Guidelines for the Selection of Evaluation Techniques to Assess R&D Programs

Prepared for LWRRDC by AACM International Pty Limited

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Abbreviations and Acronyms

ACIAR	Australian Centre for International Agricultural Research
AIDAB	Australian International Development and Assistance Bureau (now AusAID)
AusAID	Australian Agency for International Development
BCA	Benefit–Cost Analysis
BP	Beneficiary Perception
DPIE	Department of Primary Industries and Energy
EPA	Environment Protection Agency
IDA	Investment Decision Analysis
LWRRDC	Land & Water Resources Research & Development Corporation
MCA	Multiple Criteria Analysis
NPV	Net Present Value
R&D	Research and Development
SST	Social Survey Techniques

1 Introduction to Guidelines

1.1 Role of Guidelines

These guidelines have been prepared to meet the objectives shown in the terms of reference in Annex 1. The main task of the guidelines is to provide a framework to improve the quality and appropriateness of program evaluation. This framework can then be used to improve program allocations to yield the greatest benefit.

These guidelines are designed to help Land and Water Resources Research and Development Corporation (LWRRDC) Program Managers and Program Coordinators to:

- select the appropriate evaluation techniques for specific research and development programs and for specific stages in those programs;
- specify data and analytical requirements for evaluation; and
- understand the advantages and limitations of selected evaluation techniques and their implications for interpretation of evaluation results.

The guidelines include criteria for the selection of evaluation techniques according to the purpose, scope, and stage of implementation of the program.

1.2 Managing Research and Development

Research and Development (R&D) is structured into units of varying complexity and size. Projects made up of components and activities are grouped into programs. Programs are aimed at producing a series of outcomes all of which affect a major issue such as 'Development of indicators of river health'. Programs may be financed wholly from one source such as LWRRDC or they may be co-financed by two or more partners, with one partner being responsible for program management. For example, the National Dryland Salinity R,D&E Program managed by LWRRDC is co-financed by the Murray–Darling Basin Commission and the National Landcare Program.

LWRRDC wholly or partially funds a portfolio of R&D programs.

1.2.1 R&D management in an investment management framework

The principles of managing R&D programs are similar to investment portfolio management where, at one level, the investment portfolio is a suite of R&D programs, and at a more specific level it is a program comprised of a suite of projects. A portfolio is a group of assets or activities (programs), each with different levels of risk, reward, cost, and relevance to strategy. Portfolio analysis looks at ways of combining portfolio components (programs) to give an optimal result.

LWRRDC believes that it 'is important that researchers understand that LWRRDC manages its R&D portfolio as an investment activity using public funds to achieve significant public benefits' (LWRRDC 1996, p31).

An important component of R&D management is the efficient and effective allocation and reallocation of funds over time to programs, and within programs to specific projects. Evaluation generates information which assists decisions about allocation and reallocation of investments between programs and within programs. Consequently, LWRRDC gives special attention to the strategic assessment of programs.

1.2.2 Investment management cycles

Evaluation is one component in a cycle of activities used to plan, manage and review investment programs. Understanding the investment management cycle helps to clarify the role of evaluation and how results from evaluation are used. Major investors in public good programs have developed investment management cycles over the last 50 years which provide a useful reference for LWRRDC Program Managers.

Program management cycles used by major investors in public good programs such as the World Bank and AusAID, are analogous to the commissioned program management flowchart developed by LWRRDC. Figure 1.1 compares the stages in the World Bank and AusAID project cycles with each phase in the LWRRDC flowchart. The chart shows that the project cycle stages used by the World Bank and by AusAID are substantially similar to the LWRRDC Program flowchart. Figure 1.1 also shows the relevant terms describing evaluation at each stage in the flowchart or project cycle.

1.3 R&D and Levels of Evaluation

LWRRDC wholly funds or co-finances a portfolio of R&D comprising commissioned programs which consist of a series of projects, as well as specific projects resulting from an annual call. Evaluation or assessment of economic performance can take place at portfolio, program, project, project component and component activity levels. Table 1.1 shows that evaluation results can be used for management

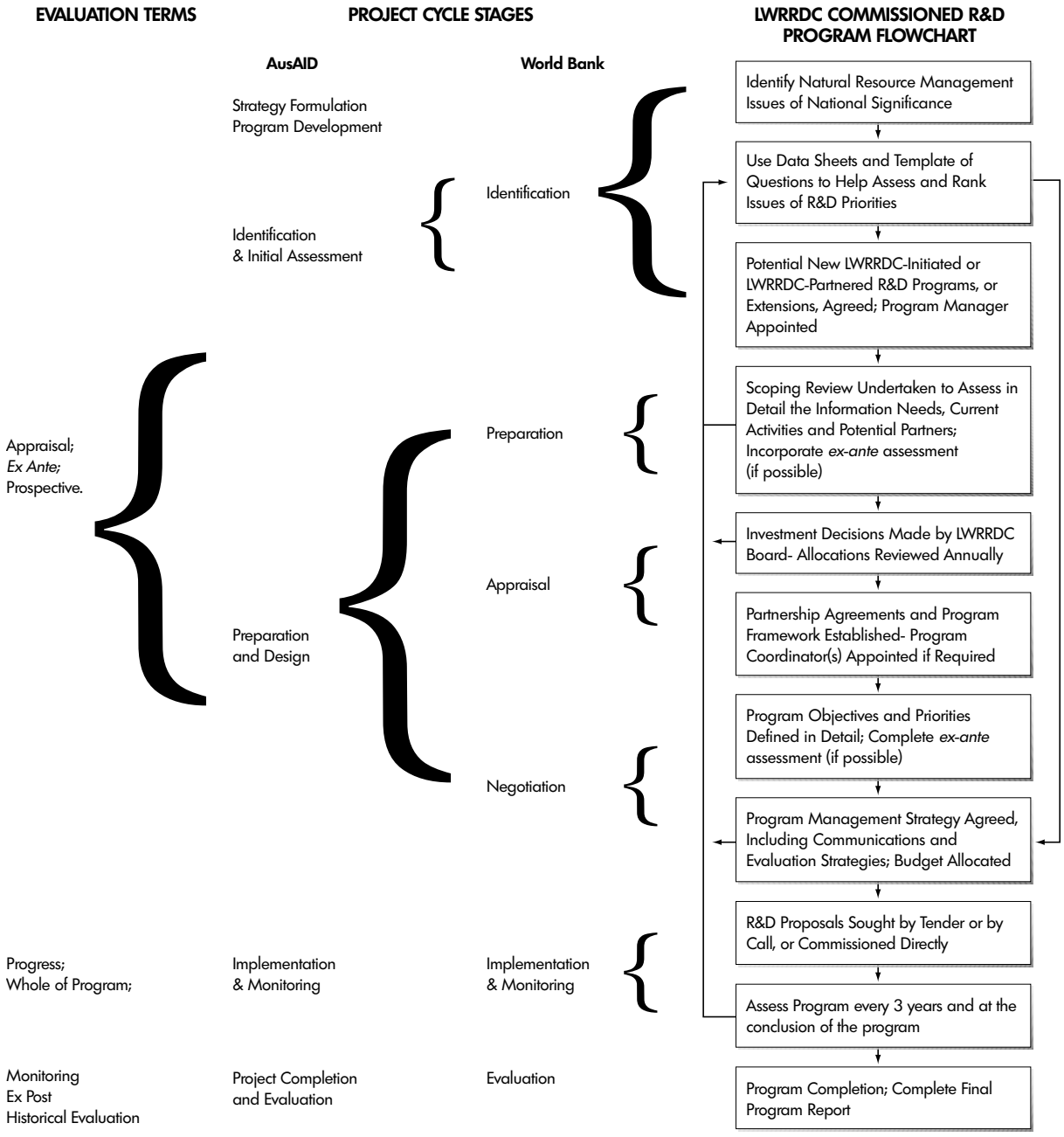

Figure 1.1 Relationship of evaluation terms and stages in project cycle and program flowchart

purposes and accountability within each portfolio, program and project, and for fund allocation according to priorities between portfolios, programs, projects and project components, using performance comparisons.

Accountabilities differ at each level. Table 1.2 shows that accountability for program evaluation is shared between the Board and Program Management Committee and Program Manager. At a program level, broad priorities are set, and allocations between programs reviewed and adjusted annually by the board. Evaluation at a program level should provide information for these functions.

1.4 Co-financed Programs

The majority of LWRRDC funds are used in national programs of commissioned R&D with a range of funding partners. LWRRDC is the only R&D Corporation which does not receive a proportion of its funds from industry. However, most research in natural resource management produces both public and private benefits, so it is appropriate for industry R&D Corporations to co-finance LWRRDC programs. Accountability for evaluation may become blurred in co-financed programs unless evaluation procedures and responsibilities, including responsibility for the clear definition of baselines to permit evaluation, are clearly incorporated in the partnership agreement for program management.

Table 1.1 Levels of evaluation

Evaluation Scope	Between		Within	
	Purpose	Accountability Level	Purpose	Accountability Level
Portfolio	Comparison and resource allocation between portfolios	Minister; DPIE, DEST, State Agencies	Portfolio assessment and management	Board, Program Managers
Program	Comparison and resource allocation between programs	Board, Program Managers	Program assessment and management	Program Management Committee; Program Manager
Project	Comparison and resource allocation between projects	Program Management Committee; Program Manager	Project assessment and management	Program Manager

2 Issues Relevant to Evaluation

2.1 Purpose

Evaluation is used for two main purposes—as a basis for allocation of funds, and to assess accountability for the use of the funds.

2.1.1 Basis for allocation of funds

Ex ante evaluation provides estimates of future outcomes of programs. Allocation of funds to these programs is based on the extent to which the estimated future outcomes match strategic priorities while taking into account current policies and social and political demands. Funds should be allocated to programs which are likely to yield the greatest economic, environmental and social benefits.

Allocation of funds should be based on estimated future outcomes, not past performance even though the estimation of benefits, costs and risks of those future outcomes may be at least partially based on historical outcomes. Past performance of a program is not necessarily a good predictor of future outcomes. However, evaluation of past performance is necessary to learn what constitutes a good project or program.

The in-principle objective of allocation of funds between programs is to maximise total expected returns by equalising the marginal value of the last dollar allocated to each program. Clearly, further investment in programs that are likely to return less than investment in other programs is illogical.

2.1.2 Accountability

Assessing accountability is to compare expected or actual implementation, outputs and outcomes of programs with objectives or other criteria so that management control can be exercised. Relevant objectives or criteria for accountability include outcomes (the most important criteria for allocating funds) and also outputs and implementation efficiency. Thus, the accountability purpose of evaluation can be focused on the implementation process or on the actual outputs and outcomes.

Table 2.1 summarises this section by showing the relevance of each evaluation type to purpose.

2.2 Timing

When evaluation is carried out before the decision to allocate funds, it is termed appraisal, prospective evaluation or *ex ante* evaluation. Assessments performed after the program has been implemented completely are termed historical evaluation or *ex post* evaluations and their purpose is to enable accountability requirements to be met and to provide a guide ton the return on research funds. Assessments carried out during the implementation of the program are termed monitoring, progress evaluation or life-of-program evaluation and are used as a measure of accountability for funding and to provide some guidance for the future allocation of funds and information for project selection.

Table 2.1 Relevance of evaluation purpose to type

Evaluation Type	Purpose		
	Fund Allocation and Reallocation	Accountability	
		Implementation Process	Actual Outputs and Outcomes
ex ante	yes	na	na
life of program	yes	yes	yes
ex post	na	na	yes

2.3 Strategic Planning and Program Management

To achieve its strategic objectives, LWRRDC invests the majority of its funds in commissioned R&D programs leaving up to 20 per cent of its total funding to be invested in projects resulting from a general call. Each commissioned program is developed with at least one partner, including a wide range of organisations such as rural industry bodies, regulatory bodies, management agencies, and research organisations.

Early stages in the decision to commission a new program are analogous to the identification and preparation stages in project cycles of such major investors in public-good programs such as the World Bank and AusAID and are concerned with establishing strategic direction on which to base funding. Subsequent stages are more program-specific and include requirements for evaluation. Data sheets and a template of questions have been designed to guide completion of the early stages of the LWRRDC sequence. As well, LWRRDC has developed a series of common steps in the program-commissioning process and a set of principles for the development of the commissioned R&D programs (LWRRDC 1996, pages 42–46).

Part of this process involves the Board applying a consistent series of questions to each of the resource-management issues. These questions serve to identify outcomes required for sustainable management of natural resources, how they can best be achieved, and what role, if any, the corporation should play. The questions are:

- What is the national significance of the particular resource management issue?
- What is the underlying cause(s) of the current failure to manage the resource sustainably?
- What form of intervention to improve resource management is likely to be most successful, and what are the costs, anticipated benefits and risks?
- How can the risks associated with the intervention be managed?
- What role, if any, should LWRRDC play?
- What is the potential return from the specific opportunities available for LWRRDC investment?

Systematic application of this set of questions to each case for allocation or reallocation of R&D funds is aimed at improving the rigour and consistency of the decision-making process. This reduces the subjectivity of decision making for the investment-allocation process, while making the process more transparent and accountable. It also provides a clear feedback loop from *ex post* evaluation which enables learning.

2.4 Program vs Project Outcomes

A program is an aggregation of projects. Program research has a number of advantages over project research such as:

- clearer formulation of social objectives;
- reduction of overlap in research effort;
- cross-fertilisation of ideas between teams;
- synergy and economies of scale; and
- the provision of opportunities for LWRRDC to join with other stakeholders to form a team of providers. (McGregor et al., 1994)

Disadvantages of program research when compared with project research include:

- greater coordination costs;
- development of inertia in programs and
- lower ability to allow for diversity and harness individual motivation effectively.

Program research is more demand-driven than project research which is more susceptible to becoming supply-driven, for example, by the availability of particular researchers with specific motivations.

The outcomes of a program include the aggregate of the outcomes of the projects in the program plus the extra outcomes which are due to synergy, economies of scale, positive interaction and improved efficiency. A program should have milestones in terms of outputs and outcomes which are more than just aggregations of project outputs and outcomes.

Program evaluation must include all project outcomes plus the extra benefits and costs due to the existence of the program as a whole. It should also include the project selection procedures within a program.

2.5 Life-of-Project (or Program) Evaluation

LWRRDC has established a series of Life-of-Project Evaluations which take a random, stratified sample of projects in the Corporation's portfolio, and subjects them to independent, external assessments at successive stages of the life of the project. In some cases, a program has been selected for Life-of-Program Evaluation.

A Life-of-Project or Life-of-Program Evaluation starts with an assessment at project or program commencement which is aimed at identifying the risks associated with achieving the technical output of the project and its translation into the required outcomes, so that the corporation and researchers can jointly address these risks while the project or program is under way. This initial assessment may also provide an *ex ante* assessment of the likely return on investment. The results of this initial assessment may cause the project or program to change direction or be linked with other R&D projects or programs. The selected sample of projects or programs will then be assessed at least once more during their life, to judge whether they are being managed adequately. After completion of the projects a final assessment will be made to determine whether actual outcomes were similar to those predicted. The assessment will also include an impact analysis to determine the overall results of the project or program, and will attempt to assess the actual return achieved on investment of public funds.

A Life-of-Program Evaluation is a structured evaluation process during the life of a commissioned program (*ex ante*, in-progress and *ex post*). A Life-of-Program Evaluation can include a mixture of evaluation methods as shown in these guidelines and can be applied to overall program evaluation and to a sample of particular projects in a program. Life-of-Program Evaluation was applied to the 'Minimising the Impact of Pesticides on the Riverine Environment, using the Cotton Industry as a Model' program (Harrison and Tisdell, 1996). This evaluation assessed the range of benefits from incorporating Best Management Practice for pesticide use. Particular projects in a program can be selected for life-of-program evaluation by random sampling, by random stratified sampling, or by non-random methods such as picking winners or by picking a range of projects stratified by their reward/risk ratios.

As with all sampling, extrapolation of the results to the population requires consideration of the implications of the sampling method. For example, evaluation of projects selected with a bias towards a high reward/risk ratio is likely to result in a higher estimate of the value of the program than would be justified if all projects were evaluated. Such results may suit the purposes of the evaluators or of the host organisation, but they will not be a best estimate of the benefit of the program.

The evaluation of the Victorian Agriculture & Food Initiative (Lew, 1996) is an example of an evaluation of a selection of projects. The study estimated that $32 million of benefits will be generated in the Victorian Agriculture sector as a result of $2 million invested in the particular projects evaluated. While this is an excellent result, the sampling bias inherent in the selection of programs for evaluation (only those which provided sufficient data for BCA) precludes extrapolation of this benefit to the remaining $230 million investment over the whole program.

2.6 What to Measure and When to Evaluate

Evaluation requires implicit or explicit comparison of circumstances with and without the relevant investment. Comparison is meaningful only when like is compared with like. Thus the selection of units of comparison is important. Most evaluation uses dollar values as the unit because this is an integral and logical unit for comparing investments. Evaluation using dollars leads to the estimation of benefits and costs in dollars and can generate investment criteria such as net present values (NPV) or benefit cost ratios to guide allocation of funds. Rigorous qualitative evaluation procedures such as multiple criteria analysis (MCA) can also be useful. MCA is essentially a qualitative benefit–cost analysis.

As well as guiding the allocation of funds, *ex ante* evaluation encourages participants to think through the implications of a prospective program in a structured way, thus providing a clear framework for monitoring expected outcomes during the program.

The selection of the appropriate technique to undertake *ex ante* program evaluation is complex due to the summing of the value of individual projects and the added value that may arise from the total program itself. As each program is normally planned to deal with particular issues, there will be large differences between programs in terms of risk and the importance of the assessment of non-market benefits. These differences make the method of evaluation *used ex ante* both complex and critical if the marginal return of programs is to be properly assessed.

It is important when establishing the *ex ante* evaluation criteria to determine if these criteria can be used as milestones throughout the project. This is essential if we are to establish a strong base line which links *ex ante* and *ex post* evaluation methods.

Historical or *ex post* evaluation (as well as monitoring and life-of-program evaluation) is facilitated by the presence of a monitoring framework including milestones relating to specific performance criteria. Evaluation at any time in the life of a program can be used to assess:

- differences between expected and actual outcomes;
- reallocation of remaining funds to improve outcomes;
- justification for allocation of further funds; and
- the performance of the program implementation agency.

2.7 What Should Evaluation Measure?

The existing portfolio of programs supported by LWRRDC has the following attributes:

- focused on public good within a government policy framework;
- focused on long term outcomes; and
- outcomes include many non-market benefits.

Discussion of what should be measured for *ex ante* evaluation and comparison of programs must take account of these attributes.

2.7.1 Outputs vs outcomes

An R&D program is usually expected to generate technical outputs and improved natural resource management outcomes. Direct measurement of these outcomes may not be possible and selection of indicators then becomes important.

The ultimate return to LWRRDC investments comes from changed behaviour of resource managers and improved condition of land and water resources. Consequently, evaluation should estimate outcomes including the outcomes of preventative measures. However, in many cases, outcomes are dependent on adoption rates or the confirmation of biophysical relationships, and so are a step removed from influence by the implementers of R&D. LWRRDC has attempted to tackle this problem by acknowledging it explicitly in all three of its objectives and by developing strategies such as improved uptake of research results, commercialisation and development of clear and unambiguous objectives and milestones in contracts to ensure attention is given to achievement of outcomes.

2.7.2 Effectiveness and efficiency

As shown in Table 2.1, evaluation at any level is concerned with two purposes: comparative allocation of funds, and management. Effectiveness is the measure used to compare outcomes from a particular investment. Efficiency is the measure used to compare the cost of achieving certain outcomes in terms of the investment and of the time required to achieve the outcomes.

2.7.3 Qualitative and quantitative data

Evaluation techniques estimate the benefits and costs of a program, and compare these with the benefits and costs without a program. They are all essentially performed using a Benefit Cost Analysis framework. Most costs can be estimated using quantitative measures such as funds spent, human resource requirements etc. However, there can be difficulties in estimating program benefits and costs which are not normally bought or sold. Examples include indirect effects of environmental degradation, changes to common resources such as waterways or the atmosphere, and changes which may occur a long time into the future.

Other benefits and costs which are not easily quantified include social and political benefits and costs. For example, the costs due to social dislocation resulting from salinity degradation such as the Tragowel Plains in North West Victoria are real but difficult to estimate quantitatively. Similarly, perceived political benefits or costs are difficult to measure but often influence investment allocation.

Timing of the achievement of outcomes can have a marked effect on performance measures because of discounting and the effect of obsolescence. Most performance measures clearly reward early achievement of outcomes. However, it is difficult to estimate when outcomes from R&D programs will be achieved because adoption rates are uncertain and climate and commodity market factors influence the behaviour of land and water resource managers.

Estimation of the effect of outcomes in terms of the difference in dollar values with or without the program is often difficult as well. The relationship between cause and effect is often insufficiently known to attribute all the outcomes to the R&D program alone. Moreover, often not all determinants of an outcome are influenced by a program. Consequently, allocation of all the credit for the benefits to the program is unjustified. Further, outcomes may be difficult to estimate quantitatively, particularly when they provide non-market benefits such as environmental or social benefits.

2.7.4 Value of non-market benefits

Research and development in natural resource management is often aimed at the development of management packages which, if implemented, slow down resource degradation or lead to resource rehabilitation and sustainable resource use. Many benefits of such R&D result from improvement in resource conditions, rather than from the improved productivity of systems which produce goods traded in markets. Consequently, economic evaluation of this R&D requires estimation of the value of non-market benefits. Techniques of estimation of non-market value of environmental benefits can be classified as:

- Market-based—preventive expenditure, replacement/repair cost, yield decrement approach, opportunity cost;
- Surrogate market-based—travel cost, hedonic price; and
- Survey data—contingent valuation, delphi technique.

These methods are discussed for example in McGregor et al. (1994), Pearce and Turner (1990) and Young (1992). However, their use often requires a high level of expertise, funds and time, and the development of standard environmental values is clearly an alternative. An example is Envalue, an environmental valuation database developed by the NSW Environmental Protection Agency (NSW EPA, 1995).

Environmental valuation techniques allow the estimation of non-market values of benefits in a consistent way so that when included with estimates of market values of benefits in an evaluation framework such as BCA, more consistent and objective results are achieved.

2.7.5 Risk and uncertainty

Ex ante evaluation of R&D is inherently uncertain. Not only are there the normal budgetary uncertainties of estimating costs, but research success is uncertain, research capability, adoption profiles, other time lags and the usual environmental, climatic and economic uncertainties may all affect outcomes. As many as possible of these risks and uncertainties should be incorporated in evaluation. The two usual methods are sensitivity analysis (see for example spreadsheet programs such as Microsoft Excel), and estimation of risk profiles and their effects using probability functions in spreadsheet add-on programs such as @RISK.

As implementation of a program proceeds, more information describing its progress should become available, thus reducing uncertainty. However, there is a time lag between the delivery of R&D outputs from a program and the achievement of land and water resource outcomes. This emphasises the importance of monitoring and life-of-program evaluation.

2.8 Benefits and Costs of Evaluation

Evaluation is required for both internal and external purposes. Care must be taken to ensure that there is a reasonable balance between the resources allocated to project implementation and to project evaluation. Thus, the requirements for evaluation should always be examined in terms of the costs and benefits of the evaluation. Evaluation should be designed to achieve effective outcomes, and should not discourage creativity in problem solving and research.

Evaluation requirements should be incorporated in the design of a project or program so that data necessary for evaluation are collected as a matter of course, thus minimising cost in terms of both funds required and time and effort required.

2.8.1 Funding for evaluation

There is no clear and universal benchmark for the proportion of an investment which should be allocated to program evaluation. From an economic viewpoint, funding for evaluation could be justified to a level of between 0.5 and 3% of total investment. However, allocation of more than 1% would require specific justification and probably unusual requirements.

Evaluations incorporated in the World Bank project cycle typically cost between 0.6 and 1.0% of total investment. More specifically, a usual *ex post* evaluation of a World Bank or Asian Development Bank project of US$5 million to US$10 million costs approximately US $50,000. The Australian Centre for International Agricultural Research allocates 0.7% of its budget to evaluation (Lubulwa, 1996).

Using the above examples as a guide, LWRRDC should consider allocating between 0.5 and 1.0% of its budget to evaluation.

3 Evaluation Techniques

3.1 Introduction

While evaluation techniques can provide relatively rigorous qualitative and quantitative indicators of comparative worth, choices by decision makers of priorities for allocating resources will still require the exercise of judgement. Evaluation techniques will produce indicators whose use will require critical judgement, not automatic application.

The basic principle underlying all evaluation techniques is estimation of the costs and benefits of the activity in a way that facilitates comparison of the results. In essence, all techniques are (or should be) variations of a basic benefit–cost analysis framework. The results of applying evaluation techniques provide a basis for informed judgement.

3.2 Benefit–Cost Analysis as the Basic Framework

A benefit–cost analysis (BCA) framework forms the basis of a continuum of evaluation techniques which can be applied *ex ante* or *ex post*. The range is:

Descriptive BCA: social surveys, qualitative measurement of beneficiary perception and outcomes;

BCA: includes quantified benefits;

BCA (Multi-Criteria Analysis): explicitly includes other criteria such as non-market benefits;

BCA(Investment Decision Analysis): explicitly includes risk.

All BCA should include:

- additional comment on qualitative factors not included in the BCA; and
- a description and assessment of major sources of risk if not explicitly included.

The key sources of risk and uncertainty which require consideration in evaluation are the likelihood of research success, researcher capability, level of adoption over time and physical and financial factors affecting production.

A range of scenarios based on the probabilities of particular outcomes is often included in a BCA to incorporate the effect of risk. Incorporation of IDA into BCA is a formal and transparent way of incorporating the effect of risk.

3.3 Qualitative BCA

3.3.1 Applicability, advantages and constraints

These techniques provide qualitative estimates of costs and benefits which are then set out in a method which allows comparison of the costs and benefits at the descriptive level. The techniques rely on the feedback of those who are either directly or indirectly affected by a program. When applying beneficiary perception and social survey methods we are attempting to determine how the beneficiaries view and value the outcomes, and often how they feel the results impact on their lives. Because of the nature of the information to be gathered, many techniques have been developed which involve using either survey research methods, or non-survey data collection.

A major difficulty in conducting social research is that several factors affect problem selection, including the research paradigm a researcher identifies with, the researcher's values, the researcher's methodology, the unit of analysis chosen, and whether the study is to be conducted over time or at a single point in time. Conventional biological and physical researchers often have doubts about such research.

3.3.2 Methodology

All program analyses in this category involve the same basic stages:

- choosing the problem;
- formulating the research design;
- gathering the data;

- coding and analysing the data; and
- interpreting the results.

3.3.3 Data requirements

Survey research methods require sufficient data to be representative of the group being surveyed. As the data must be suitable for statistical analysis they should be collected by random sampling, systematic sampling, stratified sampling or cluster sampling. This is frequently done through the use of face-to-face or mailed questionnaires. Alternatively, questions can be asked in the form of an interview, so that a more extensive view of the topic can be gained. Survey research methods are typically prescriptive, and although providing verifiable data, the results are not quantifiable and often of limited use.

Non-survey data collection methods which may be used include:

- observation;
- document study;
- ethnomethodologies; and
- simulation and games.

Typically, non-survey data collection methods focus on qualitative information. These data have face validity because they measure the perceptions of participants—by recording, for example, what people say and do—in a non-prescriptive way. Several techniques used for assessing program effectiveness and impacts, such as the problem census technique, produce valid results because survey participants not only identify impacts but also rank them in priority order. Participants often learn from or are changed by these methods.

3.3.4 Objectively verifiable indicators

Because of the subjective nature of this form of analysis, objectivity will always be in question, particularly from conventional science. However, granted that this is so, the outcomes from the survey and non survey methods should be replicable and verifiable to be considered of value, and these qualities can often be demonstrated.

These techniques complement economic approaches based on BCA to which they add depth. In particular, these methods may be more applicable to land and water management programs that are designed to change the perceptions, understandings and behaviour of land and water resource managers so that their actions and decisions improve the sustainability of resource use. In these cases, outcomes are objective measures of behavioural change. *Ex post* evaluations can use these objective measures of behavioural change as indicators for estimation of adoption.

3.3.5 Resource requirements

An extensive knowledge of a broad range of social survey skills is required to undertake this form of analysis objectively. Ideally a statistician familiar with both parametric and non-parametric tests should also be involved to ensure that methods are valid and reliable. These techniques can produce a range of cost options, depending on the scope and depth of evaluation data required.

3.4 Benefit–Cost Analysis

3.4.1 Applicability, advantages and constraints

Benefit–cost Analysis is used for quantifying and evaluating the total social costs and total social benefits associated with a research program. The technique was developed in part for use by public agencies when evaluating large-scale public investment programs in order to assess the welfare or net social benefits which would accrue from these programs. However, it has much wider applicability, and the conceptual framework is the basis for most evaluation.

There is always uncertainty surrounding the estimates of future costs and benefits associated with any investment, and the benefit–cost analysis needs to allow for this uncertainty by testing the sensitivity of the net benefits to changes in such factors as program life and interest rates.

Difficulties can arise in using benefit–cost analysis where:

- monopolies distort prices;
- taxes distort input costs;
- the project itself significantly affects price; and
- prices are overstated because of oversupply of a resource.

Problems of estimating prices may also occur for intangible products and collective products such as

biodiversity value. The question of which discount rate to use may also offer some difficulty, particularly when dealing with natural resources which may increase in value greatly over time as they become more scarce.

While benefit–cost analysis concentrates on the economic benefits of a program, it does not always consider who benefits and who bears the costs. Therefore a positive benefit–cost ratio will not necessarily mean the acceptance of a program, or the evaluation of successful outcomes from it.

3.4.2 Methodology

The main principles of benefit–cost analysis are encompassed within four key questions:

- which benefits and which costs are to be included;
- how these benefits and costs are to be valued;
- what interest rate will be used to discount future benefits and costs; and
- what are the relevant constraints.

3.4.3 Data requirements

All costs and benefits should be quantified and ranked according to their remoteness from the main purpose of the project so that more remote benefits and costs might be excluded. This requires careful definition of the spatial and temporal characteristics of the program and estimation of program life. Externalities (eg. benefits or costs affecting downstream communities) and secondary benefits and costs must also be considered.

3.4.4 Resource requirements

While the identification of benefits and costs relating to programs requires some experience, the skill level and time required for simple benefit–cost analysis is not great. However, if the project is complex, and requires the use of non-market valuation techniques, (eg. contingency valuation or travel cost method) the skill level and time required will be much greater, and often not readily available. Hence it may be necessary to employ a resource economist.

If several programs are to be assessed using benefit–cost techniques, it is essential that all those involved in the analysis are trained to apply the same standards when assessing benefits and costs, otherwise a comparison of benefits cost ratios between programs will be meaningless. The same issue applies to evaluation of projects within a program. The problem of developing consistent benefit–cost analyses across research organisations is widely acknowledged (Fisher et al., 1996).

3.5 Multiple-Criteria Analysis

3.5.1 Applicability, advantages and constraints

Multiple-Criteria Analysis is a collection of decision support techniques that range from simple graphical methods to sophisticated analytical procedures. It is both an approach and a set of techniques to help people make choices which are in accord with values held by stakeholders and/or decision makers. It is generally used to allow incorporation of priorities, determined in part by political or social factors such as meeting community concerns, into a BCA.

MCA provides a framework within which the effects of uncertainty in values can be subjectively evaluated and explored. It does not solve conflicts but is a tool which provides insight into their nature. It compares the advantages of each option in a structured manner.

The need to specify the appropriate criteria and provide weights is a practical limitation of the method, since subjectivity is inevitably involved. Weightings are used in a systematic mathematical appraisal of the various options to rank them according to their summed score of weighted effects.

This limitation is sometimes reduced by the use of Analytical Hierarchy Process which is a technique to structure complex environmental problems and derive criteria weightings. (Qureschie et al., 1995)

3.5.2 Methodology

There are a number of stages to MCA:

- specification of options and criteria;
- determination of the effects of each option;
- measuring each type of effect in a common unit across all options;
- ‘standardising’ each type of effect to compensate for the differences in scale used;
- weighting the effects; and
- determining the outcome.

3.5.3 Data requirements

Because MCA attempts to combine many options and criteria a wide range of data is required if a comprehensive study is to be undertaken.

3.5.4 Resource requirements

The time and level of skill required will depend on the complexity of the project being analysed, and the number of criteria used. A good knowledge of the program and its impact on non-market values is essential if the criteria are to be weighted correctly. The analysis needs to be no more complex than a benefit–cost analysis which attempts to include non-market values, although the results may be less quantified.

3.6 Investment Decision Analysis

3.6.1 Applicability, advantages and constraints

Investment Decision Analysis (IDA) incorporates probability into decision-making. It is based upon Bayesian probability and statistical decision theory, and was developed in its modern form from Harvard and Stanford Universities in the 1960s (Operations Research, 1995). IDA is an extension of basic benefit–cost analysis principles.

The value of IDA comes from incorporation of the results of simulated actions into the analysis, rather than the use of knowledge alone. The benefit of information comes from reducing the risk of the decision by giving us the opportunity to take an alternative action on the basis of the information.

Investment Decision Analysis offers a powerful means of organising the process of making choices and the economic appraisal of R&D. While its greatest benefits lie at the portfolio development phase because simulated outcomes can help determine allocation priorities, its application to the e*x ante* analysis of already chosen projects is also practical.

However, a large amount of specific data is required if the outcomes are to make sense, requiring a considerable amount of work. Another limitation may be the ability to include environmental benefits—where data or estimates are absent, there is a tendency to rely on tangible values. Where major gaps in data exist, or uncertainty in estimates is very large, decision analysis may not be meaningful. It may also be of little value where outcomes are unknown or applications unforeseen—for example, in pure research.

3.6.2 Methodology

An Investment Decision Analysis model has 3 basic elements:

- an influence diagram;
- a decision tree; and
- a value model.

The influence diagram is composed of decisions, chance events and values. The decision tree demonstrates the timing and sequencing of decision elements. The value model calculates the outcome for each particular setting of the variables in a benefit–cost analysis framework.

Value models are usually written in spreadsheets and linked to the influence diagrams and decision trees. Once all values of all endpoints have been calculated, the values are weighted by the probabilities to calculate the expected value of each decision alternative or decision policy. The optimum decision policy has the highest expected value, and the net value of taking that decision (eg. funding R&D) is the difference in expected value between that decision policy and the alternatives (no R&D).

3.6.3 Data requirements

As mentioned above, considerable data are required for meaningful analysis. An appropriate framework for the analysis is also necessary, as is an integrated bio-physical economic model.

3.6.4 Resource requirements

Technical and project skills are required for the application of the technique of Decision Analysis. It is unlikely that all organisations will have easy access to all these skills, and the analysis may have to be contracted out.

Accurate analysis requires considerable time, particularly if a suitable bio-physical model has to be constructed, and much information collected. Thus, both cost and time requirements would be rather greater for this form of analysis than for benefit–cost analysis.

4. Evaluation Technique Selection

4.1 Guidelines

Table 4.1 summarises the major capabilities of the relevant program evaluation techniques and when their use is and is not appropriate.

Table 4.2 provides a guideline to selection of the evaluation method most appropriate for programs at differing stages of the investment cycle. Because some programs are larger than others, and some require substantially more investment than others, care should be taken when choosing the evaluation method. For example, while IDA provides more information than either BCA or MCA on the value of a program, it can be an expensive evaluation tool. In the same way, projects which will be greatly affected by community preference or prejudice should be evaluated by using MCA in conjunction with BCA, rather than BCA alone. In addition, different techniques may be appropriate for *ex ante*, life-of-program and *ex post* evaluation.

4.2 Comparison across Programs

These methods can be used to compare returns across programs provided care is taken to ensure that:

- the appropriate technique has been chosen to determine the outcome from each program;
- the time frames used in the comparisons are comparable;
- discount rates are the same across programs;
- realistic adoption rates have been used in all program analysis; and
- externalities and risk have been properly identified and accounted for.

Table 4.1 Capability and appropriateness of evaluation techniques

Characteristic	Evaluation Technique			
	Descriptive BCA	BCA	BCA (MCA)	BCA (IDA)
Major capability	qualitative estimates of benefits and outcomes	rigorous comparison of costs and benefits in summary form	incorporation of non-market and qualitative benefits and outcomes	explicit inclusion of risk where bio-physical relationships are known
Most appropriate when:	outcomes are qualitative and may be affected by community perceptions	outcomes and benefits are easy to quantify	non-market and qualitative benefits are significant	evaluation of large scale programs with incorporation of risk is required
Not appropriate when:	outcomes are quantified and may be affected by risk	non-market or qualitative benefits are significant, and may be affected by risk	risk of research success and outcomes requires consideration	programs are of insufficient scale

Table 4.2 Guidelines for selection of technique for evaluating programs at different stages

Evaluation Purpose	Evaluation Method			
	Descriptive BCA	BCA	BCA (MCA)	BCA (IDA)
Ex ante allocation of funds between programs	Used if community preferences may affect outcomes	Used if community preferences do not differentiate between programs and are unlikely to affect outcomes	Used if community preferences are likely to affect outcomes	Used if large programs are to be evaluated and compared, and risk is explicitly included
Monitoring during life-of-program	Used to assess if community preferences do affect outcomes	Used if community preferences are not likely to affect outcomes	Used if community preferences are likely to affect outcomes	not applicable
Measuring effectiveness of program ex post	Used to assess qualitative outcomes, information uptake, and attitude and behavioural change.	Best used where results are not greatly affected by community preference	Used if results have major community impact	not applicable
Determining research uptake	Used to assess qualitative outcomes, information uptake, and attitude and behavioural change.	Used where adoption of research outcomes leads to objectively verifiable changes in indicators valued by existing markets	Used where physical indicators are associated with non-market values	Could be used where outcomes include reduction of risk
Assessing how LWRRDC programs complement programs of other R&D funding bodies	Used if community preferences may specific R&D funding bodies	Used if benefits can be partitioned between funding bodies	May be used where overlap of programs is not expected to be great	Gives good indication of program overlap and benefits to other funding bodies
Comparing programs	Used where community perception of program benefits is important	Selected where non-market benefits are minimal	Selected where non-market benefits are significant	Selected as an important application where risk varies between programs

These requirements mean that not only must the appropriate technique for evaluating the program be chosen, but there is a need for great attention to detail and communication between Program Managers so that valid comparison can be made. Alternatively LWRRDC may wish to set standards to be used when evaluation is undertaken. These may include:

- discount rate;
- values for biodiversity, native vegetation, water quality and other non-market goods;
- adoption rates;
- realistic increase in production figures; and
- time frames.

The Meat Research Corporation has discussed this problem in its report ‘Assessing Market Potential: Guidelines for Funding Applicants’ (O’Keefe et al., 1994). This report focuses on factors influencing market potential and develops a scoring system to assist researchers to estimate the maximum and likely annual rates of adoption. The problems of consistency in BCA of R&D are referred to in Fisher et al. (1996). The paper included as an annex a particularly useful list of sources of inconsistency such as that:

- adequate, consistent and accurate data are often not available;
- methodological differences exist in benefit estimation;

- evidence is lacking on the probability of research success and adoption rates;
- estimates of research lead time are unrealistic; and
- definition of the target area/population is inadequate.

Factors discussed in this section lead to the conclusion that LWRRDC must develop standards for use in evaluation.

4.3 Project versus Program Evaluation

Because the evaluation of a program incorporates project evaluation, the same cautions must apply to project evaluation as to program evaluation. Projects will vary within a program, and will therefore require different evaluation techniques. This results in the same complexities of issues as were mentioned above, involving adoption rates, discount rates, risk and externalities. Care must be taken to get this right at the project level so that these figures are realistic and comparable and provide meaningful input into the program evaluation process. Once again, LWRRDC may wish to set standards which must be used when evaluation is undertaken.

When combining project evaluations to determine program outcomes the risk of ‘double accounting’ must be guarded against, as projects often depend on each other, and the projected increase in income resulting from each project can not simply be added to provide program outcome figures. Once again this may be a subjective issue, and may require a set of guidelines which indicate the maximum level of adoption or production increase which can realistically be expected from any one program. Project evaluation may then have to be adapted accordingly.

5 Process for Implementing Evaluation

5.1 Integration of Evaluation into LWRRDC Strategic and Program Management

LWRRDC (1996) shows how evaluation is integrated into program management. For example, program management committees are discussed on page 24, and page 44 shows the flowchart for commissioned R&D programs.

The first *ex ante* evaluation occurs in Step 4 in the flowchart which comprises the scoping review. This is after issues have been identified, assessed and ranked, and potential programs have been agreed. It includes feedback from progress and *ex post* evaluations of related programs which is also incorporated in the use of data sheets and questions.

The next mention of evaluation is in Step 8 which is where program management strategies including evaluation strategies are agreed or revised. The last two stages specify program assessment every three years (life-of-program) and after program completion (*ex post*).

5.2 Internal vs External Capability and Resources

The Board is responsible for allocation of investment between programs and should therefore be part of the *ex ante* evaluation process. It should also be aware of the results of progress evaluation and monitoring and particularly any *ex post* evaluations and the application of these results to criteria used in *ex ante* evaluation. Using the information gathered in the data sheets, and to the template of questions, LWRRDC Directors each year re-examine the allocation of investment to individual programs and make adjustments as necessary.

LWRRDC staff should be responsible to ensure that the implementation of evaluation meets defined standards and levels of accountability. The evaluator should be independent from those with responsibility for managing the program. LWRRDC staff Program Managers should understand the roles of evaluation, the application of specific evaluation methods and the integration of evaluation in the overall management of programs. They should not be expected to be proficient implementers of evaluation techniques, but should be skilled in managing contracts for the external provision of evaluation services.

The LWRRDC flowchart for commissioned program development clearly shows the stages where communication is required and the procedures show what papers are required.

6 Program Evaluation Strategies Used by Other Organisations

6.1 Selection of Organisations

Several organisations have been selected for comparison because they have similar investment criteria to those of LWRRDC. The World Bank projects are equivalent to LWRRDC programs in terms of complexity and size of investment. AusAID bases its investment management on a project cycle which includes specific evaluation and monitoring requirements and which appears relevant to LWRRDC. The Meat Research Corporation has organised the majority of its research funding into commissioned programs. Both the Rural Industries Research and Development Corporation and LWRRDC are funded mainly or wholly by the Government and not statutory levy payers, and are therefore more dependent on their Boards rather than industry (as is the case for most other RDCs) for funding decisions. Both the Dairy and Sugar R&D Corporations evaluate programs in differing ways which can provide some guidance to LWRRDC.

6.2 World Bank

The World Bank Project Cycle is approximately analogous to the Commissioned R&D Program Flowchart for LWRRDC and comprises the following stages—Identification, Preparation, Appraisal, Negotiation, Implementation, and Evaluation.

Identification is where projects that support strategies and meet prima facie tests of feasibility are selected.

Preparation is the selection of the best institutional and technical alternatives for achieving the project objectives. It includes *ex ante* evaluation using benefit–cost analysis to determine the rate of return on investment for specific investment components. It also identifies risks to those investments and outlines recommended risk-management strategies.

Appraisal includes an *ex ante* evaluation, is a comprehensive review of the technical, institutional, economic and financial aspects of the project, and is the basis for implementation, monitoring and *ex post* evaluation.

Negotiation is the finalisation of the investment and funding decisions, and allocation of evaluation indicators and responsibilities to project managers.

Implementation is the phase in which the project is put into action or ‘constructed’ and includes regular monitoring both by the project manager and by independent evaluators appointed by the Bank. Monitoring is the life-of-project assessment.

Evaluation is the *ex post* assessment of the extent to which the project met its objectives, and can be the beginning of the identification and preparation of follow-up projects.

6.3 AusAID

The AusAID project-management cycle has been adapted from the World Bank Project Cycle and comprises six stages, the last four being specific to individual projects:

- Strategy Formulation;
- Program Development;
- Identification and Initial Assessment;
- Preparation and Design;
- Implementation and Monitoring; and
- Project Completion and Evaluation.

Annex 2 reproduces the AusAID Project Management Cycle.

6.4 Meat Research Corporation

MRC has structured the majority of its R&D into programs and uses an investment cycle adapted from the World Bank model outlined above.. Each program has been evaluated *ex ante* in a similar manner to the project appraisal carried out by the World Bank. This

includes preparation of a detailed business plan for the program. Each program also has had or will have a mid-term review and a final review conducted independently by consultants. These reviews are used for portfolio analyses based on BCA and are reported directly to the MRC Board. As well as the three independent evaluations, progress is continually updated internally. Bias inherent in the internal reports is identified by using the independent evaluations.

While MRC has a structured and formalised approach to evaluation, it is aware of the need to provide a balance between expenditure on evaluation compared with expenditure on R&D. MRC has also recently conducted an indicative evaluation of the whole portfolio of R&D for which it is responsible. This was performed by carrying out a superficial assessment of all components of the portfolio and a detailed assessment of selected components.

Consultations with an MRC Program Manager (John Webster) lead to the view that allocation of funds between programs is based to some extent on relatively coarse estimates of benefit–cost ratios, tempered with a subjective overview.

6.5 Rural Industries Research and Development Corporation

RIRDC has developed a quantitative Portfolio Analysis System (PAS) to assist its Board in allocation of resources to programs (Prinsley and Barlow, n.d.). Key features include:

- the establishment of research priorities by each industry;
- the specification of and use of four decision criteria to support transparent decision-making;
- a system that allows the Board to quantitatively analyse components of the decision criteria and systematically discuss their results;
- information which supports the Board's decisions; and
- the ability to calculate return on investment for different programs.

The decision criteria or evaluation indicators selected are:

- Gross Economic Benefits;
- Sustainability;
- Option Value; and
- RIRDC involvement score.

The Board uses PAS when allocating funds to each industry program, when evaluating research project applications and in the final *ex post* evaluation of each program.

As is the case with most evaluation methods and processes, the 'RIRDC Board has found that the process of evaluation, focused interaction and systematic thinking integral to the Portfolio Analysis System are its major benefits rather than the specific numbers that emerge from it.' (Prinsley and Barlow, n.d., p12) The PAS is seen as the first step in a comprehensive ongoing R&D program-evaluation system which comprises Portfolio, program and project evaluation at *ex ante*, progress and *ex post* stages.

While the quantitative results of PAS do influence allocation of funds between programs, the Board still exercises judgement in the allocation process.

6.6 Dairy Research and Development Corporation

BCA is used for project evaluation but not for program evaluation. Program evaluation in the DRDC is a balance of analytical and intuitive procedures (McKerrow, pers comm.). The analytical framework used is based on a collective estimate of the benefits that the projects making up a program is likely to confer on the industry. The estimate of benefits is based on the predicted situation when the program outcomes reach a steady state and has two components—effect on product price or revenue by changing the nature or the volume, and effect on cost. Allocation of funds across programs is then based on the collective experience of the Board in association with Program Managers.

A basic reference used by DRDC to assist their understanding of the amount and distribution of program benefits to industry is Freebairn (1992).

6.7 Sugar R&D Corporation

The Sugar R&D Corporation has used a business systems analysis of the Australian sugar industry to develop a more rigorous framework for the analysis of R&D needs and potential benefits in relation to costs. Their R&D Plan for 1995 to 2000 estimates productivity improvements in each program and the probability of achievement together with adoption profiles. Expected industry benefits for each program were then estimated using an industry model. MCA was used where it added useful information for priority-setting above quantitative estimates of benefits and costs.

While this approach has intuitive appeal, it relies on a well specified industry model for the estimation of industry benefits from each program. However, the benefits of LWRRDC R&D programs typically do not focus on specific industries, and estimation of the benefits through an industry model is not possible.

6.8 Australian Centre for International Agricultural Research

The Research and Development Program of ACIAR includes an Economic Evaluation unit. In 1993–4, it used 0.7% of the program funds. The objectives on the unit include the provision of economic assessments and enhancement of the Centre's public accountability. One report from the unit (Lubulwa, 1996) tabulates total project research costs, total benefits over 30 years and IRR. The report concludes that benefits of the research evaluated are expected to total A$107 m over 30 years and the projects cost A$14 m leading to a BCR of more than 7. About 30% of the benefits are expected to accrue in Australia.

The paper does not make it clear whether ACIAR provided all the funds or whether total costs had been used in the estimate. A major use ACIAR sees for these evaluations is public accountability.

6.9 Conclusion

There is no formula which can be applied to dictate the optimum allocation of funds between programs. However, the use of the relevant evaluation techniques as suggested in section 4 will provide a fund-allocation basis which then requires adaptation according to judgement. As well as offering a basis for the initial estimates for allocation of funds, use of the evaluation techniques described above allows the decision-making process to be transparent and accountable.

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Annex 1

Terms of Reference for Evaluation Techniques Consultancy

LAND AND WATER RESOURCES RESEARCH AND DEVELOPMENT CORPORATION

CONSULTANCY TERMS OF REFERENCE

The Preparation Of Guidelines For Program Evaluation

BACKGROUND

The Land and Water Resources Research and Development Corporation (LWRRDC) is one of fifteen R&D corporations within the Commonwealth Primary Industries and Energy Portfolio. The formal mission of LWRRDC is:

> To improve the long-term productive capacity, sustainable use, management and conservation of Australia's land, water and vegetation resources through a directed, integrated and focused research and development effort.

The purpose of the Corporation is to identify and fund research and development activities aimed at maintaining the natural resource base used by, or affected by, the rural primary industries. The natural resources concerned include soils, water resources and vegetation.

The Corporation presently has a portfolio of around 300 projects, including a majority which fall within thirteen large, commissioned research programs; the remaining are individual R&D projects funded from within a general call for research applications.

LWRRDC is seeking to improve the return on investment to the community of its limited resources through the use of methods that are more objective, quantitative, transparent and generally more rigorous to help guide allocation decisions. Due to the complexity of natural resource management issues, and the difficulty of obtaining reliable estimates of the economic benefits of sustainable resource use, the corporation has found that current methods of prospective cost:benefit analysis are not satisfactory in many cases.

With these concerns in mind, the corporation investigated the use of the Investment Decision Analysis (IDA) approach in the assessment and development of a new R&D program. Specifically the IDA was to apply a Benefit Cost Analysis (BCA) taking account of uncertainties and risks through the use of probabilities (using Decision Programming Language) to the issues identified as being of high priority. The anticipated outcomes were B/C ratios in terms of NPVs for each issue, the return on investment for a range of investment levels, the optimum investment strategy for a given risk profile, and sensitivity analyses.

Following the outcomes of the IDA approach, the Board agreed at its December meeting that guidelines be prepared for the use of techniques and tools in evaluation of R&D programs. These include benefit cost analysis, IDA, multiple criteria analysis and other relevant methods. These guidelines will be utilised by the corporation to help determine the level of program budget and the program components likely to yield the greatest public benefit. In some circumstances. the evaluation techniques will be incorporated in a scoping review to determine the feasibility of establishing a new program. Further evaluations may be conducted during the life of the program, to assist decisions or changes in program funding. The level and type of analysis will vary dependant upon the scope and size of the program.

The Corporation now seeks tenders to prepare guidelines for the use of tools and techniques in the evaluation of R&D programs. Tenders will be shortlisted against the following criteria:

- experience and knowledge in research evaluation procedures and processes;

- ability to understand and appreciate environmental issues and outcomes.

OBJECTIVES

1. The consultant will be required to prepare guidelines on assessment techniques to guide investments in R&D programs, including:

   - a description of each technique and incorporating the following headings:

     Usage (including appropriate timing);
     Methodology;
     Data requirements;
     Level of skills required and availability; and Cost.

   - the preparation of criteria for the use of particular techniques dependent upon the purpose, scope and size of the program; and

     a desktop review of program level evaluation techniques used by other R&D funding bodies.

DELIVERABLES

A report with an Executive Summary which addresses the above objectives.

FURTHER INFORMATION

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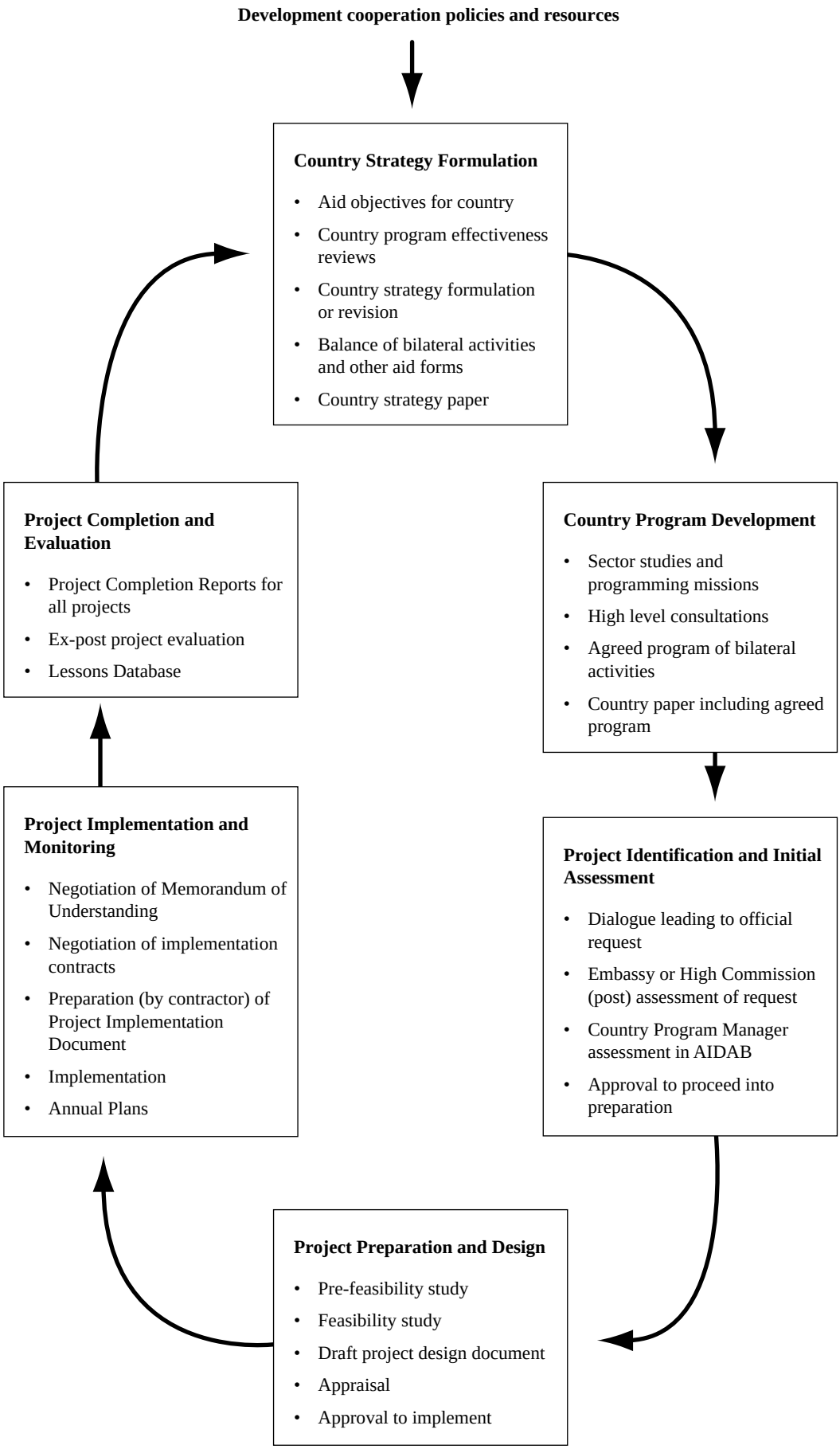
Annex 2

AIDAB (AusAID) Project Cycle


Development cooperation policies and resources
Country Strategy Formulation
• Aid objectives for country
• Country program effectiveness reviews
• Country strategy formulation or revision
• Balance of bilateral activities and other aid forms
• Country strategy paper
Country Program Development
• Sector studies and programming missions
• High level consultations
• Agreed program of bilateral activities
• Country paper including agreed program
Project Identification and Initial Assessment
• Dialogue leading to official request
• Embassy or High Commission (post) assessment of request
• Country Program Manager assessment in AIDAB
• Approval to proceed into preparation
Project Preparation and Design
• Pre-feasibility study
• Feasibility study
• Draft project design document
• Appraisal
• Approval to implement
Project Implementation and Monitoring
• Negotiation of Memorandum of Understanding
• Negotiation of implementation contracts
• Preparation (by contractor) of Project Implementation Document
• Implementation
• Annual Plans
Project Completion and Evaluation
• Project Completion Reports for all projects
• Ex-post project evaluation
• Lessons Database