choice between:

- owning an existing or new building;
- leasing; and
- pre-commitment leasing (of new buildings only).

There is often also a 'do nothing' or 'do little' option, which depends on the actual existing situation. For example, if the organisation occupies leased space, the minimum option might involve refurbishment of this accommodation rather than leasing a new or alternative building. Similarly, if the organisation were occupying owned space, the minimum option might involve refurbishment of this accommodation rather than leasing a new or alternative building.

In the *owning* case, most costs are incurred *upfront* and have, in a sense, to be financed through occupancy – and there are also residual assets (in the building and the land that it occupies) at the end of the period. The residual value of those assets is the greater of the present value of income beyond the end of the period of the analysis and the sale value of the assets.

Instalment purchase is a variation of the owning option whereby the Australian Government purchases a building from a developer in planned annual instalments rather than incurring costs as they fall due. The option exposes the Australian Government to any flow-on effect from the developer's own borrowing costs, which are likely to be higher than those of the Australian Government. The offsetting advantage is that instalment purchase may offer is a smoother pattern of outlays over a specified number of years.

In the lease case, financial costs are incurred *progressively;* also there are no residual assets and hence no possibility of capital gains and losses. *A pre-commitment lease* is a variant of this option in which the customer contracts to lease a building from a developer prior to its construction. In some instances, and particularly where there is no appropriate accommodation available in the private sector for leasing, pre-commitment leasing becomes for the Australian Government the effective practical alternative to owning in its own right.

Taxation considerations may complicate matters. If the Australian Government leases a building (on an ordinary or a pre-commitment basis), the rent income that the owner receives from the Australian Government is subject to income tax. Thus any incremental taxation revenue reduces the true or net cost to the Australian Government of leasing. In this respect the Australian Government differs from *any private* lessee, for whom there is no potential 'clawback' from its leasing costs.

10.5 Financial evaluation of a property proposal: case study

1 Background

This case study is based on a financial property evaluation undertaken by the Department of Finance and Administration in 2003. The objective of the financial evaluation was to examine the feasibility of refurbishing, and subsequently tenanting out, an existing commercial building owned by the Australian Government. Office accommodation in the building is primarily A Grade in quality. The building includes car parking, which is charged to tenants in addition to the office space rent.

To justify the Government's long-term investment in retaining the property, the project had to be financially viable and to be comparable to a private sector equivalent. The Australian Government's required rate of return on property is set nominally at 10 per cent (which is approximately 7 per cent in real terms) – the Commonwealth Property Principles (CPP) rate.

2 Methodology

One of the methodologies used to determine the viability (financially) of refurbishing the building was discounted cash flow (DCF). This is a common method for determining the value of commercial properties. The DCF was conducted on the basis of a 20-year lease term but inevitably involved making several assumptions. Some key assumptions are outlined in the table below:

Table 10.2 *Assumptions*

ASSUMPTIONS	
Building Value	$5,000,000
Rent growth – All Areas	5.0%
Outgoing escalation	5.0%
Rent Reviews	Annual
Discount Rate (target Internal Rate of Return)	10.0%
Average inflation level	3 to 4%
Base office rent	$350 per square metre
Development cost	$35,000,000
Mid-term refurbishment (today's values escalated)	$100 per square metre
Operating costs	$50 per square metre

The financial evaluation was conducted using a structured and logical process. The first step involved analysing the construction (including development and refurbishment) costs, ongoing building management costs, and consultants' costs to determine the overall cost of the proposal. All costs associated with the project were modelled using industry benchmarks and forecasts. The second step was to apply a market-based rental for leasing out this quality of building. The market rate for A Grade office space was estimated at $350 per square metre. This rental was escalated each year by a fixed rate of 5.0 per cent. The Consumer Price Index, as published by the Australian Bureau of Statistics, can also be used as a basis for estimating rental increases.

The third step was to discount the rental (office and car-parking) stream (including escalations) and operating expenses (including escalations) over the life of the tenancy (20 years) to determine the net cash flows. These net cash flows, including a terminal value of the project in the final year of the lease term, were then discounted back to determine the Net Present Value (NPV). In addition to calculating the NPV, the Internal Rate of Return (IRR) of the project was also determined – taking into account the cost of the refurbishment in the early years and the future income stream in subsequent years.

Various scenarios of rental, rental escalation and construction costs were modelled to determine their impact on the NPV and to determine whether under these scenarios the project would outperform or match the hurdle rate of 10 per cent. In addition, different rental structures (which fall within market ranges) were analysed to see whether they would achieve an IRR that would exceed the required hurdle rate. Note: the cash flow stream may also be varied by offering tenants a choice (such as paying higher rent with lower escalations) which would still be financially feasible (i.e. outperforms or matches the hurdle rate).

If an optimal rental and escalation could be found that was commercially achievable (that is, the tenants are willing to pay rent at this optimal level) and financially acceptable (i.e. the IRR exceeded the hurdle rate), the project would be financially viable to the Australian Government.

3 Results and sensitivity analysis

The table below outlines how the net cash flows of the proposal were determined.

Table 10.3 *Cash flows*

Year Commencing			Year 0 July 2004	Year 1 July 2005	…	Year 21 July 2025	Year 22 July 2026
Growth rate Adopted				5.0%		5.0%	5.0%
INCOME	**AREA**	**$ per m²**					
A Grade Office Space	10,000 m²	$350	$3,500,000			$8,844326	$9,286,542
Basement	1000 m²	$100	$100,000			$240,662	$252,695
Total car spaces *(Cars in open area + under cover)*	11,000 m²		$3,600,000			$9,084,988	$9,539,237
Cars in open area	100	$500	$50,000			$120,331	$126,348
Cars under cover	50	$1,500	$75,000			$180,496	$189,521
Total car spaces *(Cars in open area + under cover)*	150		$125,000			$300,827	$315,869
Gross Income			**$3,725,000**	**$0**		**$9,385,815**	**$9,855,106**
less Operating expenses	11,000 m²	$50	$550,000			$1,522,187	$1,598,296
Net Income			**$3,175,000**	**$0**		**$7,863,628**	**$8,256,810**
INVESTMENT COST (land and building value + capital inputs)			$5,000,000	-$18,500,000		$0	$0
SALE PRICE							
Capitalisation rate	10%						$82,568,098
Selling costs	5%						$4,128,405
NET PROCEEDS			$0	$0		$0	$86,696,503
NET CASH FLOW			**-$5,000,000**	**-$18,500,00**		**$7,863,628**	**$94,953,312**

The net cash flows were then discounted by 10 per cent to determine the NPV. For example, the present value in the final year (year 22) was calculated as follows:

$$\text{Present Value} = \frac{NCF}{(1+i)^t}$$

$$= \frac{\$94,953,312}{(1+0.10)^{22}}$$

$$=\$11,664,632$$

The estimated NPV of the project was $1,453,624 and the estimated IRR was 11.41 per cent. Based on this analysis, the project will exceed the rate of return target i.e. the IRR exceeds the hurdle rate of 10 per cent.

A sensitivity analysis was conducted as part of the evaluation. This involved changing the magnitude of key variables and measuring their modified impact on the NPV. For example, the impact of changes to the base office rent rate was assessed. If the base rate were to fall from $350 per square metre to $340, the NPV will fall by $1,111,141 to $342,483 (therefore generating an IRR of 11.1 per cent). Alternatively, an increase in rent from $350 per square metre to $360 per square metre results in a $1,111,141 increase in the NPV to $2,564,765 (therefore generating an IRR of 11.72 per cent).

4 Conclusion

Based on the financial analysis, the refurbishment and tenanting of the building will result in a net benefit of around $1.5 million and generates an IRR in excess of the hurdle rate of 10 per cent. Therefore, under the assumptions adopted, the refurbishment and subsequent tenanting out of the building is a financially viable option.

10.6 Main points in summary

- A financial evaluation compares receipts and expenditures, generating a net cash flow. This is usually conducted in constant prices and discounted to yield a discounted net present value or cost.
- A financial evaluation is conducted from the perspective of the organisation, not from that of the community as a whole.
- Financial evaluations are used to determine the financial viability of projects or, in other words, whether receipts will cover expenditures and provide a return on capital. They are required when an agency is required to operate commercially.
- The discount rate in financial evaluation should be selected on the same basis as in cost-benefit analysis (Chapter 5). However, where a project involves only an alteration to the timing profile of a fixed pattern of payments and where market risk is not a relevant concern, the discount rate should reflect the direct cost of funds to the Australian Government.

11

Alternative Methodologies: Cost-Effectiveness Analysis

11 Alternative Methodologies: Cost-Effectiveness Analysis

Cost-effectiveness analysis differs from cost-benefit analysis in that benefits are not expressed in money units. Instead, benefits are expressed in physical units (for example, tonnes of coal, lives saved) while costs, as in cost-benefit analysis, are expressed in money terms. Thus cost-effectiveness analysis compares alternatives in terms of their effectiveness and their cost.

Cost-effectiveness analysis provides a priority ranking of projects or programmes on the basis of comparative 'cost per unit of effectiveness', or alternatively, of comparative 'units of effectiveness per dollar'. Sometimes analyses which compare only the costs of alternatives are described as cost-effectiveness analyses: for the description to be valid, the value of output of the alternatives must be the same – that is, the alternatives must be equally effective.

Two examples may illustrate the nature of this type of analysis. The cost-effectiveness of alternative strategies for the prevention of heart disease has been analysed in terms of the *cost per prevented case* (Hall et al, 1988). The strategies assessed included the 'whole population' media campaign approach (considered most cost-effective), an approach involving screening the population at large to identify high-risk individuals, and identification of groups that are likely to be high risk (the latter considered least cost-effective).

Secondly, a study carried out by the United States Department of Transportation (summarised in Downs and Larkey (1986)) ranked road safety improvement measures in order of their cost-effectiveness. The study assessed and ranked 37 road safety measures in order of the *cost per fatality forestalled*. The measures ranged from mandatory safety belt usage at one extreme ($US500 per fatality forestalled), through measures such as alcohol safety action counter-measures and median strip barriers, to new roadway alignments and gradients ($US7,680 per fatality forestalled) at the least cost-effective end.

11.1 When to use cost-effectiveness analysis

Cost-effectiveness analysis relaxes the requirement of cost-benefit analysis that benefits, as well as costs, be specified as far as possible in money terms. The method can be useful where it is easier to identify benefits than to value them. It is not surprising therefore to find that cost-effectiveness analysis is used widely in health, safety and education fields where there are difficulties in expressing in money terms the benefits of output values such as reduced mortality, reduced morbidity, and educational quality.

In another sense, however, cost-effectiveness analysis is more stringent in its analytical requirements than is cost-benefit analysis. The method tends to focus on a *single* measure of effectiveness or category of benefit, to the exclusion of all others. This means that the analyst must be satisfied that the chosen measure of effectiveness adequately captures the *predominant* output and/or impact of all of the alternatives under consideration. If this condition is not met, the resulting cost-effectiveness ranking of alternatives has little or no validity.

Even where the condition is substantially met, the cost-effectiveness method is likely to involve some loss of information and simplification relative to a cost-benefit approach. To illustrate, in the road safety example one might also wish to know the extent to which the various control actions avert property damage and non-fatal injuries from accidents. Considering these other categories of benefit and then calculating net benefits might lead to a different ranking. The measure considered most cost-effective, mandatory seat belt usage, would probably reduce the severity of non-fatal injuries but do little or nothing to reduce property damage from accidents. On the other hand, the least cost-effective actions, such as bridge widening and roadway and gradient alignment, would avert accidents altogether, thus reducing property damage, injuries, and loss of life. It is always important therefore to understand the simplification involved when using cost-effectiveness analysis.

There are at least three other contexts in which cost-effectiveness analysis is appropriate and useful. However, in each it is a precondition that the alternatives being compared should have a common predominant effect.

First, cost-effectiveness is useful when the issue is the optimal use of a fixed (or substantially fixed) quantity of resources; that is, where it is necessary to prioritise alternative expenditure options but where the more fundamental questions of whether the Government should be involved in the activity at all, or of how much the Government should be willing to spend, are not at issue.

Second, and relatedly, the method is applicable when projects or programmes are in place and expected to continue, but not necessarily in their current form; that is, where there is an interest in improving the allocation of resources but within a framework of set policy objectives.

Third, cost-effectiveness analysis may be useful when a large number of alternatives are under consideration. Because cost-benefit analysis aims to be comprehensive in measuring costs and benefits, the number of alternatives that can be compared may be limited. This is not an impediment in cost-effectiveness analysis where a more restricted set of benefits is assessed. Cost-effectiveness rankings are also readily intelligible for purposes of comparison.

11.2 When not to use cost-effectiveness analysis

Unlike cost-benefit analysis, cost-effectiveness analysis provides no absolute criterion for accepting or rejecting projects. In cost-benefit analysis projects are acceptable (subject to budget and other constraints) if the present value of their net benefits is no less than zero; in cost-effectiveness analysis, however, we have only a self-referencing ranking of projects. Because of this difference, cost-effectiveness analysis should as far as possible be avoided when decision-makers are seeking information to aid a decision on the level of resources to allocate to a particular area.

In some cases it is possible to introduce an 'external' monetary benchmark, in effect superimposing a rough cost-benefit framework on the cost-effectiveness analysis. For example, in the study of 37 road safety measures, Government could allocate resources to all measures where the estimated cost per life saved is below a benchmark such as $2.0 million per life saved, but not where the cost per life saved is higher than this (see Appendix II). However, it has to be recognised that in many cases off the shelf valuations in money terms may not be available.

Secondly, cost-effectiveness analysis should not be used when alternatives differ significantly in their predominant effects (output values). Any cost-effectiveness ranking which ignores such differences can only be misleading.

11.3 Measures of effectiveness

It follows from the preceding section that considerable care is needed in identifying appropriate measures of effectiveness in cost-effectiveness analysis. As a general rule, the closer the measure is to the ultimate objective of the activity, the more likely it is to avoid the dangers of overlooking significant benefits from the activity, and of not being meaningfully comparable with the other alternatives under consideration. Thus in assessing a health-related programme, estimates of the 'cost per hospital bed-day', which are based on intermediate outputs, may be inferior to estimates of the 'cost per successful case', which are based on the final output or outcome. Of course, estimates of the former type may be useful in terms of providing basic management information on the use of inputs; the problem is that comparing unit cost information is only of value when the objectives of the activities being compared are themselves similar.

Measures of effectiveness may also imply a bias towards particular client groups. For example, ranking health policy alternatives in terms of 'cost per life saved' may favour options that benefit older people. On the other hand, policy alternatives that are assessed on the basis of 'costs per year of life saved' will tend to bias decisions in favour of younger people. Such bias can be overcome by adjusting the chosen measure for the improvement in quality of life which is expected to result (Australian Institute of Health 1990, Drummond et al, 1987).

11.4 Putting the analysis together

The end product of a cost-effectiveness analysis is the ratio of cost to the measure of effectiveness for each alternative being considered. Because cost-effectiveness analysis is well suited to the analysis of programmes that have been in place for a period of time, it should usually be possible to obtain a substantial amount of information in both the cost and effectiveness categories. Additionally, a large amount of feedback can be expected from the 'programme community' – that is, its implementers, supporters and clients. These considerations imply the need for a particularly high standard of care and thoroughness in the collection and analysis of data, and presentation of results.

It is also important in cost-effectiveness studies to try to separate out the impact of the project on effectiveness from that of variables over which the project has little or no control. Formal quantitative estimates would depend on the availability of an adequate number of observations to provide a sample for a regression model. This is a particular problem where final rather than intermediate effectiveness measures are used. Yet if it is not done, improvements in effectiveness can be erroneously assigned to spending on a particular programme.

11.5 Cost-effectiveness analysis of new medical technologies

The following case study is based on two assessment reports released by the Medical Services Advisory Committee (MSAC) in August 2001.[3]

1 Background

It is Australian Government policy that an evidence-based review, including cost-effectiveness analysis, be undertaken before a new medical technology becomes eligible for funding under Medicare benefits arrangements. In this context, 'technology' means processes of care, not just devices or products. Reviews are conducted by the independent and expert MSAC. This case study relates to two technologies that were the subject of medical industry applications to MSAC. The technologies are listed and briefly explained below.

- Photodynamic therapy (PDT) with verteporfin for macular degeneration. This is a treatment for a form of macular degeneration, a disease which causes vision loss and eventually blindess, especially in older people. There is no other treatment which is considered standard therapy for the particular form of macular degeneration for which PDT was reviewed.
- Near patient cholesterol testing (NPCT). Cholesterol testing is widely used in Australia but Medicare benefits are limited to tests performed in a pathology laboratory following a referral. The application was for consideration of cholesterol testing in a primary care (that is, general practice) setting.

2 Methodology

MSAC conducted an incremental cost-effectiveness analysis taking into account whole of health system costs (that is, 'who pays' does not figure in evaluations, and costs are normally limited to health system costs). The process involved:

- defining relevant research questions. For example, which patients would the technology benefit and what is the health outcome being sought?
- undertaking a systematic review of clinical evidence for health benefits of the technology; and
- identifying costs of the technology, both immediate and downstream. This is usually achieved through a mixture of analysis of historical resource use and modelling.

[3] These reviews (numbers 1026 and 1039) can be obtained from the MSAC website at www.msac.gov.au

The PDT review considered evidence from clinical trials including use of a placebo. Outcomes of the clinical trials were expressed in terms of loss of visual acuity assessed by whether patients had lost the ability to read fifteen or less 'lines' on an eye chart. Given that this is not a meaningful measure of health benefit for cost-effectiveness analysis, economic analysis was performed in terms of costs per year of vision year gained. It is important in cost-effective analysis that outcomes are measured in terms that are useful when put into an economic analysis, even if they do not allow direct comparison with other health outcomes. For example, trials of some treatments for coronary artery disease are reported in terms of lumen patency, that is the internal diameter of the coronary arteries before and after treatment. However cost per additional millimetre of lumen is not useful for decision making compared with, say cost per adverse cardiac event avoided.

Resources taken into account included costs for an average course of treatment based on clinical trials, applicant data and Medicare benefits data for related services. Account was also taken of resource use avoided, such as community nursing. This inclusion of non-health system costs was considered slightly unusual for MSAC.

The NPCT review analysed how many additional people would be found to have elevated cholesterol as a result of provision of service through primary care setting compared with referral to laboratories, the additional health benefits that would accrue to these individuals from being so identified, and the costs of NPCT.

Compared with the PDT review, substantially more modelling was required to estimate clinical effects and cost-effectiveness for NPCT. Although there was trial information on the diagnostic performance of the tests, there was little clinical data on how this might affect patient health outcomes. Therefore, decision analytic models were developed to compare the laboratory and primary care scenarios based on performance of the test, data on prevalence of elevated cholesterol in the community, overseas data on rates of testing comparing primary carers who perform tests themselves versus primary carers who refer patients for testing, and evidence on outcomes (including mortality rates) for patients with elevated cholesterol who do and do not have lipid lowering therapy. Resources included costs of testing and lipid-lowering therapy. Incremental cost-effectiveness ratios (ICERs) were calculated for cost per additional patient detected with elevated cholesterol, cost per additional patient reaching target lipid levels and cost per life year saved.

3 Results

The PDT review found that the treatment retarded rates of vision loss in the patient group with the relevant kind of macular degeneration. The economic analysis found the ICER was $26,850 to $35,453 per vision year gained (at 2001 prices) for treatment effects of up to two years - the length of patient follow-up in the clinical trials. The range resulted from statistical uncertainty in the trial results and sensitivity analyses, which varied assumptions about resources use or use avoidance. Analyses were performed for a five-year timeframe. This produced ICERs ranging from $6,120 to $20,935 per vision year gained. These findings were more uncertain due to assumptions that had to be made about duration of retardation of vision loss due to the treatment.

The PDT review produced ICERs of $392 per additional patient detected with elevated cholesterol and $1,287 per patient achieving target lipid levels. These may appear to be attractive figures, however the analyses also estimated the cost per life year gained at $132,934 (with a range of $48,699 to $188,189 in sensitivity analyses) at 2001 prices. This again highlights the importance of choosing relevant outcomes when doing CEA.

The high ICER for life years gained was driven by a number of factors. While the incremental cost per patient of NPCT testing was small, and some additional patients were detected with elevated lipid levels:

- overseas evidence suggested a doubling to tripling of the rate of testing;
- there was only a small change in numbers of patients achieving target lipid levels; and
- the average survival gain per patient tested was extremely small. In fact, as the MSAC report noted, to find a difference at all the analysis had to be performed at a level of arithmetic precision probably not warranted by the available data.

4 Conclusions

For the PDT proposal, MSAC recommended that funding of over $30 million per year be made available for the relevant patient group for this purpose.

On the other hand, in terms of the NCPT proposal, MSAC recommended that it should not be eligible for funding under Medicare benefits arrangements. However, MSAC recommended that the technology should be investigated further. Australian trials of NPCT, together with other new patient tests, are being developed.

11.6 The main points in summary

- Cost-effectiveness analysis differs from cost-benefit analysis in that benefits are expressed in physical units rather than in money units; costs, as in cost-benefit analysis, are expressed in money terms.
- In relaxing the requirement of cost-benefit analysis that benefits, as well as costs, be specified as far as possible in money terms, cost-effectiveness analysis is particularly useful in areas (such as health and safety) where it is often easier to specify benefits than it is to value them.
- Because cost-effectiveness analysis focuses on a single measure of effectiveness, to the exclusion of all others, the analyst must be satisfied that the measure of effectiveness adequately captures the predominant output and/or impact of all of the alternatives under consideration. This is a stringent condition to meet. Even where it is met, the cost-effectiveness method is likely to involve some loss of information and simplification relative to a cost-benefit approach.

11 Alternative Methodologies: Cost-Effectiveness Analysis

- If satisfactory effectiveness measures can be found, cost-effectiveness analysis is a useful technique when the issue is the optimal use of a fixed (or substantially fixed) quantity of resources; or where there is an interest in improving the allocation of resources but within a framework of set policy objectives. It may also be useful when a large number of alternatives are under consideration.

- Unlike cost-benefit analysis, with its rule of accepting projects the benefits of which are no less than zero, cost-effectiveness analysis provides no absolute criterion for acceptance and rejection of projects. Because of this difference, it should be avoided, if possible, when decision-makers wish to know whether an activity is worthwhile, and/or how much they should be willing to allocate to it.

12

Concluding Remarks

12 Concluding Remarks

When cost-benefit analysis is used in a decision-making context, the decision-maker can expect to be presented with a quantitative comparison of options together with supporting information on the costs and benefits that have resisted quantification ('intangibles') and on distributional or equity considerations. Thus the decision-maker may be presented with several 'bundles' of information – which can only be tied together with the use of individual or collective judgement.

This observation reinforces the fundamental point that cost-benefit analysis is an *information aid* to decision-making, and not a substitute for it. There is invariably a large role for judgement, based on a wide range of considerations, including social, ethical and political ones, as well as those relating to residual measurement uncertainties.

Nevertheless, the role of cost-benefit analysis as a decision-making aid is often an important one. In particular, the method can clarify the relationship between the cost of a project or programme and its expected impact. This arises from the *commensurability* of costs and benefits that the method requires, as well as from the concept of the 'benefit' itself: that is, as a measure of the value of the 'product' to the consumer or end-user rather than to the supplier or to other interest groups. In this way, cost-benefit analysis is focused sharply on the higher level goals and objectives of the project or programme, rather than on the intermediate and ultimately less significant objectives.

Cost-benefit analysis has an important role to play *in programme evaluation* – that is, in the evaluation particularly of the *effectiveness and appropriateness* of Government programmes. Other evaluation methods do not insist on the use of a common measure for costs (inputs) and benefits (outcomes); but cost-benefit analysis remains similar to them in its orientation towards the assessment of the *effectiveness* of particular activities.

The stringency of the cost-benefit method – in particular, the need to have commensurable costs and benefits – makes it particularly well suited for ex ante decision-making, when substantial resource allocation is most likely to be at issue. Yet, provided that benefits are sufficiently quantifiable, the method can also be used at later stages in the project/programme cycle. Indeed, it should be used whenever it can offer relevant information to intended users of that information.

Finally, it is useful to consider the implications for format and presentation of the use of cost-benefit analysis (together with cost-effectiveness analysis and financial evaluation also) as an information aid. It is essential that an analysis, which is an information aid, is highly *user friendly*. The *assumptions* underlying the analysis should be presented clearly and comprehensively, both numerically and verbally. The main results should be demonstrated on a one-page spreadsheet.

Cost-benefit analysis is a method which is *explicit* about the economic opportunity costs and the economic impacts of decisions; much is lost if the presentation itself is not similarly explicit.

Appendices

Appendix I: Avoidable Pitfalls

Mistaking transfers for costs or benefits

Unless it is judged that one individual or group derives more value from the resources involved than another individual or group, transfer payments do not affect production or consumption possibilities and therefore the welfare of the community as a whole. Instead they make someone better off at the expense of others and therefore should not be included in cost-benefit analyses. However, distributional incidence tables should be included, to help decision-makers balance resource allocation and distributional implications, of the project. Constructing a distribution table is also helpful in identifying transfers.

Double-counting costs and benefits through inclusion of secondary effects

Project effects that are the consequences of costs and benefits which have been incurred (and therefore already counted) should not themselves be counted as costs and benefits. An example is the increased real estate values caused by the travel time savings resulting from a road upgrading. Projects producing intermediate goods (such as transport) are especially prone to producing such effects, which often represent *transfers* of costs and benefits to other parties.

Routine assessment of multiplier effects

Inclusion of a multiplier effect from income and spending generated by a project is justified only when (a) the affected resources would otherwise have been unemployed and (b) the activities displaced by the project would not also have made use of the idle resources. Careful empirical justification is necessary in using multipliers.

'Before/after' instead of 'with/without'

Measured costs and benefits should represent the changes that are incremental to the best estimate of what would have happened in the absence of the project. It is incorrect to calculate costs and benefits by reference to the *pre-project* situation as this implies that no further relevant changes would have eventuated in the absence of the project.

Looking at sunk costs instead of opportunity costs

An asset that is owned prior to the project should not be treated as 'sunk' and therefore of no value if the asset has an alternative use with a positive realisable value. Errors can be avoided by keeping in mind the concept of opportunity cost (that is, the value in the best alternative use). Use of the concept will also prevent incorrect assignment of accounting or historical costs to a project – that is, presuming an asset does have a value when it has *no* alternative use and is indeed 'sunk'.

Including interest payments on capital

The opportunity cost associated with the use over time of resources in *this* project rather than an alternative is captured by the discount rate and the discounting procedure. Thus to include interest payments on borrowed funds, or dividend payments on equity, in the analysis is to *double-count* project costs. This is true in cost-benefit analysis and financial evaluation (unless the latter explicitly includes both loans received as income and loan repayments and interest payments as expenses).

Including charges for capital depreciation in operating costs

Capital costs are recorded on a lump-sum or cash basis in cost-benefit analysis in the period in which they occur. To include periodic depreciation (in line with accounting practice) in addition will lead to double counting of these costs. Again this applies in both cost-benefit analysis and financial evaluation.

Excluding all taxes and subsidies in estimating shadow prices

Decisions on whether or not to exclude taxes and subsidies in estimating shadow prices turn on whether the input or output being valued is incremental to the project or displaces existing supply or output. In the output case, *incremental* output is valued at its market price (that is, inclusive of taxes and exclusive of subsidies) since this is the price that consumers are willing to pay. However, output that is displaced should be valued at its economic cost: that is, market price less taxes plus subsidies. Similarly, the incremental project *input* is valued at its economic cost while the project input that is displaced (that is, diverted from another producer) is valued at its market price.

Choosing between projects on the basis of internal rates of return or benefit-cost ratios

The fundamental criterion for choosing between projects is the maximisation of net present value. Ranking projects on the basis of internal rates of return, benefit-cost ratios or payback periods may lead to an incorrect choice – in the sense that overlooked options may have a higher net present value. But the latter three criteria may provide useful *supplements* to the net present value rule in providing information to decision-makers.

Forecasting bias

Overestimation of future benefits and underestimation of future costs may be minimised if conservative assumptions are adopted regarding future rates of growth – erring on the low side in respect of benefits and erring on the high side in respect of costs. Also, complete disclosure of the assumptions underlying forecasts will help to minimise forecasting bias.

Appendix II: Measuring Costs and Benefits

Measuring costs and benefits

Chapter 3 describes the main valuation principles and their application especially to marketed goods and factors of production. A core principle is that goods are worth what people are willing to pay for them, which is equivalent to saying that they are worth what people are willing to give up to obtain them. This appendix describes some important techniques for valuing goods that do not have obvious markets (though they may have near markets) as well as public goods and externalities. In some cases, the externalities are negative and the value accordingly is also negative.[4]

It is useful to note first that there are, broadly speaking, three main categories of value – productivity, health and amenity benefits. Productivity benefits are increases in the quantity or quality of goods or reductions in production costs. Health benefits are increased longevity or any improvement in health status. Amenity benefits are non-market improvements in recreational experiences or the quality of life. There are of course many kinds of benefit within each of these categories. Nevertheless, this classification helps us to understand the nature of the benefits that have to be valued.

Note also that we often need to know what people are willing to pay (WTP) for different quantities of public goods. This means not simply estimating what individuals are WTP for a specific proposal, but rather estimating a set of WTP amounts, like estimating a demand curve, for different amounts of the public good.

There are two main approaches to valuing non-market goods: by analysis of behaviour (which is described as revealed preference analysis) or by surveys of individuals' preferences (stated preference analysis). Using the revealed preference approach, the economist analyses individual actions in a variety of situations and infers WTP values from these actions. The stated preference approach seeks to elicit values for public goods by asking people to state their values or choices. In this Appendix, we summarise these valuation methods and indicate some of their applications.

Revealed preference methods of valuation

Here we describe the four main revealed preference methods of benefit valuation – using information from market transactions, hedonic price analysis, travel cost analysis, and defensive household behaviour.

[4] This Appendix draws on Abelson, 2003, *Public Economics, Principles and Practice*, Chapter 10.

Markets and close substitutes

Many types of goods can be valued by drawing on some kind of market information. For example, the value of education and training can be estimated from changes in individual earnings as a result of eduction and training. The value of travel time in work can be estimated from wage rates (which reflect the value of a person's marginal product). The value of travel time in non-work hours can be estimated by examining travel choices where people trade off time and money, as for toll roads or the choice of travel modes. All of these valuations draw, in one or other way, on market information. Thus it should be evident that both product and factor markets are a major source of information about individual preferences and benefits.

Turning to other examples, the value of non-priced or subsidised final goods can often be inferred from the prices paid for close substitutes. For example the value of public housing may be inferred from private market rent. The value of public tennis courts can be inferred from the prices that people are WTP for use of private courts. The value of free public entertainment can be gauged from market prices for close substitute events at which prices are charged. In developing countries the value of publicly supplied water can be inferred from the price that households are WTP for privately supplied water.

In some cases, valuations of goods can be obtained from experimental markets. These are artificially constructed markets in which money changes hands. The funds for the transactions are usually provided by the experimenter(s). The experiment may take place in a laboratory setting or in the field. For example, in the early 1980s the US government provided vouchers for housing expenditures to a sample of low-income households to determine whether such vouchers would increase expenditure on housing or on other goods. However, because experiments are usually one-off events, care has to be taken in drawing general conclusions from them.

Market information can also provide a great deal of information on the value of both final and intermediate goods via their impact on productivity. For example, health care programmes that reduce morbidity increase productivity and earnings. Soil conservation programmes improve soil productivity and farm output and reduce farm costs. Programmes to clean waterways improve water quality and reduce the costs of water treatment to water supply companies and other industrial users of water. In each case, the productivity benefit is the sum of the benefits from the value of increased output and lower costs. The benefits can usually be estimated from market data on net earnings or asset values. The latter are of course simply the capitalised values of future earnings (at a market determined discount rate).

Box AII.1 Valuing travel time saving

Travel time saving frequently comprises 80 per cent or more of the expected benefits of transport projects and therefore valuation of these savings is very important. Two approaches are used widely in valuing time saving: an imputed opportunity cost approach for working time saved and behavioural assessment based on willingness to pay principles for leisure time savings.

Where travel time saved is seen to result in extra work rather than additional leisure, the value of time is often taken to be the gross wage rate plus possibly some related overheads. The assumption here is that the relevant loss is shown by the employer's full cost in employing labour: that is, the wage plus the cost of additional benefits (for example, paid annual or long service leave, worker's compensation insurance, employer contributions to superannuation funds) as well as overheads such as office space or capital equipment, the quantity of which is related to the number of employees. This approach assumes that travel time savings are large enough to yield an identifiable reduction in labour costs. It also assumes that the worker is indifferent between time spent travelling and working.

Much empirical research has focused on the value of time savings to commuters. Researchers have looked at the value of time implicit in the choices commuters make when they can trade off trip time against financial cost: for example, the choice between taking the jet cat or ferry across Sydney Harbour. Alternatively, regression models which 'explain' car and bus utilisation in terms of the price, service and time cost attributes of each mode of travel have also thrown up implicit values of time saving. There is considerable consistency across studies in the assessment that commuters value time savings in a range between 20 and 50 per cent of gross earnings. However, care needs to be exercised when applying such broad averages to particular groups. Values specific to the relevant user group are to be preferred.

There has been less research on the value of time savings in other contexts: for example, for people on holiday. There is no reason to expect that these valuations will be similar either to one another or to commuting valuations. In most cases, the after tax hourly wage will represent an upper limit.

An increasing focus of research is the sensitivity of time valuations to the intrinsic characteristics of the journey itself. For example, Truong and Hensher (1984) found that values greater than the 20-50 per cent wage rate range were associated with time spent waiting (for public transport) and time spent walking (Table AII.I). The estimates in the table do not correct for other factors such as income; thus the higher value of travel time savings of car drivers may reflect, in part, their higher incomes, rather than a higher preference for travel time savings relative to income.

Table AII.1: *Value of commuting travel time savings as percentage of average hourly wage rates*

	Car Driver	Car Passenger	Bus Passenger	Train Passenger
In-vehicle time	50	35	34	22
Waiting time	82	na	96	138
Walking time	126	173	34	79

Hedonic price studies

Whereas market prices show the values of goods or assets, hedonic analysis shows the implicit prices of the attributes of goods (or assets). Hedonic analysis can be applied to any product with multiple attributes and to any occupation with multiple workplace attributes. The basic idea is the value of something is the sum of the value of its attributes.

A common application of the hedonic price method is the valuation of environmental amenity by analysis of house prices associated with the environmental attributes of the houses. This is usually done by a multiple regression study of house prices and their determinants, including environmental attributes. Consider a simple general relationship between house prices (P^h) and environmental and other variables,

$$P^h = p\,(S, A, E)$$

where S, A and E are sets of structural, access and environmental attributes of houses. If the equation has a linear functional form, the partial derivatives, dPh/dS and so on, show the implicit price for each attribute.

To estimate a hedonic price equation like this, three issues must be resolved. First, appropriate independent variables must be selected. Equations are mis-specified if important variables are omitted or if there is strong multi-collinearity between variables. Second, the variables must be measured. Third, the appropriate functional form must be selected. For example, the equation could have a log linear rather than a linear functional form. In this case, the coefficients could be interpreted as elasticities.

The hedonic method has been applied extensively to residential properties. For example, many studies indicate that a one unit increase in traffic noise (measured by Leq) causes house prices to fall by between 0.14 and 1.26 per cent. Other studies show that a 1 per cent increase in suspended particulates (air pollution) causes house prices to fall by between 0.05 and 0.14 per cent. The variations in the results reflect differences in local demand and supply conditions as well as statistical practices.

Hedonic price studies provide estimates of the implicit prices of many goods, based on actual behaviour. They are usually approximate WTP values. Estimated values can be transferred from these research studies to policy areas if the environments have similar demand and supply characteristics. However, the results are sensitive to the statistical methods used. Also, the implicit prices may not represent WTP values for large changes.

Note that whereas hedonic price studies are usually conducted with reference to the value of goods, hedonic wage studies relate earnings to the attributes of workers and their working conditions. Thus these studies can be used to infer the productivity value of education (which depends on the relationship between earnings and education). Hedonic wage studies can also be used to infer the value that workers attach to safety, which depends on the wage premium required for more risky occupations. Hedonic wage studies have been used extensively to estimate the value of safety in the workplace and thereby to infer the value that individuals may be said to attach to life (see Box A.III)

Travel cost studies

Using the travel cost method of valuation, consumer surpluses and demand curves can be derived from travel costs. Figure AII.1 illustrates the method. Suppose that the residents of two zones (x and y) face travel costs to a park of C_x and C_y and make an average T_x and T_y trips per capita to the park each year. Given enough zones, a negative visitation relationship (V_1) between trips and travel costs can be estimated. Note, however, that travel costs are not themselves WTP prices or consumer surpluses. Assuming a linear relationship, a visitor to the park from zone x has an average surplus per trip of 0.5 (C_n - C_x), where C_n is the travel cost that deters all visits. A visitor from zone y has an average surplus of 0.5 (C_n - C_y). The total value of the park is obtained by summing the consumer surpluses over the populations in all relevant zones.

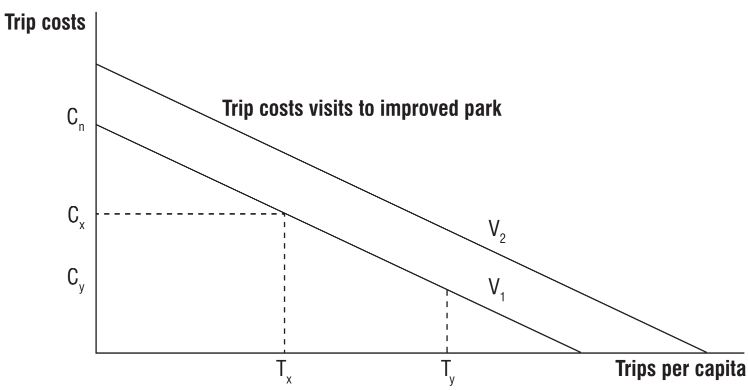


Figure AII.1 *Park visits and consumer surpluses*

The travel data, generally obtained by a visitor survey, can be used to derive a demand curve for the park. The key assumption is that visitors would respond to admission fees as they do to increases in travel costs. For example if a fee equal to (C_x - C_y) were charged, trips from zone y would fall from T_y to T_x. Summing over all zones, the total number of visitors prepared to pay a fee equal to (C_x - C_y) is estimated. Other points on the demand curve are found by further notional variations in the admission fee. In this case, the total consumer surplus for the park is equal to the whole area under the demand curve.

Travel cost analysis has often been used to estimate the value of recreational activities. Drawing on over 200 recreational studies in the US, Walsh et al. (1992) estimated that the average value of a recreation day at a site of low or average quality was $33. At a high quality site, the average value rose to $72. The highest values were for salt water and anadromous fishing and non-motorised boating. The lowest values were for camping, picnicking and swimming. On the other hand, Willis (1991) found that the average recreational surplus per visitor day to 15 UK forests was only about $4. Most results are sensitive to the treatment of travel time, the effects of substitutes, and the selection of functional form.

The travel cost method depends on accurate measures of travel costs, including vehicle operating and travel time costs. Travel time on a recreational trip through attractive country has a lower cost than commuting time. A critical assumption of the travel cost method is that the trip has a single purpose. If a trip has several purposes, travel costs must be allocated between them. Also, policy makers are often concerned with changes in the quality of a park (or natural asset) rather than with creating or losing a whole park. Here the analyst must either estimate the visits that would occur with the improved park (V_1 in Figure A.I) and the associated change in consumer surpluses or draw on estimated values of activities in similar parks.

Defensive expenditures

There are many kinds of defensive expenditures. They include expenditure that mitigates or eliminates the impact of an event before it occurs and expenditure that reduces or eliminates an impact after it is experienced. For example, government may have to move public facilities as a result of a major project. The replacement cost for an equivalent facility would be the relevant cost. Firms may have to clean offices more often in an air-polluted environment.[5] When water pollution causes ill-health, the medical costs are a defensive expenditure. On the other hand, households may boil water to reduce the risk of stomach disorders from drinking polluted water or install double-glazing to reduce the impact of traffic noise.

When government, business or households spend money to restore the value of assets, including health, there is a clear and evident cost. In other cases, the costs are as real but perhaps less clear. When households spend money to mitigate an event beforehand, the values of goods can be inferred from such expenditures by assuming that a household will purchase averting inputs or make corrective expenditure to the point where the cost of reducing an extra unit of the unwanted effect equals the marginal benefit. For example,

[5] This valuation method is sometimes called the dose-response method. The dose is the impact of some event and the response is the cost of restoring the asset to its pre-dose state.

if each unit of noise reduces household welfare by $100, a rational household will spend $100 to reduce noise by that extra unit. The marginal benefit of noise reduction can be inferred from the observed marginal expenditure of households.

There have been many studies of defensive expenditures by households. These include the use of seat belts and smoke detectors to reduce the risk of death (Blomquist, 1979, and Dardis, 1980 respectively); averting and mitigating expenditures to measure the cost of polluted water supplies (Harrington et al., 1989); and the costs of cleaning buildings in the US due to air particulates (Watson and Jaksch, 1982). Values inferred from defensive expenditures are thus based on observable behaviour.

Stated preference methods for benefit valuation

There are two main stated preference methods of analysis: contingent valuation and choice modelling. Using contingent valuation (CV), people are asked in various ways to state their WTP for various goods. Using choice modelling (CM) techniques, values are elicited from respondents' choices or ranking of options given to them in surveys, where the options include a monetary component.

Contingent valuation methods

In contingent valuation surveys, individuals are asked to state what they would be WTP for a specified public good if it were provided. To elicit accurate answers, a CV survey must first establish the nature of the good to be provided and the 'bid vehicle'. The bid vehicle is the way in which payment would hypothetically be made, for example in user fees, higher local taxes, contributions to a non-profit environmental fund, and so on. The actual question eliciting WTP values can be asked in various ways.

The most direct way is by open-ended question. People are asked simply what they would be WTP for a good. However, many respondents find it difficult to answer such a direct question, especially if they lack previous experience of the issue. Using the payment card method, interviewers present respondents with a range of values from which to select. Payment cards may provide implied cue values, including minimum, average and maximum values, which bias responses.

Using the bidding game technique, individuals are asked to respond to a specified figure. If they are WTP this amount, the figure is increased until the respondent reaches their maximum WTP amount. If the respondent is not WTP the initial figure, the amount is reduced until an acceptable figure is reached. In this case, responses may be influenced by the starting figures provided: which is called starting point bias. Potential biases with starting points, as with payment cards, may be overcome at a cost by administering questionnaires with different starting points or payment ranges to separate households.

With the close-ended bidding technique or referendum model, individuals are usually presented with a single payment, which they are asked to accept or reject. This approach is considered to eliminate question bias, but it reduces the information provided by respondents and significantly increases the sample size necessary to generate useful information.

There are several other issues with CV studies. An important issue is the possibility that respondents will not answer honestly. In particular, they may exaggerate the value of some thing if they do not have to pay for it. Another major issue is information bias arises when answers depend on the information provided about the environment. Box A.II describes a CV study to determine values for preserving an area in the Kakadu National Park in Australia from mining. The results varied significantly with the information about the possible damages to the park presented respectively by the mining group and the Australian Conservation Foundation. A third issue is that respondents may ignore possible budget and other constraints.

A subsequent major issue is the willingness of the respondent to accept the premise of a CV survey that they may have to pay for a policy change. For example, elderly people eligible for medical benefits in the UK and Scandinavian countries have been found reluctant to state WTP amounts for health services that they are accustomed to receive free of charge. Many responded to CV questions with protest zeros. CV studies are of limited use where there are established property rights, which are perceived to be under threat.

Research has shown that CV studies do produce reasonable values when the results are compared with those derived from other valuation techniques, for example hedonic property price and travel cost studies described. Pearce and Markandya (1989) reviewed 8 studies containing 15 such comparisons and concluded that all the CV results were within plus or minus 60 per cent of the estimates in the comparison studies. They argued rather boldly that these are common ranges of error in demand estimates. Smith (1993) outlines another six tests of CV. These include use of constructed markets in which goods are actually purchased, consistency with demand theory (for example stated WTP should rise at a plausible rate with household income), stability of CV results in test/retest comparisons, laboratory experiments, and comparisons of purchase intentions revealed in surveys with actual purchases. He cites ten studies that draw on one or more of these tests.

Importantly, tests are required to assess the validity of any CV study. Validity refers to the degree to which the study measures the intended quantity. The main practical criteria for the acceptability of a one-off CV study are internal consistency of responses, consistency with the predictions of economic theory, and consistency with the results of other credible studies dealing with a similar topic in a not dissimilar environment.

Box AII.2 Contingent valuation of conservation value of the Kakadu Conservation Zone

The largest CV study in Australia (Imber et al., 1991) aimed to estimate the conservation value of the Kakadu Conservation Zone, an area of 50 km2 surrounded by 20 000 km2 of the Kakadu National Park, for which mining was proposed. Respondents were presented with two scenarios: expected minor and major impacts that corresponded to the views of the mining company and the Australian Conservation Foundation respectively. The impacts related to mine traffic, chemicals used to extract minerals, mine process water, and waste rock material.

The sample was 502 respondents from the Northern Territory and 2034 respondents from the rest of Australia. The latter was based on random selection of eight people over 18 years of age from a stratified random sample of 256 areas across Australia.

The study employed a two-stage referendum model to elicit WTP values. Individuals were asked: 'would you be willing to have your income reduced by about $X a week, that is $Y per year, for the next 10 years to add this area to the Kakadu National Park rather than use it for mining'? The starting values used were $5, $20 $50 and $100 a year, with different numbers used for different respondents. If a respondent answered yes/no, he or she was presented with the same question with a higher/lower figure. Whatever the response to the second question, there were no further WTP questions.

The mean WTP answers (in $ per annum) were as follows:

Area	Scenario	
	Minor damages	Major damages
Rest of Australia	$53 p.a.	$124 p.a.
Northern Territory	$ 7 p.a.	$ 14 p.a.

The estimated value of preserving the Kakadu Conservation Zone was between $0.6 billion and $1.5 billion.

Features of the study that were believed to validate the results were the strong relationships between WTP values and scenario damages, individual attitudes toward the environment and levels of education.

Features that were believed to cast doubt on the results were the bi-modal nature of the results (with most respondents in the highest or lowest WTP categories), the lack of any relationship between WTP values and income, and the gap between the responses of local residents and others. Some commentators explained that the local residents were well informed; others viewed them as rednecks. Curiously, respondents from the rest of Australia who had visited the Kakadu National Park also gave lower WTP values than respondents who had never visited the area. This seems to raise the question of information bias.

Choice modelling

In choice modelling studies, respondents are presented with a number of alternatives and asked to choose between them. Choice modelling, which is also known as conjoint analysis, is based on the idea that any good can be defined in terms of its attributes and the levels that these take. For example a waterway can be defined in terms of its recreational uses, vegetation, fish life, birds and other fauna. Changing attribute levels essentially changes the good that is produced. CM focuses on the value of changes in these attributes. For the purpose of CM, one of the attributes must be a cost item.

The term 'choice modelling' embraces four main ways of making choices:

- Choice experiments: the respondent is usually asked to choose between two alternatives and the status quo.
- Contingent ranking: the respondent ranks a series of alternatives.
- Contingent ranking: the respondent scores alternatives on a scale of say 1 to 10.
- Paired comparisons: the respondent scores pairs of scenarios on a similar scale.

Pearce and Ozdemiroglu et al (2002) describes these CM methods in more detail. A CM study is usually limited to about eight options. And each option should contain not more than four or five attributes, including cost. More options or attributes are confusing. Respondents are then presented with a set of options to choose between.

Valuations of goods can be inferred from the choices made and the monetary trade-offs implied by the choices. Given the choices of the respondents, the probability of making a choice is modelled as a function of the attributes including cost. This typically involves formulating a random utility model. In most applications the utility of an option is modelled as a simple linear combination of costs and attributes. There are many complex estimation models. But, taking a simple binary choice (between two alternatives), the binary logit model may be written as:

$$Ln(P_{1q}/1-P_{1q}) = \Sigma_i \beta_k X_{kq}$$

where the left hand side is the logarithm of the odds that a representative individual will choose alternative 1, the X_k are the values of the variables (k) relative to the alternative choice and the β_k are the parameters to be estimated. In general the marginal willingness to pay (MWTP) for any attribute is given by:

$$MWTP = -b_k / \beta_c$$

where β_c is the coefficient on cost and b_k is the coefficient on attribute k. MWTP gives the monetary value of the utility coming from an extra unit of the attribute k. This ratio is also described as the implicit price of the attribute.

CM surveys have some advantages compared with CV studies. Because the monetary component is more hidden, respondents perceive less reason to lie about their WTP for goods.

Also, by varying the levels of the attributes, the analyst can to obtain a more detailed view of the components of value and how the desired attributes vary with prices. However, respondents do not always find it easy to respond consistently to the array of choices that they are offered. When choices are inconsistent, inferences about WTP values must be made cautiously.

Box AII.3 The value of life

Early valuations of life used the human capital method. This equated the value of life with the present value of output (income) foregone. However, this is an ex-post value of life based on what is lost after the event of death. For welfare economics and public policy purposes, we want to know what individuals are WTP to reduce the possibility of early death.

Economists have developed the concept of value of a statistical life (VOSL) because most public policies reduce the risk of death rather than avert specific deaths. Suppose that individuals are WTP an average of $x for a one in 1000 reduction in the probability of their death, collectively they are willing to pay 1000 times $x to prevent one statistical death. If $x is $2000, VOSL would be $2.0 million.

WTP values for safety, thus defined, are derived in three main ways: from contingent valuation (CV) surveys; wage-risk studies; and consumer behaviour (defensive expenditure) studies.

In CV surveys, individuals are asked what they are WTP in exchange for a risk reduction. The questionnaire approach goes directly to the wealth-risk trade-off and elicits individual valuations of safety. However, there are concerns that respondents may not give accurate answers to questions involving small risk reductions and that answers may depend on how questions are presented. CV studies have produced a wider range of results than revealed preference studies. On the other hand, some recent studies represent sophisticated attempts to deal with these known problems, for example the study by Krupnick et al (2000) in Ontario, Canada.

Most estimates of VOSL are based on hedonic wage-risk studies. In these studies, workers are assumed to be willing to give up income for improved workplace safety or to require (accept) income for taking on more risk. The wage-risk equation is typically of the following kind:

$$W_i = \alpha_0 + \alpha_1\pi_{fi} + \alpha_2\pi_{nfi} + \alpha_3 SE_i + \varepsilon_i \qquad (1)$$

where W is the wage of worker i, π_{fi} and π_{nfi} are the probabilities of a fatal or non-fatal injury for worker i, SE_i are socioeconomic characteristics of each worker (such as age and level of education), and ε_i is an error term. The wage-risk method presumes that workers understand risk differentials, which are often small, that the model distinguishes between the premiums for fatal and non-fatal accidents (which are often correlated) and that the results are not statistical artefacts of the way in which the model is specified. These are significant and possibly questionable assumptions, which have led some analysts to be sceptical of the claimed results.

Valuation methods: applications and conclusions

Examples of public goods, the benefits they provide, and valuation methods are shown in Table A.1. The goods include educational and health services, safety, transportation services, recreational facilities, and various environmental goods.

Table AII.2 *Examples of public goods, benefits and valuation methods*

Nature of public good / benefit	Revealed preference method	Stated preference
Educational skills / training	Increased market earnings	
Public library services	Prices of substitutes	CV / CM
Value of life	Hedonic wage analysis Defensive expenditures	CV / CM
Value of health	Increased earnings Defensive expenditures Savings in expenditures	CV / CM
Police protection / safety	Hedonic property price analysis	CV / CM
Travel time savings (work)	Value of increased output	
Travel time savings (leisure)	Analysis of travel choices	CV / CM
Reductions in vehicle operating costs	Savings in expenditures	
Active recreational facilities	Prices of substitutes	CV / CM
Parks / passive recreational areas	Travel cost analysis	CV / CM
Environmental inputs to production	Value of increased output Savings in expenditures	
Environmental amenities	Hedonic property price analysis	CV / CM
Flood / fire protection	Hedonic property price analysis Savings in expenditures	CV / CM

(a) CV = contingent valuation. CM = choice modelling

Table AII.3 *Summary on willingness to pay valuation methods*

Valuation method	Main strengths	Main weaknesses
Revealed preferences		
Market data	Easily observable Provides important data on productivity impacts	Does not measure non-market goods like quality of life
Hedonic wage method	Provides main market-based method of valuing safety	Wages not always a reliable indicator of risk
Hedonic property prices	Has many applications and is a reliable method	Requires extensive data
Travel cost analysis	Produces reliable answers if site is accessible and study well-done	Has to deal with multi-trip purposes and the value of travel time
Defensive expenditure	Provides a useful lower bound to values	Caution required when expenditure has several benefits
Stated choice methods		
Contingent valuation	Has many applications	Respondents often find it difficult to express a monetary value for a non-market good. Answers may be biased.
Choice modeling	Respondents may give more accurate answers than in CV surveys	Requires substantial professional resources

Revealed preference valuation methods of one or other kind are available for all the services or benefits shown. Indeed, to value productivity gains (output gained or costs saved), market prices of some kind are usually the natural form of valuation. The main strengths and weaknesses of the methods are shown in Table AII.

Stated preference surveys (contingent valuation or choice modelling) can be applied to all other kinds of benefit and indeed to any attribute of any policy or good. Such surveys are an invaluable instrument for obtaining information about private values of many public goods. However, because of their hypothetical nature and other issues such as information bias, respondents may not always give accurate or honest answers. Stated preference surveys require careful design and interpretation. Where possible, the results of stated preference surveys should be supplemented with analyses of revealed preferences in market or other behavioural situations.

Of course, it is often not feasible to conduct primary research for an economic evaluation. Analysts must adopt and modify benefit values found in other studies, especially research studies, rather than undertake a large amount of primary data collection and analysis. The process of benefit transfers involves the transfer of existing estimates of non-market values to the present study, which invariably differs in some features from the original studies. Ideally, a meta study would have analysed the reasons for the differences between studies, so that the most relevant values can be selected. However, it is common practice to adopt mean estimated values from studies that are considered broadly similar. In some cases it may be appropriate to adopt a higher or lower value to reflect special local conditions.

Appendix III: Alternative Decision Rules

This Appendix examines three decision rules that are widely used in project evaluations: the benefit-cost ratio, the internal rate of return, and the payback period. In each case the rule is contrasted with the net present value rule discussed in Chapter 4.

Benefit-cost ratio

The benefit-cost ratio (BCR) of a project can be calculated in two ways. The more useful way is by dividing the present value (PV) of net recurrent benefits (benefits less operating or other recurrent costs) by the present value of the capital costs:

BCR = PV net recurrent costs / PV capital costs (Equation AIII.1)

The aim of this measure is to estimate the return to a scarce resource (capital).

The other way to calculate the BCR is by dividing the present value of all benefits by the present value of all costs.

BCR = PV benefits / PV costs (Equation AIII.2)

Using either method, we would require that for a project to be acceptable the BCR must have a value greater than one. If the BCR is greater than 1, the NPV is positive (greater than zero) and, vice versa, if the NPV is positive the BCR is greater than 1. Some people find thinking in terms of benefit-cost ratios easier than thinking in terms of net present values.

However, differences between the NPV and BCR approaches emerge when choices have to be made between mutually exclusive viable projects, as distinct from an accept-reject decision. As the following example shows, the NPV and BCR rules may rank projects differently. In this example, the NPV ranks the projects B, C and then A. The BCR ranks the projects C, A and then B.

Project A:
PV costs = $1.0 million
PV benefits = $1.3 million
NPV = $0.3 million

$$R = \frac{1.3}{1} = 1.3$$

Project B:
PV costs = $8.0 million
PV benefits = $9.4 million
NPV = $1.4 million

$$R = \frac{9.4}{8.0} = 1.2$$

Project C:
PV costs = $1.5 million
PV benefits = $2.1 million
NPV = $0.6 million

$$R = \frac{2.1}{1.5} = 1.4$$

Which ranking is correct? If an agency has no budget constraint in the sense that it can carry out all projects at the decreed opportunity cost of capital or discount rate (say 6 per cent real), it maximises net present value by choosing projects according to their NPV ranking. In the case of this example, it would choose project B. The fact that it absorbs more capital does not matter because the agency has the funds to carry out all other projects that provide a 6 per cent return or more. In this case, ranking the projects according to their benefit-cost ratios would lead us to an incorrect decision. Using either BCR equation would cause a bias towards small projects.

However, if an agency has a budget constraint and cannot carry out all projects that achieve an expected 6 per cent or more return, it can be shown (see Abelson 2003) that the agency should select projects in order of their BCR (in the example this means choosing project C). This is consistent with maximising NPV when an agency has such a budget constraint.

Note, however, that this is true only if we use Equation (AIII.1) to estimate the BCR. This shows the return to scarce capital.

A problem with the benefit-cost ratio as defined by Equation (AIII.2) is that the outcome is sensitive to the way in which costs are defined. Disbenefits such as aircraft noise nuisance and other negative externalities may be added to the cost stream or subtracted from the benefit stream. The way in which current or operating costs are treated can be similarly variable. Consider this example:

Table AIII.1 *Benefit-cost ratio estimation*

	Project A	Project B
PV benefits	2000	2000
PV current costs	500	1800
PV capital costs	1200	100
NPV	+300	+100

Benefit-cost ratio (*R*) if current costs are netted out of benefits:

$$R_1 = \frac{2000-500}{1200} = 1.25 \qquad R_1 = \frac{2000-1800}{100} = 2.0$$

This gives us a recommendation to select project B.

Benefit-cost ratio if current costs are added to capital costs:

Project A	Project B
$R_2 = \frac{2000}{1700}$	$R_1 = \frac{2000}{1900}$
$R_2 = 1.18$	$R_2 = 1.05$

In this latter case, the recommendation would be to select project A. This would be the correct recommendation because project A has the higher NPV ($300 compared with $100 for project B), However, unless the analysis shows the NPVs in addition to the benefit-cost ratios, there would be no reliable basis on which to prefer one alternative to the other.

Internal rate of return

The internal rate of return (IRR) is the discount rate that equates the present value of benefits and costs. Thus if the present value of costs is $10 million and annual benefits are $2 million, the IRR is found through the following equation:

$$10 = \frac{2}{(1+IRR)} + \frac{2}{(1+IRR)^2} + \ldots + \frac{2}{(1+IRR)^n}$$

The IRR approach reverses the procedure used to calculate a net present value. Instead of computing a net present value at a predetermined discount rate, an internal rate of return is computed at a predetermined net present value of zero. Figure AIII.l shows that, at a discount rate of 10 per cent, a project has a net present value of about $950. At a discount rate of 16 per cent it has a net present value of $0: thus its internal rate of return is 1 6 per cent.

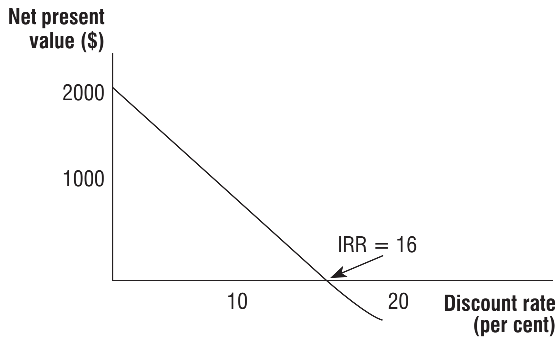


Figure AIII.1 *The internal rate of return*

Like the benefit-cost ratio, the IRR rule is often a misleading guide when alternative projects differ in scale. Consider two projects which are strict alternatives to one another (Table AIII.2). Project A has an investment cost of $1000 and is expected to generate net benefits of $300 each year in perpetuity. Project B has an investment cost of $5000 and is expected to generate net benefits of $1000 each year in perpetuity:

Table AIII.2 *Net benefit profile of two alternative projects*

Year	0	1	2	3	4	n
Project A	-1000	+ 300	+ 300	+ 300	+ 300	+ 300
Project B	-5000	+ 1000	+ 1000	+ 1000	+ 1000	+ 1000

Using the equation setting the present value of costs equal to the present value of benefits, the IRR of project A is found to be 30 per cent, while that of project B is 20 per cent. However, at a 10 per cent discount rate, the net present value of project A equals $2000, while that of project B equals $5000. Project B should be selected, not project A. The estimated IRR assumes implicitly that project surpluses can be invested at the estimated internal rate of return. But this is not possible if the discount rate is computed accurately. In this example, project surpluses can be re-invested at 10 per cent, but not at 30 or 20 per cent.

Thus, the IRR rule is liable to mislead when projects have different lengths of life. A project where benefits accrue soon after the end of the investment period may yield a higher IRR than one where benefits accrue later but in larger amount. Use of the net present value rule in this situation overcomes this bias.

A different kind of problem arises when the decision-maker is selecting a portfolio of projects subject to a budget constraint. Under the net present value criterion, the rule is to select that set of projects which maximises total net present value subject to the constraint. Internal rates of return are ordinal, not cardinal: they cannot be summed. Also any attempt to put projects on a common basis, for example by calculating the IRR per dollar of cost, falls foul of the scale and length asymmetry problems discussed above.

Fourthly, if a project has negative net benefits more than once during the project period, it will usually not be possible to determine a unique rate of return. Projects where major items of equipment are purchased periodically may fall into this category, as do construction projects with major periodic refurbishments. Similarly, mining projects often have cash outflows in their final years, because of land reclamation and reafforestation costs to meet environmental requirements. Figure AIII.2 shows a number of notional net benefit profiles: in profile (a) a unique solution to the IRR is available; profile (b) captures a project involving periodic equipment replacement (multiple solutions); profile (c) is the typical mining project with a negative outflow in its closing phase (multiple solutions); and profile (d) characterises a project where net benefits are always positive (no solutions).

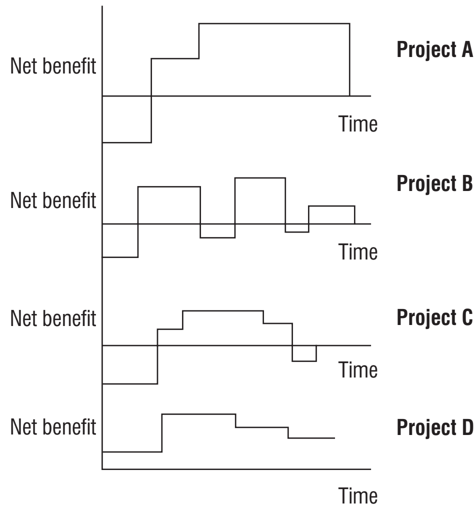


Figure AIII.2 *Contrasting time-profiles of net benefits*

Appendix III: Alternative Decision Rules

Payback period

Organisations sometimes require that the initial outlay on a project be recoverable within some specified cut-off period. The 'payback period' of a project is found by counting the number of years it takes before cumulative forecasted cash flows equal the initial investment.

To use the rule, an organisation has to decide on an appropriate cut-off date for payback. Unfortunately, any such rule is arbitrary as the worth of a project has little to do with such a date.

Consider for example, three projects that are to be assessed against a payback rule with a cutoff period of three years. In Table AIII.2, Projects A and B repay the initial investment in three years. Project C repays it in four years, but has a substantially higher net present value. Project C is the better project, yet would be discarded under the payback rule, in favour of either A or B.

Table AIII.2 *Comparison of payback periods and net present values*

Cashflow ($)							
Year	0	1	2	3	4	NPV (8%)	Payback Period (years)
Project							
A	-3000	+ 1000	+ 1000	+ 1000	+ 4000	2331	3
B	-3000	0	0	+ 3000	+ 4000	2150	3
C	-3000	0	0	+ 1000	+ 10000	4763	4

Another feature of the payback rule is that it gives equal weight to cash flows irrespective of when they occur before the cut off date. Criticism of this equal weighting has led to a modification known as the *discounted payback rule*. The rule involves accepting the project with the *shortest* discounted payback. Use of this rule in our example leads, as it happens, to the correct choice. With a net present value of $4763, project C repays the $3000 investment in 3 to 4 years. Projects A and B, in contrast, have not achieved discounted payback at the four year point. However, the rule can be quite misleading when the time profile of benefits differs significantly among alternatives.

To illustrate, consider a modification of our example whereby the length of life of each of the projects is extended to six years (Table AIII.3). Project C now differs from the other two projects in having sizeable benefits in the sixth and final year. Projects A and B achieve discounted payback in 4 to 5 years. Project C requires 5 to 6 years, but still has the highest net present value.

TABLE AIII.3 *Modified comparison of payback periods and net present values*

	Cashflow ($)				
Year	4	5	6	NPV (8%)	Payback period (years)
Project					
A	+ 4000	+ 1000	+ 4000	7185	4-5
B	+ 4000	+ 4000	+ 4000	7004	4-5
C	+ 3000	+ 3000	+ 15000	10643	5-6

Advantages of the alternative rules

Notwithstanding the problems associated with the three alternative decision rules, they do have some positive features.

First, each rule has greater intuitive appeal than does the net present value rule. Benefit-cost ratios of greater or less than one carry an immediate intelligibility. An internal rate of return, of say 12 per cent, can be compared with either an agreed discount rate or with the decision-maker's own view of what an appropriate rate of return is. The length of the payback period tells the decision-maker how long he or she must wait before beginning to earn a profit.

Second, the benefit-cost ratio and internal rate of return rules can provide rough indicators of the riskiness of the project. Because both rules are measured by the *ratio* of benefits to costs, projects which rate well against these rules are less affected by unexpected increases in costs or falls in benefits. Looking again at projects A, B, and C in the benefit-cost ratio section, project C, with a ratio of 1.4, is less sensitive to cost increases than is project B, with a ratio of 1.2 but with the highest NPV. A 30 per cent increase in project B's costs would result in a NPV of minus $1 million (a reduction of over $2 million) while a proportionate increase in project C's costs would result in a NPV of $150,000 (a reduction of $1.25 million). As discussed in Chapter 5, the preferred way to deal with uncertainty in cost and benefit streams is to test the sensitivity of the project's NPV against variation in the key parameters. This would both expose the sensitivity of project B's net present value to cost increases and, by virtue of the probabilities assigned to the various parameter changes for all alternatives, permit a complete and considered comparison of the riskiness of the three alternatives. Nevertheless, the value of the benefit-cost ratio and internal rate of return as a quicker and more approximate indicator of riskiness is something for analysts to keep in mind.

Conclusion

The net present value rule should be the primary basis for recommendation and decision-making in every project evaluation. It should *always* be included in an analysis.

Rules other than the net present value rule may provide useful supplementary information but should be employed only where they will not imply incorrect or misleading recommendations.

The *internal rate of return rule* will provide a correct result, and should be used, only when *all* of the following conditions apply:

- the choice of project or projects is not constrained by budget limitations;
- project alternatives do not preclude one another; and
- the net benefit stream is first negative and then positive for the remainder of the project's life (or vice versa).

Overseas aid projects, which are routinely appraised on an individual basis and in an environment of substantial budgetary flexibility, may fall into this category.

Similarly, the *benefit-cost ratio* is as reliable as the net present value rule only when project alternatives are not mutually exclusive and the decision is to accept or reject a project. When projects are mutually excusive, the ranking by net present value is generally preferred. An exception arises when there is a budget constraint and all viable projects can not be accepted, then ranking by benefit cost ratios maximises the net present value from the constrained capital base.

In the case of the *payback period* rules, while the discounted rule is superior to the non-discounted one, and while analysts may, with experience, learn to select a cut-off period which reduces the frequency of inferior choices, the rules are never as reliable as the net present value rule. They should therefore be avoided in the decision-making context.

Full risk analysis uses a technique known as the Monte Carlo method to establish an expected net present value of a project based on a probability distribution of all the potential project outcomes. It can be undertaken when the number of uncertain variables is too large for a meaningful judgement about the real riskiness of the project to be reached using sensitivity analysis (see Chapter 6).

The steps in the process are as follows:

1. the probability distribution of values for each variable affecting the outcome is specified;
2. a value for each of these variables is then selected at random;
3. the net present value implied by the randomly selected values is estimated;
4. the process of assigning random values to the variables is repeated many times to build up a probability distribution of outcomes (net present values); and
5. the process is concluded when further calculations no longer affect the relative frequency of outcomes.

In particular, the output will provide the mean (E) and standard deviation (S) of the distribution of net present values (Figure AIV.1). In addition, a cumulative probability distribution may be displayed, showing, for example, that there is an approximately 25 per cent probability that option A's net present value falls below zero whereas the comparable probability for option B is about 15 per cent (Figure IV.2).

The main weakness of the simulation method described above is that variables that are closely correlated are not correlated in the simulation. One way to mitigate this difficulty is to aggregate variables: that is, to include the product or sum of the correlated variables as the independent uncertain variable in the analysis, rather than the correlated variables. However, the loss of detail in this approach may offset the potential inaccuracy resulting from the independence of variables that are correlated. Alternatively, computer programmes can be devised to allow for the covariance of the relevant variables.

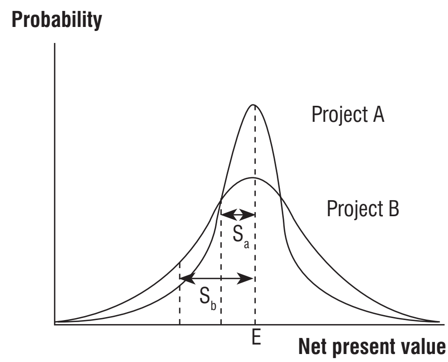


Figure AIV.1 *The distribution of the net present value of two projects*

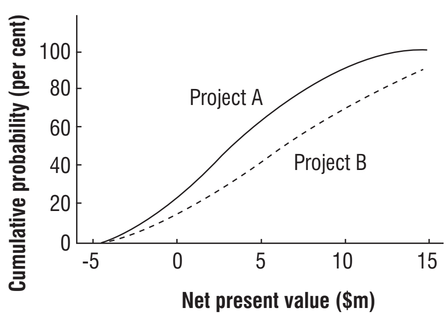


Figure AIV.2 *The cumulative probability of the net present value of two projects*

Generating a probability distribution

As Linard (1983) observes, the problem of generating an appropriate probability distribution appears to be the main deterrent to the more widespread use of probability analysis. However, it is neither possible nor necessary to find the 'true' distribution of each variable.

Probability distributions should be based on the best available information, if necessary interpreted by subjective judgement. Pouliquen (1975) describes an iterative process developed at the World Bank in which an analyst presents the original appraiser with continually modified distributions until the latter is satisfied. However, World Bank appraisers were found to play too passive a part in the process, being apt to accept virtually any smooth distribution which they were shown.

A distribution which has been found to overcome this problem is the *step rectangular* distribution (Figure AIV.3). In this approach the total range of variation is first divided into two intervals (Figure AIV.3(a)); the ranges and further subdivisions are then developed and modified with the active participation of the appraiser (Figure AIV.3(b)). This approach has the merit that it is easy to refine if further information becomes available. Further, computer random number generators find this distribution easy to handle: in contrast, for continuous distributions, mathematical transformations may be necessary before random numbers can be generated.

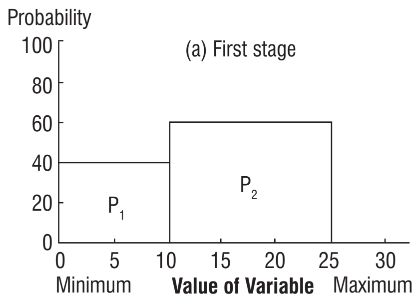


Figure AIV.3(a) *Constructing a step rectangular distribution of the value of a variable*

The main objective of the probability distribution choice should be to make use of all the information available, but not to require more information than is available. The step rectangular distribution is especially well suited to this objective. However, other distributions are sometimes required.

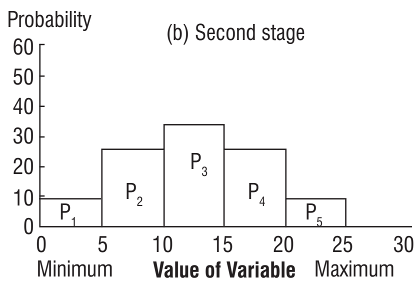


Figure AIV.3(b) *Constructing a step rectangular distribution of the value of a variable*

Conclusions

Many computer packages have been developed to perform Monte Carlo simulations, making risk analysis an accessible process. These packages produce pseudo random numbers that are acceptable for simulations and can rapidly solve the necessary equations for full risk analysis.

Final note: quantifying variability

By way of a definitional note, variability, or the dispersion around the mean of a project's return, may be quantified by the:

- range;
- variance;
- standard deviation; and
- coefficient of variation.

The *range* is the difference between the largest and smallest possible outcomes. Its use is not recommended as it takes no account of the probabilities attached to various outcomes and is determined by extreme values that may be unlikely to occur.

The *variance* is the average squared difference between each possible outcome and the expected value, while the *standard deviation* is the positive square root of the variance. Both are helpful indicators, with the latter more commonly used. For a normal distribution of probabilities, the mean expected outcome, plus or minus one standard deviation contains 68 per cent of the probabilities; the mean plus or minus two and three standard deviations contains 95 per cent and 99.7 per cent of the probabilities respectively. Thus, for two projects with equal mean expected outcomes and different, but normal, probability distributions, the chance that the actual outcome will fall below the mean expected outcome by more than a specific amount will be less for the project with the smaller standard deviation in its distribution of probable outcomes (option A in Figure IV.1).

The *coefficient of variation* is the standard deviation divided by the expected value. This is often more useful than the standard deviation in comparing projects of different sizes and with different expected values.

Appendix V: Annotated Bibliography

The literature of cost-benefit analysis is a large one and has not been covered exhaustively in researching for this handbook. This appendix list, by chapter, presents those readings that have been found particularly helpful in preparing the handbook.

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Appendix V: Annotated Bibliography

Chapter 5: Setting discount rates

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Appendix VI: Appraising a Cost-Benefit Analysis: A Quick Guide

The following questions provide a useful checklist for appraising a cost-benefit study.

1. *What questions does the study attempt to answer?*

2. *What alternative strategies are considered?*
   - 2.1. Do you have any comments on the way the choices have been set out?
   - 2.2. Are there other choices that could (should) have been considered at the same time?

3. *Are you happy with the cost estimates made?*
   - 3.1. Are the methods of evaluation satisfactory?
   - 3.2. Are any relevant costs omitted?

4. *Is the study based on reliable evidence?*
   - 4.1. What further information would you require?
   - 4.2. Is such information available and, if so, where and from whom?

5. *Are you happy with the method(s) of benefit measurement employed in the study?*
   - 5.1. If not, what method or approach would you propose?
   - 5.2. If yes, are you content with the values derived?

6. *Does the study allow for:*
   (a) uncertainty (or errors) in the expected costs and benefits?
   (b) the differential timing of costs and benefits?
   - 6.1. If the answer to (a) or (b) is Yes, are the methods used in the study satisfactory?

7. *Finally, assuming you were advising decision makers, what would be your recommendation?*
   - 7.1. Would you feel confident in your recommendation?

We are indebted to Tom Murphy (Charles Sturt University) and Ken Lee (Leeds University) for this checklist.

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Glossary

Glossary

Accrual accounting Accounting for revenues in the period in which they are earned and for expenses in the period in which whey were incurred. To be distinguished from cash accounting (as used in cost-benefit analysis and financial evaluation), which is based around the timing of actual money receipts and payments.

Appraisal A considered 'before the fact' assessment of a project or a programme. The process involves defining objectives, examining options, and weighing up costs and benefits. An 'ex ante' evaluation.

Balance sheet A financial statement that reports the assets and liabilities of an organisation at one point in time.

Base case A statement of what would have happened in the absence of the project or programme.

Baseline See 'Base case'.

Benefit A gain in utility or welfare resulting from a project or programme.

Benefit-Cost analysis See 'Cost-Benefit analysis'.

Benefit-Cost ratio The ratio of the expected present value of net recurrent benefits to the present value of project capital costs.

Beta A measure of 'market risk' of a stock or a portfolio of stocks. Stocks are assessed as 'low risk' or 'high risk' by reference to the beta of the market portfolio, which is one.

Cash flow A common shorthand for 'net cash flow', which is the difference between the expenditures and the receipts over time of a project or programme.

Choice modelling A technique whereby values are elicited from respondents' choices or rankings of options given to them in surveys, where the options contain a monetary component.

Constant prices Prices that have been adjusted for changes in the purchasing power of money, ie inflation, between periods. Alternatively, 'real' prices.

Consumer surplus A measure of the benefit to a consumer, net of the sacrifice he or she has to make, from being able to buy a good at a particular price; the difference between the amount a consumer is prepared to pay for a good (rather than go without it) and the amount actually paid.

Contingent valuation A method of inferring the value of benefits or costs in the absence of a market. Individuals are asked to say what they would be willing to pay or willing to accept *if* a market existed for the good.

Correlation The degree to which two variables are linearly related, whether through direct causation, indirect causation, or statistical chance.

Cost The measure of what has to be given up in order to obtain something. While frequently the same thing, the financial cost of a good is conceptually distinct from its opportunity cost. The 'opportunity cost' is the value of the best alternatives or other opportunities which have to be forgone in obtaining an item or achieving an objective.

Cost-benefit analysis A method of economic evaluation for projects, programmes or policies that measures benefits and costs as far as possible in money units. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.

Cost-benefit rule The rule that a project should, subject to budget and other constraints, be accepted when the value of its discounted benefits exceeds the value of its discounted costs, each discounted at the opportunity cost of public funds.

Cost-effectiveness analysis A form of analysis which compares options in terms of their substantive effectiveness and their cost. Whereas, in cost-benefit analysis, benefits, as well as costs, are as far as possible expressed in money units, here benefits are expressed in the appropriate 'physical' unit.

Counterfactual See 'Base case'.

Decision rule A criterion employed in making choices regarding project and programme options. See: 'Benefit-cost ratio'; 'Internal rate of return'; 'Net present value'; 'Payback period'.

Depreciation Reduction in the value of an asset, generally from wear and tear, over time. See also 'Residual value'.

Disbenefits A loss in utility or welfare resulting from a project or programme. Distinguished from a 'cost' in referring to an impact or effect of a project/programme, rather than an input.

Discounted cash flow The technique of appraising projects based on the idea of 'discounting' future costs and benefits to their present values.

Discounting The process of applying a rate of interest to a capital sum. Used to find the equivalent value today of sums receivable or payable in the future; also of sums received or paid in the past.

Distributional incidence analysis A means of displaying who gains and who loses from a project or programme. The distributional categories are chosen according to the project/programme, for example, income groups, adjacent and non-adjacent communities, etc.

Distributional weights A numerical factor applied to changes in income of different individuals or groups and embodying some distributive judgement for the purpose of evaluating the consequences of a project, programme or policy.

Double-counting The analytical error of misidentifying costs or benefits so that they are counted twice instead of once only.

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Economic evaluation Methods of evaluation that use a money metric and assess the real value of goods and services to individuals based on economic principles. The term is sometimes used synonymously with cost-benefit analysis but may also include cost-effectiveness analysis.

Effectiveness The extent to which the objectives of a project or programme are substantively achieved.

Efficiency The extent to which programme inputs are minimised for a given level of programme outputs, or to which outputs are maximised for a given level of inputs. This concept is synonymous with 'productive' (or 'technical')efficiency', but should be distinguished from 'allocative efficiency' which deals with whether the most highly valued set of outputs is created. The broader term 'economic efficiency' is sometimes used to encompass productive and allocative efficiency.

Elasticity A measure of the percentage change in one variable in respect of a percentage change in another variable. Thus the price elasticity of demand is the percentage change in quantity that is demanded expected in respect of a percentage change in the price of the same good.

Evaluation A considered assessment of a programme, project or activity. Whereas an 'appraisal' is invariably 'before the fact' (ex ante), an evaluation may take place 'after the fact' (ex post), or while an activity is in progress.

Expected value The analogue in probability analysis of an arithmetic mean; it is the value of each possible project outcome times the probability of the outcome taking place, summed over all possible outcomes.

Externality A benefit or a cost falling on third parties who normally cannot pay or be compensated for it through the market mechanism. An external benefit is often termed a positive externality; an external cost a negative one.

Financial evaluation An assessment of the financial effects of a project or policy from the perspective of some defined agency, which may include the whole of government. Gains and losses accruing elsewhere in the economy are not included.

Hypothetical market See 'Contingent valuation'.

Inflation A sustained rise in the general price level; the proportionate rate of increase in the general price level per unit of time.

Intangibles Costs or benefits that resist quantification.

Internal rate of return The discount rate at which a project has a net present value of zero.

Marginal cost The extra cost of producing an extra unit of output.

Market risk As identified in the Capital Asset Pricing Model framework, the risk to which all business enterprises are exposed that arises through the cyclicality of the economy and business conditions. Unlike other risks, the market risk of a particular investment cannot be diversified away by expanding the portfolio.

Monopoly A market situation in which a single seller controls the entire output of a particular good or service.

Multiplier The ratio of a change in income to the initial change in expenditure that brought it about.

Net benefits Benefits less costs.

Net cash flow See 'Cash flow'.

Net present value The discounted value of the expected benefits of a project, less the discounted value of the expected costs.

Nominal prices The prices prevailing in each specific period or year.

Opportunity cost See 'Cost'.

Payback period The time taken for a project to recover the initial investment. Similarly, the 'discounted payback period' is the time taken for the present value of the project's earnings stream to cover the initial investment.

Perfect competition A widely used economic model in which there are assumed to be a large number of buyers and sellers for any good and in which each agent has no effect on market prices.

Present value See 'Net present value'.

Probability distribution A summary, in the form of a table of numbers or of a mathematical relationship, which gives the probability with which a random variable which follows the distribution takes on certain values, or falls between certain limits.

Profit and loss statement A statement of revenues and expenses, and the difference between them, for an accounting period.

Programme A discrete set of activities and associated expenditure, often embracing a number of projects; not confined to activities with a capital component (see 'Project' below).

Producer surplus The excess of the total earnings of a supplier of a good over the payment he or she would require to continue to maintain the same level of supply. Analogous to 'Consumer surplus'.

Project A discrete one-off form of expenditure, often, but by no means exclusively, of a capital nature, for example, a road project.

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Public good A good which, because it cannot be withheld from one individual without being withheld from all, must be supplied publicly. National defence, street lighting, and general police protection are examples. Non-rival goods are also considered public goods because supplying them to one person does not reduce the supply to another person.

Regression analysis A set of statistical techniques, whose purpose is to quantify the relationship between two or more variables. Widely used in the quantitative forecasting of demand.

Residual value The amount for which an organisation expects to be able to sell an asset at the end of its service life.

Revealed preference An approach to estimating consumer preferences, based solely on observations of how consumers react to changes in prices and income. 'Regression analysis' techniques are often combined with revealed preference data to forecast future demand.

Risk When applied to a project, the extent of expected variability in the project's return.

Risk analysis An analysis which determines the effect on a project's net present value of the totality of expected variation in the project's critical variables. The analysis yields a probable net present value, rather than the usual point estimate. See also 'Sensitivity analysis'.

Secondary effects The consequences of the consequences of a project or programme. Beware double-counting in quantifying secondary costs and benefits. Also known as 'indirect' or 'second-round' effects.

Sensitivity analysis A technique involving changes to the parameters of a project/programme evaluation to see how they affect the outcome; a straightforward and rapid technique to gauge the robustness of net present value estimates. See also 'Risk analysis'.

Shadow price A price which is imputed as the true marginal value of a good or opportunity cost of a resource and which may differ from the market price.

Social opportunity cost of capital An approach to setting discount rates for evaluation purposes based on the gross return available from alternative public or private uses of capital. To be distinguished from the ' rate of time preference' approach which is based on individuals' preferences for current rather than deferred consumption.

Sunk cost An asset, the opportunity cost of which is zero, or as close to zero as makes no difference.

Transfers Payments which redistribute income but which do not reflect either the value of a good to a consumer or the costs of its supply. As such they are excluded from a cost-benefit analysis, but are included in the distributional incidence assessment.

Utility Consumer satisfaction, welfare, happiness, or well-being.

Valuation The practice of placing money values on costs, benefits, externalities, etc.

Welfare See 'utility'.

Willingness to pay The valuation placed by an individual on a good or service in terms of money. The valuation is in two parts: 'market price and consumer surplus', if any. 'Willingness to accept' is the analogous approach of finding out how much people are willing to pay to avoid a loss, or how much they are willing to accept in the way of compensation to put up with the loss.

Without project See 'Base case'.